Hauser Globalization Colloquium Fall 2009:
Interdisciplinary Approaches to International Law

Professor Ryan Goodman
Furman Hall 120
Wednesdays 2:00 pm-3:50 pm
(unless otherwise noted)

Schedule of Sessions (subject to modification)

September 2 - Professor Andrew Guzman, Boalt Hall, University of Berkeley
(co-author: Prof. Jody Freeman, Harvard Law School)
Topic: "Climate Change and U.S. Interests"
Discussants: Profs. Richard Stewart, NYU, and Ryan Goodman, NYU

September 16 - Professor Beth Simmons, Harvard University & NYU Straus Institute
(co-author Prof. Allison Danner, Vanderbilt Univ. School of Law)
Topic: "Credible Commitments and the International Criminal Court"
Discussants: Profs. Jose Alvarez, NYU, and Ryan Goodman, NYU

September 30 - Professor Oona Hathaway, Yale Law School
(co-author: Prof. Bruce Ackerman, Yale Law School)
Topic: "Limited War and the Constitution"
Discussants: Profs. Stephen Holmes, NYU, and Ryan Goodman, NYU

October 7 - Professors Eyal Benvenisti, Tel Aviv University Faculty of Law; NYU, and George Downs, NYU
Topic: "National Checks that Balance Global Institutions: Judicial Review of International Organizations"
Discussants: Profs. Beth Simmons, Harvard Univ. & NYU Straus Institute, and Ryan Goodman, NYU

Friday, October 16 - Professor Gary Bass, Princeton University ***(FH 120, 2-3:50 PM)***
Topic: "Freedom's Battle: The Origins of Humanitarian Intervention"
Discussants: Profs. David Golove, NYU, and Ryan Goodman, NYU

October 21 - Professor Kathryn Sikkink, University of Minnesota
Topic:"Explaining the Deterrence Effect of Human Rights Prosecutions"
Discussants: Profs. Philip Alston, NYU, and Ryan Goodman, NYU

October 28 - Professor Paul Slovic, University of Oregon
Topic: "Can International Law Stop Genocide When Our Moral Intuitions Fail Us?"
Discussants: TBA and Ryan Goodman, NYU

Friday, November 13 - Professor James Morrow, University of Michigan ***(FH 120, 2-3:50 PM)***
Topic: "The Laws of War as an International Institution"
Discussants: Profs. Matthew Evangelista, Cornell Univ., Nina Tannenwald, Brown Univ., and Ryan Goodman, NYU

November 18 - Professor Robert Keohane, Princeton University
Topic: TBA
Discussants: Prof. Robert Howse, NYU, and Ryan Goodman, NYU

CLIMATE CHANGE & U.S. INTERESTS

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NOTE: This draft is intended for circulation in connection with the Hauser Colloquium at NYU Law School. We ask that participants excuse any stylistic failings in the draft. The paper is currently going through the law review editing process which has improved the paper in many respects, but because the process if not yet complete, some imperfections remain in the form of incomplete footnotes, notes to the authors or law review editors, typographic errors, and the like. We have tried to clean the draft for circulation, but have no doubt missed some things. Thank you for your understanding.

ABSTRACT

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 this threat. In this Essay we take on and debunk 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 ignore the ways in which climate change impacts abroad are likely to spillover into the United States through economic effects, national security, migration and disease, thereby creating additional costs. By focusing on absolute rather than relative costs, this Essay shows that climate change is not simply a problem for the rest of the world.

A more complete accounting of the costs reveals that the United Sates would be better off paying the full cost of mitigating its impact by itself (even if some countries do not cooperate) 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 part of the cost. 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 unilateral and action by the United States even before other countries act.[1] At a minimum, the United States should put considerable energy into negotiating and achieving widespread ratification and adherence to a substantive and effective international treaty to address climate change concerns. 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.

[1] Among the reasons that 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 4%. See infra note 311 and accompanying text.

Seawalls Are Not Enough: Climate Change & U.S. Interests

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The authors are grateful to Christopher Kutz, Dan Farber, Michael Gerrard, James Hines, Erin Murphy, Kal Raustiala, Kenneth Bamberger, Eric Posner, David Weisbach, participants at the Berkeley Law faculty workshop, the Latin American Law and Economic Association (ALACDE) 2009 Annual Meeting, and…for helpful suggestions during the preparation of this draft. We are indebted to Leslie Bryant, Earth Duarte-Trattner, Karis Gong, Michael Kolber, Matt Littleton and Elaine Meckenstock for outstanding research assistance.

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.[2] A consensus on the appropriate U.S. response, however, remains elusive. Nevertheless, there are some signs that a program may soon be in place: President Obama has made a cap-and-trade regime a central part of his energy and environment plan,[3] and Congress is actively considering legislation.[4] 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.[5] Yet there is serious debate in academic and policy circles over whether either of these steps would be in the national interest. Indeed, some argue that a straightforward cost-benefit analysis weighs against U.S. action.[6]

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[2] 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%), believe that global warming is real and already underway (74%), believe that there is a scientific consensus on the reality of climate change (61%), and already view climate change as a somewhat to very serious problem (76%)." (citation omitted)); see also National Academy of Sciences, Understanding and Responding to Climate Change (2008), available at http://dels.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf, (stating "[t]here is no doubt} climate change is occurring); Nicole Branan, Strange Bedfellows? Evangelicals and Scientists Join Forces on Climate, Geotimes, Sept. 2007, 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 consensus among economists" regarding the costs of climate change). Although the consensus among experts is near universal, there remain skeptics in the general public and in Congress.

[3] Obama for America, 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 Aug. 6, 2009) (on file with the *Columbia Law Review*). 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, Executive Office of the President, 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 newly appointed Environmental Protection Agency (EPA) Administrator, Lisa P. Jackson, has already ordered a review of the interpretive rule that formerly defined CO_2 as being outside of the Clean Air Act's jurisdiction, presumably to move towards its regulation. Press Release, U.S. Envtl. Prot. Agency, EPA Administrator Jackson Orders Review of Key Clean Air Act Document, (Feb. 17, 2009), available at http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/3274377ad2d9fc42852575600077efb5!OpenDocument (on file with the *Columbia Law Review*) .

[4] See John M. Broder, Climate Bill is Threatened By Senators, New York Times, Aug. 6, 2009; Juliet Eilperin, Democrats Pen Principles for Climate Change Bills, Wash. Post, Feb. 4, 2009, at A02 (reporting that Senate Democrats announced principles to guide climate change legislation); Suzanne Goldenberg, Democrats Set December Deadline for Cap on US Emissions, The Guardian, Feb. 3, 2009 (summarizing statements of Sen. Barbara Boxer, D-CA, Chair of Senate Environment & Public Works Committee).

[5] 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).

[6] See infra notes 7--9 and accompanying text.

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.[7] 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.[8]

This Essay takes issue with the climate change winner argument just described. 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 exact upon 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.[9] 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 climate change will be distributed unequally.[10] 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 that are the

[7] 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].

[8] 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) (arguing "Americans should not suffer for symbolism while countries such as China and India emit increasingly large quantities of greenhouse gases without consequences"); contra Gregg Easterbrook, Global Warming: Who Loses---And Who Wins?, The Atlantic Monthly, Apr. 2007, at 52, 64, available at http://www.theatlantic.com/doc/200704/global-warming (on file with the *Columbia Law Review*) (concluding United States should act to control greenhouse gases).

[9] See generally infra Part III.

[10] 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].

poorest in the world.[11] Poor nations as a group are likely to fare worse than rich ones for three distinct reasons.[12] First, wealthier nations have greater adaptive capacity and can therefore more readily respond to the effects of climatic change. Second, poorer countries tend to depend much more heavily on agriculture, a sector that is especially vulnerable to climate change. Third, poorer countries are, generally speaking, located in warmer, lower latitudes, which is likely to make increases in temperature especially harmful.[13]

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.[14] As one prominent commentator argues, "It remains clear that purely unilateral emissions reductions by either China or the United States would not be in the domestic self-interest of either the United States or China."[15]

B. Limits of the Climate Change Winner Argument

The climate change winner argument relies on economic models of the impact of global warming on the United States.[16] 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 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.[17] The

[11] Robert Mendelsohn et al., The Distributional Impact of Climate Change on Rich and Poor Countries, 11 Envtl & 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).

[12] See Stern Review, supra note 11, at 139; 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] (noting that "[i]n the poorer regions . . . the negative impacts tend to dominate the positive impacts"); William Cline, Global Warming and Agriculture: Impact Estimates by Country 67--71 (2007) (estimating impact of global warming on agriculture by country).

[13] Id.

[14].Sunstein, Complex Incentives, supra note 8, at 1677 ("[American] unilateral reductions would impose significant costs and by themselves produce no significant benefits."); see also 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 Economy 315 (Robert Mendelsohn & James E. Neumann eds., 1999) ("[M]odest warming would have a small but beneficial impact on the U.S. economy."); id. at 321 (noting several models "predict that mild warming will result in a net benefit rather than a net loss to the [U.S.] economy"). 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.").

[15] Sunstein, Complex Incentives, supra note 8, at 1677.

[16] See sources cited supra notes 10--11.

[17] See infra Part II.

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.

A complete assessment of what the United States stands to lose from climate change must capture a broader range of costs than any study has to date. 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.[18] Most models also ignore nonmarket costs, such as loss of biodiversity and ecosystem services, and fail to consider the possibility of catastrophic losses.[19] These omissions are not anyone's fault, but rather, as many economists point out, result from the result inherent limitations of economic modeling.[20] Policy discussions, however, often forget the limitations imposed by these models. The shortcomings of the models lead to a consistent bias toward an understatement of climate impacts.[21] 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.[22]

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.[23] This obligation arises, it is said, because the United States has been the largest historic

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[18] Most models calculate these costs by estimating direct market losses to agriculture, commercial water supplies, human health, and the like. See generally Stern Review, supra note 10; Tol, Dynamic Estimates, supra note 12; Cline, supra note 12.

[19] See generally Robert L. Fischman, The EPA's NEP 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.").

[20] See, e.g., Richard S.J. Tol, The Economic Impact of Climate Change 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); Richard S.J. Tol, Estimates of the Damage Costs of Climate Change. Part I: Benchmark Estimates, 21 Envtl. & Resource Econ. 47, 63--64 (2002) [hereinafter Tol, Benchmark Estimates] (noting omitted impacts including: amenity, recreation, tourism, extreme weather, fisheries, construction, transport, energy supply, morbidity, and others, and stating "no comprehensive, quantified impact studies have been reported"); Tol, Dynamic Estimates, supra note 12, at 157 (noting "[o]ne 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"); Mendelsohn et al., Country-Specific, supra note 11, at 567 (noting their models exclude nonmarket effects and have various other limitations); Mendelsohn & Neumann, supra note 14, at 317 (noting that their model excludes nonmarket impacts, particularly health, aesthetic, and nonmarket ecosystem effects like species and wetlands loss); Sunstein, Complex Incentives, supra note 8, 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).

[21] See infra Part II.

[22] See, e.g., Sunstein, Complex Incentives, supra note 8, at 1688 ("The United States and China are the largest emitters, and on prominent projections, they also stand to lose relatively less from climate change.").

[23] 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 (2008) [hereinafter Farber, Climate Change 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.").

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).[24] Alternatively, some suggest that the United States has an ethical obligation to future generations.[25]

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 that the moral arguments for U.S. action on climate change are compelling, we doubt that they will, on their own, convince U.S. policy makers of the need for mitigation. American international environmental policy, as with U.S. foreign policy generally, is typically driven by utilitarian calculations about the national interest.[26] 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.[27] Now, as then, many commentators express concern that the rest of the world would free ride on any American economic sacrifice.[28] This resistance to action is remarkably powerful: It persists even in the face of an increasingly solid scientific consensus that climate change is manmade, pressure from a number of American states in the form of state and regional climate programs,[29] a rebuke from

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[24] See Executive Summary, Stern Review, supra note 11, at xi, available at http://www.hm-treasury.gov.uk/d/Executive_Summary.pdf (noting "[since] 1850, North America and Europe have produced around 70% of all the CO_2 emissions due to energy production"); Farber, Climate Change Compensation, supra note 23, at 394--400 (detailing corrective justice argument); Daniel A. Farber, Adapting to Climate Change: Who Should Pay? 20--22 (UC Berkeley Pub. Law Research Paper 980361, 2007) (considering corrective and distributive justice in determining who should pay for climate change adaptations); Benito Müller, Varieties of Distributive Justice in Climate Change, 48 Climatic Change 273, 277 (2001) (considering distributive justice in emission allocations); 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) ; Eric Neumayer, In Defense 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).

[25] See generally Page, supra note 24.

[26] 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 U.S. clearly outweighed the costs. See, e.g., Daniel Cole, Climate Change and Collective Action 16--17 (2008), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1069906 (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.

[27] See Byrd-Hagel Resolution, S. Res. 98, 105th Cong., (1997) (stating "the 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, including significant job loss, trade disadvantages, increased energy and consumer costs").

[28] See, e.g., Eric Posner & Cass Sunstein, Climate Change Justice, 96 Geo. L.J. 1565 (2008).

[29] See, e.g., California's Global Warming Solutions Act, Cal. Health & Safety Code §§ 38500--38599 (2008) (detailing California's state program to combat global warming); Regional Greenhouse Gas Initiative, Overview of RGGI CO_2 Budget Trading Program, available at http://rggi.org/docs/program_summary_10_07.pdf (last visited Aug. 7, 2009) (on file with the *Columbia Law Review*) (describing cap-and-trade coalition of Northeastern states); Western Climate Initiative, Statement of Regional Goal, available at http://www.azclimatechange.gov/download/082207_statement.pdf (last visited Aug. 7, 2009) (on file with the *Columbia Law Review*) (describing collaboration of Western states dedicated to slowing global warming).

the U.S. Supreme Court over the EPA's failure to regulate greenhouse gases,[30] demand from powerful industrial players that domestic controls are necessary to create a predictable business environment,[31] and intensified moral pressure from other countries for the United States to re-engage in international negotiations over a global climate agreement.[32]

Given this history of reluctance to act 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 effects 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 relatively better than many other states in a warmer world, but because what matters are not the relative costs, but the *absolute* ones. The question for policy makers, 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. 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;[33] economic spillovers, such as higher oil and other resource and commodity prices, along with supply shocks, demand shocks and disruption to financial markets;[34] spillovers resulting in the spread of infectious disease;[35] significant human migration;[36] and the risk of food and water shortages, species extinction, and biodiversity loss.[37]

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 recent financial crisis have

[30] Massachusetts v. EPA, 549 U.S. 497, 533--35 (2007).
[31] Companies that have joined the U.S. Climate Action Program (U.S. CAP), which advocates for strong federal regulation of greenhouse gases, include General Electric, Caterpillar, Inc., Shell, and the Environmental Defense Fund. U.S. Climate Action Partnership, at http://www.us-cap.org/ (last visited Aug. 6, 2009) (on file with the *Columbia Law Review*).
[32] In January of 2009, for example, Stavros Dimas, the E.U. environment commissioner, published an open letter calling on the United States to take a leadership role in efforts to reduce carbon emissions. *See http://www.environmentalleader.com/2009/01/29/us-faces-rising-pressure-to-act-on-climate-change/*; *see also* James Kanter, *Europe to U.S.: You're a Big Polluter*, New York Times, Jan. 27, 2009.
[33] See infra Part III.B.
[34] See infra Part III.A.
[35] See infra Part III.D.
[36] See infra Part III.C.
[37] See infra Part II,B.4.

made clear that we live in a world in which events in one region of the globe can have seismic impacts in another.[38] Economic, political, military,[39] and public health developments[40] in other countries can and frequently do cross international borders, and would likely do so in response to global warming.[41]

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. 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 suggests when it assumes that the United States will fare relatively well in a warming world.

Even if a strategy of going it alone were possible, it would be extraordinarily expensive to try 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.[42] Although such costs are hard to quantify, the quantitative difficulties are 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 the assumptions they are making and typically make them clear.[43] The relevant studies are important inquiries by outstanding scholars and our

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[38] 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. Schwarz, Systemic Risk, 97 GEO. L.J. 193, 249 (2008) (noting "systemic [financial] collapse in one country inevitably will affect markets and institutions in other countries").

[39] 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--94 (Gabriele G. Suder ed., 2006) (describing rapid spread of security risks across countries).

[40] 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) (noting "[g]lobalisation increases the likelihood that an infectious disease appearing in one country will spread rapidly to another").

[41] C.B. Field et al., North America, *in* Intergovernmental Panel on Climate Change, Climate Change 2007: Impacts, Adaptation and Vulnerability: Fourth Assessment Report of the Intergovernmental Panel on Climate Change 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.").

[42] See, e.g., Dale W. Jorgenson et al., U.S. Market Consequences of Global Climate Change iii-iv (prepared for Pew Center on Global Climate Change) (2004).

[43] To offer just one illustration, consider the explicit acknowledgement of excluded factors in one study:

> [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 crops and livestock agriculture may have consequences or 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.

understanding of climate 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.[44]

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 on utility 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 that 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. . . .[45]

Our point is simply that the spillovers mentioned in this excerpt, or the many other ways in which existing estimates understate impacts[46] cannot be bracketed and ignored. Rather, 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

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More importantly, this analysis does not consider the nonmarket 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.

[44] See supra note 17 and accompanying text.

[45] Eric A. Posner & Cass R. Sunstein, Climate Change Justice, 96 Georgetown L. J. 1565, 1581 (2008).

[46] See James Brosnan & Shan Carter, Winners and Losers in a Changing Climate, N.Y. Times, Apr. 2, 2007, at http://nytimes.com/2007/04/02/us/20070402_CLIMATE_GRAPHIC.html (on file with the *Columbia Law Review*) (graphic showing spillover costs); O'Brien & Leichenko, supra note 14, at 97--99; Easterbrook, supra note 8 (explaining potential for climate change to disrupt real estate markets); cf. Global Warming Could Boost Tourism, Farming, Augusta Chron., June 15, 2007, at A03 (citing Professor Robert Mendolsohn 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., 133 Cong. Rec. H11,420-05 (daily ed. Dec. 15, 1987) (statement of Rep. Roe) (noting "any attempts to mitigate climate change will also lead to conflicts---in part because there will be national winners and losers in the climate change sweepstakes"); William K. Stevens, In a Warming World, Who Comes Out Ahead?, N.Y. Times, Feb. 5, 1991, at C1 (explaining possibility some regions could benefit from global warming).

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.[47] 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 further 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.[48] 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 global warming 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 conceptually to separate the climate change winner argument we seek to debunk from *other* reasons why the United States might hesitate 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 that 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 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 be, in fact, 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

[47] See, e.g., Sunstein, Complex Incentives, supra note 8, at 1699 (arguing "[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").
[48] *See infra* Part IV.

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.[49] 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 will 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 that the United States would be better off paying the full 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 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 constitute an additional cost as of yet unconsidered. Part IV explains why the more complete assessment of costs justifies aggressive action by the United States to address climate change, notwithstanding the fact that some other countries have so far 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 global warming is indeed occurring,[50] that its rapid acceleration in the last 150 years has been caused primarily by human

[49] See Sunstein, Complex Incentives, supra note 8, at 1693 (speculating on possible national security implications).

[50] 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 100 (Susan Solomon et al., eds., 2007) [hereinafter IPCC, Physical Science Basis]. As of August 2009 it was approximately 384 ppm. Earth System Research Laboratory Global Monitoring Division, National Oceanic and Atmospheric

behavior (notably the emissions of greenhouse gases as a byproduct of burning fossil fuels to produce energy),[51] and that it poses significant risks of substantial harm from a variety of impacts---as a starting point.[52] Although the consensus is not universal, it does have considerable support across the political spectrum within the United States[53] and around the world.[54] Notably, the climate change winner perspective we seek to rebut also assumes that man-made climate change is real.[55] Thus, we will take that assumption as a given in this Essay.

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.[56] 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).[57]

Administration, "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 Earth to warm by an average of half of one degree, and will lead to at least an additional half degree of warming in the coming decades. Stern Review, supra note 11, at 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 which 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; satellite data show a loss of annual average arctic sea ice of approximately seven percent per decade. Press Release, U.S. Nat'l Snow & Ice Data Ctr., Models Underestimate Loss of Arctic Sea Ice, According to Study, at http://nsidc.org/news/press/20070430_StroeveGRL.html (Dec. 7, 2002) (on file with the *Columbia Law Review*). And the incidence of flooding is up around the world, including in North America. Millennium Ecosystem Assessment, Current State & Trends Assessment 517 (2005).

[51] The most recent Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC FAR), which represents the consensus of the international scientific community, concludes that anthropogenic greenhouse gas emissions are "very likely" responsible for "most of the observed increase in globally averaged temperatures since the mid-20th century." Richard B. Alley et al., Summary for Policymakers, *in* IPCC, Physical Science Basis,10 (Susan Solomon et al. eds., 2007) [hereinafter IPCC, SPM, Physical Science Basis]. 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.

[52] See, e.g., IPCC, SPM, Physical Science Basis, supra note 51, at 3, which states that human activities since 1750 have resulted in unprecedented levels of greenhouse gases in the atmosphere. The Report claims a "very high level of confidence" that the net effect of human activities over this time is responsible for radiative forcing. Id.

[53] Leiserowitz, supra note 2; see also National Academy of Sciences, supra note 2; Branan, supra note 2; Revkin, supra note 2; Pooley, supra note 2.

[54] See IPCC, SPM, Physical Science Basis, supra note 51; 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 183 countries that have ratified Kyoto Protocol).

[55] See, e.g, Sunstein, Complex Incentives, supra note 7, at 1676--77 (indicating United States and China have contributed to climate change).

[56] IPCC, SPM, Physical Science Basis, supra note 50, at 18.

[57] Id. at 11 tbl. SMP-2.

At current emission rates, greenhouse gases (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.[58] The more likely scenario, however, is that emissions will not remain static but will increase as economies grow, especially those in the developing world. Taking this into account makes it likely that GHG concentrations will reach 550 ppm by 2035.[59] The IPCC FAR anticipates that under a "Business as Usual" scenario, there is a greater than 50% chance of warming in excess of 5°C early in the next century. To illustrate the impact of such a change, the world is about 5°C warmer now than it was during the last ice age,[60] when ice sheets stretched across North America.

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.[61] Warmer temperatures are also expected to contribute to more extreme weather events, including more severe storms and hurricanes,[62] as well as droughts, heavy precipitation, and more intense heat waves.[63] 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.[64] 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.[65]

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[58] 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).

[59] "For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES [Special Report on Emission Scenarios] emission scenarios. 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." IPCC, SPM, Physical Science Basis, supra note 51, at 10. A rough consensus among climate scientists suggests that under compared to pre-industrial levels, business as usual CO_2 concentrations will double by 2100, resulting in a temperature increase between 1.8 and 5.4ºF. 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).

[60] Eystein Jansen et al., Palaeoclimate, *in* IPCC, Physical Science Basis, supra note 50, at 465.

[61] IPCC, SPM, Physical Science Basis, supra note 51, at 12 ("Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios. In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century.").

[62] Id. ("Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs [sea surface temperatures].").

[63] Id. ("It is *very likely* that hot extremes, heat waves and heavy precipitation events will continue to become more frequent.").

[64] 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%. Intergovernmental Panel on Climate Change, Summary for Policymakers, *in* IPCC, Impacts, supra note 41, at 11 [hereinafter IPCC, SPM, Impacts]. Meltwater from glaciers and snow packs supply water to more than 15% of the world's population. Id. at 11.

[65] 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 much, however, food production potential is expected to decrease. And 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.

These global estimates of impact mask the fact that impacts will vary from one place to another.[66] Nor is there much 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.[67] Not only is the United States geographically well-situated to withstand the warming trend, it possesses both strong domestic institutions and a relatively healthy, diversified economy, providing it with a comparatively robust adaptive capacity.[68]

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. The climate change winner argument is thus largely irrelevant to the policy question of what the United States should do. 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 GDP attributable to climate change.[69] 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.[70]

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

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[66] 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) [hereinafter Tol, Distributional Aspects].

[67] See Nordhaus & Boyer, supra note 11, at 96--98 (discussing countries' vulnerability to increases in temperature); Stern Review, supra note 11, at 179; see also Olivier Deschênes & Michael Greenstone, The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather, 97 Am. Econ. Rev. 354, 381 (2007) (finding net positive economic effects on U.S. agricultural sector from climate change).

[68] The United States is not unique in this respect; other nations will also be less adversely affected. See Nordhaus & Boyer, supra note 11, at 96 (Japan, Russia, and China); Mendelsohn et al., Distributional Impact, supra note 11, at 170 (former Soviet Union and Eastern Europe); cf. Stern Review, supra note 11, at 110--13 (discussing weak adaptive capacities of many developing nations).

[69] For examples of such models, see Mendelsohn et al., Country-Specific, supra note 11, at 554 (Global Impacts Model); Nordhaus & Boyer, supra note 11, at 3--7 (Regional dynamic Integrated model of Climate and the Economy (RICE) and Dynamic Integrated model of Climate and the Economy (DICE)); Tol, Dynamic Estimates, supra note 12, at 135--36 (unnamed IAM); Rachel Warren et al., Spotlighting Impacts Functions in Integrated Assessment 3--5 (Centre for Climate Change Research Working Paper No. 91, 2006), available at http://www.tyndall.ac.uk/publications/working/papers/twp91.pdf (on file with the *Columbia Law Review*) (discussing several notable IAMs, including Policy Analysis of Greenhouse Effect (PAGE) model used in Stern Review).

[70] See Joel B. Smith et al., Vulnerability to Climate Change and Reasons for Concern: A Synthesis, *in* IPCC, Impacts, supra note 41, at 943 fig.19-4 (summarizing several prominent IAM studies); William Nordhaus, A Question of Balance: Weighing the Options on Global Warming Policies 6 (2008) (concluding "the best guess of this book is that the economic dangers 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").

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.

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^{o}C, which is in line with the IPCC FAR's low emissions scenario.[71] The resulting economic impact is in the range of 0--3% of global GDP lost.[72] If, however, one considers the possibility of warming in the 5--6^{o}C range, the economic impact is 5--10% of global GDP.[73]

These levels of temperature increase are consistent with the IPCC estimates mentioned above.[74] Though it is possible that these estimates overstate future warming,[75] it is more likely that they underestimate the dangers we face. First, measurement difficulties cause some effects that may amplify warming trends to be ignored by existing models. Water vapor, for example, may increase the effects of rising CO_2 concentrations, but we do not know with any confidence how large such an effect could be.[76]

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."[77] 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.[78] Also excluded are a number of feedback mechanisms that could have dramatic effects on temperature rise, such as large releases of methane from frozen clathrates in the arctic polar region that will melt as temperatures warm.[79]

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[71] *See* IPCC, Physical Science Basis, Summary for Policymakers, Tbl. SPM.3

[72] Stern Review, supra note 11, at 166 fig.6.2 (looking at models of Nordhaus, Tol, and Mendelsohn).

[73] Nordhaus & Boyer, supra note 11, at 95 fig.4.3.

[74] See supra Part II.A.

[75] See, e.g., David Henderson, Governments and Climate Change Issues, 8 World Econ. 183, 194--209 (2007) (arguing IPCC process is run by "true believers," has made numerous mistakes, especially in its treatment of economics, and is insufficiently transparent).

[76] Schrag, supra note 51, at 173.

[77] Id. at 174.

[78] IPCC, SPM, Physical Science Basis, supra note 51, 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. . . .").
IPCC, SPM, Physical Science Basis, supra note 51, at 14.

[79] See Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios (Nebojsa Nakicenovic et al. eds., 2000), available at http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf (on file with the *Columbia Law Review*); Intergovernmental Panel on Climate Change, Synthesis Report 67 (2007) [hereinafter IPCC, Synthesis Report] (noting "[f]eedbacks between the carbon cycle and climate change affect the required mitigation and adaptation response to climate change…., but mitigation studies have not yet incorporated the full range of these feedbacks"). The leading models also tend to ignore the effect of slow feedback processes on the climate. Recent

Third, almost every surprise about climate change thus far has underestimated 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.[80] Indeed, it now appears that the arctic will be seasonally free of sea ice thirty years ahead of expectations.[81]

Fourth, the process that generated the projections makes understatement more likely than overstatement. The IPCC consists of the IPCC Plenary (the Panel), and three Working Groups with clearly defined mandates.[82] The Panel has been described 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 (WMO) member states.[83]

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,[84] to claims that parts of the Report offensive to some high oil producing and energy consuming states have been softened or deleted.[85] Although it is possible that scientists engaged in the process might collectively be biased in favor of overstating the results, it seems

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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 58, at 219--20 (2008).

[80] See Julienne Stroeve et al., Arctic Sea Ice Decline: Faster Than Forecast?, Geophysical Res. Letters 34, L24501 (2007). The study was conducted by scientists at the National Snow and Ice Data Center and the National Center for Atmospheric Research.

[81] Press Release, National Snow & Ice Data Center, Models Underestimate Loss of Arctic Sea Ice (Apr. 30, 2007), available at http://nsidc.org/news/press/20070430_StroeveGRL.html. Existing predictions estimate that the arctic could be seasonably free of ice between 2050 and 2100. *Id.*

[82] Intergovernmental Panel on Climate Change, About IPCC: How the IPCC is Organized, http://www.ipcc.ch/organization/organization_structure.htm (last visited March 5, 2009).

[83] See Bernd Siebenhüner, The Changing Role of Nation States in International Environmental Assessments---The Case of the IPCC, 13 Global Envt'l Change 113, 118 (2003) (characterizing Plenary in terms of "political dominance" while describing IPCC's subject-specific Working Groups which are open to government representatives but largely dominated by scientists, in terms of "[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 "[S]cientific Dominance." Id.

[84] 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 global warming, was replaced by Dr. Rajendra Pachaurii, who, at the time, was perceived to be more industry-friendly. This change was initiated by the U.S. and was followed by allegations that the U.S. 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.

[85] Following the release of the Fourth Assessment Report in 2007, David Wasdell, who served as "an accredit 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 report. This happened both in the treatment of positive feedbacks from global warming in the future and in its discussion of recent observations of collapsing ice sheets and an accelerating rise in sea levels." Fred Pearce, Climate Report "Was Watered Down," 193 New Scientist 10, 10 (2007). IPCC Coordinating Lead Authors wrote a letter responding to Wasdell, arguing that "[a]ny draft versions of the chapters or the Summary for Policymakers (SPM) were just that, documents in which inconsistencies were rectified, gaps were closed, and complicated matters were explained more clearly and in more accessible terms." Piers Forster et. al., Climate with Care, 193 New Scientist 26, 26 (2007).

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.[86] The process by which IPCC assessment reports are produced is highly constrained by the need for consensus, from, requiring the nomination and selection of authors and reviewers, to 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.[87] The final version of the Fourth Assessment Report involved the input of more than 2,800 different authors, review editors, and reviewers.[88] It is also fair to suggest that as a matter of disciplinary training and shared norms, scientists will tend to err in the direction of conservative estimates that can be defended on the basis of 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.[89]

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[86] "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 of the University of Leeds in England . . . ." David Biello, Consensus Document May Underestimate the Climate Change Problem, 296 Sci. Am. 16, 16 (2007). Scientists anticipatorily remove assertions which they feel may lead to controversy. See id. (noting "[b]y excluding statements that provoked disagreement and adhering strictly to data published in peer-reviewed journals, the IPCC has generated a conservative document that may underestimate the changes that will result from a warming world, much as its 2001 report did").

[87] See IPCC, Procedures for the Preparation, Review, Acceptance, Adoption, Approval, and Publication of IPCC Reports, Appendix A to the Principles Governing IPCC Work, available at http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a.pdf.

[88] See IPCC, The Physical Science Basis, supra note 50, at v (more than 752 authors and reviewers from Working Group I); IPCC, Impacts, supra note 41, at 4 (1,311 authors and reviewers from Working Group II); Intergovernmental Panel on Climate Change, Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change vii (Bert Metz et al. eds., 2007) [hereinafter IPCC, Mitigation] (738 authors and reviewers from Working Group III).

[89] 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 (2004); Martin Weitzman, On Modeling and Interpreting the Economics of Catastrophic Climate Change, 91 Rev. Econ. & Stat. 1, 18 (2009).

The remaining uncertainties obviously create a challenge for both policy makers as well as scientists. Policy makers need a sense of how various choices will affect outcomes so that 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 alone provide a menu of policy-outcome choices. So scientists are forced to offer their best projections, with careful qualification, and policy makers 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 Thomas C. Shelling, Climate Change: The Uncertainties, the Certainties, and What they Imply about Action, 4 Economists' Voice, July 2007, Art. 3, at 4 (2007), available at http://www.bepress.com/ev/vol4/iss3/art3 (noting "this idea that costly actions are unwarranted if the dangers are uncertain is almost unique to climate"); Kenneth J. Arrow, Global Climate Change: A Challenge to Policy, 4 Economists' Voice, July 2007, Art. 2, at 3 (2007), available at http://www.bepress.com.ezp-prod1.hul.harvard.edu/ev/vol4/iss3/art2 ("Are the benefits from climate change worth the costs?")..

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

Many models also assume that GHG emissions will eventually level off or decline. For instance, a recent study by Bows and Anderson shows stabilizing CO_2-equivalent 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.[90] 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.[91] Annual GHG emissions in the United States are projected to rise from 7.2 gigatons CO_2-equivalents in 2005 to 9.7 gigatons in 2030,[92] and economic growth in the developing world is projected to dramatically increase emissions.[93] 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 be focused on a higher expected temperature change (along with associated changes in precipitation and other weather events). This focus would significantly affect the predicted economic analysis. According to the Nordhaus and Boyer estimates, for example, assuming a temperature rise of 3--4°C instead of 2--3°C causes an additional loss of approximately 1% of GDP.[94]

2. Asymmetry Around Point Estimates

An additional problem comes about because discussions about climate change so often focus on a single point estimate (meaning a single number rather than range) of temperature changes as an input. The point estimate is intuitively satisfying, but also leads to misleading results because economic harm increases at an accelerating rate as temperatures rise.[95]

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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.

[90] Alice Bows & Kevin Anderson, Reframing the Climate Change Challenge in Light of the Post-2000 Emission Trends, 366 Phil. Transactions of the Royal Soc'y A 3863, 3877 (2008).

[91] IPCC, Synthesis Report, supra note 79, at 58 fig.4.1 (2007) (indicating that, under the IPCC's A2 "business as usual" scenario, GHG emissions are expected to *increase* by 30 gigatons CO_2-e between 2000 and 2030).

[92] See McKinsey & Company, Reducing Greenhouse Gas Emissions: How Much and at What Cost? 6 (2007) (citing data from U.S. Energy Information Administration, EPA and other government departments).

[93] Jayant Sathaye et al., Sustainable Development and Mitigation, *in* IPCC, Mitigation, supra note 87, at 706--07.

[94] Nodhaus & Boyer predict a 0.0--0.75% loss for the United States if temperatures rise 2--3°C, but a loss of .75-1.75% for a 3--4°C change in temperature. Nordhaus & Boyer, supra note 11, at 96 fig.4.4. Note that this adjustment to conventional estimates seems small when taken in isolation, but because similar adjustments are appropriate to account for several different weaknesses in existing models, they add up to a substantially higher estimated impact, as shown in Table 3 below.

[95] 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 (2001). 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.

Increases in temperature around a given average will generally have a larger impact on economic well-being than will reductions in temperature. To illustrate this point, return to the estimates in the first paragraph of this sub-section. A 2--3^{o}C rise in temperature is expected to cause a 0--3% loss of GDP while a 5--6^{o}C rise would reduce GDP by 5--10%. Notice that, using the upper end of the relevant ranges, a doubling of the assumed temperature increase from 3^{o}C to 6^{o}C leads to more than a tripling of the predicted economic impact, from 3% to 10%.[96] An accurate estimate of economic impacts, then, requires that the full probability distribution of potential climatic changes be considered.[97]

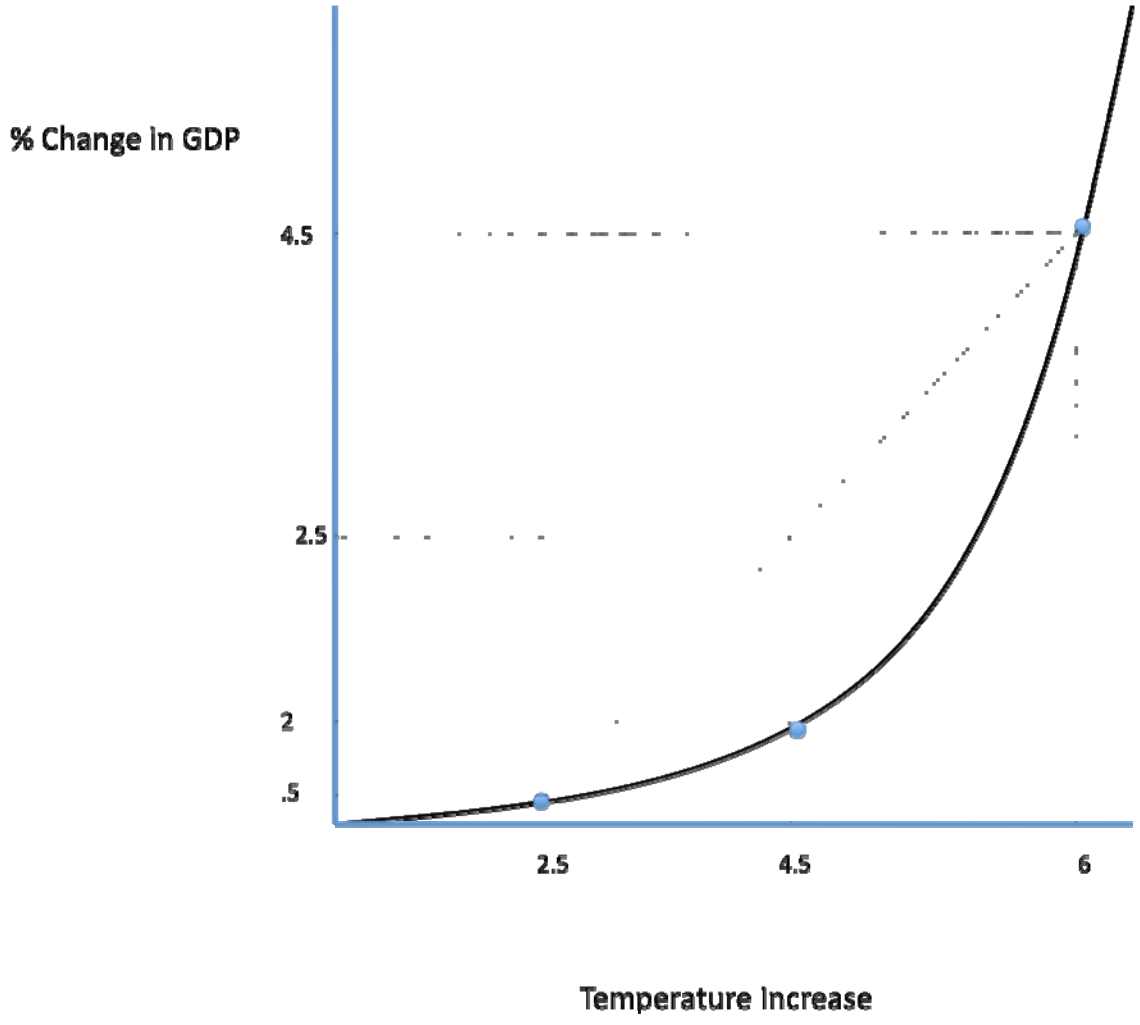
The issue here is that using single point estimates will understate the economic impact of climate change. A better estimate would be to average the estimated economic impact over a range of possible climate outcomes. The figure below illustrates the problem. If one assumes that there is a 50% chance of a 2° increase in temperature, and a 50% change of a 5° increase, what matters for policy purposes is the expected economic impact. If one simply calculates the expected temperature change as a point estimate, the result is an expected increase in temperature of 3.5°. That increase in temperature yields an economic impact of perhaps 3% of GDP. If, by contrast, we average the GDP impact over the possible outcomes, the expected impact is 5%.[98] The proper estimate of harm is the latter---it calculates the expected economic impact.

[96] Stern Review, supra note 11, at 166 fig.6.2 (showing path of Nordhaus & Boyer estimates for global GDP loss with different changes in temperatures).

[97] Working with the average expected change in temperature also ignores the fact that the climate models themselves do not take into account 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 that might amplify the impact of warming. 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 temperatures while the latter addresses the fact that increases in temperature make extreme weather events.

[98] These numbers are used for illustration only. They do not reflect actual estimates.

FIGURE 1



Many (perhaps most) IAMs address this problem by estimating multiple scenarios with alternative climatic assumptions.[99] When these results are deployed in policy discourse, however, it is too often the case that only one of the scenarios is cited, often the mid-range one.[100] Thus while the information about more than one result is available, the natural tendency is to think carefully only about a single point estimate. The result, as shown above, is a tendency to understate the expected economic impact of climate change.[101]

Nordhaus and Boyer estimate a range from 2.5°C to 6°C. The impact on GDP ranges from 0.5 to about 4.5% of GDP.[102] The midpoint temperature increase would be 4.25°C, which Nordhaus and Boyer estimate would have an impact of 2% of GDP.[103] But averaging the impact of a 2.5°C temperature increase (.5% of GDP) and a 6°C (4.5% of GDP) yields an expected economic harm of 2.5% of GDP. For these estimates, then, averaging over economic outcomes rather than climatic outcomes increases the expected harm by 0.5% of GDP.[104]

3. Failure to Account for Catastrophic Events

Because IAM estimates are at their core an extrapolation of existing experiences to expected climatic changes, they are unable to account for the risk of low probability, high magnitude ("catastrophic") climate events.[105] This omission, what Martin Weitzman calls the "fat tail" problem, has the potential to overwhelm all of the effects IAMs currently take into account.[106] There is no doubt, for example that climate change will increase the incidence and the magnitude of floods, droughts, and storms,[107] with potentially serious consequences and high costs.[108] Yet these costs are not adequately considered in most IAMs.[109]

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[99] See, e.g., Nordhaus & Boyer, supra note 11, at 96 (presenting estimates of economic harm over range from 1°C temperature increase to 6°C increase).

[100] 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 & Boyer model); Posting of Jerry Taylor & Peter Van Doren to Cato.org, What Will Climate Change Cost Us? (Dec. 18, 2008), available at http://www.cato.org/pub_display.php?pub_id=9850 (highlighting only mean, median, and modal summary estimates from IAMs). It should be noted, though, that in some secondary analyses, the use of point estimates is occasionally compelled by mathematical limitations. See, e.g., U.S. Environmental Protection Agency, EPA Analysis of the Lieberman-Warner Climate Security Act of 2008 (2008), at 109 (noting confidence intervals could not be accommodated in IAM employed by study, so point estimates from other studies were used).

[101] See id. at 68--98.

[102] Nordhaus & Boyer, supra note 10, at 96 fig.4.4.

[103] Id.

[104] This figure is very sensitive to the particulars of a given study, but it will always be the case that averaging over the economic outcomes will yield a larger (and more appropriate) estimate of harm then will averaging over temperature changes.

[105] See Stern Review, supra note 11, at 170--72.

[106] Martin Weitzman, On Modeling and Interpreting the Economics of Catastrophic Climate Change, 91 Rev. Econ. & Stat. 1, 2 (2009) Weitzman argues that the low-probability, highly uncertain scenarios of very large global average temperature increases (on the order of 10º C or more by 2200) merits further investigation, because the potential economic impacts of these extremely 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 is not negligible and merits more thoughtful consideration in IAMs. Id. at 8--9.

[107] See supra Part II.A.

[108] The costs from natural disasters can be quite large. The damages due to Hurricane Katrina, for example, were estimated by the Congressional Budget Office to be up to $130 billion. Douglas Holtz-Eakin, Macroeconomic and

However, Nordhaus and Boyer do make an effort 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.[110] In contrast to other studies, however, theirs pays close attention to the increased potential for catastrophic risk.[111] 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.[112]

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.[113] Including the other sectors considered by Nordhaus and Boyer (agriculture, sea level rise, other market sectors, health,

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Budgetary Effects of Hurricanes Katrina and Rita 3 (testimony before the Committee on Budget, House of Representatives, Oct. 6, 2005), available at http://www.cbo.gov/ftpdocs/66xx/doc6684/10-06-Hurricanes.pdf. More recent hurricanes have also left astronomical damages. See Press Release, Risk Management Solutions, Inc., RMS Estimates Insured Losses of $4 Billion to $10 Billion for Hurricane Gustav (Sept. 1, 2008), http://www.rms.com/newspress/pr_090108_gustav_industry_loss.asp; Press Release, Risk Management Solutions, Inc., Hurricane Ike Insured Losses Estimated at $7 Billion to $12 Billion (Sept. 17, 2008), http://www.rms.com/newspress/pr_091708_ike_industry_loss.asp. Therefore, if climate change increases the frequency or severity of hurricanes, the costs to the United States could be substantial.

[109] See Warrren et. al., supra note 69, at 6 (concluding, on basis of study of several IAMs, that "models have various ways of simulating damage due to rapid or catastrophic climate change, but all are necessarily simplistic"); Megan Ceronsky et al., Checking the Price Tag on Catastrophe: The Social Cost of Carbon Under Non-Linear Climate Response (Hamburg University and Centre for Marine and Atmospheric Science, Working Paper FNU-87, 2005), available at http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/catastrophewp.pdf (investigating cost implications of three non-linear mechanisms that could dramatically compound climatic effects: change in thermohaline circulation, release of methane clathrates, and climate sensitivities at high levels of temperature increases; and criticizing mainstream models for not doing same).

[110] The model we refer to is the RICE model (Regional dynamic Integrated model of Climate and the Economy) developed in Nordhaus & Boyer, supra note 11.

[111] Nordhaus & 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 get some 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 use additional survey data to estimate people's willingness to pay to avoid the risk resulting from a 30% loss of global GDP. Nordhaus & Boyer, supra note 11, at 87--89.

Nordhaus & 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 & Boyer (i.e., a 30% GDP loss) may not represent anything near the true ceiling for climate change-induced global catastrophe.

[112] Id. at 91 tbl 4.10. The impact on the United States is 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 (1.9%). Id.

[113] Id.

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%.[114]

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.[115] 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.

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.[116] 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.[117] 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.[118] The only leading study to make a serious attempt to quantify loss of biodiversity is the Stern Review.[119] 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.[120] 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. The most obvious are perhaps the ethical issues connected with human activity leading to large-scale extinctions. 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

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[114] Id. at 96 fig.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. 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.

[115] Id.

[116] See Richard S.J. Tol et. al., How Much Damage Will Climate Change Do? Recent Estimates, 1 World Econ. 179, 191 (2000) [hereinafter Tol et al., *Damage*] (stating "[n]on-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").

[117] See Juliet Eilperin, Study Says Polar Bears Could Face Extinction, Washington Post, Nov. 9, 2004, at A13.

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

[119] See Stern Review, supra note 11; cf. Tol, Climate Change Impact, supra note 20 (pointing out that no major economic studies of climate change impacts adequately address biodiversity).

[120] See, e.g., Nordhaus & Boyer, supra note 11, at 85--87 (noting "rather wild" economic valuations of species extinction and serious need for quantitative work in area).

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.[121] To illustrate, a 1997 study estimated the total value of ecosystem services to be at least $33 trillion.[122]

Recent studies have produced information that reduces the uncertainty regarding the ecological effects of climate change. One such study found what amounts to patterns of habitat loss due to global warming as species move northward and upward in search of cooler climates.[123] This study found that the range limits of species have shifted on average 6.1 km. toward the poles per decade.[124] Utilizing these numbers, another study estimated that 15--37% of all species will be extinct by 2050 due to habitat loss attributable to "climate unsuitability."[125] This finding is consistent with the most recent IPCC report which states that "[a]pproximately 20--30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5--2.5^{o}C."[126] The estimates become 40--70% if temperature increases exceed 3.5^{o}C.[127]

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 million, or about 1.8 times the value of global GNP at the time.[128] The portion of this value attributable solely to biodiversity is difficult to estimate as many ecosystem services are of mixed biological and non-biological origin.[129] Another 1997 study limited their valuation of ecosystem services to those in which biological sources contribute. It estimated the value of biodiversity to be $389 billion annually for the US and $3.57 trillion annually for the world.[130]

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[121] 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).

[122] Id. at 259; Gordon C. Rausser & Arthur A. Small, Valuing Research Leads: Bioprospecting and the Conservation of Genetic Resources, 108 J. Pol. Econ. 173, 192 (2000) (citing work of Simpson et al., which attempts valuation). 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 one-quarter to one-half of species worldwide---overwhelms the argument that the value of any single species to new discoveries is negligible. Amy B. Craft & R. David Simpson, The Value of Biodiversity in Pharmaceutical Research with Differentiated Products, 18 Env. & Res. Econ. 1, 2 (2001).

[123] Camille Parmesan & Gary Yohe, A Globally Coherent Fingerprint of Climate Change Impacts Across Natural Systems, 421 Nature 37 (2003).

[124] Id. at 38.

[125] Chris D. Thomas et al., Extinction Risk from Climate Change, 427 Nature 145, 145 (2004) (finding figure of 15% if there is 0.8--1.7ºC increase in global temperature, and 37% if increase in global temperature exceeds 2.0ºC).

[126] IPCC, Impacts, supra note **Error! Bookmark not defined.**, at 11.

[127] Id.

[128] See Costanza et al., supra note 121, at 254 (calculating figures in 1994 U.S. dollars).

[129] See Hsiung & Sunstein, supra note 118, at 1715--1716. Non-biological services include, for example, ozone in the atmosphere for UVB protection and the weathering of rock in the soil formation process.

[130] Daniel Pimentel et al., Economic and Environmental Benefits of Biodiversity, 47 BioScience 747, 748 (1997), *cited in* Hsiung & Sunstein, *supra* note 118. Pimental et al.'s numbers were calculated primarily from the products of ecosystem services, or their human-generated substitutes, that pass through markets, such as waste disposal, soil,

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.[131] 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 as $539--1322 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.[132]

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.[133] 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.[134] 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% GDP.[135] 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% GDP.[136]

These are dramatic estimates, but they should nevertheless be viewed as conservative. The authors used a low estimated temperature change range of 0.8°C--1.7°C and a high range of greater than 2°C.[137] If the actual temperature increase were much higher---say 5°C---then the impact on biodiversity could be far worse.[138] The likelihood that the study's results understate the actual costs is further increased by the fact that the models they rely on are themselves 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.[139]

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nitrogen fixation, pollination, biocontrol of pests, crop and livestock breeding, wild food production, biotechnology, and pharmaceuticals from plants. Id. at 748 tlb.2.

[131] Hsiung & Sunstein, supra note 118, at 1715--18.

[132] Id. at 1718--19. The low range in their estimates corresponds to a 0.8--1.7ºC increase in global temperature, and the high range corresponds to an increase in global temperature that exceeds 2.0ºC.

[133] Id. at 1715, 1722.

[134] Id. at 1708, 1730.

[135] *Id.* at 1734 (estimate excludes nonvertebrate life and fish; low range corresponds to 0.8--1.7ºC increase in global temperature, and high range corresponds to global temperature increase that exceeds 2.0ºC).

[136] Id. (low range corresponds to 0.8--1.7ºC increase in global temperature, and high range corresponds to global temperature increase that exceeds 2.0ºC).

[137] Id. at 1703 n.37.

[138] Id. at 1737.

[139] See Costanza, supra note 121, at 253 (noting their estimate represents a 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 Warming, Species Loss, and the Use and Abuse of Quantification in Climate Change Policy Analysis, 155 U. Pa. L. Rev. 1901, 1907 (2007) (arguing these numbers overvalue species because of possibility that many substitute species could take place of extinct species and provide needed services). An example of the complex interactions not accounted for by the above numbers is if a species near the base of the food chain, such as phytoplankton, goes extinct, many other species will be affected and could face extinctions because of that one species. 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.

The impact of species extinctions on human health and the pharmaceutical industry in particular is illustrative of the magnitude of these costs. In terms of commercial potential, approximately 60% of anticancer and anti-infective drugs are either derived from natural products or are modeled after them.[140] To give just one example, coral reefs are especially vulnerable to changes in water temperature and have limited adaptive capacity.[141] There are credible claims that coral reefs are home to more species than have already been discovered in the rainforests.[142]

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.[143]

In addition to unexplored potential, some species which currently provide important services to human populations may be threatened by climate change. Rosy Periwinkle, the source of two anti-cancer drugs,[144] is native to eastern Africa; the Himalayan yew tree is the source of a third anti-cancer drug.[145] Both native habitats are threatened by climate change.[146] 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 the precise cost or harm to the ecosystem is difficult to estimate, there is strong evidence 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 biodiversity 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 most studies calculate costs on a sector-by-sector basis, summing the impact on individual sectors to arrive at an overall estimated aggregate impact.[147] This approach, though understandable given the complexity of attempting to consider all sectors simultaneously, understates the impact of climate change because it fails to account for a variety of interactions among the examined sectors. It does not account, for example, for

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[140] Walther H. Adey, Coral Reef Ecosystems and Human Health: Biodiversity Matters!, 6 EcoSystem Health 232--33 (2000).
[141] IPCC, Impacts, supra note 41, at 19.
[142] Adey, supra note 140, at 233.
[143] Craft & Simpson, supra note 122, at 2.
[144] Rausser & Small, supra note 122, at 178 (noting rosy periwinkle's use for anti-cancer drug vincristine and vinblastine)
[145] Id.. (noting yew's use for taxol).
[146] See supra note 67 and accompanying text (noting Africa and Asia will be among hardest hit by climate change); see also infra notes 211--212 and accompanying text (discussing projected harm to Himalayan region).
[147] See, e.g., Robert Mendelsohn & Michael E. Schlesinger, Climate-response Functions, 28 Ambio 362, 363 (1999); Mendelsohn et al., Country-Specific, supra note 11, at 557; Robert Mendelsohn & Larry Williams, Comparing Forecasts of the Global Impacts of Climate Change, 9 Mitigation & Adaptation Strategies for Global Change 315 (2004); Tol, Dynamic Estimates, supra note 12, at 137--45; Nordhaus & Boyer, supra note 11, at 10--12.

the fact that a substantial melting of the Sierra snowpack might have consequences for water shortages in the western United States.[148] Nor does it 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.[149]

To illustrate, we draw on the leading work of Robert Mendelsohn, who in several co-authored 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.[150]

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.[151] He identifies several sectors (agriculture, 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.[152] 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), carbon dioxide concentration, and a set of additional parameters (e.g., land area, economic growth, length of coastline).[153] Mendelsohn then sums the sectoral impacts to produce an aggregate impact for a country. To produce a multi-country aggregate outcome, he sums the country-level market impacts.[154]

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[148] See Smith et al., supra note 70.

[149] See Tol et. al., Damage, supra note 116, at 192 (pointing out cross-sectoral, compounding spillovers may be understated by current models). 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 modeling 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 11, at 172--73.

[150] Mendelsohn et al., Country-Specific, supra note 11.

[151] Mendelsohn's different papers use different models, reflecting advances in the models of climate change. Mendelsohn et al., Country-Specific, supra note 11 at 555 (using two models: UIUC11 model from Michael E. Schlesinger & Mikhail Verbitsky, Simulation of Glacial Onset with a Coupled Atmospheric General Circulation/Mixed-Layer Ocean-Ice-Sheet/Asthenosphere Model, 2 Paleoclimates, Data & Modeling 179 (1996); and UIUC2 from Michael E. Schlesinger et al., "Modeling and Simulation of Climate and Climate Change, Past and Present Variability of the Solar-Terrestrial System: Measurements, Data Analysis and Theoretical Models," *in* Proceedings of the International School of Physics 'Enrico Fermi', 25 June--5 July 1996 (1997)); Mendelsohn & Williams, supra note 147, at 316 (using five models: CGCM1, from George Boer et al., A Transient Climate Change Simulation with Greenhouse Gas and Aerosol Forcing: Projected Climate for the 21st Century, 16 Climate Dynamics 427 (2000); CSIRO, from Hal Gordon & Siobhan O'Farrell, Transient Climate Change in the CSIRO Coupled Model with Dynamic Sea Ice, 125 Mon. Weather Res. 875 (1997); CCSR, from Seita Emori, Coupled Ocean-atmospheric 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) (United Kingdom Meteorological Office, Climate Research Technical Note 71, 1996); and HAD3, from Chris 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)).

[152] Mendelsohn et al., Distributional Impact, supra note 11, at 161.

[153] Id. at 161, 163.

[154] Id. at 161.

These models omit economic effects that implicate multiple sectors.[155] 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 carbon dioxide levels.[156] The impact of climate change on energy prices, however, will not be reflected in these agricultural estimates; nor will the impact on water resources.[157] What Mendelsohn is attempting 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.

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.[158] 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.[159]

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, and perhaps substantially. 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. This means that 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

[155] The climate-response functions do take into account the fact that the economy will grow over time, but it ignores the possibility that harm in one sector may impact other sectors or that harm abroad could affect the United States.
[156] Mendelsohn et al., Country-Specific, supra note 11, at 558 tbl.1.
[157] See id.
[158] Id.. Even this assumption could be challenged, however. As temperatures rise, some activities---agriculture, for example---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.
[159] See Part II.B.1.

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.

Fankhauser and Tol estimate the impact of such a reduction in saving and investment[160] 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.[161] 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

We now turn to a different problem that leads existing models to understate the likely costs of climate change: overlooking international spillovers. Virtually all models generated to date have focused on how climate change will impact 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.

Consider that when calculating the cost of climate change to the United States, observers generally examine only the direct costs of a change in the environment, and that environment is understood to be geographically local.[162] That is, they consider the impact of an increase in temperature on agriculture or flooding *in the United States*. Yet this approach ignores the interdependence of the United States with the rest of the world.[163] It hardly needs emphasizing

[160] Samuel Fankhauser & Richard S.J. Tol, On Climate Change and Economic Growth, 27 Resource & Energy Econ. 1, 3--6 (2005).
[161] Id. at 13.
[162] Although we are concerned in this article 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 global warming 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.
[163] 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

that in this era of globalization the economic well-being and security of the United States relies heavily on political and economic stability 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 discussed above predicts that a 6°C warming would reduce European GDP by about 17%.[164] 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.[165]

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: 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 these models are used in policy making, it is critical to keep their 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 United States? None of these scenarios is particularly far-fetched. 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 of this type is not taken into account by existing IAMs.

U.S. that would come from the very fact of serious economic harms in other nations." Sunstein, Divergent Reactions, supra note 49, at 525 n.113.

[164] Nordhaus & Boyer, supra note 11, at 96 fig.4.4.

[165] There are other synergistic and multiplier effects that might arise if one considers the possibility of both cross-sectoral *and* international spillovers (see infra Part II.B.5; Part III). The 2º 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 2º 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.

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 is typically thought.

The analysis below focuses on a number of areas in which the United States likely will suffer negative consequences from the impacts that climate change is projected to have more directly on other states. These include a host of potential economic spillovers, as well as burdens that may arise due to multiplied national security threats and 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 these 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. Even if this estimate overstates the actual impact, many parts of the world stand to be badly affected which would create 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 will affect American interests and require U.S. investment of resources.

A. Economic Spillovers

Although the costs of reducing GHGs will be significant,[166] the cost of not reducing them may well be even greater. There is widespread, if not universal, agreement that climate change will likely have a large impact in many parts of the world, including relatively wealthy Europe, where rising seas are projected to bring severe flooding, land loss, salinisation of groundwater, and the destruction of physical infrastructure.[167] It is possible that up to 20% of existing coastal wetlands in Europe may disappear by 2080.[168] 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.[169] Also projected is an increase in extreme weather events, which will induce more frequent flooding.[170] 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 percentage of river basin areas in the "severe stress" category will increase from 19% today to approximately 35% by 2070.[171] The number of people living in water-stressed areas in the EU15 and Switzerland and Norway is projected to increase from 16 million today to 44 million.[172] 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 the west, stress there could certainly spread.

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[166] See infra Part IV.

[167] IPCC, Impacts, supra note 41, at 551; see, e.g., Robert J.N. Devoy, Coastal Vulnerability and the Implications of Sea-Level Rise for Ireland, 24 J. Coastal Research 325 (2007) (discussing impacts for Ireland).

[168] IPCC, Impacts, supra note 41, at 551.

[169] Id. at 549--50.

[170] Id. at 556.

[171] B.T. Lehner, P. Doll Heinrichs, & J. Alcamo, EuroWasser – Model-Based Assessment of European Water Resources and Hydrology in the Face of Global Change 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.

[172] D. Schröter et. al., Ecosystem Service Supply and Vulnerability to Global Change in Europe, 310 Science 1333 (2005).

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.[173] 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.[174] In Latin America, water stress and extreme loss of biodiversity are expected in fragile ecosystems.[175]

Existing discussion of climate change tend to assume that the U.S. 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.[176] Imports into the United States were valued at $2.2 trillion, or 17% of GDP.[177] Beyond these trade statistics, the United States and private parties based in the United States are integrated into the global financial community---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 so on, 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 fresh water in the Persian Gulf region will it take to cause major disruption in the oil supply? The price and availability of oil is critical to the American economy, but it is difficult to predict how supply will be affected by climate change.[178] Will Europe adopt protectionist strategies in reaction to the pressures generated by climate change? Again, this 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.

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[173] IPCC, Impacts, supra note 41, at 471.
[174] Id. at 435.
[175] Id. at 583.
[176] U.S. Census Bureau, Foreign Trade Div., U.S. Trade in Goods and Services, Annual Totals, 1960--Present (Balance of Payments (BOP) Basis), available at http://www.census.gov/foreign-trade/statistics/historical/gands.txt. (2009) (data for 1960--2008) [hereinafter Census---U.S. Trade (BOP Basis)]; GDP from World Development Indicators, World Bank Group, http://www.worldbank.org/data/onlinedatabases/onlinedatabases.html [hereinafter World Bank Indicators].
[177] Id.
[178] See infra Part III.B (discussing enhanced security risks caused by climate change and associated with American demand for oil).

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 impacts such as these into account.

1. Shocks to International Trade

As already mentioned, the United States is part of the world economy, and one reflection of this integration is the substantial amount of international trade that Americans undertake. As foreign states are affected by climate change American trading interests are 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 are affected. The effect of climate change on both imports and exports may be aggravated if states (including the United States) respond to the challenge of climate change with trade protectionism.

For each of the above markets there is reason to expect significant supply shocks in the short term. Imagine, for example, how supply might be affected by severe economic and social dislocation in South and South-East Asia caused by flooding, drought, and extreme weather events.[179] 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 that these shocks may last beyond the short-term. First, because climate change is not a one-time event but rather is 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 a long 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 20, 30, or 50 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 such a long period of time it may not be possible to rebuild the productive capacity of the continent, in which case the above supply-shock would have significant long-term consequences for the United States.

[179] See infra notes 210--214 and accompanying text.

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[180] and so may be unable to build up entirely new industries. Moreover, given the vast differences in population, even if the environmental conditions in Latin American 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 would wreak havoc on production world-wide 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.[181] 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.[182] 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 would not be a short-term issue, but rather could represent a permanent or near-permanent change. Any adaptation – which would require massive population movements and new infrastructure, not to mention conflict over resources – to this change would 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

[180] Supra note 175.

[181] 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 50 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 input) are scarce the productivity of labor is reduced and prices (though not wages) rise.

[182] See infra notes 210--214 and accompanying text.

might arise over water resources in the Middle-East or Nigeria, which affects the supply of oil to the rest of the world, including the United States.[183] The result would be a long-term increase in the cost of energy, which can certainly be expected to harm the American economy.

A similar dynamic could occur if global food production is badly affected by climate change. Food production is quite likely to be negatively affected by climate change, at least for a period of decades.[184] 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 this will require both time and money.

The second reason to expect a fall in global food production 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 reveals the amount of water available annually to a region, and this is a critical variable for agriculture. It 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, when an additional water supply is needed.

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 climate change on foreign states. This, in turn, will harm the American 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 2 shows the contribution of export to the U.S. economy in recent years.

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[183] See infra notes 226--229 (describing effects of climate change on Nigeria).
[184] See, e.g., supra note 174 and accompanying text (discussing food shortages in Africa).

Table 2: U.S. Exports as Percentage of GDP[185]

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[186]	1457
2007	11.6[187]	1646
2008	12.9[188]	1843

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.[189] 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 realization are on

[185] World Development Indicators, World Bank Group, http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20398986~menuPK:64133163~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html [hereinafter World Bank Indicators].

[186] Value of exports for 2006 from U.S. Census Bureau, Foreign Trade Div., U.S. Trade in Goods and Services, Annual Totals, 1960 – Present (Balance of Payments (BOP) Basis), available at http://www.census.gov/foreign-trade/statistics/historical/gands.txt (2009) (data for 1960--2008) [hereinafter Census – U.S. Trade (BOP Basis)].

[187] Value of exports for 2007 from Census – U.S. Trade (BOP Basis).

[188] Value of exports for 2008 from Census – U.S. Trade (BOP Basis).

[189] Scott C. Bradford, Paul L.E. Grieco & Gary C. Hufbauer, The Payoff to American from Global Integration, *in* The United States and the World Economy: Foreign Economic Policy for the Next Decade (C. Fred Bergsten, ed. 2005) [*hereinafter*, *Payoff to America*]; Gary C. Hufbauer, Answering the Critics: Why Large American Gains from Globalization are Plausible, Peterson Institute for International Economics, Speeches, Testimony, Papers (2008); Drusilla K. Brown, Alan V. Deardorff & Robert M. Stern, Computational Analysis of Multilateral Trade Liberalization in the Uruguay Round, *in*, The World Trade Organization: Legal, Economic and Political Analysis (2005); L. Josh Bivens, The Gains from Trade: How Big and Who Gets Them?, Economic Policy Institute Working Paper, Dec. 17, 2007.

the order of $1 trillion.[190] Because this represents a permanent increase in national income, the gain is enjoyed every year.[191] 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 dollars, which represents slightly more than one quarter of one percent of U.S. GDP in 1995.[192]

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.[193] 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, consider how exports have been affected by the recession of 2009--2010:

Table 3: U.S. Monthly Exports[194]

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

[190] Bradford, Grieco & Hufbauer, Payoff to America, supra note 189, at 68.
[191] Id.
[192] Brown et al., supra note 189, at 31; GDP amount from World Bank Indicators, supra note 176.
[193] Id. at 28 tbl.1.
[194] U.S. Census Bureau, Foreign Trade Statistics, Foreign Trade Div., U.S International Trade in Goods and Services, FT900: U.S. International Trade in Goods and Services, http://www.census.gov/foreign-trade/Press-Release/current_press_release/exh1.pdf.

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 2 shows, this would not be out of line with fluctuations in imports that we have seen over the last 15 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 $19 billion (and increase in imports of $18 billion).[195] 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. In 2003 the United States had just over $1 trillion in exports.[196] 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.[197] 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 change-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 continue 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 would likely shrink.

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[195] See supra notes 192--193.
[196] See Census---U.S. Trade (BOP Basis), supra note 176.
[197] See U.S. Dept. of Commerce, Bureau of Economic Analysis, News Release, June 17, 2009, http://www.bea.gov/newsreleases/international/transactions/2009/pdf/trans109.pdf.

Of course financial markets matter for more than simply bringing the current account into balance. Private parties in the United States invest abroad and would 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, Exxon-Mobil, 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 products.[198] 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.[199] Losing a significant share of those profits due to economic weakness abroad would quite clearly 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. Similar global slowdowns could be triggered in the future by climate change 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.[200] In the last few years, however, a number of important studies of the connection between climate and security have emerged from academic, government, and non-government 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.[201] 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.[202] 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 resources, increase the threat of terrorism, disrupt trade,

[198] See Part III.A.1.

[199] U.S. Dep't of Commerce, Bureau of Econ. Analysis, National Income and Product Accounts Table, Tbl 6.16D. (2009), http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=228&Freq=Qtr&FirstYear=2006&LastYear=2008.

[200] Jon Barnett, Security and Climate Change 2 (Tyndall Center for Climate Change Research, Working Paper No. 7, 2001) (citing small number of studies making some connection between climate change and national security).

[201] Id.

[202] Nat'l Intelligence Council, The National Security Implications of Global Climate Change Through 2030 (2008) (classified Report unavailable to public) [hereinafter NIC REPORT].

and produce millions of refugees, all of which would seriously affect U.S. national security interests.[203]

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"[204] because it will have serious impacts on many parts of the world of strategic importance to the United States, which will create significant and costly spillover effects.[205] The consistent message is that climate change is likely to exacerbate political instability around the world as weak or poor governments struggle to cope with its impacts. In especially hard hit nations, deteriorating economic conditions could lead to the fall of governments, creating, at worst, safe havens and, at best, fertile recruitment 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.[206] Climate change also threatens to interrupt the free flow of trade in critical resources such as oil and 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, and even if it does so, it 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

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[203] Id. 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.

[204] NIC Report, id.; see also National Security Implications of Global Climate Change: Joint Hearing Before the H. Select Comm. on Energy Independence and Global Warming and the H. Permanent Select Comm. on Intelligence, 110th Congress (June 25, 2008) (statement of Thomas Fingar, NIC Chair) [hereinafter Fingar Statement], available at http://globalwarming.house.gov/tools/2q08materials/files/0069.pdf (stating that "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 and International Studies (CSIS) & Ctr. for a New American Security (CNAS), The Age of Consequences, The Foreign Policy and National Security Implications of Global Climate Change (Kurt Campbell et al. eds., 2007), available at http://www.cnas.org/climatechange [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"); Ctr. for Naval Analysis, National Security and the Threat of Climate Change (2007), available at http://www.securityandclimate.cna.org/; Joshua W. Busby, Climate Change and National Security: An Agenda for Action, at 4--10 (Council on Foreign Relations Special Report No. 32, Nov. 2007) (describing resulting "spillover security effects on the United States" of climate change on vulnerable locations); John Podesta & Peter Ogden, The Security Implications of Climate Change, 31 The Washington Quarterly 115 (2007--2008) ("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"); Barnett, supra note 200, at 6, 8, (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 Science Info. Network, Working Paper 2008), available at http://www.ciesin.columbia.edu/documents/Climate_Security_CIESIN_July_2008_v1_0.ed070208.pdf.

[205] "We judge that the 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." Fingar Statement, supra note 204, at 4. The cost of addressing such problems will only rise over time as they become more acute. "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." Podesta & Ogden, supra note 204, at 116.

[206] See infra Part III.C.

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.[207] We offer some examples below.[208]

In Asia, warming global temperatures are projected to result in reduced agricultural productivity, stresses over water supplies, and increased risk of flood, drought and extreme weather events.[209] Heavily populated areas in South Asia are expected to be hard hit by climate change.[210] 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 fresh water in parts of Asia and South Asia.[211] Many glaciers in these areas could, at current rates of global warming, disappear within the coming decades, which 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.[212] 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 is likely to be offset by growing populations and consumption in the region, leading ultimately to considerable stress on water supplies.[213] In addition, agricultural output is expected to drop between 2.5 and 10 percent in South, Southeast and East Asia, putting as many as fifty million people at risk of hunger as soon as 2020.[214]

These impacts likely would 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, will find the fifth of its country comprised of

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[207] Consistent with the leading assessments, we adopt a broad definition of "national security". See Fingar Statement, supra note 203, at 3, describing the NIA definition: "We first considered if the effects would directly impact the US homeland, a US economic partner, or a U.S. ally. We also focused on the potential for humanitarian disaster, such that the response would consume US resources. We then considered if the result would degrade or enhance one of the elements of national power (Geopolitical, Military, Economic, or Social Cohesion), and if the degradation or enhancement, even if temporary, would be significant."

[208] 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 204, at 12, 14, 15, 43, 51..

[209] IPCC, Impacts, supra note 41, at 471.

[210] As the IPCC states, "coastal areas, especially heavily populated mega-delta regions in South, East, and Southeast Asia, will be at greatest risk due to increased flooding." Intergovernmental Panel on Climate Change, Summary for Policymakers, *in* IPCC, SPM, Impacts, supra note 64, at 13.

[211] Nearly 70% of the world's freshwater is locked in glaciers and icebergs, which are already melting because of global warming. Id.

[212] 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. IPCC, Impacts, supra note 41, at 493.

[213] See Fingar Statement, supra note 204, at 9 (projecting between 120 million and 1.2 billion people will experience water stress).

[214] Id. at 8--9.

low-lying regions, uninhabitable.[215] Bangladesh has already become a security concern for the United States as the impact of Islamic extremism has grown. To illustrate, in 2005, the number of terrorist attacks in Bangladesh exceeded the number from the prior five years combined.[216] The effects of population displacement from flooding, along with additional economic stress in an already unstable region, are likely to create fertile grounds for terrorist groups.[217]

China, a rising international power of tremendous strategic importance to the United States, also stands to be hard hit by climate change.[218] The direct impact of climate change on China likely will be felt in reduced water supply in the North, extreme weather events in the South, and sea level rise that threatens hundreds of millions of people in densely populated coastal regions.[219] China faces serious indirect costs, as well. China increasingly depends heavily on imports from Africa and 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.[220] 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, and depends on a set of events triggering other events, but it is certainly plausible. And although it is hard to predict the impact of instability in China on the United States, it is fair to say that the effects could be considerable and costly, given China's military and economic might, and its capacity to make trouble in a volatile region.

India also stands to be hard hit from climate change, creating important potential spillovers for 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.[221] 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 counter-weight to a nuclear Pakistan.[222]

The impact of climate change on many nations in Africa is projected to be especially severe, largely because of the continent's relative dependence on agriculture, the fact that it straddles the equator, and its weak political institutions. With high risk of impact and low adaptive capacity, Africa stands to fare badly as global temperatures increase.[223] One might take the view that much of the suffering in Africa will not affect the United States unless we are

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[215] Podesta & Ogden, supra note 204, at 117; Stern Review, supra note 11, at vii.

[216] Sudha Ramachandran, The Threat of Islamic Extremism to Bangladesh (PINR, July 27, 2005), available at http://pinr.com/report.php?ac=view_report&report_id=334&language_id=1.

[217] "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." Podesta & Ogden, supra note 204, at 118.

[218] See China Sees Climate Impacts Ahead, BBC News, http://news.bbc.co.uk/2/hi/science/nature/6585775.stm/

[219] Id.

[220] Id. at 41--2.

[221] 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. Podesta & Ogden, supra note 204, at 117.

[222] Any number of contemporary news stories could be used to illustrate the fragility of Pakistan. See, e.g., Jane Perlez & Pir Zubair Shah, Truce in Pakistan May Mean Leeway for Taliban, N.Y. Times, Mar. 5, 2009, available at http://www.nytimes.com/2009/03/06/world/asia/06swat.html?scp=1&sq=pakistan%20peshawar&st=cse (discussing influence of Taliban in Pakistan and government efforts to appease that group).

[223] See IPCC, Impacts, supra note 41, at 435.

inclined to support humanitarian relief,[224] yet this overlooks the increasing strategic importance of the continent. Africa possesses critical natural resources over which there is increasingly intense competition;[225] and various countries in Africa pose a risk to the United States as current of 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.[226] Disruptions in supply would have a significant impact on the world oil market.[227] Nigeria already faces severe challenges as rebel groups undertake attacks in an effort to disrupt oil production.[228] 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 majority of which are under the age of thirty.[229]

In sum, Nigeria is an important oil producing country, already engaged in a violent struggle with insurgents, which plausibly faces 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, but 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 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, sometimes with catastrophic results. We have recently seen Kenya, once an example of African stability, descend into chaos.[230] Even countries that have enjoyed relative economic success remain vulnerable to back-sliding as a result of corruption and violence.

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[224] It bears repeating once again that in the face of large-scale human suffering and deprivation the U.S. may have reason to take action in an attempt to help Africans cope with climate change. The morality of refusing to assist people in dire need is difficult to defend. Nevertheless, because this Essay is intended to address the narrow self-interest of the U.S., it does not dwell on the potential catastrophe that is climate change in Africa except inasmuch as it impacts the U.S.

[225] For example, Nigeria alone supplies 1/5 of U.S. oil imports.

[226] The United States imports several thousand barrels of oil a day from Nigeria, making Nigeria the fifth largest exporter to the United States. Energy Information Administration, Crude Oil and Total Petroleum Imports Top 15 Countries, at http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/company_level_imports/current/import.html (last visited July 20, 2009).

[227] Nigeria is the eighth largest oil exporter in the world. Jad Mouwad, Growing Unrest Posing a Threat to Nigerian Oil, Apr. 21, 2007, N.Y. Times, available at http://www.nytimes.com/2007/04/21/business/worldbusiness/21oil.html.

[228] Id.

[229] Cent. Intelligence Agency, The World Factbook, available at https://www.cia.gov/library/publications/the-world-factbook/geos/NI.html.

[230] Kenya is among Africa's most "influential and capable countries" along with South Africa, Nigeria, Ghana and Senegal. See Council on Foreign Relations, More than Humanitarianism: A Strategic Approach Toward Africa, Independent Task Force Report No. 56, at 11 (Anthony Lake & Christine Todd Whitman, Chairs, 2006).

Against this backdrop, climate change is expected to reduce dramatically supplies of water and food in Africa,[231] 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 that might be exploited by terrorist groups.[232] 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%. Losses among key professional groups are extremely high.[233] And there is a generation of AIDS orphans that might be vulnerable to radicalization.[234] Climate change would not only exacerbate the impact of AIDS to the extent it further incapacitates weak governments, but it is projected to add to the mix new diseases that might also create 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 population in the region more than doubled between 1970 and 2001 and it is expected to double again by 2050.[235] The Middle East and adjacent North Africa have 6.3% of the world's population, but only 1.4% of its renewable fresh water.[236] The large majority (about 75%) of the water in the region is in Iran, Iraq, Syria, and Turkey.[237] Other states in the region, including Kuwait, Libya, and Saudi Arabia have very little fresh water within their borders.[238] With the exception of Turkey, every country in the region depends on water that originates outside its borders.[239] Climate change will likely adversely affect surface availability of major rivers in the region, like the Euphrates and the Tigris, which will swell in the winter and decrease in the spring.[240] The danger here is that competition for freshwater will exacerbate existing regional tensions and lead to perhaps violent

[231] IPCC, SPM, Impacts, supra note 64, at 13. "In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020."
[232] It is interesting to note that perhaps the greatest risk to the U.S. 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, 12 Security Studies 43, 66 (2002).
[233] CFR Africa Report, supra note 230, at 62--3.
[234] Id. at 60.
[235] Id.
[236] Farzaneh Roudi-Fahimi, Liz Creel, and Roger-Mark De Souza, Finding the Balance: Population and Water Scarcity in the Middle East and North Africa (Population Reference Bureau Policy Brief, 2002), available at http://www.prb.org/pdf/FindingTheBalance_Eng.pdf.
[237] Id.
[238] Id.
[239] Pdesta & Ogden, supra note 204, at 122.
[240] See IPCC, Impacts, supra note 41, at 483.

conflicts.[241] This is entirely plausible given the history of serious conflicts over precious water resources in the region.[242].

Even in relatively stable parts of the world where the United States finds close allies, climate change can exacerbate or create national security threats. For example, there is little doubt that Europe stands to be adversely affected by climate change, as noted above, but the extent to which this impact will affect the United States depends on one's assumptions about the strength and stability of European institutions.[243]

Because Europe is wealthy and stable, it seems likely that it can avoid significant violence and unrest under any but the most severe climate change scenarios. Yet the United States reasonably might concerned about the potential for climate change impacts to contribute to economic and political unrest. Given current tensions between immigrant and native populations across Europe, it is entirely plausible that economic downturns could lead to increased political volatility. The United States already has concerns about the rise of extremist groups within Europe, and economic and social stress would magnify that risk.

Moreover, American security is positively affected by strong, confident, and outward-looking European allies. Europe was a critical American ally during the Cold War, and is similarly essential to American efforts to combat terrorism and negotiate with the Arab world. Diminution in European willingness or ability to participate in the effort, and increases in the threat posed by terrorism from within Europe, both raise concerns for American security.

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 that 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 fall of 2008, for example, the Congressional Record Service estimated that the Iraq war accounts for approximately $657 billion in congressionally approved spending.[244] 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

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[241] See Press Release, UNEP, Fast Melting Glaciers from Rising Temperatures Expose Millions in Himalaya to Devastating Floods and Water Shortages, UNEP ROAP News Release 07/10 (June 5, 2007), available at http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=512&ArticleID=5600&l=en.

[242] 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.

Water allocation also remains a contentious issue in Israel-Palestinian negotiations and in Israel-Syrian negotiations over the Golan Heights. Israel remains highly dependent on water from outside its borders. Podesta and Ogden, supra note 204.

[243] IPCC projections estimate a 20% decline in both water availability and crop yields in Southern Europe (associated with a 2^{o}C increase in global temperatures).[243] The percentage of the continent under high water stress will increase from 19% today to 35% by 2070. This implies an increase in the number of people affected from 16 million to 44 million.[243] In addition, Europe is projected to experience more droughts, heat waves, and flooding.

[244] Amy Belasco, Cong. Res. Serv., The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11 (2008), available at http://www.fas.org/sgp/crs/natsec/RL33110.pdf.

cost of caring for injured veterans and the opportunity cost of having so many people away from their normal lives.[245] One estimate of all the relevant costs of the war concludes that the war will ultimately cost 3 trillion dollars: an amount equal to about 20--25% of U.S. annual GDP.[246] In other words, if climate change can be expected to cause one additional conflict like the Iraq war every 25 years, putting aside all other costs related to security threats, then the expected cost of climate change in on the order of 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 global warming 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 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.[247] 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.[248]

In order to determine the impacts of migration on the United States, at this point we will ignore human suffering outside the United States, no matter how acute.[249]

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 is, for example, the story of migration from East to West within the United States. Yet even this form of migration can generate social stress.

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 settled in Indian

[245] Id.
[246] Joseph Stiglitz & Linda Bilmes, The Three Trillion Dollar War: The True Cost of the Iraq Conflict (2008).
[247] See supra Part II.A.
[248] "Mass movements of people across the world are likely to be one of the most dramatic effects of climate change in the coming century." Michael McCarthy, Climate Change 'Will Cause Refugee Crisis', CommonDreams.org, Oct. 20, 2006, http://www.commondreams.org/headlines06/1020-05.htm.
[249] In this section, we consider policy responses from the United States that seem from a moral perspective questionable, but we do so only to make the point that even adopting a parochial perspective that does not take humanitarian aims into account, global migration will impose significant costs on the United States.

territory.[250] 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.[251] One five-hour massacre left more than 1,700 dead.[252]

Migration induced by changing environmental conditions is common. Historically, people have sought more favorable conditions in response to environmental stresses.[253] During the 1930s, large numbers of Americans left their homes in response to prolonged drought and severe dust storms that plagued the Great Plains.[254] 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.[255] Given that climate change is expected to affect developing countries much more dramatically than developed countries,[256] and that developing countries are less capable of handling the stresses of climate change,[257] mass migrations are certainly plausible. Some climatic refuges will likely seek refuge in the United States. Even if the United States refuses to admit these refugees, it is reasonable to expect that many will enter illegally.[258]

Approximately one billion people worldwide live within a few meters of sea level,[259] and the most common estimate of total climate change migrants is 200 million people by the year 2050.[260] 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 due to 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 experience suggest that at least some migrants will reach our borders, and that this represents 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 illegal immigration on the United States is significant. Official estimates project that nearly seven million, or close to sixty percent of all unauthorized immigrants residing in the United States in 2007 are originally from Mexico.[261]

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[250] Ashok Swain, Displacing the Conflict: Environmental Destruction in Bangladesh and Ethnic Conflict in India, 33 J. Peace Research 189, 195--97 (1996).
[251] Id. at 198.
[252] Id.
[253] Oli Brown, Migration and Climate Change, at 21 (International Organization for Migration Research Series Paper No. 31, 2008), available at http://www.iisd.org/pdf/2008/migration_climate.pdf.
[254] Id. at 23.
[255] Id. at 23--24 (finding such inter-continental migrations tend to follow pre-existing pathways); see also Rafael Reuveny, Environmental Change, Migration and Conflict: Theoretical Analysis and Empirical Explorations, at 18 (Human Security and Climate Change Workshop Paper, 2005), available at www.gechs.org/downloads/holmen/Reuveny.pdf (noting migration can be intra- or interstate).
[256] See supra notes 11--13 and accompanying text.
[257] Id.
[258] Reuveny, supra note 255, at 20--21.
[259] Id. at 20.
[260] Oli Brown, supra note 253, at 11--12 (citing Norman Myers, but not endorsing Myers estimate).
[261] U.S. Dep't of Homeland Security, Office of Immigration Statistics, Estimates of the Unauthorized Population Residing in the United States: January 2007, tbl. 3 (Sept. 2008), available at http://www.dhs.gov/xlibrary/assets/statistics/publications/ois_ill_pe_2007.pdf [hereinafter DHS 2007 Unauthorized

Between 2000 and 2007, an average of 470,000 people entered the United States illegally each year. Of those, about 330,000 came from Mexico.[262] This is in addition to more than one million legal permanent residents each year, of which 148,000 to 170,000 are from Mexico.[263]

Northern Mexico is expected to suffer severe water shortages as the earth warms, creating a large increase in immigration to the United States.[264] If the United States is unwilling to admit larger numbers of Mexican immigrants legally, we can expect them to cross the border illegally. Thus all the pressures and challenges of illegal immigration will be amplified. There will be more illegal immigrants in need of health care and education for their children, as well as work and housing.

Increases in both legal and illegal immigration can be expected to result in political and economic consequences within the United States.[265] 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 so on. Competition for resources and ethnic tension may be particularly likely to foster conflict between U.S. citizens and climate-induced migrants.[266] Historically, environmentally-induced migrations have resulted in violent conflict between existing and new populations.[267] During the 1930s Dust Bowl migration, for example, newcomers to California suffered beatings and lost their houses to arson.[268]

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 illegal immigration, as well as to control

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Estimates]. In the past, official projections have underestimated the population of illegal immigrants. Compare Jeffrey Passel, The Size and Characteristics of the Unauthorized Migrant Population in the U.S., (Pew Hispanic Center 2006), available at http://pewhispanic.org/files/reports/61.pdf (estimating total of 11.1 million illegal immigrants, including 6.2 million from Mexico, based on 2005 data) with U.S. Dep't of Homeland Security, Office of Immigration Statistics, Estimates of the Unauthorized Population Residing in the United States: January 2005 (September 2006), available at http://www.dhs.gov/xlibrary/assets/statistics/publications/ILL_PE_2005.pdf (estimating total of 10.5 million illegal immigrants, including 6.0 million from Mexico, based on 2005 data).

[262] DHS 2007 Unauthorized Estimates, supra note 261, at 2--3.

[263] U.S. Dep't of Homeland Security, Office of Immigration Statistics, U.S. Legal Permanent Residents: 2007, at 3 (Mar. 2008), available at http://www.dhs.gov/xlibrary/assets/statistics/publications/LPR_FR_2007.pdf (data is for the years 2005--2007).

[264] See Age of Consequences, supra note 204, at 56 (2007) (stating "Northern Mexico will be subject to severe water shortages, which will drive immigration into the United States in spite of the treacherous border terrain"); see also Dep't of Water Res., State of Calif., Water & Border Area Climate Change: An Introduction, Special Report for the XXVI Border Governors Conference, at 35 (2008), available at http://www.water.ca.gov/news/newsreleases/2008/081508bgcreport.pdf (noting expected exacerbation of hot, dry conditions along border). Some of this migration has already begun to occur. 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, available at http://assets.panda.org/downloads/upinsmoke_lac.pdf (2006) (noting in 2004, slowed food production was part of reason more than 400 thousand people immigrated to United States from Mexico).

[265] See generally Peter Brimelow, Alien Nation (1995).

[266] Rafael Reuveny, Climate Change-Induced Migration and Violent Conflict, 26 Pol. Geography 656, 659 (2007) (arguing migrations do not necessarily have to result in conflict) [hereinafter Reuveny, Climate Induced Migration].

[267] Id. at 662--68.

[268] Id. at 660.

the flow of drugs and reduce the threat of terrorist attacks.[269] In addition to government efforts, private vigilante "border patrol" groups have emerged to police the border.[270] It is easy to image that a dramatic increase in migration (both legal and illegal) might prompt a more aggressive response both the government and private groups, leading potentially to significant political and social conflict.[271] Furthermore, efforts to control immigration are likely to be costly. [272]

In any event, even an expensive wall along the U.S.-Mexico border---which some people advocate as an appropriate measure to prevent illegal immigration---likely would prove insufficient to stop the flow of illegal immigrants to the United States, some of whom can be expected to arrive by sea. For example, hurricane activity in the Caribbean basin is projected to be intensified by climate change,[273] causing rising sea levels that will flood coastal areas of Caribbean islands, where most of the Caribbean population lives.[274] It is certainly plausible that Caribbean citizens may, under these circumstances, seek to migrate in relatively large numbers to the United States. Already, about twenty million Latin American and Caribbean nationals reside outside of their home countries, mostly in the United States.[275] Quite apart from one's views on illegal immigration, substantial additional migration caused by climate change would have economic implications in the United States.

While it is impossible to quantify the costs associated with climate-induced migration, it seems clearly wrong to treat those costs as zero. Even if the most obvious impacts of illegal 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 to 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,[276] and 2) The resources necessary to contain disease are likely to be less available, making the spread of contagious disease more likely. These threats, like those posed by national security concerns, are difficult to quantify but are

[269] For instance, the United States has discussed keeping illegal immigrants out by constructing an impenetrable border fence. See, e.g., Secure Fence Act of 2006, 109 Pub. L. No. 367, 120 Stat. 2638 (codified as amended in scattered sections of 8 U.S.C.).
[270] Reuveny, Climate Induced Migration, supra note 266, at 172--74.
[271] Id. at 168, 171.
[272] See Government Accountability Office, Secure Border Initiative Fence Construction Costs (Jan. 29, 2009) available at http://www.gao.gov/new.items/d09244r.pdf (detailing construction costs of different types of existing border fence); Sean Holstege, Border Fence Likely to Miss 2008 Deadline, The Arizona Republic, Sept. 11, 2008, at 1 (noting high per-mile costs of constructing secure border fence, and failure of "virtual fence" technology).
[273] G. Magrin et al., 2007: Latin America, in IPCC, Impacts, supra note 41, at 583.
[274] Celine Charveriat, Natural Disasters in Latin America and the Caribbean: An Overview of Risk 56--58 (Inter-American Development Bank Working Paper No. 434, 2000), available at http://www.iadb.org/sds/doc/ENVNatDisastLACeline.pdf.
[275] Id. at 595
[276] Infra notes 277--278.

nonetheless real; and like national security impacts of climate change, estimates of economic costs have to date excluded the cost of disease.

The global disease burden will almost certainly increase as a result of climate change.[277] 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. The potential omissions include many infectious diseases, the health consequences of drought and famine (beyond those included in current estimates of malnutrition), 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.

At least a dozen different diseases, ranging from avian flu to yellow fever are more likely to spread as a result of changes in climactic conditions.[278] The extent of these health impacts will likely be augmented by the volume of migration and population displacement discussed above.[279] Although some countries are in fact anticipating environmental refugees, and presumably preparing in some ways for the influx,[280] it is unlikely that the ultimate destinations of most refugees will be adequately prepared.[281] Thus, public health infrastructures will 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."[282]

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[277] IPCC, Synthesis Report, supra note 79,, at 12 (summarizing range of certainty for various climatic effects and resulting impacts on health, including increases in infectious diseases). Anthony J. McMichael, et al., Global Climate Change 1609 *in* Comparative Quantification of Health Risks (Majid Ezzati ed., World Health Organization 2004).

[278] Climate Change Seen Aiding Spread of Deadly Diseases, Reuters, Oct. 7, 2008, available at http://www.reuters.com/article/topNews/idUSTRE4968HQ20081007?feedType=RSS&feedName=topNews&pageNumber=1&virtualBrandChannel=0. Changes in climatic conditions will also increase in geographic range and temporal transmission windows of malaria and dengue fever. U.B. Confalonieri, et al., Human Health *in* IPCC, Impacts, supra note 41, at 409--10 (summarizing studies to date on projected climate change impacts on dengue fever and malaria, noting some projected decreases but more projected increases). The number of people at risk for dengue fever is projected to grow dramatically as a result of climate change, from 3.5 billion to 5--6 billion. Id. at 408. In addition to infectious diseases, significant increases in diarrhoeal diseases and malnutrition are already attributable to climate change, and these effects are expected to grow. Id. at 407.

[279] See supra Part III.C.

[280] Anthony McMichael, et al., Human Health and Climate Change in Oceania: A Risk Assessment 106 (Commonwealth of Australia 2002), available at http://www.healthconnect.gov.au/internet/main/publishing.nsf/Content/2D4037B384BC05F6CA256F1900042840/$File/env_climate.pdf.

[281] The increased health risks of mass displacements are already apparent from the incidence of disease and other health problems in existing refugee settlements. And those settlements mostly do not reach the scale anticipated as a result of climate change. 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. Envt'l Health Research 99 (2006); C. Kamugisha, et al., An outbreak of measles in Tanzanian refugee camps, 187 J. Infectious Diseases S58 (2003).

[282] Confalonieri, supra note 278, at 407.

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 a factor in the emergence of new diseases.[283] Furthermore, several of the other factors that increase the risk of new diseases are likely to be exacerbated by global warming, including migration (as noted above) and breakdowns in public health infrastructures.[284] It is impossible to say with certainty that climate change *will* result in new diseases---such emergences are highly complex, multi-factored developments---but it is very clear that climate change will substantially increase the risk of new diseases.

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.[285] These direct effects on the United States are significant, but the indirect effects are much greater.[286] 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.[287]

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, as people stay home and avoid contact with others,[288] resulting in employee absenteeism and substantially reduced demand on the

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[283] 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 pig industry in Malaysia, 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).

[284] Id.

[285] See IPCC, Impacts, supra note 41, at 625.

[286] 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 Health Sector of the U.S. National Assessment, Environmental Health Perspectives 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).

[287] In fact, some have even characterized avian flu as "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).

[288] The hotline at the Centers for Disease Control 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 fifteen percent of his time on SARS, and manufacturers of face masks saw sales increase significantly. Id.; Sheryl Gay Stolberg, The SARS Epidemic: The American Scene; Lessons of Anthrax Attacks Help U.S. Respond to SARS, N.Y. Times, May 2, 2003, available at http://query.nytimes.com/gst/fullpage.html?res=9C0DE1D6163CF931A35756C0A9659C8B63&sec=&spon=&pagewanted=1. There were economic consequences in communities across the United States. Rumors flew, people stayed home or away from certain restaurants, stores or communities, and businesses suffered. Dean E. Murphy, In U.S., Fear Is Spreading Faster than SARS, N.Y. Times, Apr. 17, 2003, available at http://query.nytimes.com/gst/fullpage.html?res=9E01E7DB163AF934A25757C0A9659C8B63&scp=5&sq=SARS&st=nyt.

services sector.[289] In addition, infectious diseases can and do affect animals, including valuable livestock. Avian flu---both the disease itself and control measures to prevent its spread---have in recent years reduced the poultry stock in some countries by 15--20%.[290] 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.[291] Projections for an influenza pandemic are much higher.[292]

Even if one assumes that both the increased incidence of existing diseases and the arrival of new ones (an assumption that strikes us as unwarranted) the United States has reason for concern. Preventing the introduction and spread of infectious diseases is extraordinarily difficult and, depending on the nature of the disease, could prove impossible. Diseases can and do arrive through a variety of pathways, including migration of people or animals,[293] travel,[294] and transportation of goods.[295] West Nile virus, malaria, avian flu, monkeypox, SARS, and Rift

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[289] World Bank, Spread of Avian Flu Could Affect Next Year's Economic Outlook 2 (2005), available at http://siteresources.worldbank.org/INTEAPHALFYEARLYUPDATE/Resources/EAP-Brief-avian-flu.pdf [hereinafter World Bank, Avian Flu].

[290] Id. at 1.

[291] Id.

[292] Id. at 3.

[293] 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 (2004). Both of these factors will increase as a result of global warming. Much of the developing world countries will be severely impacted by climate change, see, e.g., supra notes 173--175 and accompanying text, widening the health gap with the U.S. And, as conditions worsen elsewhere, more and more desperate attempts to migrate to the United States are predictable. Infra Part. III.C. In addition, warmer temperatures in the United States itself 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 health care due to poverty or immigration status, as delays in treatment increase the window during which a mosquito can acquire and pass on the infection. John R. MacArthur, Probable Locally Acquired Mosquito-Transmitted Malaria in Georgia, 1999, 32 Clinical Infectious Disease 1248 (2001). Such populations also tend to underreport infectious diseases within the United States itself, as evident in multiple studies of dengue fever in Florida. Gill, et al., Imported Dengue – Florida 1997--1998, 48 Morbidity & Mortality Weekly Report 1150, 1152 (1999). Furthermore, underreporting undermines an adequate and effective response to any emerging threats to public health. Patz, supra note 286, at 373.

[294] Disease can be spread through human travel or accidental simultaneous transport of carriers like mosquitoes. Recall that researchers still are not sure how West Nile virus arrived in New York, and human travel or accidental insect transport are both possible means. 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, David J Rogers & Simon I Hay, Estimating the Malaria Risk of African Mosquito Movement by Air Travel, 5 Malaria J. 57, 59 (2006).

[295] 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. R.C. Bengis, supra note 283, 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. Thomas E. Walton, The Impact of Diseases on the Importation of Animals and Animal Products, 916 Annals of the N.Y. Academy of Sci. 36, 40 (2000) (describing U.S. ban on imported beef and ruminant products from Europe and estimated cost of $3 billion dollars to UK as result of outbreaks). Finally, another established mode of transmission is through migratory animals, especially wild birds. Migratory birds have played a significant

Valley fever, among others, have all jumped national borders through one or more of these means. The difficulty of containment has been demonstrated by the H1N1 virus and SARS, of course, but also before that by the 1999 outbreak of West Nile encephalitis in New York.[296] Thus, in the United States, we must be concerned about transmission of disease along numerous pathways.[297] Logically, as the global disease burden grows, the incidence of such transmissions (including to the United States) can be expected to grow as well.[298] Given all of the possible pathways for transmission of disease, it is clear that no country can prevent the introduction of infectious agents without radical changes that seem politically and economically infeasible, such as substantial prohibitions on travel and radically reduced trade.[299]

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role in the transmission of the avian flu strain between domesticated chickens in Asia and those in Europe. Bjorn Olsen, et al., Global Patterns of Influenza A Virus in Wild Birds, 312 Science 384, 384 (2006).

[296] 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, or the unintentional introduction of infected ticks or mosquitoes. R. S. Lanciotti, Origin of the West Nile Virus Responsible for an Outbreak of Encephalitis in the Northeastern United States, 286 Science 2333, 2336 (1999). Mosquitoes and other carriers travel internationally by the same means as people and goods. See Elbe, supra note 287, at 121.

[297] In fact, local transmission of malaria, to choose one disease, within the United States is already increasing, perhaps due to globalization. MacArthur et al., supra note 293, at e124 (noting 77% of locally-acquired malaria cases in United States were "in the last fifteen years").

[298] The likelihood that refugees and immigrants will arrive carrying an infectious disease will also be greater than at present, because the incidence of such diseases will rise. Supra notes 277--282 and accompanying text. Obviously, migrants harboring infectious disease that is transmissible from human to human could infect local populations within the United States. In addition, we have already witnessed transmission of a vector-borne disease (malaria) from migrant workers to local residents in the United States, where mosquitoes bite an infected person, incubate the disease and then bite and infect someone else. MacArthur, supra note 293, at e127. Certainly, measures can and are put in place to reduce such transmissions (for example, spraying to reduce mosquito population). But those measures have costs too, and not just economic ones, all of which will be discussed infra notes 305--306 and accompanying text. And we should not assume that control measures themselves are 100% effective. Despite them, in fact, the incidence of local malaria transmission has been rising. Monitoring began in 1957, but 77% of the cases in the U.S. have been in the last 15 years. Id. at e124. As the incidence of disease increases, it seems most likely that this trend will continue and sharpen. That leaves the difficult question of "by how much?"

[299] The United States already recognizes the importance of preparedness, surveillance and detection, and containment in other countries to reduce or prevent the spread of disease. President Bush and Congress authorized $434 million in overseas expenditures to facilitate these activities in other nations, in order to reduce the risk of a pandemic flu outbreak. U.S. Dep't of State, United States International Engagement on Avian and Pandemic Influenza (Nov. 28, 2007), available at http://www.state.gov/documents/organization/95933.pdf. Control measures 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 protections by and for health-care workers. Spraying to eliminate and reduce mosquito populations helps limit the incidence of West Nile virus in the United States. And disinfecting airplanes after flights from malarial regions helps reduce the number of cases of "airport malaria." Andrew J Tatem, David J Rogers & Simon I Hay, supra note 294, at 62. Some of these measures, such as insect control, can be accomplished independently by the United States, though these measures are themselves not without costs and controversy. The state of Louisiana is estimated to have spent over $8 million on mosquito abatement as a result of a West Nile outbreak in 2002. While that number might seem small in the context of the federal budget or the costs of climate change generally, it must be understood in its proper scale. Armineh Zohrabian, West Nile Virus Economic Impact, Louisiana, 2002, 10 Emerging Infectious Diseases 1736, 1740 (2004). There were 329 cases of West Nile in Louisiana in 2002, and 4,129 cases total in the United States that year. If Louisiana's per person abatement costs are extrapolated for all 4,129 American cases, the national figure would be something like $100 million. Presumably these expenditures would be required on an on-going basis.

Perhaps the largest challenge to disease control is the fact that stemming an outbreak of many diseases requires substantial international cooperation. This was apparent with SARS, which was successfully contained only because of unprecedented international cooperation among governments, scientists and public health experts.[300]

The reality of this dependence on other nations for reporting, research, and control measures (including identification and destruction of infected livestock, quarantines, etc.) means that efforts by the United States to limit or prevent importation of infectious elements will be hampered by the direct effects of climate change in other countries, because such efforts are dependent on information and communication from, as well as control measures in, the place of origin.[301] Even in developed countries, where limited resources and political instability are lesser concerns, compliance with control measures may not be complete.[302]

In other words, social, economic and political factors can and already do inhibit acknowledgement of the emergence of a virus, even if public health is infrastructure sufficient to detect the outbreak exists in the country.[303] Now, consider that all of the relevant resources, including the detection infrastructure, will be severely stretched by the other impacts of climate change (lack of food and water, flooding, severe weather events, heat waves, etc).[304]

Again, SARS is illustrative of 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, 115,270 people were quarantined and over 2.7 million passengers had their temperatures

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[300] 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 educational efforts for health care workers and the public. The initial isolation of the virus alone involved work in eleven laboratories in nine countries. Id.

[301] We have seen this already on a smaller scale with underreporting or delayed reporting of avian flu and SARS cases. Id. at 252 (noting delay of over month between arrival of WHO team in China and government approval for on-site investigation in Guandong).

[302] 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. Mad Cow Case Is Found in Canada, Associated Press, Apr. 17, 2006, available at http://www.nytimes.com/2006/04/17/world/americas/17canada.html?scp=2&sq=%22mad+cow%22&st=nyt (noting latest cases of mad cow disease could indicate lack of compliance with ban on feeding cattle proteins to cows). This commitment is necessary to encourage poultry raisers to report (rather than hide) outbreaks. World Bank, Avian Flu, supra note 289, at 2.

[303] Elbe, supra note 287, at 121 (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").

[304] Current underreporting occurs because individuals, as well as regional or 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 (The New Press 2005). Governments, too, fear loss of revenues from trade, tourism and other sources: "No country wants to bear the stigma or the economic costs associated with disease. In a world where international trade and investment are the main engines of prosperity, a disease, or any other condition that discourages foreign traders and investors from visiting and doing business, is a kiss of death. Disease is invariably associated with huge business losses." Thomas Abraham, Twenty-First Century Plague: The Story of SARS 24 (The Johns Hopkins University Press 2005).

taken.[305] Moreover, Taiwan is a country with 18 airports, only two of which are international, and a population of approximately 23 million people. Imagine trying to replicate something like that for a country the size of the United States. The costs, both economic and social, would be astronomical.

Imagine further, though, what would be required to address the outbreak of infectious disease in, say, Indonesia, a country of 222 million people and 71 airports (17 international). In that country, or any one of many others 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 made more 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 says is necessary to prevent widespread outbreaks.[306]

With respect to disease, as in many other aspects of 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.

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[305] Kow-Tong Chen, et al., SARS in Taiwan: An Overview and Lessons Learned, 9 Int'l J. of Infectious Diseases 77, 79 (2005). In addition, it is important to keep in mind 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.

[306] WHO, Epidemic and Pandemic Alert and Response, available at http://www.who.int/csr/en/. The fact that the United States has, to date, avoided major outbreaks should not be taken as a sign of invulnerability. The actual effect of a given disease or pathogen in a specific environment is extraordinarily difficult to predict and often appears to involve a good deal of chance. The fact 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, available at http://query.nytimes.com/gst/fullpage.html?res=9A03E6DB173DF936A15757C0A9659C8B63&scp=47&sq=SARS&st=nyt; see also World Bank, Avian Flu, supra note 289, at 1 ("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 unpredictably, West Nile virus has not spread nearly as widely or as rapidly in Europe as in the United States, and 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, are therefore essential to prevent transmission.

IV. THE RATIONAL CASE FOR ACTION

The dilemma of climate change is often described (accurately) as a collective action or public goods problem.[307] No single country has an incentive to optimally control its emissions of GHGs 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 in such 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 do anything 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."[308] 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.[309] Of course, thus far, the highest emitting developing countries---notably India and China---have signaled consistently their strong reluctance to make binding commitments before the developing world commits to doing much more, and even then they are likely to insist on significant transfers of funding and technology. The result, of course, is a dangerous stalemate.

Of course, 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 *by itself* reverse global warming. Yet that reality does not answer the question: Is it in the interest of the United States to take action to address global warming---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 of the benefits from the production of collective goods to make it worthwhile to invest in those goods. To be precise, every player, large or small, has an incentive to take action up to the point where the state's marginal cost of further action exceeds the marginal benefit. A large hegemonic player like the United States internalizes a significant fraction of the global gains, making is worthwhile to bear at least some costs.

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[307] See, e.g., Arrow, supra note 89, at 3 ("[G]lobal climate is a public good (bad) par excellence."); Daniel H. Cole, Climate Change and Collective Action, manuscript at 4 ("[C]limate change presents a sizeable collective action problem.").

[308] Posner & Sunstein, supra note 45, at 1569.

[309] Could cite to some floor statements or hearings from when Waxman Markey bill was passed and note the provision in the bill that allocates emission allowances to energy-intensive and trade exposed manufacturing.

To illustrate this point in the climate change context, 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.[310] World GDP in 2007 was approximately 54 trillion dollars, 14 trillion dollars of which was accounted for by the United States.[311] 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 15 trillion in 2008.[312] Taken together, then, the United States and the EU account for 58% of global GDP, and if they were to jointly bear 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,[313] meaning that the cost of stabilization would be approximately 1.3% of the GDP of OECD countries.

It is true that 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. 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.

If we assume that GHGs could be stabilized at 500--550ppm by 2050, and that the total global cost of doing so would cost in the range of 4% of U.S. GDP, we have something 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: 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

[310] 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 11, at 279.
[311] World Bank Indicators, supra note 185.
[312] World Bank Indicators, supra note 176.
[313] Id.

Optimism About Temperature Rise[314]	0	1
Asymmetry Around Point Estimates[315]	0	0.5
Catastrophic Events[316]	0	0.5--3
Nonmarket Costs[317]	0	1.4--3.5[318]
Export Losses[319]	0	1.5
SUB TOTAL	0.5	5.4--10
Growth and Productivity[320]	0	Double Above Impacts
TOTAL	0.5	10.8--20

It is important to note that several factors discussed in this Essay are omitted from this table because we are unable to estimate their impacts other than by qualitative description. These include cross-sectoral effects, supply shocks from foreign economies, impacts on financial markets of global climate change, national security issues, migration, and disease. These are not minor issues. National security, for example, could easily generate costs that exceed any of those listed in Table 3. The estimate produced in Table xxx, 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 they are crude estimates. Despite these qualifications, we think the impacts we have identified and tried roughly to quantify represent a critical set of issues for policy debates about climate change. Taken individually, they are each speculative. Yet 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 in Table 3, the resulting impact of climate change on GDP reaches 7.7%,[321] excluding the impact on growth and productivity. If we follow Fankhauser and Tol's results[322] 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).

[314] See Part II.B.II.B.1.
[315] See Part II.B.II.B.2.
[316] See Part II.B.II.B.3.
[317] See Part II.B.II.B.4.
[318] This includes only biological costs.
[319] See Part III.A.
[320] See Part III.B.II.B.6.
[321] Where there is a range of costs in Table 3, we have used the midpoint to calculate the total impact.
[322] Fankhauser & Tol, supra note 160, at 12--14.

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 cost of mitigating the impact of climate change by itself (even if not 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 be participating.

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.[323] Rather, the point is that even if one assumes that international cooperation in general is difficult, and that cooperation with India and China may be especially so given their political and economic contexts, 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. In fact, we can say still more: The United States is better off acting alone (or more realistically with Europe and other interested states) than not acting at all.

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.[324] 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 mentioned above would not support an argument for substantial expenditures today.

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[323] Among the reasons that 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 in the above text.

[324] The most central reason for a low discount rate is more philosophical than economic. It relies on the notion that th welfare of future generations should be valued on par with our own. See Stern Review, supra note 12, at p. 35, ch. 2A; Robert O. Mendelsohn, A Critique of the Stern Report, Regulation, Winter 2006-2007; Martin L. Weitzman, The Role of Uncertainty in the Economics of Catastrophic Climate Change, Working Paper 07-11, AEI-Brookings Joint Center for Regulatory Studies, May 2007, http://ssrn.com/abstract=992873; William Nordhaus, A Question of Balance, New Haven, CT: Yale University Press (2008), at 169-190.

There remain some potentially credible arguments against unilateral action by the United States. These include the futility, leakage and fairness arguments we mention 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 a numerical defense. On futility, the question is how much mitigation is so little that it is not worth acting?[325] 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.[326] 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.[327] On leakage, the question is whether unilateral action will in fact lead to massive flight of energy intensive industry, and whether there are no 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 possible that a credible U.S. threat to do nothing until these countries agree to share the burden of mitigation could conceivably increase the prospects of persuading other countries to participate in a new global climate change regime. Yet whether this is true or not the climate change winner argument--- that the U.S. 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.

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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 in the U.S. interest not 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 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; others they simply do not count because the impacts 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 affects, 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. There is also the as yet unresolved debate about which discount rate to use to value benefits that will accrue so far into the future, and whether it is intellectually coherent to use one at all, given the time scale involved.

All of these shortcomings economists may well appreciate, 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 without acknowledging their significant limitations. A fuller accounting of the costs associated with climate change does more than call the climate change winner argument into question: It 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 perhaps by using the existing Clean Air Act to address global warming 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 policy makers, 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 it 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 of yet no sign that the United States is considering funding mitigation efforts abroad. In other words, American policy is still quite fluid and there is much left to be decided. We have no doubt that the climate change winner argument will continue to be made by those who support weaker American policies. We hope that this Essay has debunked that 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.