Monetized Impacts of Climate Change: Why Are the Numbers so Small?

Evidence submitted to the Stern Review by
Dr. Frank Ackerman, Global Development and Environment Institute, Tufts University
Ian Finlayson, Massachusetts Executive Office of Environmental Affairs

December 8, 2005

Abstract

Most of the extensive research on the economics of climate change has concerned the costs of mitigation. This is sufficient for cost-effectiveness analysis of climate policies; however, cost-benefit analysis also requires estimates of the monetized value of climate impacts. Both the IPCC (2001) and the House of Lords assessment (2005) commented on the relative paucity of cost-benefit analyses, and on the surprisingly small impacts identified in the few available cost-benefit studies.

We present a three-part discussion of estimates of monetized impacts:

- First, we describe the principal categories of benefits of moderate warming that play a major role in the best-known cost-benefit analyses, drawing on our own recent research paper (which is attached) and other sources;
- Second, we explain why the benefits of moderate warming may be overestimated, both because they are incomplete, and because they overlook the harmful effects of increased variance in climate outcomes;
- Third, we argue that it would be a mistake to base policy decisions on the perceived benefits of moderate warming, since this would only accelerate the arrival of more severe warming. Policies should address the ominous long-run trajectory of climate change, rather than focusing on an unexpectedly pleasant, early stop along the way.

We conclude with a brief proposal for additional research to address these questions in greater depth, with a budget of £30,000.

Introduction

There has been extensive research about the economics of climate change, but the distribution of research effort and of the resulting knowledge has been uneven. Most of what we know about climate economics concerns the costs of mitigation, primarily the costs of reducing carbon emissions -- including the technological uncertainties, methodological assumptions, and policy choices that affect those costs. Estimates of mitigation costs are sufficient for cost-effectiveness analysis, calculating, for example, the most cost-effective strategy for keeping atmospheric carbon concentrations below a specified level.

However, the more ambitious and controversial approach of cost-benefit analysis requires additional information about the monetized value of climate impacts. This is necessary in

order to calculate the "optimal" policy, or to determine whether a particular policy is "worthwhile." Both the IPCC's latest report (IPCC 2001, Table 19-4, page 940) and the recent House of Lords assessment (House of Lords Economic Affairs Committee 2005, Table 10, page 53) highlight the same short list of cost-benefit studies. And both reports comment on the surprisingly small impacts calculated by these studies. The IPCC report, while stressing the uncertainties surrounding estimates of aggregate impacts, comments that "Market impacts are estimated to be lower than initially thought and in some cases are estimated to be positive, at least in developed countries." (IPCC 2001, page 942). The House of Lords says more bluntly, "The monetized estimates do not seem to be consistent with the more alarming pictures of global warming damage painted in much of the scientific literature." (House of Lords Economic Affairs Committee 2005, page 53)

Our own recent research has involved an examination of the impact estimates in one of the well-known cost-benefit studies of climate change (Ackerman and Finlayson 2005). A copy is attached with these comments. Our results illustrate the wide variability in plausible outcomes resulting from applying cost-benefit approach to long time horizons. That research has made us skeptical about the underlying assumptions that form the basis for the existing estimates of the monetized impacts of climate change.

In these comments, we offer a three-part examination of monetized impacts of climate change. First, we describe the principal sources of benefits of moderate warming incorporated in the best-known studies. Second, we critique those benefit estimates, both for their incompleteness and for their failure to consider the effects of increased variability of weather. Finally, we argue against basing policy decisions on the estimated benefits of moderate warming, since that can only argue for short-term inaction and thus accelerate the more severe warming which everyone agrees will be harmful.

We focus on the three studies discussed by the IPCC and the House of Lords report, since the repeated citation suggests that these studies have been particularly influential. However, we are aware that there is a broader literature with other, newer contributions addressing the same questions. At the end of these comments, we offer a research proposal for further study of monetized impact estimates, including a more thorough review of the latest literature and coverage of other models.

1. The best-known cost-benefit studies of global climate change assume that moderate warming will create benefits in a few specific areas: subjective enjoyment of warmer weather, agriculture (following adaptation), and reduction in temperature-related mortality.

Using the DICE model, William Nordhaus and Joseph Boyer have estimated that a 2.5° C warming would lead to a loss of 1.5-1.9% of world GDP (Nordhaus and Boyer 2000). It is by far the most negative of the three recent forecasts in the IPCC and House of Lords tables; indeed, it is similar to the IPCC Second Assessment Report estimate shown in those tables. Paradoxically, Nordhaus and Boyer model climate change in some detail, emphasizing the scientific evidence on its hazards, and still conclude that the optimal policy is to do almost nothing. Their optimal policy is a carbon tax which begins at $6 per

ton and rises only to $140 by 2195; the projected result of this policy is a mere 0.2° reduction in warming, relative to "business as usual," by 2195 (Ackerman and Finlayson 2005).

Our examination of the Nordhaus-Boyer calculations found that their benefit estimates are dominated, in the early years, by their assumption of large subjective benefits from warming. They cite limited evidence about time use and temperature in the United States, from which they conclude that people enjoy warm weather outdoor recreation much more than cold weather activities. They believe that the "positive amenity impact" of warming is maximized at a mean annual temperature of about 20° C. Thus they conclude that a 2.5°C warming would be experienced as desirable in all major regions other than South Asia, the Middle East, and Africa (Nordhaus and Boyer 2000, Table 4.10, page 91).

Nordhaus and Boyer find all other impact categories to involve negative externalities (net costs) of warming. In agriculture and health, sectors where some other studies see benefits, they estimate that 2.5° of warming is clearly harmful. However, their monetary valuation of the subjective benefit of warming is so large that they find no net global damages until temperatures have risen 1.3° above the pre-industrial level.

Other studies use different methods of analyzing impacts; neither Robert Mendelsohn and his colleagues nor Richard Tol, the authors of the other well-known cost-benefit studies, include any estimates for the subjective enjoyment of changing temperatures. Mendelsohn et al. calculate that there would be small net benefits, worldwide, from a 1°, 2°, or even 3.5° warming in 2100 (Mendelsohn et al. 2000). Their benefit estimates are dominated by gains in agriculture due to warming; their figures for other sectors are smaller, and contain a mix of positive and negative effects that effectively cancel each other out. In agriculture, they extrapolate solely from earlier studies of the US, and assume rapid, successful adaptation: "Some sectors of the economy are well known to adapt quickly. Agriculture, for instance, tends to respond to new crop programs with great speed." (Mendelsohn et al. 2000, page 559).

Tol likewise assumes that significant adaptation is possible in agriculture, and includes an additional benefit from increased carbon fertilization as atmospheric carbon levels rise (Tol 2002). Without adaptation, his "best guess" is that a 2.5° warming would lead to agricultural losses everywhere except in Europe, the former Soviet Union, and China; but with adaptation, he expects agriculture to gain from a 2.5° warming everywhere. The optimal temperature for agriculture, in his model, is 2.1°-3.4° above 1990 levels everywhere except Europe (where the optimum is a 0.45° increase over 1990).

Tol also estimates significant benefits from moderate warming in another area, the reduction in cold-related cardiovascular mortality. Literature on climate and mortality suggests that a 1° increase in mean temperature would significantly reduce cold-related mortality everywhere. This effect far outweighs heat-related mortality throughout the OECD countries, the former Soviet Union, and China, and roughly equals heat-related mortality in Latin America. As a result, there is a noticeable net global reduction in temperature-related mortality for a 1° increase in mean temperature. Tol estimates that

the value of lives saved can be set at 200 times the regional per capita income, allowing a monetization of this benefit. (Tol is in other respects sensitive to equity issues, proposing a novel "equity weighting" of climate impacts to give greater importance to impacts on the poor. However, his link between the valuation of life and per capita income echoes a bitter conflict that surrounded this issue in IPCC's 1995 report. The controversy is summarized in (Ackerman and Heinzerling 2004, pages 73-74).)

Combining the agriculture and health benefits with the negative impacts in other sectors, Tol concludes that while South/Southeast Asia and (especially) Africa always lose from climate change, other regions of the world will experience net benefits for much of the 21st century, and in several cases the early 22nd century as well (Tol 2002, Figure 13, page 156).

2. The estimates of net benefits from moderate warming are biased by incompleteness, and overlook the harmful effects of increased climate variability.

We maintain that the estimates of net benefits from the first 1°-2.5° of warming, discussed in the previous section, are unpersuasive on several grounds:

- The Nordhaus-Boyer estimate of subjective benefit of warming is simply implausibly large.
- All the estimates are incomplete, and omit or underestimate major categories of impacts that would lead to an opposite conclusion.
- The failure to consider increased climate variability renders the estimates quaintly counterfactual: they describe benefits that might be achieved in an unreal world of smooth, uniform, gradual warming. That is not the world that we are creating through anthropogenic carbon emissions.

2.A. How large are the subjective benefits of warming?

Nordhaus and Boyer propose, on the basis of relatively slim evidence about warm versus cold-weather recreation in the US, that the subjective enjoyment of the climate is maximized at a year-round average temperature of 20°C. This is roughly the temperature of Houston or New Orleans, cities where anyone who can afford it uses air conditioning for most of the year; it is well above the current global average temperature of about 14.5°C.

Other analysts, studying the question in greater detail, have found much more moderate temperature preferences. A recent study explored the link between climate and subjective well-being across 67 countries, finding that the small anthropogenic changes in climate expected over the next 25 years will lead to increased happiness primarily in a handful of the coldest, northernmost countries. Most of the world, including most developed countries, will already be unhappy with climate trends in the near future, long before a 2.5°C warming occurs (Rehdanz and Maddison 2005).

2.B. Omitted or underestimated impacts

In contrast to the subjective benefits of warming, the agriculture and health estimates by Mendelsohn et al. and Tol are based on a broader foundation of evidence. However, even if these estimates were precisely correct for their own sectors, they represent only portions of an incomplete picture. There are numerous, diverse impacts of climate change; in all the studies cited here, the researchers include disclaimers stating that there are important omitted categories, and their results are therefore incomplete. Partial calculations of benefits may contribute incrementally to the accumulation of knowledge, but they do not necessarily provide a good interim estimate of the balance between positive and negative effects.

Indeed, it is easy to imagine incremental research leading farther away from an accurate balance, if one side of the picture is much easier to study than the other. That is exactly what we believe has occurred. Two major categories, the "existence value" of endangered species and ecosystems, and the co-benefits or ancillary benefits of emission reduction, received little or no attention in the cost-benefit analyses discussed here. More adequate treatment of these categories would tend to reduce the reported net benefits of moderate warming.

Of the cost-benefit studies discussed here, Mendelsohn et al. explicitly restrict their attention to market impacts; they omit questions of existence value by design. Nordhaus and Boyer, and Tol, recognize the importance of existence value, but offer almost casual estimates. In the absence of any relevant data or detailed analyses, Nordhaus and Boyer arbitrarily assume that all climate-sensitive human and natural systems are worth only a fraction of one year's output (10% of GDP, or $500 billion in 1990, for the US). They then assume that people are willing to pay just 1% of that amount annually -- $5 billion for the US -- to avoid all the human settlements and ecosystem damages caused by a 2.5°C warming. This implies an annual willingness to pay to avoid climate damages of almost $54 per household, for the 93.3 million households in the US as of 1990. By way of comparison, studies conducted in the 1980s and early 1990s found an average annual willingness to pay for the protection of endangered species averaging $70 per household for the Northern spotted owl, $63 for Pacific salmon, and $46 for grizzly bears (Loomis and White 1996). Nordhaus and Boyer thus assume that people view global warming as a distinctly second-tier problem, a little more serious than the potential loss of grizzly bears, but less worrisome than the loss of spotted owls or Pacific salmon.

Tol offers what he himself refers to as "crude and sweeping assumptions" based on a limited literature review; he calculates the value of ecosystem damages from a 1° warming at $17 billion for OECD America (US and Canada). This appears to be a one time valuation, which is not directly comparable to the annual willingness to pay in Nordhaus and Boyer. As Tol suggests, these estimates should be replaced when better information is available (Tol 2002, pages 54-55).

Valuation of the existence of species and ecosystems raises some of the most difficult philosophical questions in environmental economics. Existence values are extremely

important, in the sense that many people care deeply about nature and are willing to act on that commitment; but attempts to assign monetary values to such commitments are paradoxical and often ethically troubling (Ackerman and Heinzerling 2004). The valuation of human life, required for the monetization of temperature-related mortality, is similarly problematical. However, these deep problems are not resolved by assigning zero value (explicitly or by default), nor by the use of small, ad hoc estimates.

Another area of incompleteness is the failure, shared by Nordhaus and Boyer, Mendelsohn et al., and Tol, to consider the co-benefits or ancillary benefits of emission reduction. Most of the greenhouse gas emissions that contribute to climate change are carbon dioxide emissions from fossil fuel combustion. Most strategies for reduction of such emissions will reduce other fuel combustion emissions at the same time. There are well known health and environmental hazards caused by sulfur, particulates, mercury and other pollutants caused by fuel combustion. In many cases, there is an emerging consensus about the value that should be placed on these pollutants, as in the case of the US sulfur emissions trading system which establishes a market price for sulfur reduction. If carbon reduction strategies lead to a shift away from coal, sulfur emissions will be reduced, creating a readily monetized indirect benefit. Failure to include such benefits biases the cost-benefit calculations against carbon reduction, exaggerating the potential for net benefits from the beginnings of global warming.

2.C. Impacts of variability

Aside from the issues of omitted sectors and categories, there is an analytical problem in the treatment of benefits from moderate warming. The researchers naturally assume that climate change implies an increase in mean temperature; in the important case of agriculture, they go on to assume rapid and successful adaptation to the change in temperature. However, it is becoming clear that climate change is causing not only an increase in mean temperature, but also an increase in the variability (variance) of weather conditions. The well-known recent examples of extreme weather events are at least suggestive of the damage that could be done by increased variability (although it is notoriously hard to associate specific individual events with climate change).

While there are some cases in which a slight increase in mean temperatures could be beneficial, it is hard to imagine a situation in which an increase in variance is helpful. Some people might, as implied by Nordhaus and Boyer, enjoy the steamy temperatures of normal times in New Orleans; but no one enjoys a hurricane that destroys the city. People in many parts of Europe might enjoy another degree or two of warmth, on average, and a predictable, mild warming might well bring a reduction in cold weather deaths. But no one enjoyed the European heat wave of 2003, which also demonstrated the unfortunate capacity of weather variability to increase the death rate.

In agriculture, many crops are dependent on narrowly defined ranges of temperature and precipitation at key stages in their development; adaptation to change will frequently involve switching to new crops that are more appropriate to the changed conditions. But what crops are more appropriate to a more variable, unpredictable climate? In a recent

paper, Mendelsohn and a co-author confirm that research shows climate variance is generally harmful to crops (Mendelsohn and Williams 2004). If cost-benefit analyses begin to include the impacts of climate variance, the reported agricultural benefits of moderate warming will be diminished, if not eliminated.

3. Climate dynamics and economic myopia

Suppose that it is true that, for the reasons proposed in the models discussed above, a little bit of warming provides some net global benefits. All of the studies agree that the benefits disappear as temperatures continue to increase; a bit more warming, and all indicators turn negative. However, the unfortunate practical result of studies that highlight the benefits from moderate warming is to strengthen the argument against active emission reduction policies -- and thus to make it more likely that climate change will gain momentum, barreling forward into the higher temperature regime where no one benefits. Rather than a static end state to be evaluated on its own, the beneficial result of moderate warming could be seen as the initial, deceptively pleasurable stage of an ultimately dangerous addiction.

The extremely long-term physical dynamics of the climate problem present a challenge to economic analysis. Carbon dioxide in the atmosphere has a half-life (average residence time) of 100 years; even longer time spans are required for the oceans to reach thermal equilibrium, and for sea levels to stabilize, following a temperature change. Thus the benefits of climate policy initiatives such as emission reductions are experienced over a period of centuries after the initiatives, and their costs, have occurred. The treatment of time can be decisive to the economic analysis: the seemingly simple bottom-line question, "do the benefits of a climate policy exceed the costs?" depends on the answer to a more abstract and technical question, "how much is the future worth, relative to the present?"

The three studies discussed here all take different approaches to the economic analysis of long-term climate dynamics. Nordhaus and Boyer adopt the standard theoretical approach, discounting long streams of costs and benefits to convert them to present values. Recall that they believe there are net benefits from the first 1.3° of warming; in their base case, it takes about 50 years to reach that level (their model starts at 0.4° above the preindustrial baseline in 1995). So their cost-benefit analysis is weighing 50 good (net benefit) years in the immediate future, versus centuries of bad years thereafter. Their use of a moderately high discount rate ensures that the 'good' years are weighed heavily, relative to the later, harmful effects of climate change.

As we demonstrate in our paper, a lower discount rate makes a dramatic difference in the Nordhaus-Boyer cost-benefit comparison, justifying a sharply higher carbon tax as the optimal policy. To test the model sensitivity, we set the "pure time preference" component of the discount rate, i.e. the rate that would apply in the absence of income growth, to zero; this is a common recommendation in discussions of intergenerational sustainability. With the resulting lower discount rate (based solely on income growth), the later years when climate change is clearly harmful are weighed more heavily, so that

much greater initiatives to reduce emissions today are warranted (Ackerman and Finlayson 2005).

The other two studies take different approaches, avoiding or minimizing the quandaries of choosing a discount rate; however, they also understate the importance of the more damaging, later stages of climate change. Mendelsohn et al. present a snapshot of the world in 2100, with and without varying degrees of warming. This approach has the potential to describe the first century of climate change, but implicitly dismisses or overlooks the accelerating changes in later years. Tol presents graphs of net gains or losses by region, for the next 200 years; within that period, the eye is naturally drawn to the more dramatic changes within the first 100 years. This reflects at best two centuries, at worst just the same 100 year time frame covered by Mendelsohn et al. While these approaches are simpler, and appear visually more powerful than discounting, they lack the theoretical rigor and expandability of the Nordhaus-Boyer present value calculation.

The same pattern that we identified in the Nordhaus-Boyer analysis will occur in any present value calculation with a positive discount rate. The lower the discount rate, the more important the later, hotter years of the analysis will appear in present value terms. The myopia that, in effect, tells us to enjoy the moderate warming of the near-term is an artifact of high discount rates. Recall the summary judgment from the House of Lords report quoted above: are the monetized estimates "consistent with the more alarming pictures of global warming damage painted in much of the scientific literature"? In addition to the other caveats presented here, the answer depends crucially on the discount rate.

The problems of discounting and intertemporal comparisons shed a new light on the question of cost-benefit versus cost-effectiveness analysis. Because the benefits of climate mitigation occur much later than the costs, the discount rate is far more important in a full cost-benefit analysis than in a cost-effectiveness analysis of (comparatively near-term) mitigation costs. Cost-effectiveness analysis seems less theoretically satisfying, and cannot derive optimal policies; at the same time, cost-effectiveness calculations avoid some of the deepest theoretical dilemmas. The discount rate is of lesser importance, and the difficulties of valuing nonmarket impacts such as loss of ecosystems, extinction of species, and loss of human life, can largely be avoided.

On the other hand, for those who are committed to using cost-benefit analysis, and therefore need to monetize climate impacts, it is important to have an understanding of the hidden assumptions that drive the surprisingly low estimates from existing models. Rather than finding low impacts across-the-board, the estimates reflect debatable treatment of a handful of key impact categories, and the explicit or implicit modeling of the vast intervals of time spanned by climate mitigation costs and benefits.

Proposal

These comments have only started the process of systematic evaluation of monetized benefits estimates. We believe that there is a need for more work along these lines. As interest in and acceptance of cost-benefit calculations continues to grow, the impacts side of climate change is in need of much greater scrutiny. We are interested in continuing this line of research, and offer the following brief proposal. We will be happy to elaborate it into a more formal proposal or discuss modifications in its terms.

We will carefully review the literature on monetization of climate impacts, examining the latest work from the authors cited above, plus other models that monetize climate impacts, such as MERGE and MARIA. We will identify the factors causing larger versus smaller impacts, for instance comparing agricultural sector estimates, and the treatment of nonmarket values, across models. The result will be a revised and updated description of the state-of-the-art, identifying the methodological problems and paradoxes that arise, the areas where impact calculations appear particularly incomplete, and the studies that present the best available estimates.

We will present our preliminary results by summer 2006, in a memo suitable for use as an input into the government's autumn 2006 climate review. We will develop a final report on our work, and an article to be submitted for publication in a scholarly journal, by the end of 2006.

Budget

Researcher salaries and benefits (300 hours each)	£23,500
Office costs and administrative support	£3,500
University overhead (10%)	£3,000
TOTAL	£30,000

About the researchers

Dr. Frank Ackerman, the principal investigator for this project, directs the Research and Policy program at the Global Development and Environment Institute (GDAE) at Tufts University in Boston. He has written extensively on the economics of climate change and other environmental policy issues, both in the US and internationally. He was a contributing author to the IPCC Third Assessment Report (Working Group III), and directed a study for the United Nations Framework Convention on Climate Change (UNFCCC) on greenhouse gas emissions from waste management. Currently he is codirecting a study of the impact of US-Japan trade on greenhouse gas emissions, jointly with Professor Masanobu Ishikawa of Kobe University (Kobe, Japan).

In other environmental research, Dr. Ackerman has directed two major studies of European chemicals policy, both of them presented at the European Parliament in

Brussels, "The True Costs of REACH," for the Nordic Council of Ministers (2004), and "French Industry and Sustainable Chemistry" (2005). The European Environment Agency has chosen him to write the economics chapter in the agency's forthcoming book on precautionary approaches to environmental policy.

In the US, Dr. Ackerman has become known as a leading critic of the Bush administration's narrow approach to cost-benefit analysis of environmental policy, based on his book *Priceless: On Knowing the Price of Everything and the Value of Nothing* (jointly with Lisa Heinzerling, 2004), and a series of related, peer-reviewed articles. Dr. Ackerman received his Ph.D. in economics from Harvard University, and has taught economics at Tufts University and at the University of Massachusetts.

Ian J. Finlayson is the State Sustainability Program Manager at the Massachusetts Executive Office of Environmental Affairs. He is a co-author with Frank Ackerman on "The Economics of Inaction on Climate Change: A Critique" currently submitted for publication, and previously co-authored the chapter "Reframing Regulation: Changing Forms of Law and Practice in U.S. Environmental Policy" (in J. van der Heijden and A. Slob (eds), Meervoudig ruimtegebruik [Multifunctional Planning], Delft, Netherlands: Eburon, 2005).

A native of the UK, Mr. Finlayson currently holds both British and US citizenship. He has worked in local and state government in the United States and Japan, and internationally as a consultant to the UN World Food Program, Save the Children and for the Marine Stewardship Council. He received his Masters in City Planning (MCP) in Environmental Policy from MIT, and his undergraduate degree in Economics and Philosophy from the University of Edinburgh. He was a GDAE Researcher and a Harvard University teaching fellow in Economics in the academic year 2004/5.

References

Ackerman, F. and I. J. Finlayson (2005). "The Economics of Inaction on Climate Change: A Critique." *(Under review for publication).*

Ackerman, F. and L. Heinzerling (2004). *Priceless: On Knowing the Price of Everything and the Value of Nothing*. New York, The New Press.

House of Lords Economic Affairs Committee (2005). The Economics of Climate Change, Volume I: Report. London, House of Lords

IPCC (2001). *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Cambridge, UK, Cambridge University Press.

Loomis, J. B. and D. S. White (1996). "Economic benefits of rare and endangered species: summary and meta-analysis." *Ecological Economics* **18**(3): 197-206.

Mendelsohn, R., W. Morrison, M. E. Schlesinger and N. G. Andronova (2000). "Country-specific market impacts of climate change." *Climatic Change* **45**: 553-569.

Mendelsohn, R. and L. Williams (2004). "Comparing forecasts of the global impacts of climate change." *Mitigation and Adaptation Strategies for Global Change* **9**: 315-333.

Nordhaus, W. D. and J. Boyer (2000). *Warming the world: Economic models of global warming*. Cambridge, Massachusetts, MIT Press.

Rehdanz, K. and D. Maddison (2005). "Climate and happiness." *Ecological Economics* **52**: 111-125.

Tol, R. S. J. (2002). "Estimates of the damage costs of climate change." *Environmental and Resource Economics* **21**: 47-73 and 135-160.