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Reconciling the Science and Economics of Climate Change

Eban Goodstein
Bard Center for Environmental Policy

CLEMENS LECTURE SERIES 2010

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His books include *Economics and the Environment, Fighting for Love in the Century of Extinction: How Passion and Politics Can Stop Global Warming*, and *The Trade-off Myth: Fact and Fiction About Jobs and the Environment*. Dr. Goodstein has published in a wide variety of scholarly journals (including *The Journal of Environmental Economics and Management, Scientific American, Land Economics, Ecological Economics,* and *Environmental Management*) and newspapers (including *The New York Times, The Washington Post, Time, The Economist, USA Today,* and *The Chronicle of Higher Education*).

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It's been hot here this week in Minnesota – record breaking. Across the U.S., record high temperatures are outpacing record lows by 6-1. And globally, the first nine months of 2010 have been the hottest in human civilization. It's hot and it is going to get hotter. Today's young people will live through a global warming of 4 degrees F; and depending on our actions in the next decade, that number could stabilize, or rise to 10 or 11 degrees F.

Those are the underlying facts. But there is a wide gulf between some prominent economists and the scientific community on the right response to global warming. IPCC chair Rajendra Pachuari argues that we have only a few short years to act aggressively, to get on a trajectory to cut heat-trapping emissions 80% by 2050. Meanwhile, some economists advocate a "start-slow, ramp-up" policy, that would allow emissions to increase by 50% over the same period.

Perhaps nowhere is the contrast between scientists and economists as great as in the dueling metaphors governing the impact of high end warming: "Collapse" (following Jared Diamond) versus "Reductions in the Rate of Growth" (following all standard integrated assessment models in economics, including those of Nicholas Stern and the IPCC).

By way of reference, mid-range estimates of business-as-usual warming are currently around 4 degrees C. During the last Ice Age, global temperatures were only 4.5 degree C colder then they are today. Many climate scientists, I would argue, believe that high end warming (> 4 degrees C) will likely impoverish much of humanity.

By contrast, economic models calmly integrate this warming of greater than Ice Age magnitude, only in the opposite direction, into scenarios assuming continued growth, albeit at reduced levels. Sir Nicholas Stern, for example, working on behalf of the UK government, provided an integrated estimate of the costs of climate change, forecasting likely reductions in global output as high as 20% below the baseline. This is a big number, justifying immediate and large cuts in emissions on a benefit-cost basis.

And yet, even for Stern, that baseline assumes steady economic growth of 1.3% per capita, implying that by 2200, people on the planet will be 12 times as wealthy as they are today. Ackerman notes that even assuming what Stern characterizes as an extreme worst case scenario – a 35% reduction in income below baseline – then the world would "only" be 8 times richer in 2200. Similarly, the IPCC's four "marker scenarios" all forecast developing country per capita GDP to equal that of industrial countries in 1990, beginning in 2050 (scenario A1B), to out beyond 2100 (scenario A2).

Why no collapse? Economists are acutely aware of a powerful history of a century and a half of economic growth. Tracing the course of GDP, calamities such as the Great Depression, major regional wars, global epidemics like AIDs, or the recent burst in the global housing bubble barely put a dent in long run growth. The default assumption is that capitalism will march relentlessly on, regardless of climate change (or peak oil, or fresh water and top soil shortages). Sidestepping the issue of whether continued economic growth enhances welfare, the conventional economist's position seems well-grounded in historical experience.

Against this record, one school of economists – ecological economists – have developed a sophisticated neo-Malthusian response: that high population and growing affluence mean the future will not be like the past, and that the economics of a full planet make continued global economic growth untenable. As a book of cautionary tales, Diamond's *Collapse* presents lesson after lesson of how resource constraints, married with an inadequate policy response, cascaded into political crisis and undermined the economic foundations of pre-industrial societies. And yet this perspective – a high likelihood of collapse – has not gained much currency among mainstream economics.

Collapse versus slower than business-as-usual growth reflects a paradigmatic difference between physical science and economics regarding the impact of climate change. Even so, among economists, there are some working to close the gap – and others seeking to keep it as wide as possible.

Estimating the Costs of Climate Change

A good way to illustrate the range of opinion is through different economists' estimates of the "social cost of carbon" – the global warming damages arising from the emission of an additional ton of carbon dioxide (CO_2). Richard Tol and William Nordhaus, at one end, view economic damages arising from the emission of a ton of carbon dioxide to range from the low teens to negative – meaning that global warming might actually yield net benefits! (More on this below). Stern, and American economists like Frank Ackerman, derive estimates closer to $100 a ton. The Nordhaus/Tol $10 tax per ton of carbon dioxide implies an increase in the price of gas of about a dime – in other words, don't worry, be happy. The Stern/ Ackerman view of $100 per ton implies the need for an immediate steep increase in the price of gas of $1 to reflect the underlying true social costs.

The climate debate between scientists, and among different camps of economists, is not about the likely physical effects of high end warming. These impacts are incorporated into all economic models. Rather, the differences emerge as different economists focus on the costs of climate change that their models can measure.

What will the economic impact be of a given temperature increase? Calculating the social cost of carbon requires projections of the costs incurred by rising temperatures to the global economy, projections made over the next 100 years for temperatures outside the range of human experience. Impact estimates for a given amount of warming vary significantly.

Richard Tol (2008), the original developer of the FUND integrated assessment model, points out that:

> ...cost estimates omit some impacts of climate change; they tend to ignore interactions between different impacts, and neglect higher order effects on the economy and population; they rely on extrapolation from a few detailed case studies; they often impose a changing climate on a static society; they use simplistic models of adaptation to climate change; they often ignore uncertainties; and they use controversial valuation methods and benefit transfers.

To illustrate this complexity, compare the baseline cost estimates for the United States for one of the major integrated assessment models, DICE, developed by economist William Nordhaus (2008) at Yale, with an alternate set of estimates recommended by University of California – Berkeley economist Michael Hanemann. Hanemann (2010) provides a category-by-category critique of Nordhaus, and recommends increasing the DICE baseline estimates by a factor of 4. The figures reported here are for a 4.5°C warming above 1990 levels.

	Nordhaus (DICE)	Hanemann
Market Impacts		
Agriculture	$6	$23
Engergy	$0	$8
Water	$0	$15
Sea Level	$9	$53
Non-Market Impacts		
Health, Water Quality, Human Life	$3	$15
Human Amenity, Recreation, Leisure	-$26	$-8
Human Settlements and Ecosystems	$9	$17
Extreme and Catastrophic Events	$38	$38
Total	$39	$161
Excluding Extreme and Catastrophic	$1	$123

Table 1. Annual US Economic Impacts of a 2.5˚C Warming, in $2008 Billions. Sources: Nordhaus, 2008 and Hanemann, 2010.

This comparison begs many questions, and is used here primarily to illustrate that Nordhaus's DICE model is conservative in many of its underlying assumptions about climate change impacts when compared with the Hanemann model. Excluding the category of "Extreme and Catastrophic Events" (measured as annual national willingness to pay for insurance against the possibility of catastrophic events such as rapid sea level rise). Nordhaus's net overall annual U.S. cost estimate is $1 billion – smaller than a rounding error in today's $14 trillion U.S. economy.

Part of the reason for this low estimated cost is that Nordhaus assumes large recreational and amenity benefits ($26 billion) from warmer weather; for example, more good golf days. Beyond that, his cost estimates by category are all in the low billions of dollars. Given that western U.S. water supplies are expected to be dramatically impacted by declining snowpack, Nordhaus's assertion of a zero dollar figure for that category is surprising. Given likewise that a 4.5°C warming is anticipated to drive 20–30 percent of the species on the planet into extinction, including via accelerated acidification of oceans, the figure of $9 billion for ecosystems and human settlements combined also seems low (IPCC, 2007). The disparity between Nordhaus's and Hanemann's estimates provides a sense of the challenge economists face in estimating the impacts of future climate change.

Uncertainty in the temperature-damage function is natural, because we do not fully understand the physical changes to the planet that will result from a given temperature increase. Consider for example the two estimates in Table 1 for sea-level rise costs: $6 versus $25 billion. Plausible estimates of sea-level rise during this century – due to thermal expansion of seawater, melting of temperate glaciers, and the potential collapse of the Greenland and West Antarctic Ice Sheets – range from a manageable tens of centimeters to a truly devastating two meters (Pfeffer et al., 2008).

Serious sectoral analysis of high-end warming impacts are few. One example is Nicholls et al. (2008), who explore the case of a 5-meter, 100-year sea-level rise resulting from a hypothetical, rapid collapse of the Greenland and/or West Antarctic Ice Sheets. Some 400 million people currently live in land that would be potentially inundated. Actual inundation and relocation would depend on the degree of coastal protection initiated. The authors suggest that coastal protection of up to 50% would be justified on a benefit cost basis, reducing actual displacement to fewer than 15 million people over 100 years. Now this conclusion is hedged by several caveats, most prominently, that in some countries the costs of protection would rise prohibitively, to above 1% of GDP, and that Katrina (and add the BP blowout) show that optimal defensive investments are seldom made. Nevertheless, the paper has a startling bottom-line that is very, very far from collapse: a five-meter, rapid sea level rise might imply displacement of only 150,000 people per year, on average. Nothing worse here then your average earthquake year.

To sum up: economic analyses that model marginal changes have a hard time grappling with the economics of disaster. That said, academic economists nevertheless have waded in, and do tend to be aware of the limitations of their modeling exercises, providing appropriate caveats in the text. But those caveats often disappear from the bottom line policy purposes to which such studies are put. Thus we get the projections of continued future economic growth from the IPCC, and Stern.

Beyond trying to assess and price the actual physical damages – some mitigated through adaptation – that humans will face in a hotter world, economic estimates of the social cost of carbon also are highly sensitive to the analyst's choice of the discount rate used in their models.

Discounting the costs of climate change

Briefly, economists generally measure future benefits and costs in present value terms, as the amount of money that would have to be invested today at the going rate of return to generate a comparable cost or benefit in the future. Discounting is integral to decision-making in a cost-benefit framework, but is problematic over long-time horizons.

In the case of global warming, the argument for discounting is as follows. Preventing impacts from CO_2 emissions – for example by building a sea-wall or investing in solar energy – bears an opportunity cost. The incremental dollars spent on sea walls or solar panels might have built a school or financed research and development in new pharmaceuticals. Discounting future climate costs insures that society does not over-invest today in stabilizing the climate, but instead weighs those investments equally with other investments of potential benefit to future generations.

The argument for discounting is most persuasive when analyzing the benefits and costs of projects with a time-horizon occurring within a single investor's lifetime, such as a 30-year mortgage. However, a ton of CO_2 released today will continue to impose economic costs for at least 100 years. Discounting truly does "discount" costs that are incurred in the future. Costs of $100 that occur at the end of this century are reduced to a present value of $40.90 at a discount rate of 1 percent, $7.00 at 3 percent, and only $1.20 at 5 percent.

For short-time horizon cost assessments, discount rates of 3 to 5 percent are reasonable; they often reflect the foregone opportunity costs of investing dollars in one area and not another. When discounting at 5 percent, however, a logic that tells us not to spend $1.20 today to prevent, in 90 years, $100 in economic costs to our descendants is troubling to most people, including many economists. Discount rates that rise above 3 percent result in analyses that dramatically reduce the present value of any costs to people or the planet beyond a 30 to 40 year time horizon, largely excluding climate impacts on future generations from the cost-benefit calculus.

Lack of intergenerational equity may be the best-known and most intuitive criticism of the use of high discount rates for long-time horizon analyses. This concern has been reinforced by numerous economic studies focusing on a number of other technical issues. Given these problems, the U.S. EPA (2008) concludes:

> A review of the literature indicates that rates of three percent or lower are more consistent with conditions associated with long-run uncertainty in economic growth and interest rates, inter-generational considerations, and the risk of high impact climate damages (which could reduce or reverse economic growth).

In spite of the many persuasive arguments against the use of high discount rates, Tol and Nordhaus continue to advocate for the use of 5% discount rates. And in fact, in Tol's FUND Model, the use of a 5% rate typically results in a estimate of the social cost of carbon of less than zero – implying that global warming will yield positive net benefits to human society from business-as-usual global warming, i.e., around 3°C over current temperatures by 2100.

This rather surprising result emerges because FUND assumes large positive impacts from mild global warming in the early years, that are later overwhelmed by economic costs as the earth's atmosphere continues to warm up. However, at the 5 percent discount rate, the later impacts and costs are more than offset by the early benefits, leading the model to conclude that humans are better off, on net, with business-as-usual global warming. DICE has a similar structure with large initial benefits. In its latest iteration, however, the model finds that at a 5 percent discount rate business-as-usual global warming has positive, but very small, net costs. What are these up-front benefits?

As noted above, DICE assumes large amenity and leisure benefits from the early stages of warming – for example, people will have longer fall and spring seasons for outdoor recreation. FUND includes an assumption that on net, a reduction in cold-related deaths will greatly outweigh an increase in heat-related deaths. FUND's designer, Richard Tol (2008), and co-authors have argued that a 1°C increase in the global mean temperature would save, on net, more than 800,000 lives a year by 2050. Both models also assume that agriculture will initially benefit from CO_2 fertilization and longer growing seasons, before eventually experiencing net costs.

DICE assumes that human enjoyment of the weather is maximized at a year-round average temperature of 20°C. As Ackerman et al. (2009b) note: ". . . 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." Redhanz and Madison (2005) find that outside of the most northern countries, there will be few amenity benefits from even the first few decades of warming.

Regarding the health benefit estimates in FUND, Ackerman and Stanton (2008) demonstrate that their existence depends on the questionable assumption that humans would not adapt to local temperature changes. Finally, the magnitude of alleged agricultural benefits has been challenged by Schenkler et al. (2005), Hanneman (2010), and others.

This debate over whether or not large benefits from global warming exist in the short-term brings us back to the difficulty of specifying temperature-damage functions and provides yet another example of the perverse impacts of high discount rates.

Even assuming that the amenity, health and short-term agricultural benefits identified by Nordhaus and Tol are real, the 5 percent discount rate clearly privileges these short-term net benefits enjoyed by the current generation, as the planet warms slightly, over longer term net costs imposed on our grandchildren and generations to follow, as the earth heats up dramatically. The result is a model outcome arguing the counterintuitive case that unchecked global warming will, on balance, benefit humanity.

To sum up: deriving a social cost of carbon is a horrendously assumption-laden exercise, both in terms of guessing the many sectoral costs of climate change across a whole range of potential temperature increases, and then in choosing the discount rate.

That said, and staying within the dominant economic framework that assumes continued global economic growth, it is nevertheless possible to argue a strong economic case for sharp near-term reductions in global warming pollution, with a goal of stabilizing at a 2 degree C warming. Economic models that assume continued growth – but also, low discount rates, high business-as-usual emissions, high climate sensitivity, and a high temperature damage function – generate estimates for the social cost of carbon of greater than $100 per ton, consistent with strategies that force a near term peak in global CO_2 emissions and support cuts in carbon of 80% by mid-century.

Collapse, Growth and Insurance

Is there a role for actual collapse in economic modeling? Harvard's Martin Weitzman provides a useful metaphor for high-end warming (>4 degrees C): it will leave humanity inhabiting "a terra incognita biosphere." In an unrecognizable bio-physical world, continued global economic growth is possible – it is hubris to categorically assert otherwise– but Diamond-like catastrophic outcome would also seem to have uncomfortably high probabilities, especially for regional economies.

Science suggests that high-end warming does have this kind of probability under business-as-usual pollution – well into the double digits. Under these circumstances, rather than think about the optimal amount of pollution as determined by the "right" carbon price, it is better to consider investments in climate stability as a form of insurance.

If growth continues, this insurance will be quite cheap: colleagues and I have shown that very aggressive climate policy, targeting CO_2 levels of 350 ppm by the end of the century, would likely divert about 3% of GDP per year from consumption to investment. In a world economy growing on a per capita basis at 1.3% per year, that would mean our descendants in 2075 could inherit a clean energy economy and a stable climate, but have to wait two and a half years, until the middle of 2077 to be as rich otherwise as they would have been on a dirty energy trajectory.

If climate catastrophes do emerge under business-as-usual – reversing growth in some regions or perhaps globally – then, of course, this insurance investment in the form of a world rewired with clean energy, would pay off in spades.

When climate scientists venture into policy, it is often with reference to the biblical hell and high-water that high-end warming will unleash: floods, droughts, famine, fire, plague, mass extinction. Will economic growth continue through these turmoils? Here is where economists and scientists differ. But even if there is a 90% chance that growth continues, and a 10% chance of collapse, the standard economic answer would be: buy insurance to reduce the odds of catastrophe. In turn, the underlying assumption of long run growth makes that insurance quite affordable. Bottom line: by balancing the risks of economic collapse against the powerful engine of global growth, insurance investments in climate security can reconcile economic and scientific perspectives on climate change.

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