# Chapter 7: Gary Yohe, Wesleyan University

The *Review*, of course, has turned into a little bit of a "full employment act" for economists who know a little bit about climate. We are likely to be busy for quite a while in the wake of its release, and so it is good to pause for a day to take stock of what we know and what we need to do, now.

I've been asked to think a little bit about the stabilization side of the *Review*. As I do, I want to start by identifying Richard Tol as a collaborator and co-author in much of what I've put together over the past three months in response to the *Review* [see Tol (2006), Tol and Yohe (2007), Yohe (2006), Yohe and Tol (2007) for a chronicle of our thinking]. Richard and I have both learned an enormous amount as we have tried to work through its details.

In turning to consider the mitigation side, it is still important that we continue to recognize the most recent science as presented by the *Review,* but I think that it is important to apply that science to best serving decision-makers who face the question of what to do over the near term. In that regard, it seems to me important to them out from the burden of solving the climate problem. That is simply not going to happen. We are not going to set policy in 2007 for the entire century. Today's decision-makers must acknowledge the problem, to be sure, but they should try to design policy for the near term that minimizes expected adjustment costs as the science evolves while they work to create a long-lasting institutional structure within which that science can be taken on board without political manipulation.

To reiterate some of the important natural science points raised in the *Review,* the recent literature suggests that climate change is changing more rapidly than we thought five years ago. It also concludes that impacts are likely to become more severe as time goes on and temperatures rise. Some impacts have already been observed and attributed to human activity; and others are likely to be felt sooner than thought only five years ago. Rachel Warren and colleagues (Warren, et al., 2006) crafted a wonderful supporting document to emphasize these points. Their assessment of the science is, in fact, entirely consistent with contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) that was approved in Paris two

weeks ago at the end of the most recent plenary meeting of the Conference of the Parties of the United Nations Framework Convention on Climate Change.

Figure 1 replicates the summary figure of impacts from Chapter 3 of the *Review*. The major conclusions are displayed in its lower panel, but it strikes me that the most important conclusion is portrayed in its upper panel: no temperature target can be guarantied by any feasible concentration limit. The best that we can do is to characterize the range of uncertainty (expressed in terms of increases in global mean temperature) that could be achieved by any specific concentration stabilization target. We can then look to the lower panel to see what climate risks might still exist, but we cannot assume a one-to-one association between temperature and concentration. This conclusion makes it clear that the question of choosing near-term climate policy is best approached as a risk-management problem and not the result of a tractable cost-benefit calculation.

Many authors have argued with the cost estimates presented in the *Stern Review,* just as many have criticized its benefit estimates. It seems to me, however, that focusing on either set of numbers runs the risk of missing the point if the question is how best to inform decisions about near term mitigation. How, more specifically, can we design near-term policy that would be consistent with the long-term objectives that will, of necessity, change as our understanding of the science evolves? And as the science evolves, how should we allocate our scarce time and research efforts to sort through persistent uncertainties and confounding controversies most efficiently? For a good friend of mine, Lester Lave, from Carnegie Mellon, the answer to the second question is two – i.e., if resolving the uncertainty about a specific factor doesn't make a difference of a factor of two in a variable of interest (like temperature change or the likelihood of an abrupt impact), then it is "inside the noise" and you should probably move on and look for something else to worry about.

I will apply Lester's criterion in a minute, but first I want to spend a minute or two on the risk-based per capita consumption metric that the *Review* employees in making its damage estimates. It is provocative and innovative application of sound fundamental economic theory; and it can help. From what I understand, the *Stern Review's* author team computed multiple per capita consumption runs using Chris Hope's PAGE2002 model [see Hope (2006) for documentation]. They then computed the

discounted utility for each one of those runs at 0.1 % discount rate. Then they computed expected discounted utility across the full set of runs given the probability weights from the PAGE2002 model. And finally they computed a certainty equivalent level of consumption, which, if it were to grow at 1.3 % per year starting in 2007, would generate a level of discounted utility equal to the expected utility across all of the underlying runs. They captured, in other words, all that complication and all that future into one number; and the damages attributed to climate change were simply the difference between in those numbers with and without climate change.

This process produces results that express the expected damage associated with unabated climate change across a wide variety of futures as the equivalent of a 5.3% reduction in per capita consumption "now and forever". This does not mean that we will wake up tomorrow and notice that we have lost 5.3 % of our per capita consumption. It means that the discounted values of damages driven by 200 years of climate change *and* the risk premiums associated with the current state of knowledge (i.e., current range of uncertainty in critical parameters) sum to a number that is the equivalent of that reduction. The quoted damages estimates are nothing more than a cardinal metric of utility loss calibrated in terms of per capita consumption.

As I suggested before, some have argued with the *Review's* estimates of mitigation costs; most claiming that they are significant underestimates at best. Mitigation costs depend, of course, on policy design (flexibility, persistence, and predictability) and what the government might do with any revenue that it might collect. That said, I am personally a little puzzled about why the *Review* focused on the 550 ppm concentration target that had been justified by earlier studies released in the United Kingdom on the basis of much smaller damage estimates. If damages are now so much larger, why not discuss a lower target?

Would changing the concentration target satisfy Lester Lave's factor of two rule? That is hard to say. The reason for going through the description of the certainty equivalence applied in damage calculation was to show why it is so difficult to compare damages (and thus the benefit side of the policy equation) with mitigation costs that the *Review* expressed in terms of the percent of GDP lost through 2050. Indeed, readers are never able to really see in the review comparison of those numbers. They are never able

to judge the results of a proper cost-benefit comparison, as a result; and they are never told how much the cost of mitigation might decline if the metric included the value of reduced risk implied by various mitigation targets (i.e., reduced variation across discounted consumption streams generated by the more certain futures of restrained emissions).

Richard and I responded to this omission by conducting our own comparison using *Stern's* consumption equivalent metric. To do so, we constructed a very, very simple climate model with three regions. We imbedded a few assumptions about climate sensitivity, rates of economic growth across regions, different calibrations of vulnerability to climate impacts, and so on. We calibrated the model so that unabated climate change would achieve maximum concentrations at about 1000 ppm and support a damage estimate equal to losing 5.3% in per capita consumption equivalence. Table 1 shows the results for various concentration targets. A reduction in damages from 5.3 % down to 2.2 % was achieved by a 550 ppm limit; and a 400 ppm target lower damages below 1%. Clearly, changing the concentration target of climate policy satisfies Lester's rule. To be clear, though, these estimates of benefits (damages avoided) do not indicate the net value of mitigation, because the cost of mitigation is not included in the calculation.

Are there any other simple factors that sort of would satisfy Lester's rule? The discount rate has, of course, attracted a lot of attention. In our little model, lowering the discount rate from 0.1 % to 0.01 % caused damages to increase only slightly from 5.3 % to 5.4%. It follows that the 0.1 % rate chosen by *Review* authors is a pretty good approximation of zero; pushing further in that direction doesn't do much and Lester would warn against spending much time doing so. Raising the rate to 1.5 % would, however, reduce damages by more than 50%; in this regard, we simply confirm something that was to be expected.

We also wondered what would happen to damage estimates if vulnerability were not assumed to be a static percentage of GDP. What if vulnerability fell with income in poor countries? We calibrated this reduction so that vulnerability there would match current vulnerability in the developed world if and when per capita consumption reached

current levels in the developed world. The result was another 50 % reduction in aggregate damages.

Notwithstanding these issues, I think that the *Review* does provide enough information to support an economic case for immediate action. The *Review* portrays climate risks, as currently perceived, quite clearly. Any reader identify a risk that he or she would call "dangerous", translate that into a temperature target of "tolerable climate change", and then examine the effects of achieving various mitigation targets (expressed in terms of greenhouse gas concentrations) on the likelihood of crossing his or her critical threshold. This is why Figure 1 is my favorite picture in the whole *Review*. The red arrows highlight a list of possible events that could be considered "dangerous" by one reader or another. It identifies temperature triggers for each event. And it shows what happens to the likelihood of crossing that threshold if concentrations were limited to 550 ppm, or 450 ppm, or 650 ppm.

A reader who agrees with the European Union that two degrees is a good target would, for example, see that that a 550 ppm concentration limit would still leave a 70 or 80 % chance of exceeding the temperature threshold. A 400 ppm limit would leave a 30% chance, and so on. A reader who was less concerned with impacts that could begin with another 2 to 3 degrees of warming might pick a 3 degree target. A 550 ppm concentration limit would make it a coin toss that this reader would be disappointed; and a 400 ppm would make it a role of a dice.

Once this mental exercise has been completed, then the simple economics of the Hotelling rule applies. To a first approximation, any concentration target is a cumulative emissions constraint. As a result, the long-term climate policy problem becomes an exhaustible resource problem for which the solution is well known: pick an initial scarcity rent and let it grow at the rate of interest.

What about the short-term policy problem? Debate over what to do now must acknowledge climate risk in the context of its inherent long time horizon, but it must also think about the political tractability. A carbon price of $30 per ton of $CO_2$ (or $100 per ton of carbon) seems to be a magic number for which electric power plants might switch from coal to natural gas and where a number where carbon sequestration might become economic. But the price of carbon does not have to be at $100 per ton in 2007 to be

effective. If it is going to increase at the rate of interest in a predictable and persistent way, then the initial price (scarcity rent) must be set at a level for which the present value calculations of the private sector investors (using private sector discount rates that are not vulnerable to all of the controversy about how to discount the distant future) favor less carbon-intensive processes.

A $50 per ton price on carbon ($15 per ton of $CO_2$ or twice the level currently incorporated in draft legislation before the Senate Energy Committee) would, for example, reach $100 around 2021 with a 5% interest rate. Investors are smart. They would see that coming. They would factor that into their calculations; and the near-term policy would not have to be draconian. The fundamental notion is to try to figure out ways to avoid enormous locked-in investments that would commit the economies of the world to high-carbon-intensity means of production and transportation for decades to come. The opportunity to make money by being a first mover in response to a predictable policy environment should be the goal.

There are at least two critical points to be made about adaptation in a discussion of mitigation. First of all, adaptation to climate *will be required* regardless of what we do in the near term. Even if we shut down emissions of all greenhouse gases tomorrow, we are already committed to almost another half a degree of warming over the next 50 to 100 years. Secondly, human systems will adapt to climate change *and to climate policy* as the future unfolds. Some have argued that we have overestimated damages because we have underestimated the ability of communities and systems to adapt. That may or may not be true, but parallel reasoning suggests that we may have also overestimated the cost of mitigation because we have underestimated the ability of systems to adapt to the policy.

In closing, I want to thank Sir Nicholas and his team for having the courage to take on this enormous challenge and for coming here and continuing the debate and for teaching me so much about all of this. I also want to thank Yale for allowing me to return to New Haven to participate in the continuation of the community's review of their work.