The Impacts of Climate Change: Perspectives from the *Stern Review*

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Launched on 30 October 2006, the *Stern Review on the Economics of Climate Change* has received attention in academic, political, and popular circles worldwide, possibly unprecedented for a government report of its kind.[1] The *Review* was set up to provide the U.K. prime minister and chancellor with a wide-ranging and comprehensive economic assessment of climate change, and was led by Sir Nicholas Stern, adviser to the U.K. government on the economics of climate change and development, head of the U.K. Government Economic Service, and, among other things, a former chief economist for the World Bank. Now nearly 700 pages long, the *Review* contains a tremendous volume of analysis on all aspects of climate change economics and policy, including the consequences of business-as-usual greenhouse gas (GHG) emissions, as well as the costs, benefits, and design of policies to reduce these emissions and adapt to climate change that cannot be avoided. It has become best known for the conclusion that, unabated, climate change could eventually have impacts on global economic growth and human development on a scale comparable to the great wars and economic depression of the twentieth century. The *Report* also found that these impacts can still largely be avoided by a decisive shift away from production of GHGs, a shift which can be achieved with far less cost than we will incur if nothing is done.

While this will come as no surprise to many, the *Review* sounds a different note to most previous economic analyses despite using the same models as these previous studies. The *Review's* prescriptions are based on two foundations. One is a strong ethical commitment to safeguarding opportunities for future generations. This commitment is made in the way the *Review* discounts the future, that is, in the way it calculates the

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value in today's money of the impacts of climate change in the future. Economists are familiar with the concept that money is worth more today than it is in the future, so a high "discount rate" can make the future costs of climate change seem very small indeed. The second foundation is an acknowledgement of the uncertainties associated with climate change. We must entertain the prospect of huge changes in physical and human geography, even if they make the practices of economic analysis and policy making more difficult. Such changes could have tremendous impacts on the international economy, in particular as a result of the distribution of impacts between North and South and the potential for global security threats through migration and violent conflict. While it is difficult to quantitatively determine the harm that each of these individual problems might cause, there is certainly basis for acting to prevent or minimize climate change. While such pursuits may be costly, they must be viewed as a form of global insurance—taking costs upon ourselves in the present to avoid a potentially disastrous future.

Predictions of Global Warming

The current stock of GHGs in the atmosphere is equivalent to about 430 parts per million (ppm) carbon dioxide, as compared to a stock of about 280 ppm prior to the industrial revolution (around 1750).[2] This stock is rising at around 2.3 ppm every year and is likely to reach 550 ppm some time between 2030 and 2060. Global mean temperature is our index of climate change, though climate change is experienced through temperature, rainfall, wind, sea-level rise, and how all of these vary in day-to-day weather patterns. The earth has warmed 0.7 degrees celsius since 1900 and is now warming rapidly even by twentieth century standards: all ten of the warmest years in recorded history have occurred since 1990. If atmospheric GHGs reach 550, global mean temperature may further increase by two to five degrees celsius above pre-industrial levels. Although temperatures will take time to reach these record highs, warming over the coming decades would be comparable to the difference between global mean temperatures during the last ice age and those of today. If we continue to emit GHGs at today's rate, the atmospheric stock would likely be more than three times higher than pre-industrial levels by 2100, committing the world to between three and ten degrees celsius of warming in the end. Furthermore, it is critical to remember that temperature increases on land are higher than those over the oceans, meaning warming will be more dramatic on land, especially at high latitudes (perhaps double at the poles).

Additional evidence demonstrates it is possible that temperatures could be even more sensitive to GHGs than the above ranges suggest.[3] For example, warming could trigger positive natural feedback processes in the climate system such as a thawing of

high-latitude permafrost, which would release large quantities of the potent GHG methane. These feedbacks could add another one to two degrees celsius by 2100.[4] Though some studies yield contradictory results, the predictions sketched out here come from a comprehensive sweep of the scientific literature on climate change as a whole.[5] They tell us that while the central expectation in the science may consider warming to be gradual, continuous, and reversible, we cannot exclude the possibility of rapid, discontinuous, and irreversible change. This has important implications for our policy response.

Climate Change Impact Disparities

Developing countries are most vulnerable to climate change, particularly poor communities already living at the margin of survival. Many developing countries are located in tropical regions where they already endure some of the world's most extreme climatic conditions, such as very high temperatures, rainfall that arrives intensely over just a few months of the year, and conditions that vary strongly from year to year. During the summer of 2003, for example, peak temperatures in India hit 45 to 49 degrees C,[6] and in 2002 the monsoon rains failed altogether, resulting in a rainfall deficit of 19 percent and ultimately a loss in India's GDP of 3 percent.[7] Climatic conditions are set to be even more challenging in the future. In some cases, just small changes from the status quo could induce large impacts, where current conditions are already at the limit of tolerance.

Economist Robert Mendelsohn describes the relationship between latitude, temperature, and economic productivity as a "hill," with low productivity at the poles, high productivity in temperate, mid-latitude regions such as Western Europe and North America, and low productivity in low-latitude, tropical regions.[8] Controlling for other factors, climate change could propel high-latitude regions up the curve of rising productivity for a time—by lengthening the growing season for agriculture, for example. But by the same token, low-latitude regions are widely expected to fall further down the curve of declining productivity as climatic conditions become more and more adverse—such regions are already too hot. Mendelsohn finds this to be true not just of agriculture, but also of the five sectors of the economy sensitive to climate change: agriculture, water, energy, forestry, and coastal zone activity.

Yet economists are divided on the issue of whether geography in general, and climate in particular, can have a lasting impact on economic development. Do these factors explain why some countries are poor while others are rich? Jeffrey Sachs has been a strong advocate of the perspective that climatic factors such as intense heat and humidity explain tropical disadvantages in agriculture.[9] We should be careful,

though, not to confuse the effects of climate with other factors that are correlated with climate.[10] The traditional focus of economic growth theory has been the accumulation of capital assets, education, technological advancement, and, more recently, the role of institutions and policies. Thus, other studies have contested the role of physical geography, arguing that it has at most an indirect effect on development through the historical imprint it has had on the quality of institutions and governance, for example on corruption and the rule of law.[11] One of the main obstacles to identifying the role of climate in development has been a lack of data. Past studies have struggled to find environmental indicators available at the sub-national level. Accordingly, they have struggled to disentangle the effect of climate from that of institutions and governance, which are more genuinely national-level factors. Additionally, they have had to measure physical geography indirectly, using crude proxies. Recent work by William Nordhaus points the way forward. Amassing a large dataset of economic activity at a fine spatial scale, he re-evaluates this old debate to find that tropical geography does indeed have a negative effect on economic activity.[12]

In addition to exposure, poor countries are more vulnerable to climate change than their rich counterparts, in part because agriculture and related activities still make up a large proportion of economic activity in most poor countries. The intimate connection between people in poor regions of the world and the natural environment extends beyond measured areas of economic activity: natural resources sustain the economy but also provide food, shelter, and health products. Unsurprisingly then, environmental degradation is a major driver of rural–urban migration in the developing world.[13] In urban areas that receive migrants, people are often forced to live on marginal lands that are more vulnerable to extreme weather.

The third factor that makes developing regions more vulnerable to climate change is their incapacity to adapt. Part of this deficiency is the result of lacking infrastructure. For example, Ethiopia has a far more variable water supply than North America, yet it possesses less than 1 percent of the per-capita artificial water storage capacity (dams and groundwater) of North America.[14] Additionally, low incomes, limited access to credit, and typically weak social safety nets make it difficult for the poorest members of society to overcome extreme weather.

Implications for Global Security[15]

The degradation of natural resources in developing regions of the world led the *Review* to raise obvious and important questions about the potential for migration and conflict due to climate change. There are apparent precedents for these phenomena occurring as a result of environmental change in recent history. The ongoing conflict in the Sudanese

region of Darfur has been linked to long periods of drought in the 1970s and 1980s. Similarly, drought in Mali in the 1970s forced many semi-nomadic Tuareg people to seek refuge in camps, urban areas, or neighboring countries. The poverty and social exclusion suffered has been identified as a factor contributing to the "Second Tuareg Rebellion" in 1990.

Careful analyses of the evidence tend to cast doubt on the sweeping hypothesis that climate change increases environmental scarcity and in turn brings about conflict, however seductive that hypothesis might be.[16] Such analyses consider all the cases in which environmental scarcity has *not* resulted in conflict. Some studies in fact point to a quite opposite cause of conflict: *abundance*, rather than scarcity, of natural resources causes conflict by engendering competition.[17] So how should we understand the potential of climate change to trigger violent conflict and threaten security?

The hypothesis that climate change can cause migration is similarly problematic. The push and pull factors patterning migration are complex: environmental change is just one such factor and relative economic opportunities have often been a more powerful explanation. Yet there is increasing acknowledgement of the risk that accelerating climate change can cause large migrations. This is easiest to conceive in the world's lowest lying regions, such as Bangladesh and the Pacific islands, where migration has already begun as the lowest-lying islands become submerged. Indeed, crude measures of the total number of people at risk of displacement worldwide are impressively large. Nearly 200 million people worldwide currently live in coastal flood zones.[18] Similarly, hundreds of millions experience water and food shortages.[19] Population growth will drive these numbers still higher, all else held constant. Though climate change may lift some people out of food and water shortage, overall it is expected to push more into shortage, especially if unabated climate change drives temperatures beyond two to three degrees celsius above pre-industrial levels. If migration does occur, then climate change could be a source of violent conflict. For example, a 45 centimeter rise in sea level would force around 5.5 million people living in the Ganges Delta in Bangladesh to migrate inland, if sea defenses cannot protect the region. While many might resettle in other parts of the country, many others would likely seek to resettle in India and Pakistan. Such movements have historically been a source of conflict in these countries.[20]

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But, ultimately, a singular pursuit of causal relations between climate change, migration, and conflict seems counterproductive. Not only are we likely to come to a very qualified conclusion on the potential for security threats of this sort, we are also restricting ourselves in defining security so narrowly. The United Nations Development Programme defines *human security* as "concerned with how people live and breathe in

a society, how freely they exercise their many choices, how much access they have to market and social opportunities—and whether they live in conflict or peace."[21] According to this definition, the risks climate change poses for "food security"—protection from hunger—and "water security"—protection from water shortage—are themselves worthy of concern, not just as drivers of migration.

Welfare Economics and Climate Change

Given that we understand what problems could potentially arise as a result of climate change, the question becomes one of what actions can and should be taken in response. How much should we really worry about climate change, and should we aim to strongly reduce our emissions of GHGs? International negotiations may target atmospheric concentrations of GHGs or increases in global mean temperature, but action ultimately necessitates an attempt to "value" the resultant impacts. Towards this end, applied welfare economics usually equates value to the monetary equivalent of human welfare, which means that the cost of climate change comprises both monetary costs that we can observe, like crop damage and extra air conditioning, and costs that are more difficult to quantify but are no less important, such as illness, death, and the loss of valuable species and ecosystems. While different ethical perspectives deserve careful consideration, the great advantage of this approach is that it makes the costs and benefits of climate change policy comparable with the costs and benefits of other public policies. We will need to call upon this welfare approach, because it is most likely that the policies leading to GHG emission reductions have an opportunity cost in terms of resources that could be spent on other policy problems.

Such an approach is the starting point of the "skeptical environmentalist"—Bjørn Lomborg. In his recent *Copenhagen Consensus*, he places GHG emission reductions in a cost/benefit analysis framework, alongside other major problems of world development such as communicable disease, illiteracy, and trade barriers.[22] He asks how we should spend tens of billions of dollars of public money in order to do the most good. The conclusion of the *Consensus* is that climate change should be ranked rather low as a world problem. In fact, this ambitious exercise is reflective of most past efforts to prescribe climate change policy based on cost/benefit analyses.[23] To summarize the skeptics' reasoning, climate change is a very long-run, gradual phenomenon. As such, we will be much richer when its worst impacts arrive, and it is in any case a long way off. These are reasons to downplay the consequences of climate change, according to their logic. Skeptical economists formalize these reasons through the discount rate, much as they would in any business investment analysis. In addition, because we will be much richer, we will be able to adapt to most of the impacts of climate change,

especially in the short and medium term, at much less cost than would be required to avoid them through GHG emission reductions. And, though it is undisputed that developing regions will be hit hardest and quickest, other regions may benefit. Many of the beneficiaries are rich, high-latitude countries, and since purchasing power and thus the prices of goods and services are higher in rich countries, their benefits are valued more in absolute terms than is the cost of climate change to poor countries. We would be better off transferring resources to poor countries to adapt to climate change or compensating them for damage done, so the argument goes, rather than sinking the same resources into global reductions in GHG emissions. In a broader sense, this argument implies that we in the present have little to worry about, or for that matter to *do*, regarding climate change.

Discounting the Future

The *Stern Review* tells a different story than have past studies by making two main improvements on the previous accounts. The first is that the *Review* assigns greater weight to the utilities of future generations than have previous studies. It is usually assumed that people display a preference for enjoying good things sooner rather than later, and that this is reason enough to place low weight on the utility of future generations. This is called "pure time preference." In past studies, the discount rate has been scaled up from individual preferences over a lifetime to the tradeoffs that the economic planner faces over many generations. Welfare economists are naturally predisposed to doing things in this way because they view individual preferences as sovereign. The discount rate also reflects the fact that economic growth should make the world better off in the future, even when climate change is taken into account. Changes in income are generally held to be worth less the richer we are: a dollar is worth more to a poor person than to a millionaire.

Yet, the science of climate change strongly challenges the prevailing tendency to discount future utility based on the preferences of the current generation. For example, the incremental benefit of holding back the emission of one ton of GHG today will be felt for up to and beyond two centuries. Thus climate change challenges economics to move from a "positive" tradition, describing the sovereign preferences of those who happen to be around when the decision is made, to a "normative" tradition, where future generations are afforded equal moral standing. Brad DeLong summarizes the reasons for the move very well. Considering the implications of discounting for "pure time" at 2 percent per year, he writes: "2 percent per year is unconscionable—it means that somebody born in 1960 "counts" for twice as much as somebody born in 1995, who in turn "counts" for twice as much as somebody born in 2020; somebody born in

1960 "counts" for 256 times as much as somebody born in 2160."[24]

What distinguishes the *Stern Review* is its position on pure time preference, the discounting due to date of birth; there is no pure time preference per se.[25] Such a position has a long and illustrious tradition in scholarship, being held by Ramsey, Pigou, Harrod, Rawls, Solow, and so on. Nevertheless, since the *Review* was published, much has been written on the low overall discount rate that it implies (but note that the discount rate is positive, because we continue to discount for economic growth; it is not zero, as some have mistakenly assumed).[26] It is well beyond the scope of this essay to review the rather old debate that has been rekindled, but it should be briefly noted. Opponents contest that if present decisions are to remain consistent in their valuation of the future, then such a low discount rate implies that we must do much, much more saving for future generations than we actually do. In addition, critics say, if one wants to be "high and mighty," the outcome is not entirely ethical either—why should we increase our saving for future generations, if economic growth means that we will in fact be invariably poorer than they? Yet, as clearly as these arguments have been made, they rest on a rather restrictive model of how the economy grows and how much we need to invest to bring about that growth. They rest on an assumption that there will be little or no technological improvement, an assumption that performs poorly against economic history. Similar thought experiments and data can be used to show that the *Review's* discount rate is much more consistent with today's market place.[27] Ultimately, today's data paint a complex picture because markets are distorted—we might not in fact be detecting the right signal anyway.[28]

The bigger issue is to what extent we let the revealed preferences of the current generation dictate the ethics that we apply. Discounting at a high annual rate would mean that the impacts of climate change in the far-off future are virtually irrelevant to present-day decisions. Even if a mind boggling 50 percent of global income were to be wiped off in a one-off strike in 2200, discounted at a rate of 5 percent every year, that 50 percent of future income would be worth less than one-tenth of 1 percent of total global income today.[29]

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Avoiding Dangerous Climate Change

The discounting issue is linked to the second major reason why the *Stern Review* predicts high costs of unabated climate change: the risk of dangerous consequences of rapid warming and high temperatures which might (rather imprecisely) be labeled as "danger-

ous" climate change.[30] Concerns about dangerous climate change—such as the rapid and large scale melting of two of the world's largest ice sheets, those in Greenland and the West Antarctic—have been increasing. Substantial melting will commit the world to many meters of sea-level rise. Although this process will take centuries to occur, the incremental contribution of such melting to the rate of sea-level rise in the near future is of significant concern. Similarly, warming may induce sudden shifts in important regional weather patterns like the Asian and African monsoons, and El Niño/La Niña. Several climate models currently predict that in the future, average rainfall patterns will resemble an eternal El Niño, so that currently wet regions become significantly drier. Furthermore, the rate of temperature increase could be supplemented by such positive natural feedbacks. This possibility informed a "high climate" scenario drawn up for the *Review*. The high temperatures attained in this scenario bring us more quickly to potential thresholds where, for instance, damage to agriculture and human health, as well as the likelihood of the other large scale risks, increase rapidly.

We must keep these risks in perspective. Some label the more sensational discourse around them "climate pornography."[31] But we cannot rule these risks out and economics tells us to treat them with much circumspection. This is where the *Review* differs from many previous attempts to formally model the entire climate-environment-economy chain. A common strategy previous studies have used is to take a best guess at each link in the chain. However, this strategy quite markedly underplays the uncertainty that surrounds the chain for two reasons. First, the overall probabilities of climate change impacts are characterized by what statisticians would understand as a "long tail" to the side of severe impacts. That is, nasty surprises are more likely than nice ones, even if the most likely scenario is very moderate. Taking these probabilities into consideration pushes average impacts well above best guesses. But there is more to it than that. Economics tells us that we should be more averse to large scale, negative risks facing the whole economy. Under uncertainty, an extra dollar is worth more in a bad state of nature than it is in a good one. Put differently, decision makers should behave in such a way that risky assets are valued less than riskless ones. So, if we value risks, we reach a summary measure of the cost of climate change that is higher even than the average, because we place more relative weight on the worst scenarios.

Weighting Impacts in Poor Regions

A third factor increases the estimated cost of climate change in the *Review*: the treatment of the impacts in poor countries relative to impacts in rich countries. The problem with how the uneven distribution of climate change impacts feeds into the economic calculus has already been pointed out: because absolute purchasing power is lower

in poor countries, climate change impacts get a lower valuation than they do in rich countries. Time and again, this has resulted in studies showing large relative costs in the developing world being balanced out by small relative costs, or sometimes small relative benefits, in the developed world. But, in the *Review*, the same economics that informs how we discount the future due to increasing wealth also tells us that as the marginal utility of one extra dollar is greater for a poor person than for a rich person, then impacts in poor countries should actually receive greater weight. The *Review* does this in a simple way: it uses other studies as a benchmark, and increases its estimates by roughly one quarter. Critics point out that the amount of aid we send internationally falls far short of the ideal set out by this framework. But this brings us back to the battle between positive and normative economics. We need a serious debate over whether the ethics of an intergenerational, international (and interspecies) economic problem can be judged by scaling up the preferences of today's consumers and voters.

Insuring the Future

These three arguments support the case for strong reductions in GHGs starting now, given that the cost of these reductions is demonstrably less than the costs potentially incurred in the future. The evidence assembled by the *Review* indicates that strong mitigation is indeed most likely a cheaper option than no mitigation at all. Additionally, we would not be best served by merely aiming to adapt to the changes that come our way.[32] There is certainly ample evidence to suggest that adaptation will in many cases provide benefits in excess of cost. Indeed, adaptation is a crucial component of the overall strategy, particularly over the next few decades, in which time inertia in the climate system has already fated us to its unavoidable effects. Nonetheless, it might prove an equally expensive option for many poor countries. For instance, a project to construct 8000 kilometers of river dykes in Bangladesh is to cost around 16 percent of the country's gross national income. Moreover, adaptation to the "dangerous" risks outlined above is neither cheap nor even proven possible. This neatly presents us with the nature of the economic problem. Mitigation is an investment in the future, but in many respects it is also like purchasing insurance. The leading article from a 2006 edition of the *Economist* makes this argument eloquently:

> Governments should act not [only] on the basis of the likeliest outcome from climate change but on the risk of something really catastrophic. . . . Just as people spend a small slice of their incomes on buying insurance on the off-chance that their house might burn down, and nations use a slice of taxpayers' money to pay for standing armies just in case a rival power might try to invade them, so the world should invest a small proportion of its resources in trying to avert the risk of boiling the planet. The costs are not huge. The dangers are.[33]

Views expressed in this article, and errors made, are my responsibility only. I am grateful to Nicola Patmore and Eric Neumayer, who provided valuable input to the discussions of the science of climate change and the impacts of climate change on migration and conflict respectively.

Notes

1. Nicholas Stern, *The Economics of Climate Change: The Stern Review (*Cambridge, UK: Cambridge University Press, 2006).

2. This is the total concentration of six GHGs: carbon dioxide, methane, nitrous oxide, PFCs, HFCs, and SF6. The convention is to normalize their total concentration in terms of an equivalent carbon dioxide concentration. The total GHG concentration would be even higher if we included CFCs (approaching 450ppm), but these tend to be omitted as they are covered by the Montreal Protocol (i.e., ozone layer policy), rather than the Kyoto Protocol (climate change policy).

3. Malte Meinshausen, "What Does a 2°C Change Mean for Greenhouse Gas Concentrations? A Brief Analysis Based on Multi-gas Pathways and Several Climate Sensitivity Uncertainty Estimates," in *Avoiding Dangerous Climate Change*, ed. Hans Joachim Schellnhuber and others (Cambridge, UK: Cambridge University Press, 2006). Meinshausen reviews eleven published studies on climate sensitivity—the equilibrium warming resulting from a doubling of atmospheric carbon dioxide concentrations (roughly equal to 550 ppm carbon dioxide or equivalent)—and estimates a 2–20 percent chance that it could exceed 5 degrees C.

4. M.S. Torn and J. Harte, "Missing Feedbacks, Asymmetric Uncertainties, and Underestimation of Future Warning," *Geophysical Research Letters* 33 (2006); M. Scheffer, V. Brovkin, and Peter Cox, "Positive Feedback between Global Warming and the Atmospheric CO2 Concentration Inferred from Past Climate Change," *Geophysical Research Letters* 33 (2006).

5. Hence the exceptionally comprehensive reports of the Intergovernmental Panel on Climate Change (IPCC) come to similar conclusions.

6. U.S. De, R.K. Dube, and G.S. Prakasa Rao, "Extreme Weather Events over India in the Past 100 Years," *Journal of the Indian Geophysical Union* 9, no. 3 (2005): 178–187.

7. A. Challinor, J. Slingo, A. Turner, and T. Wheeler, "Indian Monsoon," in *The Economics of Climate Change: The Stern Review*, ed. Nicholas Stern (Reading, UK: University of Reading, 2006).

8. R. Mendelsohn and M.E. Schlesinger, "Climate response functions," *Ambio* 28, no. 4 (1999): 362–366.

9. Jeffrey D. Sachs, "Tropical Underdevelopment," Working Paper 8119 (Cambridge, MA: National Bureau for Economic Development, 2001).

10. We must also take into consideration the fact that some of the possible determinants of development are themselves determined *by* development. The latter throws up well-known statistical problems that may have beset previous studies.

11. D. Acemoglu, S. Johnson, and J.A. Robinson, "The Colonial Origins of Comparative Development: an Empirical Investigation," *American Economic Review* 91, no. 5 (2001): 1369–1401; William Easterly and Ross Levine, "Tropics, Germs and Crops: How Endowments Influence Economic Development," *Journal of Monetary Economics* 50 (2003): 3–39; Dani Rodrik, A. Subramanian, and F. Trebbi, "Institutions Rule: The Primacy of Institutions over Geography and Integration in Economic Development," *Journal of Economic Growth* 9 (2004): 131–165.

12. William D. Nordhaus, "Geography and Macroeconomics: New data and Findings," *Proceedings of the National Academy of Science* 103, no. 10 (2006): 3510–3517.

13. Ramon Lopez, "Structural change, poverty and natural resource degradation," in *Handbook of Sustainable Development*, ed. Giles Atkinson, Simon Dietz, and Eric Neumayer (Cheltenham, UK: Edward Elgar, 2007).

14. World Bank, *Managing Water Resources to Maximize Sustainable Growth: A Country Water Resources Assistance Strategy for Ethiopia (*Washington, DC: World Bank, 2006).

15. I am grateful for the clear thinking of Jon Barnett on this issue. See Jon Barnett, "Security and Climate Change," *Global Environmental Change* 13 (2003): 7–17

16. Jon Barnett, "Destabilizing the Environmental-conflict Thesis," *Review of International Studies* 26, no. 2 (2000): 271–288; Paul Collier, *Economic Causes of Civil Conflict and Their Implications for Policy* (Washington, DC: World Bank, 2000); Indra de Soysa, "The Resource Curse: Are Civil Wars Driven by Rapacity or Paucity," in *Greed and Grievance: Economic Agendas and Civil Wars*, eds. Mats Berdal and David Malone (Boulder: Lynne Reiner, 2000); Indra de Soysa, "Paradise is a Bazaar? Greed, Creed, Grievance and Governance," *World Institute for Development Economics Research Discussion Paper 2001/42 (*Helsinki: World Institute for Development Economics Research, 2001); N. Gleditsch, "Armed Conflict and the Environment: a Critique of the Literature," *Journal of Peace Research* 35, no. 3 (1998).

17. Jon Barnett, "Security and Climate Change," 7–17.

18. Defined as the number of people exposed annually to a storm surge with a frequency of 1 in 1000 years.

19. Rachel Warren, Nigel Arnell, Robert Nicholls, P. Levy, and J. Price, "Understanding the Regional Impacts of Climate Change: Research Report Prepared for the Stern Review," Working Paper 90 (Norwich, UK: Tyndall Centre for Climate Change Research, 2006).

20. A. Swain, *The Environmental Trap: The Ganges River Diversion, Bangladeshi Migration and Conflicts in India* (Uppsala, Sweden: Department of Peace and Conflict Research, 1996).

21. United Nations Development Programme, *Human Development Report 1994* (Oxford, UK: Oxford University Press, 1994).

22. The Copenhagen Consensus Center, http://www.copenhagenconsensus.com.

23. Sam Fankhauser, *Valuing Climate Change: the Economics of the Greenhouse* (London: Earthscan, 1995); David J. Maddison, "A Cost-Benefit Analysis of Slowing Climate Change," *Energy Policy* 23, no. 4–5 (1995): 337–346; Alan S. Manne, Robert Mendelsohn, and Richard G. Richels, "MERGE—a Model for Evaluating Regional and Global Effects of GHG Reduction Policies," *Energy Policy* 23, no. 1 (1995): 17–34; William D. Nordhaus, "To Slow or Not to Slow: The Economics of the Greenhouse Effect," *Economic Journal* 101 (1991): 920–937; William D. Nordhaus, *Managing the Global Commons: The Economics of Climate Change* (Cambridge, MA: MIT Press, 1994); S.C. Peck and T.J. Teisberg, "CETA: A Model for Carbon Emissions Trajectory Assessment," *Energy Journal* 13, no. 1 (1992): 55–77; Erica L. Plambeck and Chris Hope, "An Updated Valuation of the Impacts of Global Warming," *Energy Policy* 24, no. 9 (1996): 783–794; Richard S. J. Tol, "On the Optimal Control of Carbon Dioxide Emissions: An Application of FUND," *Environmental Modeling and Assessment* 2 (1997): 151–163.

24. Grasping Reality with Both Hands: Brad DeLong's Semi-Daily Journal, "Partha Dasgupta Makes a Mistake in his Critique of the Stern Review," http://delong.typepad.com/sdj/2006/11/partha_dasgaptu.html.

25. But there is a residual element to the pure rate of time preference, which is the tiny chance (0.1 percent per year) that society will not be around in the far-off future to reap the benefits of any emission reductions we make today, due to nuclear annihilation or a catastrophic meteor strike, for instance.

26. Partha Dasgupta, "Comments on the Stern Review's Economics of Climate Change," 2006; William D. Nordhaus, "A Review of the Stern Review on the Economics of Global Warming," 2006.

27. John Quiggin, "Stern and the critics on discounting," *Mimeo* (St. Lucia QLD, Australia: School of Economics and School of Political Science and International Studies, University of Queensland, 2006).

28. Cameron J. Hepburn, "Discounting Climate Change Ddamages," (paper read at GES Conference on the Economics of Climate Change, HM Treasury, London, 2007).

29. Based on projections of GDP growth in the PAGE integrated assessment model: see Chris Hope, "The Marginal Impact of CO2 from PAGE 2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern," *Integrated Assessment* 6, no. 1 (2006): 19–56.

30. Mindful of much more comprehensive efforts to define "dangerous" climate change: Stephen H. Schneider and Janica Lane, "An Overview of 'Dangerous' Climate Change," in *Avoiding Dangerous Climate Change*, ed. Hans Joachim Schellnhuber et al. (Cambridge, UK: Cambridge University Press, 2006); Suraje R. Dessai et al., "Defining and Experiencing Dangerous Climate Change," *Climatic Change* 64, no. 1-2 (2004): 11–25.

31. Simon Retallack, "The Problem with Climate Porn," *Guardian* (London), 3 August 2006, http://commentisfree.guardian.co.uk/simon_retallack/2006/08/the_problem_with_climate_porn.html.

32. "Why can't we just adapt" was a famous question posed by Thomas Schelling in "Some Economics of Global Warming," *American Economic Review* 82, no. 1 (1992): 1–14.

33. "Stern Warning," *Economist*, 4–10 November 2006, 14.