Part Two: Comments on the Stern Review

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Opposite Ends of the Globe

The *Stern Review on the Economics of Climate Change* (Cambridge University Press, 2007, hereafter *Review)* has put forth a somber assessment of the risks of climate change. It concludes that "if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more." The *Review* proposes sharp, urgent, and immediate reductions in emissions.

Although using the language and tools of economics, its results are dramatically different from many existing economic models that use similar data and structures. What is the reasoning behind this radical revision? Is it based on sound economic analysis? I will address these questions in my talk. (This talk is drawn from a longer study, *A Review of the Stern Review on the Economics of Global Warming,* forthcoming *The Journal of Economic Literature* and available at http://www.econ.yale.edu/~nordhaus/homepage/SternReviewD2.pdf .)

Areas of Agreement and Disagreement

It will be useful to list the areas of agreement and disagreement, shown on the first slide. Begin with five fundamental assumptions that are widely accepted among natural and social scientists in this area. These propositions are fundamental to the *Review* and to much other research in this area (with many qualifications and reservations).

1. Global warming is state-of-the-art science.
2. Unchecked warming may lead to large and costly long-run ecological and economic impacts.

3. The complexities and uncertainties are enormous in the science, economics, and ecology.
4. Global warming is a major global public good.
5. Solutions will involve raising the market price of carbon

I would pause on the fifth point. Like many economists, the *Review* emphasizes the need for increasing the price of carbon emissions. This might come through a carbon tax or through marketable emissions permits, such as are now traded in the European Union. I will call these "carbon taxes," but this is really a short hand for a market penalty or limitation. A carbon tax is necessary both to provide incentives to individual firms and households and to stimulate research and development on low-carbon technologies. Carbon prices must be raised to transmit the social costs of GHG emissions to the everyday decisions of billions of firms and people. This inconvenient economic truth is virtually absent from most political discussions of climate change policy. In Al Gore's documentary on global warming, he gingerly asked about the costs of slowing climate change. But then he backed away by saying that slowing climate change is an opportunity, not a cost.

The next two areas are ones where the *Review* has staked out quantitative positions that have been more controversial.

6. The trajectories of emissions, temperature, and impacts is very steep, with the potential for a large temperature increase by 2050.
7. The central estimates of climate damages are much higher than many studies while the estimated abatement costs and slightly lower.

What about the description of underlying science, economic trends, costs, and damages? Here, the critics are divided, and some of the other participants have dealt with these issues. The *Review* is a reasonable interpretation of existing science in most areas. It may exaggerate and compound the extreme events, but this may help overcome the usual

tendency to underestimate risks and forget about correlated risks. The differences here are probably differences of tens rather than hundreds of percents.

In one respect, the *Review* inflicts cruel and unusual punishment on the English language. In discussing economic impacts, I quoted above the *Review's* finding that "… the cost of climate change [is] the equivalent of a 20% cut in per-capita consumption, now and forever." This frightening statement suggests that the globe is perilously close to driving off a climatic cliff in the next few years. However, when the *Review* says that there are substantial losses "now," this does not mean "today."

In fact, these impacts are far into the future, and the calculations depend critically upon the assumption of low goods and time discounting. Take the extreme-extreme-extreme case of the high-climate scenario with catastrophic and non-market impacts. For this case, the mean losses are less than 1% of world output in 2050 and around 3% in 2100. This becomes 14% "now" because of an extreme assumption about discounting. By annualizing this damage at an infinitesimal growth-corrected real interest rate, this distant rumble turns into the "20% cut in per-capita consumption, now and forever." By my reckoning, this is an exaggeration by a factor of 1000 percent. But the reason is primarily because of discounting, not because of the estimates of damages.

There are two areas of fundamental disagreement, where, in my view, the *Review* lost its way:

8. The role of peer review, modeling, and reproducibility
9. How future economic costs and benefits should be discounted

I will deal with these two issues in my talk.

Review, Reproducibility, and Modeling

The *Review* is a political document and has advocacy as its purpose. But that is London and this is Yale, and I will address it as a scientific study. The central methodology by which science (including economics) operates is peer review and

reproducibility. The study does not play by the ground rules of standard science and economics. It was published without a prior appraisal of methods and assumptions by independent outside experts. I could not find a document with sources and methods that would allow me to reproduce the results. I could not retrace their steps.

These may be seen as bowing and scraping to hidebound academic traditions, but it is fundamental to good science and economic analysis, in London as in Yale. These practices help protect authors from correctible mistakes. They help governments from digging themselves ever deeper into their own misguided realities. The British government is not infallible in questions of economic and scientific analysis on global warming, any more than it was on Iraq's weapons of mass production five years ago (*Iraq's Weapons Of Mass Destruction: The Assessment Of The British Government*, September 2002). External review and reproducibility are essential for ensuring logical reasoning and appropriate respect for contrary points of view.

In part, these issues relate to the *Review*'s distrust of models. The Stern team picks and chooses among models. It likes the science models, but it dislikes economic models which have inconvenient findings. It is not apparent whether its policies are internally consistent or consistent with any existing model. Its main modeling effort drew upon the PAGE model, but it changed the parameters so drastically that the mean social cost of carbon was ten times higher in the *Review* runs than in the baseline runs of the modeler himself. It should be emphasized that models are for insights not truth. They are primarily accounting devices for keeping score and ensuring consistency. They help understand this enormously complicated non-linear dynamic system. The message of the *Review* is confused because of its ambivalence to keeping score.

The Discounting Controversy

My second point is that virtually the entire difference between the *Review's* results and those in most other studies lies in its approach to discounting. At the outset, we should recall the warning that Tjalling Koopmans gave in his pathbreaking analysis of discounting in growth theory. He wrote, "[T]he problem of optimal growth is too complicated … for one to feel comfortable in making an *entirely* a priori choice of [the time discount rate] before one knows the implications of alternative choices." This

conclusion applies with even greater force in global warming models, which have much greater complexity than the models that Koopmans analyzed. I think the *Review* simply got tangled up in the trees of the high theory of discounting and lost sight of the forest.

The practical implication of the discounting controversy centers on the appropriate real interest rate to use in making investments to slow climate change. (I note in passing that my discussion omits many deep qualifications concerning risk, uncertainty, taxes, borrowing constraints, and the like.) The theoretical apparatus in the *Review* leads to very low real interest rates. The equilibrium real interest rate for the world in their view is 1.4 %per year over the indefinite future.

So when comparing potential investments in climate abatement with those in, say, education in America or China, vaccines in Europe or Africa, or shelter anywhere, the *Review* would discount the costs and benefits from climate investments by this very low rate.

My main concern with the *Review* is that this procedure seriously underestimates the return on investment. Maybe not in Merry England since 1914, but definitely in the United States, China, and much of the rest of the world. Just to provide two important examples: Careful estimates indicate that the real pre-tax return on U.S. corporate capital over the last four decades has averaged about 7 %per year. To go to the wider world, James Heckman finds that there is a vast reservoir of investments in human capital in the developing world. To take China, he writes, "The true rate of return to education in China may be as high as 30% or 40%." ("China's human capital investment," *China Economic Review* 16 (2005), pp. 50–70) I am sure that Jeff Sachs could find a similar large pool of high-yield investments in health and other areas in Africa. Even 20-year inflation-indexed bonds in the U.S., currently yielding 2½ percent, have a substantially higher return than that used by the *Review*.

Economic Modeling With Low Discount Rates

It seems worth a moment to examine alternative discounting assumptions in an integrated economic analysis. Chris Hope provided an example this morning, and I will provide another, and much simpler, example. For this purpose, I draw upon an existing and well-documented model of the economics of climate change, the "DICE model,"

which has been updated to the most recently available data, economics, and science. (The most recent runs are available at http://www.econ.yale.edu/~nordhaus/DICEGAMS/DICE2007.htm.) I then make three runs.

Run 1. *Optimal climate change policy in the DICE-2007 model.* This run estimates the path of greenhouse gas abatement that maximizes net economic welfare over the indefinite future. The model assumes time discounting at 1.5 %per year and a utility function that generates market interest rates.

Run 2. *Optimal climate change using the Review zero time discount rate.* This run is the same as Run 1, but it uses the Review's assumption about time discounting and the utility function.

Run 3. *Optimal climate change using a zero time discount rate recalibrated to match market returns to investment.* Like Run 2, this run assumes zero time discounting, but it recalibrates the utility function so that the model generates market interest rates.

What do these calculations show? Figure 1 compares the future path of real returns on capital. The striking point is the different view of capital returns. To implement the low time discounting assumption of the *Review*, the world increases its savings rate sharply, and the real return with the *Review* parameters takes a steep nosedive. The other runs have a slow glide path of returns over time, reflecting the assumed slowdown in the rate of economic growth. I cannot stand here and say that I know that my view is right and that the *Review* view is wrong. But they point to no evidence suggesting that their view of returns on capital is right, and there is substantial evidence that it is wrong.

Figure 2 shows the path of global average optimal carbon taxes in each run. Recall that a carbon tax is a useful measure of the relative tightness of abatement. In the updated DICE model, the calculated optimal carbon tax for 2010 prices is around $30 per ton carbon. The *Review's* ethical parameters have an implicit carbon tax of around $300

per ton carbon. The *Review* does not have a firm recommendation for a carbon price, but they suggest something in the $120 - $140 per ton C range.

If we take the zero time discounting and recalibrate it, the carbon tax looks very much like the DICE run 1. The reason is the balancing of current and future costs and benefits takes place via the real interest rate, and the underlying time discount rate does not directly enter the calculation. The way that the *Review* gets a high carbon tax, a high social cost of carbon, and high emissions reductions is through the low interest rate, not the low time discount rate.

Just to put these numbers in perspective. The global average carbon taxes implicit in the first round of the Kyoto Protocol are approximately one-tenth of the level in the DICE optimal run 1, and approximately one-hundredth in the *Review* targets in run 2. The fiscal transfers from consumers to producers and governments for the United States would be approximately $500 billion for the *Review's* targets in run 2. The carbon restraints, if efficiently imposed, would increase the wholesale price of coal from $25 per ton to $200 per ton. These are indeed ambitious targets!

Summary Verdict

How much and how fast should the globe reduce greenhouse-gas emissions? How should nations balance the costs of the reductions against the damages and dangers of climate change? The *Review* answers these questions clearly and unambiguously: we need urgent, sharp, and immediate reductions in greenhouse-gas emissions.

My conclusion is that economic reasoning does not justify the policy recommendations of the *Review.* The *Review's* radical revision of the economics of climate change does not arise from any new economics, science, or modeling. Rather, it depends decisively on the assumptions of a near-zero time discount rate combined with a particular view on inequality. The *Review's* unambiguous conclusions about the need for extreme immediate action will not survive the substitution of assumptions that are consistent with today's market place real interest rates and savings rates. So the central questions about global-warming policy – how much, how fast, and how costly – remain open.