

Submission on the Garnaut Review Issues Paper 3

The Role of Uncertainty and Risk in Costing Climate Change

Dr Peter John Wood, April 2008

Introduction

This submission is in response to the *Garnaut Review Issues Paper 3 - Climate Change: What is the science telling us?* [1]. It is also in response to the *Garnaut Climate Change Review Interim Report* [2], in particular Section 2.2 on “Uncertainties in the climate change science” (Pages 10-13).

Much of this submission is related to recent work by Harvard economics professor Martin Weitzman that is discussed in a recent preprint *On Modeling and Interpreting the Economics of Catastrophic Climate Change* [3]. The significant uncertainties about the impacts of climate change suggest that many factors affecting its impacts should be modelled by a probability density function (PDF) rather than an average value. These PDFs often have what are known as 'fat tails'. Using this approach Weitzman has shown that the costs are dominated more by low-probability high-impact catastrophes than by the most likely possibilities. This implies that conventional cost-benefit analysis significantly underestimates the cost of climate change.

This submission will summarise Weitzman's paper and some related areas of climate change science. This will include uncertainty regarding climate sensitivity and feedback processes. We shall conclude with a discussion of what implications these results have for climate change policy.

1. The Impact of Uncertainty on Costing Climate Change

In [3], Weitzman presents a mathematically rigorous economic model of high-impact low-probability disasters and applies this to the economics of catastrophic climate change. As an example of the low probability high damage effects, estimates of climate sensitivity (the average amount of warming that would occur with a doubling of CO₂ concentrations) have 'long tails' in the direction of high temperatures, and on average there is something like a 1% chance that climate sensitivity (without taking into account slow feedbacks) is greater than 10 degrees, having potentially catastrophic consequences. Weitzman arrives at a ballpark estimate that when 'slow' feedbacks are taken into account, such as carbon cycle feedbacks, this suggests a likelihood of 1% that there will be a greater than 20 degree temperature rise. The issue however is not specific probabilities of particular extreme events, but that there is a 'fat tail' of low probability extreme events, that arises because of uncertainty. We shall now examine in more detail why there is a 'fat tail' of low probability extreme events.

Estimates from the IPCC for equilibrium climate sensitivity are shown in Figure 1. Although most of the median estimates for climate sensitivity are between 2 and 4 degrees centigrade, the probabilities of temperatures significantly greater are quite significant. The reason for the asymmetric probability distribution is described in a paper by G. Roe and M. Baker [5]. The main source of uncertainty in climate sensitivity is feedback processes. A change in radiative forcing due to greenhouse gas emissions leads to an increase in temperature that leads to feedbacks that further increase 'effective radiative forcing' and temperature. As stated in [5] “the more likely a large warming is for a given forcing (i.e., the greater the positive feedbacks), the greater the uncertainty will be in the magnitude of that warming.”

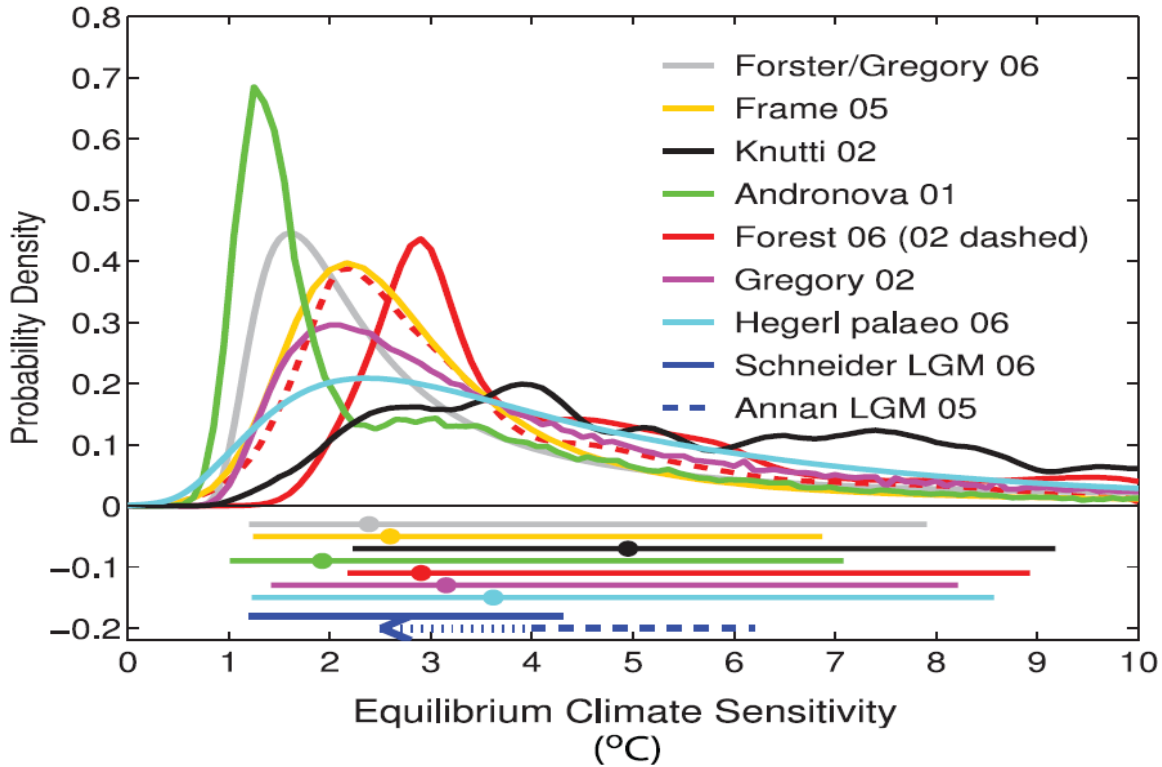


Figure 1: Estimates of equilibrium climate sensitivity (not including slow feedback processes). From IPCC [4], Figure 9.20, page 720.

The relationship between temperature and the feedbacks mentioned above can be expressed as the equation $\Delta T = \Delta T_0 + f \Delta T$, where ΔT is the temperature change, ΔT_0 is the temperature change if there were no feedbacks, and f is the feedback factor. Figure 2 (from [5], Fig. 1) illustrates how this leads to an asymmetric PDF.

Fig. 1. Demonstration of the relationships linking $h_T(\Delta T)$ to $h_f(f)$. ΔT_0 is the sensitivity in the absence of feedbacks. If the mean estimate of the total feedbacks is substantially positive, any distribution in $h_f(f)$ will lead to a highly skewed distribution in ΔT . For the purposes of illustration, a normal distribution in $h_f(f)$ is shown with a mean of 0.65 and a SD of 0.13, typical to that obtained from feedback studies of GCMs (17, 18). The dot-dashed lines represent 95% confidence intervals on the distributions. Note that values of $f \geq 1$ imply an unphysical, catastrophic runaway feedback.

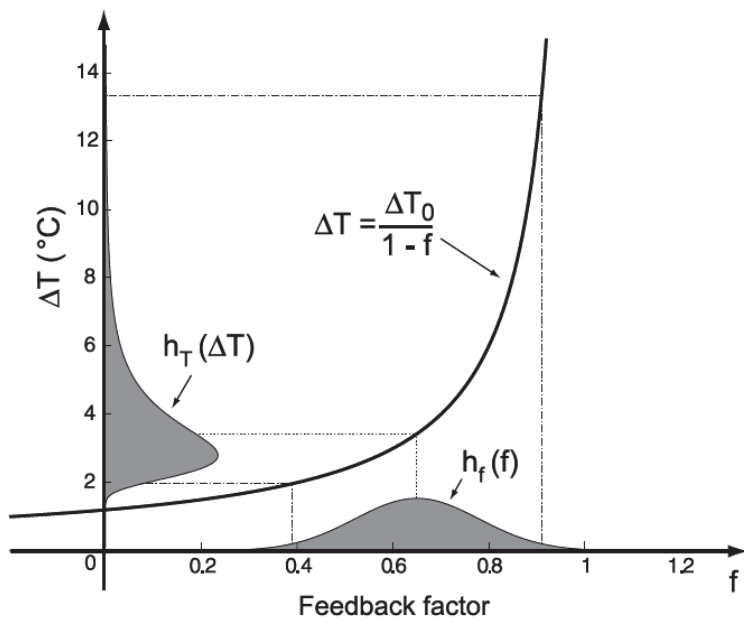


Figure 2: An illustration of how a symmetric PDF for the feedback factor will lead to an asymmetric PDF for temperature. From [5], Fig. 1, page 630.

The above estimates of a PDF for climate sensitivity do not take into account 'slow feedbacks' which include changes in surface albedo from ice melting, and carbon cycle feedbacks such as changes in greenhouse gas concentrations from loss of carbon in soil and biomass due to increased fires and drought, methane emissions from melting of permafrost, and so on. A preprint by J. Hansen et al. [6] uses palaeoclimate data to estimate that climate sensitivity including slow feedbacks (sometimes known as generalised climate sensitivity) is approximately 6°C. While [6] does not provide a PDF for climate sensitivity, we know that because of the relationship between feedbacks and uncertainty described above, the increased sensitivity taking into account slow feedbacks will most probably lead to a more asymmetric PDF with a longer tail.

If climate sensitivity is sufficiently high that either business as usual or some stabilisation scenarios involve a temperature rise that is exceedingly high, perhaps greater than 5°C, then there is likely to be a large amount of unexpected consequences. This will be even more of an issue if global average temperatures increased by 10°C.

Sources of uncertainty when estimating the impacts of climate change do not just include climate sensitivity and slow feedbacks. There is a variety of 'known knowns', 'known unknowns' and 'unknown unknowns' that affect the impacts of climate change. One 'known unknown' is the possibility of large increases in sea level from ice sheets melting in Greenland or Antarctica. The IPCC does not expect a significant contribution to sea level rise this century from melting of ice sheets, but palaeoclimatic data may suggest otherwise. According to J. Hansen et al. [7], "Our concern that BAU GHG scenarios would cause large sea-level rise this century (Hansen 2005) differs from estimates of IPCC (2001, 2007), which foresees little or no contribution to twenty-first century sea-level rise from Greenland and Antarctica. However, the IPCC analyses and projections do not well account for the nonlinear physics of wet ice sheet disintegration, ice streams and eroding ice shelves, nor are they consistent with the palaeoclimate evidence we have presented for the absence of discernible lag between ice sheet forcing and sea-level rise."

According to Weitzman, there is something quite general going on which causes many parameters to have fat tails, where we say a PDF has a fat tail if the tail probability approaches zero more slowly than exponentially. Weitzman states that "the core underlying problem is the difficulty of learning limiting tail behavior inductively from finite data. Seemingly thin-tailed probability distributions (like here the normal), which are actually only thin-tailed conditional on known structural parameters of the model, become tail-fattened (like here the Student-t) after integrating out the uncertainty." [3], page 19.

A characteristic of climate change that the above situations illustrate is that it is a situation of *potentially unlimited downside exposure*. The dangers involved and the uncertainties in the science and economics of its impacts mean that it is impossible with absolute certainty to impose an upper bound on the costs of climate change without imposing a value on "life as we know it" or something similar. Equivalently, the likelihood of catastrophic effects is non-zero. The impact of potentially unlimited downside exposure has a huge impact on cost-benefit analysis. This impact is what is examined by Weitzman in [3].

Weitzman examines what this means for cost-benefit analysis and climate change by making use of expected utility theory. Weitzman examines the expected impact on utility of climate change rather than the impact on utility of the expected outcomes of climate change. Weitzman also takes into account risk aversion and discounting the future by considering "the amount of present consumption that an agent would be willing to give up in the present period to obtain one extra unit in the future period".

By doing this, Weitzman shows that the expected cost of a situation with a long tail and potentially unlimited downside exposure is infinite. In order to examine in more detail what is going on, Weitzman introduces a very large parameter based on "something like the value of statistical life on earth as we

know it, or perhaps the value of statistical civilization as we know it". Weitzman calls it a "VSL-like parameter" because it is conceptually similar to a kind of "value of statistical life" parameter. Weitzman then proves a "Dismal Theorem" that states that if the VSL-like parameter is allowed to approach infinity, then the expected cost will also approach infinity.

Weitzman has five broad conclusions which are:

“(1) because of deep structural uncertainty about the prospects for disastrously large temperature changes, there is a strong prima facie case that the relevant probability density function (PDF) of climate change catastrophes has an extreme tail that is heavy with probability; (2) when these heavy tails are combined with very unsure high-temperature damages, this aspect can dominate the discounting aspect in calculations of expected present discounted utility (even at empirically plausible real-world interest rates); (3) all of this translates into placing severe limitations on the reliability of policy advice coming from standard cost-benefit analysis (CBA) of climate change; (4) the conventional climate-change policy ramp is an extreme lower bound on what is reasonable rather than a best estimate of what is reasonable; (5) removing the artificial limitations on conventional CBAs that comes from excluding very-high-impact disasters is capable of shifting a more inclusive economic-welfare analysis strongly away from the gradualism of a climate-change policy ramp.” [3], page 2.

2. Implications for Climate Change Policy

Applications of cost-benefit analysis to climate change so far, including the use of integrated assessment models (IAMs) have had upper and lower bounds on climate sensitivity, and therefore ignore the tail. This was illustrated in a lecture by Sir Nicholas Stern in 2008 (Figure 3).

Estimates of climate sensitivity from IAMs compared to GCMs

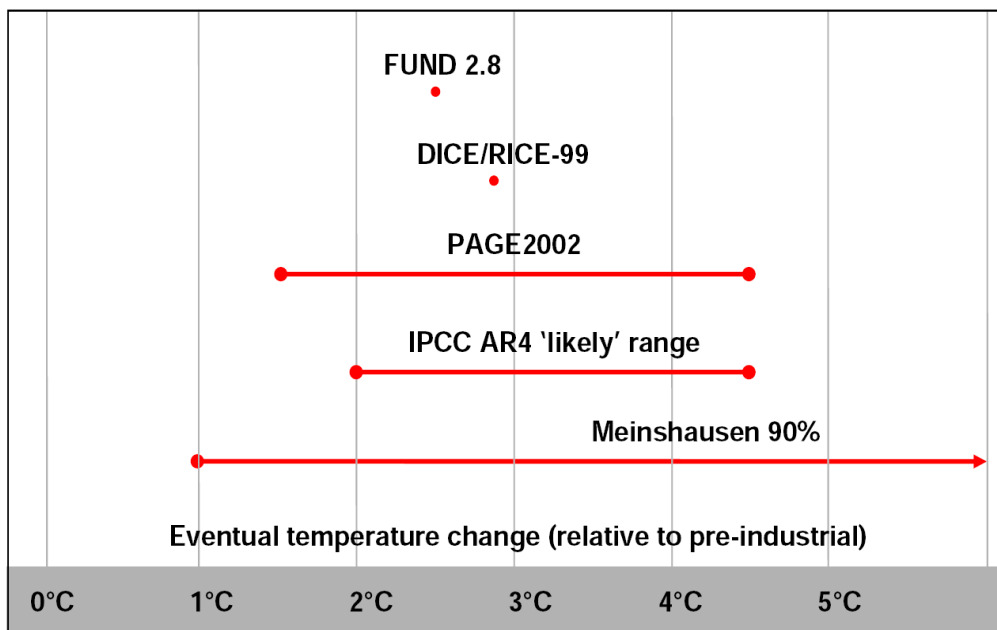


Figure 3: Integrated assessment models so far have used a tightly constrained estimate of climate sensitivity (Stern, 2008 [8]).

The issue of long tails may mean that estimates such as the Stern Review's conclusion that unmitigated climate change will have impacts on a "scale similar to those associated with the great wars and the economic depression" may be underestimates. Although some people (including Weitzman) have criticised the discount rates used by the Stern Review to arrive at this conclusion, Weitzman has concluded that "the influence on cost-benefit analysis of fat-tailed structural uncertainty about climate change, coupled with great unsureness about high-temperature damages, can outweigh the influence of discounting or anything else." [3, page 1].

It is interesting to compare the uncertainties in costing climate change with the uncertainties in costing climate change mitigation. A study by McKinsey and co. [9] estimated that the cost of reducing Australia's greenhouse gas emissions by 30% by 2020 and 60% by 2030 without major technological breakthroughs or lifestyle changes would be \$2.9 billion in 2020, which is less than 0.3% of present GDP. The McKinsey study estimates that this would take place with a carbon price of \$65 per tonne equivalent of carbon dioxide (there are significant abatement opportunities with negative cost however). It has been argued that the amount invested in climate change abatement should match the marginal cost of climate change. For this to be the case with the amount suggested by the McKinsey report, it is likely that we would have to choose a very low value for Weitzman's VSL-like parameter (to justify such a low investment in climate change abatement).

My submission [10] on the Garnaut Review Issues Paper 1 (Emissions from Agriculture and Land Use Change) suggests how some policy measures that include emissions trading and investing some of the money raised from auctioning permits in reducing emissions from land use could reduce Australia's emissions by 40% or more. The role of uncertainty in costing climate change compared to the relatively low costs of mitigation suggest that deep emissions cuts within a relatively short time period are a sensible response to the challenges that climate change presents to us.

The role of long tails may also affect how emissions trading should work. The risk of a carbon price exceeding the expected social cost of carbon is likely to be low, so a price ceiling is likely to be a bad policy choice. Conversely, the risk of a price floor leading to more abatement than anticipated is likely to be very low.

More research is needed in order to understand what impact long tails have on cost-benefit analysis and integrated assessment models. Estimates of the social cost of carbon, and choices about stabilisation targets and emissions reduction trajectories are making implicit assumptions about the value of Weitzman's VSL-like parameter (and therefore the value of "civilisation as we know it" or something similar). More research is needed to make explicit what these assumptions are.

The role of uncertainty implies that climate change is more serious than was previously anticipated. Hansen [6] suggests that we should phase out coal use except where the carbon dioxide is captured and sequestered. We should therefore look at reducing Australia's indirect emissions from coal exports by applying a tax or a cap that is steadily reduced. It has sometimes been asserted that reducing coal exports is pointless because foreign purchasers will simply purchase it from elsewhere. This assertion is erroneous because it assumes that either the global supply of coal is completely elastic or the global demand for coal is completely inelastic. Both of these assumptions are false.

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