A Recalculation of the Social Costs of Climate Change

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BACKGROUND

If governments agree to slow the pace of global warming during the next decade, it will largely be due to the efforts of the Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) to assess the science of climate change in order to provide a basis for international and national policy-making The IPPC's First Assessment Report (1990) defined cuts in greenhouse gas emissions of between 60% and 80% as immediately necessary to stabilise greenhouse gas concentrations in the atmosphere with a view to halting global warming.

Since 1990 the IPCC has been preparing a Second Assessment Report (SAR) which it hopes to publish by the end of this year. The report is authored by three working groups.

- Working Group I is reviewing the science of how the earth's climate system functions and how this might change as a result of human activities.

- Working Group II is assessing published work on the health and other effects of climate change and on the measures which could be adopted in sectors such as agriculture, energy production, industry and transportation to minimise those effects.

- Working Group III is preparing a technical assessment of the state of knowledge of the *"socio-economics of climate change mitigation"* and *"other cross-cutting issues"*, a phrase which was intended to signal a full sociological assessment of the issues at hand.

Working Groups I and II are well advanced with their reports, drafts of which have been circulated for comment in academic circles and in part on the Internet. There have been no major disagreements about these drafts' content and conclusions. The draft report by Working Group III (WG3), however, ran into severe criticism when its section on the "Social Costs" of climate change was discussed at a WG3 meeting in Geneva in July 1995.

In this paper we outline the concerns raised about WG3's social costs assessment and recalculate those social costs in the light of these criticisms.

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GCI is an independent group of people, mostly based in the UK. GCI's aim is the protection of the Global Commons. The group is currently working on the economic and political aspects of global climate change.

A FLAWED REPORT

The difficulties of placing a monetary value on the damage which is likely to be caused by global warming are legion. The costs are long-term, highly uncertain and in some cases unknowable in advance, even in principle. For many types of damage such as species extinction, the assignment of a monetary value makes little sense, and some economists go part way to acknowledging this by distinguishing between 'tangible' and 'intangible' costs.

In spite of this, the WG3 team for the "Social Costs" of climate change attempted to put a cost figure on the damage global warming might do, basing their estimates largely the work of Fankhauser[1] and Tol,[2] - both members of the group - who built on earlier work by two other members of the group - Cline[3] and Pearce[4] - together with that by Nordhaus[5] and Titus.[6]

The team's summary assessment of the global damages consequent on climate change is that monetary losses will equal to 1.5% to 2% of Gross World Product (GWP).[b] This is an estimate for a single, unspecified, year - the year when CO_2 equivalent[c] concentrations will have doubled. They assume that this doubling will happen in around 2050 or 2060.[d]

The team also make the following assumptions: -

1. the global economy will have progressed from the present to the year 2050 on a "business-as-usual" path;
2. global mean temperature will have risen by the "mean" figure of 2.5°C by that year,
3. it is useful to give policy-makers a "snap-shot" of that single year's damages, ie one divorced from a cumulative assessment of damages for the period between the present and 2050.

This figure of 1.5% to 2% of GWP is significantly lower than that reached by some other analysts - most notably Hohmeyer and Gaertner in their 1992 report to the European Union.[7] Their study estimated *accumulated* damage costs of potentially $900 trillion by 2030; that is, well beyond 100% of GWP by that year and therefore up to two orders of magnitude greater than the figures reported in the WG3 draft.

WG3 also estimated regional damage costs as being equivalent to 1% to 1.5% of GNP in OECD countries and between 2% and 9% of GNP in countries outside the OECD. These regional losses were derived exclusively from the work of Fankhauser and Tol.

In our view, both the global and regional ranges of damage figures currently drafted in WG3 contain errors, are unjustified and should be replaced. Using Fankhauser's raw damage figures as the starting point for developing our arguments, we conclude that the expected extent of global damage for the year 2050 as a result of warming is highly uncertain but probably lies in a range between <u>12% and 130% of GWP</u>. Within this, for the OECD region, the range is from <u>0.6% to 17% of Gross Regional Product</u> (GRP), while for the Rest of World (RoW) (those countries outside the OECD) it is from <u>25% to 250% of GRP</u>. This represents *accumulated* losses between 1990 and 2050 of between $50 and $600 trillion. We consider even these estimates are on the low side, as we have made many conservative assumptions and made only very limited allowance for surprises.

To address the range of temperatures which may plausibly obtain in 2050, we have made assumptions about how damage costs vary with temperature change. Clearly such variation will not be *linear* and we have assumed an S-shaped relationship, so that costs rise very slowly with the first increment of temperature change and approach a limiting value at temperature rises above 30°C. We do not consider that the present state of knowledge justifies building a more complex model. Details are given in Appendix A.

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[b] "Gross World Product" (GWP) is defined as the market value of all the goods and services sold throughout the world.

[c] "equivalent" means other greenhouse gases counted as well, but with their global warming effect converted to "CO_2 equivalence" - see IPCC WG1, the 1990 Assessment Report.

[d] For the sake of being definite, we focus on the specific year 2050 - see later for a more detailed rationale.

A PRELIMINARY SUMMARY OF CONTESTED ASSUMPTIONS

The gulf between our figures and those in WG3's current draft report can be explained in large part by our having employed different assumptions and methods to those used by WG3. The areas of dispute are summarised below and then in more detail in subsequent sections.

1 - "Willingness To Pay" versus "Willingness To Accept Compensation"

WG3 assumes "Willingness-To-Pay" (WTP) as an acceptable method of assessing damages costs. We argue that "Willingness-To-Accept Compensation" (WTAC) is a more sensible method.

2 - 2050 equals CO_2 doubling?

WG3 compute damages for the single year of CO_2 doubling, that is the year in which global mean temperatures will be 2.5°C higher than pre-industrial. We argue that it is most useful to policy makers to focus the assessment on a particular year and the period leading up to that year. This is more useful than focusing on the "moving target" of when CO_2 doubling may or may not occur. We suggest that 2050 should be used, a date within the range expected by the IPCC. However, we also argue that by 2050, various factors may well have increased CO2 and equivalent greenhouse gas concentrations in the atmosphere to more than double the pre-industrial levels and that global mean temperature is consequently likely to be higher than the stated 2.5°C.

3 - IPCC must not publish wrong arithmetic

WG3 authors calculated regional GNP losses by dividing damages corrected for "Purchasing Power Parity" (PPP) by GDP figures which have not be corrected for PPP. We argue that this procedure is arithmetically wrong and also now seen to be wrong. Even in terms of the authors' own assumptions, it seriously misrepresents the proportional damages *in* and *between* different regions of the world. Results based on this procedure must not be published by the IPCC, and regional losses must be recalculated using sound methods.

4 - No "climate sensitivity", "feedbacks" or "uncertainties" allowed for in stated bottom-line result for damages

WG3 assumes that neither "climate sensitivity",[e] "feedbacks" or other uncertainties need be portrayed in its bottom-line results. We argue that the IPCC WG3 must reflect the full range of "uncertainties" and "sensitivity" in the bottom-line figures it publishes in its final report, and in its Summary for Policy-Makers (SPM).

5 - Uncertainties should not equal zero

WG3 also assumes that in key areas where there are uncertainties over the complexity of imminent warming factors (such as positive feedbacks and sulphate aerosol removal) these can be given a value of zero in the assessed damages. We argue that they must be represented by numbers greater than zero.

6 - Significant damage categories should not be omitted

Deaths due to malaria and malnutrition have unrealistically been omitted from the WG3 draft assessment. We argue that these must be assessed and included in the report.

What follows sets out these arguments in more detail.

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[e] "Climate Sensitivity" is he IPCC's 1990 range of temperature outcomes at 'CO_2 doubling' ie 1.5°C to 4.5°C, with a 'best-guess' mean of 2.5°C. But a number of "positive feedbacks" - while mentioned in this report - were omitted from the numerical assessments of temperature rise and climate sensitivity.

1 - "WILLINGNESS-TO-PAY" VERSUS "WILLINGNESS-TO-ACCEPT COMPENSATION"

Working Group Three's damage estimates are based on the "Willingness-To-Pay" (WTP) method of assessing damage costs. WTP leads to discriminatory differential estimates in cost rates between the OECD and the rest of the world, most notably differential estimates of the value of a "statistical life".
It would have been more correct to use the "Willingness-To-Accept Compensation" (WTAC) method.

"Willingness to Accept Compensation" is regarded as the *"conceptually correct"*[8] procedure in Cost-Benefit Analysis - that is, it assesses costs in terms of what losers are willing to accept as compensation for any inflicted disbenefit. Willingness to Pay (WTP) is appropriate only for benefits. By describing potential payments for the avoidance of climate-change damage costs as "benefits", the WG3 authors give dubious plausibility to the use of WTP. In reality, however, there will be in a broad view no benefits from climate change, only different kinds of costs or disbenefits borne by different groups of people.[f]

WTA naturally results in very much higher damage costs than WTP, since the amount that people are willing to accept as compensation for major losses is not constrained by their income and - most people being poor - is many times greater than what they are willing and able to pay to prevent undesirable impacts on their lives. The use of WTP also leads naturally to the adoption of *differential* 'statistical' life evaluation, sometimes known as "Values of Statistical Lives" (VOSLs). This has been the subject of much heated debate. We state here our position.

Valuing Life and Statistical Lives

There is an extensive literature on whether it is admissible to give human life a monetary value, and, if admissible, what value life has. Some reject the idea out of hand. Nonetheless, in certain industries, it has become an accepted management tool. A good overview from the perspective of the oil industry can be found in Fleishman[9] who concludes that a valuation in the range of £500,000 to £5 million is appropriate (approximately $750,000 to $7.5 million).

The concept of "statistical" life has been introduced into the debate *not* because person A is being asked how much he or she is willing to pay or to accept for himself/herself or for person B to be definitely killed, but because of attempts to place a value on how to much to pay or accept for a relatively low probability - normally less than 1% - of any particular individual being killed. To do this, one essentially values the life at, say, $1.5 million, and multiplies by the (low) probability of an individual dying as well as by the total population size involved. If the probability of an individual being killed reaches a sufficiently high level, the whole process of valuation is rejected and the life is effectively regarded as having infinite value. According to Fleishman, there is little agreement as to how great a risk is acceptable in this sense, because it all depends on society's perception of the value of the risk-creating activity.

Major problems arise when one life is valued at more than another,[10] as is done by Fankhauser and Tol. Following Hohmeyer and Gaertner, we argue that no differentiation by nationality, race or gender should be adopted, on grounds both of straight forward ethics and of practical international politics. This is regardless of whether the life is "statistical" or not. If differential values arise logically from a theory such as WTP, that merely demonstrates the inapplicability of the theory.

The ethical argument suggests a method of valuation based on how much someone is willing to pay can only be used as an input to some kind of averaging process. The highest value we might consider is Tol's OECD value of $3 million, the lowest Fankhauser's world average of $350,000. Advocates of differential statistical life evaluation seem to think that because the risk of death is being costed rather than the certainty of death, the equity argument is nullified. We disagree strongly. In addition, using WTP, they find a single global value unrealistic. Thinking in terms of WTA, however, makes such a value quite plausible, provided that an OECD-derived value is used.[11] Following Fankhauser, we use $1.5 million.

Differential discount rates by region have also been advanced to make the "present value" - that is, the "discounted" value of future lives - different. This too is unethical and unacceptable. The "present value" of a Chinese life in 2050 must be treated as the same as the "present value" of an American life in 2050.

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[f] This is not to deny that some areas may benefit from a more benign local climate, but such effects are minor in the regional and global view.

Parity-Unit-Damage-Valuation (PUDV)

If one accepts the equal life valuation argument above, the next step is to extend the same principle to the rates for valuing all the other kinds of damage costs. In the Hohmeyer and Gaertner analysis, this was done explicitly for agricultural land values and implicitly for most other impacts. The case for doing so is presented below. While we feel the case is strong, it admittedly lacks the absolutely imperative character of equal life valuation. It can be justified prescriptively or descriptively.

Prescriptive Justification

For every identified cause of damage, a lower figure is given by Fankhauser for the impact on the Third World. To take but one example: the loss of a hectare of Chinese wetland is assessed as bearing a cost of just 10% of that of an OECD hectare. One of the stated reasons for differentiation, in this case, is the assigning of a much higher value to the loss of recreational use in the OECD than in the South. We find this ethically indefensible. Once wetland has gone, it has probably gone for many decades or centuries, if not for ever. Why should the future Chinese be assumed not to need wetlands as much as future Americans, whether for recreation or for livelihoods? Clearly from an ethical standpoint, one country's hectare of wetland should be treated as worth the same as any other country's, and similarly for all the other damage categories. (We list the categories in Appendix C).

This leads to the question of whether to value all hectares of wetland, and other resources at risk, at a rate calculated on the basis of first-world damage costs, or on some global average basis. We argue that the former could be considered the appropriate basis on the following grounds:

1. Working to a WTA-based assessment could be expected to give results much nearer to the OECD norms than to the values assumed by Fankhauser.

2. Costs assessed for the First World are more easily available than those for the Third World, because of the wider availability of statistical data. This is apparent in Fankhauser's book, where there are extensive references to academic costing estimates of First World damages, but very few of Third World ones

3. The differences within the areas OECD and Less Developed Countries (LDCs) - even within Fankhauser's breakdown of each of these into 3 sub-regions - are of the same order of magnitude as those between them. There are many groups outside the OECD, probably numbering some hundreds of millions of people in total, who are at or above the median OECD standard of living. The OECD excludes the entire Pacific rim, excepting Japan. And within the OECD itself, there is probably even greater diversity, with both large countries (e.g. Turkey) and large groups of the people (e.g. southern Italians, Native Americans) probably living at a standard not far from the Third World mean.

4. The damage in question is mostly being caused by past and present First World consumption patterns, so use of First World compensation rates is appropriate.[12]

Descriptive Justification

Fankhauser uses a methodology which effectively assumes that in the year 2050 the international breakdown of world GWP will be the same as it was in 1988. By definition, this means that the existing average income disparity between the OECD and the LDCs will remain unaltered. Others, including Nordhaus[13] and Greenpeace,[14] posit a significant degree of income convergence between the OECD and the LDCs. Such convergence is also a widely-shared policy goal. On this latter view, damage valuation, even on a WTP basis, would likewise converge and adoption of the current OECD values as a world average for 2050 becomes more plausible.

2 - 2050 EQUALS CO2-DOUBLING?

Fankhauser's damage costs are calculated for a single year - which could be 2050 or 2060 - when it is assumed that the levels of CO_2 and equivalents will have doubled in the atmosphere and global mean temperature will be 2.5°C above pre-industrial. Using this date as a reference point, he then expresses the damages in 1988 monetary values, thus giving a "snapshot" of potential future damage costs due to global warming for one year only.

"The time of CO_2 doubling" has become an accepted benchmark for discussions in the climate-change field; apparently for reasons of ease of computation and comparison. However, this approach *de*-emphasises those factors, both natural and anthropogenic, that might well speed up or retard the time of doubling. It also diverts the focus of attention from the much more serious longer-term hazards, as was noted by Cline.[15]

The IPCC in its reference scenarios IS92 a,b,e and f forecast dates of doubling between 2050 and 2075.[16] Fankhauser has assumed that the instant of doubling would probably be around 2050 to 2060; Cline and Hohmeyer and Gaertner assumed around 2030. The latest results from the Hadley Centre[17] forecast a 0.2°C (approximately) per decade rise in temperature, reaching 1.8°C above pre-industrial levels by 2050, the end date of their published charts. Extrapolating from these figures would suggest 2085 as the date by which CO_2 levels will have doubled, with 2.5°C the most likely temperature rise due to CO_2 doubling. However the Hadley Centre forecasts that doubling will be reached at 2050 assuming there is no further increase in sulphur emissions.

These sulphur emissions come mainly from power stations, and we suggest that it is only prudent to make the stronger assumption that they decrease, rather than merely fail to increase. There are already international agreements to cut back on these emissions to check acid rain, and such action is quite likely to intensify. We suggest therefore, that it as advisable for climate change impact planning to expect that the existing aerosol cooling effect will in fact be further reduced.

Thus the fashion for concentrating on a time of CO_2 doubling of about 2050 or 2060 seriously misleads the debate. On current trends, there is a real risk that CO_2 concentrations may double much earlier. With rigorous policy measures, CO_2 doubling could perhaps be avoided.

To face this very considerable policy challenge of averting climate change, what policy makers need to know is not just the range of best-guess damage estimates for the year of CO_2 doubling from a group of Cost/Benefit Analysts. What policy makers need to know is what the range of *accumulated* damage is that is likely to occur across a firmly defined period of time. In other words, 2050 is only a suitable calendar reference point for policy makers, if the intention is to assess damages up to and including that point, recognising the non-linearity of climate change in its evolution to this point (and beyond) and the consequently vast unpredictability of damages within this time-frame.

The present "snap-shot" of 1.5% to 2.0% of GWP possibly being adopted into the Social Costs chapter of IPCC WG3 is spuriously precise and more generally, raises questions about the appropriateness of cost-benefit-analysis (CBA) as a policy tool for making decisions about climate change (see below).

3 - WRONG ARITHMETIC

The distribution of the cost estimates between the OECD and the rest of the world is unsound. Crucially, the method adopted by Fankhauser and Tol for calculating these estimates expressed as percents of GDP likely to occur in the LDCs, is based on what we and many others see as a basic arithmetical error. This error has a substantial influence on the present distributional results in the Social Costs assessment.

Because the Gross National Product (GDP) of individual countries is measured in the country's own currency, international comparisons require the use of a set of conversion factors. The set used universally, until very recently, was the Trading Exchange Rates (TERs).[g] This rates an Indian rupee at the number of dollars that it can buy on the *international* money exchanges. However, the TER typically fails to reflect, by a wide margin, the *local* purchasing power of that rupee.

For an average basket of goods and services, the bulk of which are produced locally, most LDC currencies are worth double the TER values. Some are worth five times more. So in the last few years tables have been

[g] our terminology.

published and adopted by among others the World Bank and the IMF giving Purchasing Power Parity (PPP) values for countries' currencies and for their GDPs.

These tables were perhaps not available to Nordhaus, Titus and Cline when they did their pioneering costings of climate change some years ago. They were, however, available to WG3 and, according to Fankhauser, Tol and Pearce, the damage costs - at least for the LDCs - are indeed corrected for PPP.

The arithmetic mistake then arises when PPP-corrected damage costs for the non-OECD countries are divided by their uncorrected TER GDP totals to deduce the percentage of GRP losses which are quoted. Although we have been told that this is the procedure adopted, it is nowhere explained in the text, though there is a footnote now in Summary for Policy-Makers (SPM) which refers to this. The effect of the erroneous arithmetic is to give quotable LDC damage percentages of GRP up to five times higher than they should have been. This gives a false credibility to the WTP-based assessment where in the figures currently quoted in the draft in billions of dollars are $180 for the OECD and $89 for the Rest of World (ROW). When the arithmetic is done correctly, the LDC percentage losses as a whole are approximately halved.[h] In our judgement it would be wholly inappropriate for IPCC to agree to the publication - in its name - of data which is derived from a method which is known - and admitted - to be wrong.[i]

4 - CLIMATE SENSITIVITY, AEROSOLS AND FEEDBACKS

Some potential positive feedback effects (including several identified by another IPCC working group, Working Group I - see Appendix C) were not taken into account in the literature reviewed by WG3, largely because they were not represented in most or all of the climate models. We argue that an allowance for the feedback mechanisms identified in WG1 must be made. In addition, the effects of removing certain pollutants from the atmosphere must also be taken into account. For example, an additional warming effect will occur if human-made sulphate aerosols are no longer present in the atmosphere in their present concentrations as a result of necessary efforts to curtail acid rain. Sulphate aerosols have a cooling effect and thus represent latent, committed warming, which will become actual very quickly once they are removed from the atmosphere. The effect of these aerosols is now being built into global circulation models; but this was not done in sufficient detail in the earlier models on which Fankhauser's and the others' cost estimates were based, because the WG1 report[18] quantifying the effect was only published recently. This could also bring forward the time of CO_2 and equivalent doubling.

Also, the uncertainty described by IPCC Working Group 1 for the temperature rise to be expected from a given CO_2 increase - normally referred to as the “climate sensitivity” - is seriously underplayed in the

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[h] Just how big a difference the erroneous calculation can make is shown by the following example. Dr Fankhauser, calculated the damage likely to be done by global warming in China at CO_2 doubling expressed in 1988 local purchasing power terms as $16,700,000,000 which he (and the chapter) said are equivalent to 4.7% GDP losses. China's GDP in 1988 was $356,359,000,000 at current international exchange rates but $2,431,222,000,000 in terms of domestic purchasing power. In other words, if both damage and GDP are both expressed in domestic purchasing power, (the correct procedure) the losses are only 0.7% of China's 1988 GDP. Our estimates of LDC damages are summarised in Table A and are vastly higher.

[i] Before the Geneva meeting, GCI asked the IPCC Bureau that the error be acknowledged and that the authors correct it. The authors refused to do this, and still refuse. However, after the Geneva meeting in a posting to ecol-econ (the internet conference where much of this has been debated), Dr Tol (one of the economists who authored the mistake) made the following comment. *"The PPP correction reflects a slip in the literature which amazingly survived many reviews, including the IPCC's."* But he went on to say, *"IPCC cannot correct the literature, but in the present wording the slip is clear for all to see."*
GCI asserts that: 1. We are talking about a major error, not a slip. 2. It is not clear for all to see with or without the footnote. 3. The data in question is exclusively in the IPCC-assessed literature of the three authors Tol, Fankhauser and Pearce who are also lead authors for the IPCC: it is therefore completely within their power to correct. 4. It is not IPCC's role to knowingly reproduce wrong data of any kind.
Paul Ekins (economist at Birkbeck College) comments as follows. *"Of course, you can divide anything you like by anything you like . . . . . The question is what you then call the resulting ratio. If you divide PPP damage by non-PPP GDP, then you get 'PPP damages per unit of non-PPP GDP'. This does not seem to me to pass his test of a sensible ratio. What you do not get is a percentage damage, which is the ratio I would have thought one was looking for, and the one which is most often quoted."*

present WG3 results. *The crucial summaries and tables ignore it.* In addition, there are many other significant sources of uncertainty - indeed every factor under consideration is uncertain. Nonetheless, the costings are presented as point estimates, with no quantifiable indication by error bars, confidence intervals or otherwise of the range of uncertainty that accompanies them, although the text stresses the uncertainty *qualitatively*. It is stressed in the text of the SAR that the estimate of 1.5% to 2.0% of GWP is not an *uncertainty* estimate but simply a *range*, comprising the "best guesses" of the various authors.
This distinction is likely to be lost on many readers and policymakers.

5 - FOCUS ON UNCERTAINTY

Every aspect of potential climate change impacts is beset with uncertainty. We feel it is of the greatest importance to represent this adequately within any summary results. There are different types of uncertainty, which can be classified as follows:

a. Uncertainty about base conditions:

For example, economic growth rates; CO_2, SOx and other emissions; population growth rates. In our own analysis we assume that economic growth and CO_2 emissions follow a trajectory along the lines of the IPCC's IS92a scenario. CO_2 emissions are very closely linked to economic growth, as so much economic activity is dependent on fossil fuels. However, sulphur emissions come from point sources and are therefore separately controllable. And we consider it is now important to explicitly take account of that, independently of IS92a.

b. Uncertainty about how much emitted CO_2 stays in the atmosphere.

There is no guarantee current carbon sinks will continue to absorb, as they do now, about half of worldwide CO_2 emissions. There is also great uncertainty about sources, sinks and atmospheric concentration changes in the minor greenhouse gases such as methane and nitrous oxide. We do not address these points here, though there is certainly scope for unpleasant surprises.

c. Uncertainty about the impact of increased CO_2

There is uncertainty about the impact of increased CO_2 (and other greenhouse gas) concentrations in the atmosphere on the climate. This is the climate sensitivity, identified by the IPCC in 1990 and confirmed by their 1992 and 1994 reports. It is the proposition that the global average warming to be expected from CO_2 and equivalent doubling is most likely to be 2.5°C, but might be between 1.5°C and 4.5°C.

d. Uncertainty greater about the impact of sulphate emissions on the climate.

Since the effects of sulphate emissions are localised, they are much harder for climatologists to model. Only recently, in 1995 publications by the Hadley research Centre and others, have they have been quantified in any useful way.

e. Positive Feedback.

Several positive feedback mechanisms are likely to exist which could mean that, once temperatures begin to rise, factors will come into play beyond those which have been explicitly modelled and this will cause temperature to rise faster than the GCMs (General Circulation Models) predict. These factors bring forward in time the expected instant of CO_2 doubling and therefore bring forward the time of the expected temperature rise or damages. And they do increase the damages we should expect at our chosen time of 2050, and the damages to be expected per tonne of emitted CO_2. Just because they are not well understood or quantified does not mean that the positive feedbacks should be ignored, as the almost universal focus on costs at the time of doubling has ensured.[j]

f. Damage Costs.

Finally, there is uncertainty in the magnitude of each of the damage categories identified by Fankhauser. Most significantly, the damage costs are extremely sensitive to the surmised death

[j] There are similarly possible negative feedbacks, but the biggest of these, the carbon fertilisation effect, is allowed for in most or all GCMs.

rate, which has been predicted largely on the basis of a study by Kalkstein[19] into the effects of a 4°C rise on the inhabitants of fifteen US cities, and a series of extrapolations.

We combine these uncertainties using simple statistical methods, also explained in Appendix A. The main effect of the excessive simplicity in our statistics is likely to be to lead us to state incorrectly low combined uncertainty values, due to the assumptions of independence which we make.

6 - ADDITIONAL DAMAGE CATEGORIES

Fankhauser does not assume that the dozen or so damage categories he uses (see Appendix C) are a reliable guide to all the untoward impacts of climate change. Nevertheless that is how his work and that of WG3 may well be interpreted. Many areas of expected damage are omitted - i.e. costed at zero - due to inadequate knowledge. For example, he only costs deaths due to heat stress and storms, not to disease or other indirect effects, though the text of Chapter 6 of the SAR asserts that indirect health effects *"could far exceed direct effects"*. The very considerable *"costs of acclimatisation"* are not obviously quantified even though they are identified. In particular cost estimates were given in 1992 by Hohmeyer and Gaertner for the increased incidence of malnutrition and of malaria which far exceeded the direct costs.

As reported in *New Scientist* (13th May 1995), recent research by scientists at the Tropical Vegetation Monitoring Unit of the European Commission's Joint Research Centre at Ispra, Italy strongly supports the view that malaria will spread far beyond its present range. Widespread debilitation and increased mortality would result across much of the densely inhabited northern temperate zones whose populations have no natural immunity.

Hohmeyer and Gaertner have suggested 10 million extra cases of malaria worldwide by the time of doubling, (which they expect in 2030). We translate this to be a rate of 500,000 extra cases per year. In the absence of evidence to hand, we split this between the OECD and the LDCs in proportion to their population. Hopefully better estimates will become available shortly. To estimate a suitable WTA-based cost, we asked a small sample of UK citizens unconnected with GCI or other environmental group what lump-sum compensation they would be willing to accept for the increased risk of malaria and received replies ranging from £5,000 to £1,000,000, with the most often chosen value being £50,000 and the median somewhat higher. To be conservative, we have used the figure of £50,000 (i.e. $75,000). At 5% of the value ascribed to a life this seems consistent. In addition, Hohmeyer and Gaertner suggest 0.5% mortality is likely (of the 10 million total cases, not of the 500,000 annual increase), that is another 50,000 deaths per year.

Another extra cost which we feel it is important to incorporate is an estimate of the cost of forced migration to the migrant. Tol does include such a cost in his work - at a rate of three times the migrant's average annual income - but Fankhauser does not, costing migration only insofar as it induces costs in the host nation. We use a rather smaller figure than for malaria, $50,000 or 3% of the value of a life. This is approximately consistent with Tol for OECD countries.

Finally we add in the largest cost identified by Hohmeyer and Gaertner - death through malnutrition, a factor not quantified by Fankhauser. Hohmeyer and Gaertner forecast at least 10 million deaths per year - a very high number but only a doubling, according to them, of the present level. Remaining conservative, we use half this figure as our best guess, so that the high end of our forecast range will be their figure of 10 million.

We do not claim that these extra damage categories are all -- there will be others which are even harder to quantify or have simply not been thought of: remember that no-one forecast polar ozone holes when the debate on CFCs and ozone depletion was starting. So this means that our estimate, like all others, is more of a lower bound than a forecast.

OUR QUANTITATIVE CONCLUSIONS

Our re-analysis of data on costs is set out in Table A. We show the effect of our differing assumptions on Fankhauser's costings in a series of stages, represented by the columns of the table. We also show the costs in PPP (1988) US dollars and as a proportion of Gross Regional Product (GRP)[k] and of Gross World Product (GWP).[l]

Column F of Table A gives our estimates of damage costs, which range up to over 130% of GWP, many times higher than the costs estimated by Fankhauser. The discrepancy results from the extra cost categories (based largely on Hohmeyer and Gaertner's work) which we have taken into account, in particular malnutrition-related deaths. Even if these deaths are not incorporated into the calculations, however, our damage costs range up to 37% of GWP (see Column E). For the LDC region, high-end costs go up to over 250% of GRP reflecting the high impact of deaths costed at OECD rates. At the low end of our overall uncertainty range, on the other hand, global costs could be as little as 1.3% of GWP without the allowance for malnutrition-related deaths or 12.5% with it.

TABLE A - Cost Estimates on different bases

			A	B	C	D	E	F
$(1988) Billions	OECD	low		$32	$55	$55	$55	$72
		medium	$181	$181	$325	$325	$325	$387
		high		$1,100	$1,741	$1,741	$1,741	$1,916
	LDCs	low		$16	$27	$58	$221	$2,365
		medium	$89	$89	$160	$514	$1,217	$10,830
		high		$546	$868	$3,724	$6,098	$25,614
	WORLD	low		$48	$82	$114	$276	$2,437
		medium	$270	$270	$485	$838	$1,542	$11,217
		high		$1,646	$2,609	$5,465	$7,839	$27,530
%s Regional (PPP) GNP	OECD	low		0.3	0.5	0.5	0.5	0.6
		medium	1.6	1.6	2.9	2.9	2.9	3
		high		10	15	15	15	17
	LDCs	low		0.2	0.3	0.6	2.3	24
		medium	0.9	0.9	1.6	5	12	111
		high		6	9	38	63	263
	WORLD	low		0.2	0.4	0.5	1.3	12
		medium	1.3	1.3	2.3	4.0	7	53
		high		8	12	26	37	131
%s Global (PPP) GNP	OECD	low		0.2	0.3	0.3	0.3	0.3
		medium	0.9	0.9	1.5	1.5	1.5	2
		high		5.2	8	8	8	9
	LDCs	low		0.1	0.1	0.3	1.0	11
		medium	0.4	0.4	0.8	2.4	6	51
		high		2.6	4	18	29	122
	WORLD	low		0.2	0.4	0.5	1.3	12
		medium	1.3	1.3	2.3	4	7	53
		high		8	12	26	37	131

A	Fankhauser
B	plus allowance for IPCC climate sensitivity
C	plus allowance for feedbacks and sulphur emission reductions
D	plus allowance for VOSLs @OECD value
E	plus allowance for parity-unit-damage-valuation at OECD values
F	plus allowance for GCI estimates for malaria and migration costs

CBA AND CLIMATE CHANGE

The critique we have made in this paper raises wider questions about he validity of using CBA and related techniques as tools for policy making. When WG3 was restructured in 1992, its terms of reference were broad, stressing the need for the assessment to be set in the context of "Sustainable Development" and even to take account of the "cross-cutting economic and other issues".

[k] Corrected for Purchasing Power Parity (PPP).

[l] Corrected for Purchasing Power Parity (PPP).

The bulk of the work of WG3 since then has however, been carried out by economists with relatively little input from other disciplines. Thus little attention is paid to the 'other issues'.

As events unfolded, the original proposal broad discussion in WG3 "Assessing the Benefits of Responses to Climate Change" was transformed into an overwhelmingly market-valuation based assessment of global GDP losses, following the earlier work of Nordhaus, Cline, Pearce, Titus, Tol and Fankhauser.

Indeed, much of WG3's effort has been in practice an attempt to apply the technique of Cost-Benefit Analysis (CBA). CBA works very well in microeconomic decision-making, and comes naturally to economists and businessmen, but is generally very unsuitable in national and international affairs. It has not featured, for example, in the fairly successful negotiations, starting at Montreal, on ozone depletion and CFCs. CBA methods are inevitably biased towards the rich, and there is a well-documented history of conflict aggravation (rather than resolution) between winners and losers assessed with it. An excellent summary of this is given by Adams.[20] Here we summarise some of the major problems with CBA, particularly with regard to the climate debate.

1. The whole exercise of "global costing" assumes that varying - and often contradictory - values can be commensurated along a single monetary yardstick. In reality, there are still many social groups in the world (living in both monetarised and non-monetarised societies) who would reject, and in practice at present do their best to reject, attempts to value the environment and ways of living in monetary terms. Using WTP in such cases is meaningless. Likewise, to use WTAC properly involves asking them to assimilate and properly comprehend a completely different culture. Why should they have to? Indeed, "Global Cost Benefit Analysis" is attempting an impossible task. Even WTP cannot be reliably estimated in practice. In actual interview situations it is normal for 30% or more of people to refuse to reply to WTP questions or to register 'protest' answers. And of those who do reply, the values will differ hugely. WTAC values for potential climate change damage can only be assigned by (normally OECD-based) "experts" rather than the people who are supposed to be willing to accept compensation.

2. CBA neatly side-steps questions of liability for past activity, an area of potential conflict in climate change negotiations which cannot be ducked. In the WG3 negotiations LDC representatives from India and elsewhere have continually stressed the fundamental importance of understanding the effect of disparate global consumption patterns on the causation of and response to climate change, and of integrating these into the assessments being undertaken.

3. CBA focuses attention solely on what is measurably marketable, rather than what is most important to people in their daily lives, and side-steps the key issue of who decides what is valuable and how it should be valued. It thus attempts to de-politicise what is a deeply political debate.

4. CBA leads generally to unrealistically confident, unsafe and dangerous conclusions. In the case of the IPCC process, it has led WG3 to the contested conclusion that by the time CO2 concentrations have doubled in 2050 or whenever, we will experience between 1.5% -2.0% GDP-losses per annum globally.

If not CBA, then what? The techniques of multicriteria analysis (MCA) and decision analysis, mentioned in the text of the SAR but ignored in the conclusions, might help. MCA however in practice usually, and as described in the SAR, ends up by combining the different criteria into a single weighted value, and so seems essentially equivalent to CBA. Tol uses Decision Analysis,[21] but his use of advanced statistical techniques but the conclusions of this part of his work do not appear to be reflected in the SAR. Funtowicz and Ravetz[22] call for ethics-based methods that do not rely on monetary valuations. Adams says, and we agree, that *'We are stuck with the messy and protracted process of argument, discussion, negotiation and compromise. The skills in shortest supply are not economic, but scientific and diplomatic'*. In effect, CBA needs to be abandoned. Instead we need to revert to old-fashioned, if difficult, political negotiations based on a proper use of the precautionary principle and on a realistic assessment of a range of possible futures .

APPENDIX A - STATISTICAL ANALYSIS

We bring together here the quantitative derivation of the numerical results presented in the main text. The principal matter is the addressing of uncertainty.

Firstly we address the various factors influencing the mean global temperature expected in 2050. Our starting point is a business-as-usual future broadly in line with IPCC's IS92a scenario, but with 50% reduction in anthropogenic sulphur emissions from power stations.

We assume the climate sensitivity range of 1.5°C to 4.5°C can be treated as a 95% confidence interval. We focus first on a number of different kinds of feedback that have been identified by the IPCC and others, but not taken account of in climate models, such as the co-feedback with stratospheric ozone and Antarctic plankton depletion. The feedback mechanisms are listed in Appendix B below. Being feedbacks, these effects are inherently nonlinear. We have taken a simple approach of assuming that the combined effect of the feedbacks induces an increase in the temperature, above that taken from the GCMs, which is proportional to a power function of the temperature rise since pre-industrial. i.e. we assume that:

$$\Delta\Delta T=k(\Delta T)^r.$$

where $\Delta\Delta T$ is the extra temperature increase due to the feedbacks and k and r are parameters. We choose r=1.3 to give a modest acceleration of the feedback effect as the temperature rises and we choose k so that a 10% extra temperature rise at ΔT=2.5°C is triggered. This approach amounts to a perturbation of the GCMs and only makes sense for small values of $\Delta\Delta T/\Delta T$, and it assumes that meaningful results can be obtained by small perturbations to a GCM. It results in a temperature range for 2050 of 1.5º to 5.0º, with a central estimate of 2.75º. Note that this amounts to saying that CO_2 doubling is likely to occur rather earlier than 2050 given the influence of these feedbacks.

At this stage we add in the aerosol effect. The WG1 view is that sulphate/biomass aerosols now contribute a cooling effect that is substantial though highly uncertain in magnitude. The Hadley Centre's latest forecast[23] suggests that a 0.7°C extra cooling, globally averaged, can be expected by 2050 given the extra amount of sulphur emissions expected under the IS92a scenario. WG1 also stress that the aerosol cooling cannot simply be considered as a partial countereffect to greenhouse-gas warming, as the aerosols are concentrated over industrial zones. We are unable to take account of this uneven global distribution, but since the magnitude of the effect is so uncertain, this need not affect our somewhat crude calculations.

We have suggested that it is prudent build policy on the basis that, principally due to measures to address acid rain damage, but also to a lesser extent due to general pollution avoidance measures, aerosol emissions will decline drastically, rather than increase. IPCC94 figures suggest that this is capable of producing a warming pulse of up to 0.5°C; and the effect would be immediate as aerosols, unlike most greenhouse gases, have a very short residence time in the atmosphere (measured in days rather than years). We take as our best estimate of the temperature increase due to the atmospheric aerosol decline by 2050 to be half of the maximum possible, i.e. 0.25°C, and estimate the uncertainty by assuming that we are 97.5% certain that this figure is positive, and that it is independent of the GCM/feedback range of 1.5ºC to 5.0Cº. The overall effect is to produce a best-estimate temperature rise of 3.0°C at 2050, with an uncertainty range from 1.8°C to 5.3°C.

If sulphate emissions, rather than being reduced, are in fact increased as assumed in IS92a, then the expected rise is much lower. But the extra rise of 1ºC or more is then latent, and will happen relatively quickly if or when sulphate emissions are eventually reduced.

Temperature/damage relationship

At this stage we need an estimate for this relationship. It appears to be generally agreed that the relationship is not linear, and in practice of course it would be extremely complex, with a different structure for each different kind of damage. Tol [3] has produced such an estimate. What we seek to do here is to give a crude, simple, apparently new but hopefully transparent approach, by looking at how damages would hypothetically grow for temperature increase ranging from the few °C expected in 2050 up to several tens of degrees. Using such a method avoids having to input arbitrarily the very significant exponent in a power-law relationship.

We have built a number of simple models to assess possible damage effects of different temperature rises under the different damage cost evaluation cases that we address. These are of the form:-

Damage=(Limiting value)$(1-\exp(-a\Delta T))^b$ -- where a and b are positive constants, b>1.

This class of equations has the property of yielding 0 damages for ΔT (temperature rise above pre-industrial)=0, zero rate of change of damages at $\Delta T=0$, of being S-shaped, and having the damages rise towards a limiting value representing near-total destruction of society as the temperature increases to very high levels.

For the range of cases we consider, the results are similar to a simple power-law relationship for the temperature damage function with an exponent varying between 1.5 and 3.5. This is a steeper increase than that considered by Cline or Tol, though within the range discussed by Fankhauser and Pearce [18].

We have done this exercise separately for the OECD and the LDCs, for the several models of costing described above. For the limiting value we have used the sum of gross regional product, (PPP version) and an estimate of the annual increment in human capital. This latter we have computed as the value of a life ($1.5 million in most cases) multiplied by the regional 1988 population and divided by seventy (average lifespan estimate) to convert from a 'stock' value to an annual rate.

We have six models in total to compute the results shown in Table A. The parameters for each are calculated by setting the damage costs at a 30°C rise to be 90% of the limiting value, and the damage costs at 2.5° to be the values the values discussed in the main text. There are two cases for the OECD--with and without our additional damage category estimates, and four for the LDCs--Fankhauser's figures unmodified, and with the VOSL, PUDV and extra damage additions applied successively.

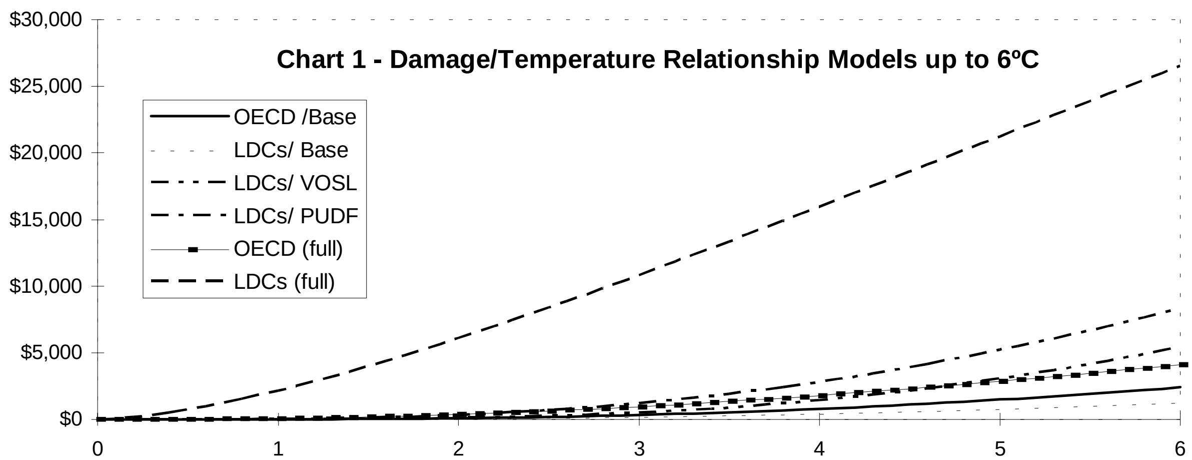
As a sanity check we report on the damages expected at a 0.5° rise--i.e. at around now. They look plausible--as there is no consensus as to what if any current costs on society are attributable to greenhouse warming, it is impossible to say whether they are 'correct' or not.

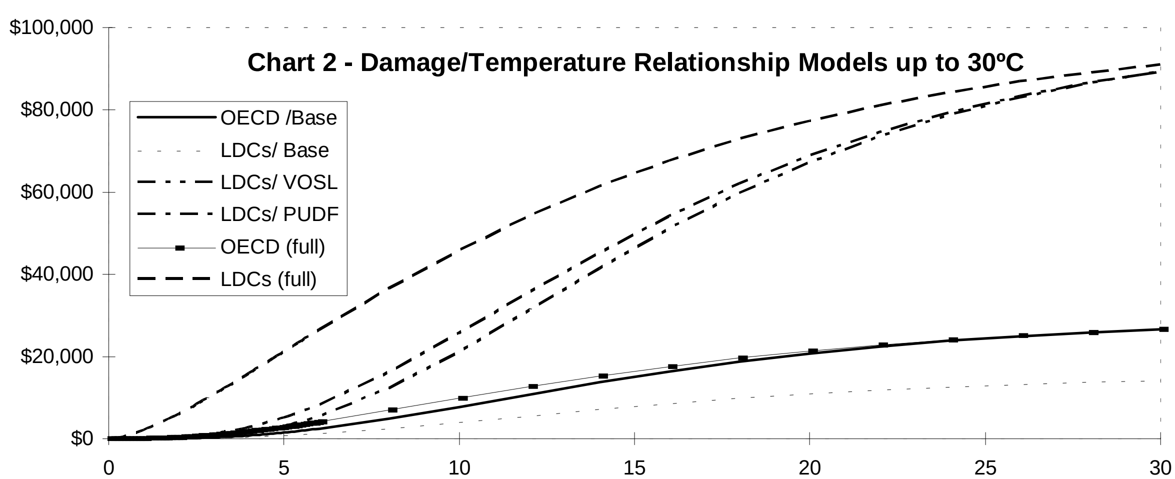
Table B shows the models we have derived and the damage values in $Billions they yield for the temperature rises of most interest. Charts 1 and 2 show the six S-curves for temperature ranges from 0°-6°C and from 0°-30°C respectively.

Adding in Damage Uncertainties

The last stage in the process is to add in the uncertainty due to the assorted different kinds of impact for a given temperature. The damage costs quoted for wetland destruction, water shortages, deaths and the rest can be no more than educated guesses. We assume that the different effects are all independent--for a given temperature or sea-level rise--and associate with each a standard deviation of half the estimate value, signifying that we are 97.5% confident that there is at least some effect of the kind estimated. We then add variances to deduce a combined uncertainty. Note that if the assumption of independence is invalid, the effect would be to increase our uncertainty estimates. The final step of deducing a 95% confidence interval assumes an overall normal distribution of damages. Given that these are a sum of assumedly independent variates, this is not as strong an assumption as it sounds; but it does of course ignore the positive skewness, which has been identified by many authors, and which is almost certainly significant. But again the effect of such skewness would only be to increase our uncertainty estimates.

TABLE B - Model Damage Costs in $ Billions							
		OECD /Base	LDCs/ Base	LDCs/ VOSL	LDCs/ PUDF	OECD (full)	LDCs (full)
Expected damages at 2.5deg rise		$181	$89	$258	$697	$222	$8,391
Asymptotic damages at very large rise		$29,405	$15,760	$99,960	$99,960	$29,405	$99,960
Target damages at 30deg rise		$26,465	$14,184	$89,964	$89,964	$26,465	$89,964
Temp. range for climate sensitivity only	1.5	$32	$16	$34	$135	$43	$3,990
	2.5	$181	$89	$258	$697	$222	$8,391
	4.5	$1,100	$546	$2,168	$3,918	$1236	$18,600
Temp range for c-s +feedbacks+aerosols	1.8	$58	$28	$67	$234	$75	$5,114
	3.0	$325	$160	$514	$1,217	$398	$10,830
	5.3	$1,738	$867	$3,715	$6,084	$1913	$22,866
Approximate present-day 'forecast'	0.5	$1	$0	$0	$3	$1.0	$742
Model parameters	a	0.1	0.1	0.1	0.1	0.1	0.1
	b	3.8	3.8	4.5	3.6	2.7	1.6





APPENDIX B: - TEMPERATURE/GREENHOUSE GAS FEEDBACK MECHANISMS

The following sources of positive feedback are identified by the IPCC 94 WG1 report and not apparently addressed by GCMs:-

1. Temperature causes drying of soils causes outgassing of CO_2.
2. Methane emissions from northern wetlands, permafrost areas and continental shelf clathrates are expected to be stimulated by increased temperatures. Recent evidence suggests this effect may be greater than has been assumed before (New Scientist, July 8th, 1995).
3. Climate change causes dieback of vegetation, especially forests, releasing CO_2.
4. A recent study by Greenpeace[24] documents the way in which this last process is being augmented by large, globally significant, fires in boreal forests.

The main negative feedback the IPCC identify is the stimulation of photosynthesis through increased CO_2 concentrations.

Other studies have identified a positive feedback loop with stratospheric ozone depletion. 'Global' i.e. surface/tropospheric warming is associated with stratospheric cooling. Colder conditions in the stratosphere increase the catalytic decomposition of ozone by chlorine compounds. The resulting increased UV flux has been observed to decrease planktonic biomass; i.e. to reduce planktonic fixing of CO_2. (Not referred to by the IPCC)

Other sources of feedback are referred to in the IPCC reports and in accounts of GCMs in ways which makes it unclear whether they are held to be adequately addressed by the GCMs or not:-

1. Climate change will have a big influence on the nature and extent of cloud cover, but even the sign of the effect is unclear, so this feedback could be positive or negative.
2. Climate change warms sea surfaces and may modify ocean circulation and up/down-welling patterns which may affect the net uptake/release of CO_2 by the oceans.

Finally we note that it is entirely possible that there are unidentified sources of positive feedback, and indeed of negative feedback. The evidence of sudden climate changes in the epoch prior to the present post-ice-age era suggests that positive feedback processes were significant in the climate some tens and hundreds of thousands of years ago. Applying the precautionary principle, in this case recognising that we probably do not know all relevant processes, should lead one to allow for extra possible effects--just as in budgeting it is common practice to add in provision for unforeseen contingencies.

Appendix C - Basic Damage Categories Used

Category	Brief Description of Costs
Sea Level Rise	Annuitised costs of preventing capital loss by buildind defences.
Dryland (Lost Benefits/yr)	Loss of area of land with commercial or other value
Wetlands (Lost Benefits/yr)	Loss of area of land with commercial or other value.
Value of Lost Ecosystems	Estimated by what people are willing to pay to preserve them
Costs to Agriculture	Lost production
Damage to the Forestry Sector	Production loss due to reduced area
Reduction in Fish Harvests	Covered by wetland valuation
Cost of Increased Energy Demand	Mainly for extra cooling of buildings.
Commercial & domestic water supply	Value loss due to reduced runoff
Mortality	Deaths from heat stress
Increased Air Pollution	Costs due to increased NOx and SOx.
Migration Costs	Costs of absorption into host economy.
Increased Tropical Storms	Extra deaths and damage to property

Derived from: Fankhauser.[25] Note the above table is a very cursory summary to indicate the general nature of the damage cost categories. For a proper understanding of what is covered and what is not, and why, please refer to Fankhauser's book.

APPENDIX D: A RECALCULATION OF THE SOCIAL COST OF CLIMATE CHANGE; A COMMENT BY SAMUEL FANKHAUSER AND RICHARD TOL

Meyer and Cooper have written an interesting article, which points out many important issues in the economic assessment of the impact of climate change. On several fronts we agree with the authors, and the criticised IPCC chapter often makes the same points as Meyer and Cooper (e.g. on the importance of uncertainty and extreme events, and the limitations of the $2xCO_2$ benchmark). In some other aspects, however, we fundamentally disagree. We would like to thank the editors of The Ecologist for giving us the opportunity to react, make clarifications on the IPCC Social Cost chapter, and point the reader to a number of misconceptions in the paper by Meyer and Cooper.

IPCC

The IPCC was established by the World Meteorological Organisation and the United Nations Environment Programme to provide sound scientific analysis that can assist policy makers in deciding on the appropriate course in climate policy. The IPCC is a scientific panel, which critically assesses the relevant literature. The IPCC does not carry out its own research, take position, or give advice. The IPCC merely reflects the literature, and presents it in a comprehensive and accessible way. IPCC reports are written by teams of internationally leading experts, carefully balanced between the geopolitical regions. The reports go through an extensive peer and government review. Non-governmental organisations are also admitted to the review procedure, and many have taken up this opportunity. Meyer and Cooper mainly comment on Chapter 6 of the Second Assessment Report of Working Group III: 'The Social Costs of Climate Change'. The chapter was written in 1994 by a team of seven researchers, headed by Prof. David Pearce of University College London. The team members are from Europe, India and the United States, and have backgrounds in economics, biology, statistics, civil engineering and anthropology. The chapter went through the IPCC review process in 1995 and was revised in the light of many helpful comments. The revision included a literature update, so that the chapter reflects the state of the art in early 1995. No later publications are taken into account. The chapter is now finalised and awaits official adoption by the governments of the United Nations.

Comparison of Estimates

Meyer and Cooper list a series of issues - willingness to pay versus willingness to accept, regional differentiation, aggregation, cost benefit analysis, timing, market exchange rates versus purchasing power parity, uncertainty and omitted damage categories - and we address the major ones. Lumping everything together, Meyer and Cooper derive damage estimates of 12-130% of Gross World Product (GWP) for $2xCO_2$, compared to the 1.5-2% best guess of IPCC Chapter 6.

But the two sets of estimates are based on different assumptions, and are therefore not comparable.
The studies underlying Chapter 6 estimate the impact of a climate change induced by $2xCO_2$ on the present economy. In line with IPCC Working Group 1 we assumed 2.5°C warming. Since the analysis is static, issues such as the timing of $2xCO_2$, feedback effects, and aerosols, which Meyer and Cooper cover in some depth, are irrelevant for $2xCO_2$ damage estimation. Currently, research is being undertaken on the impact of other-than-$2xCO_2$-climate-change on other-than-the-present-economy. The results are too premature to be taken up in the IPCC, given the explicit requirements laid down by IPCC to authors.

Meyer and Cooper analyse different scenarios with warming mostly greater than 2.5°C. Calculating different scenarios is useful. However, for a reasonable comparison we have to compare like with like. Their estimate closest to the 2.5°C warming scenario of IPCC would probably be in the order of 30% of GWP (given that the move from their scenario B to C increases medium damage by 175%). The discrepancy is thus much smaller, although theirs is still a much larger figure. The difference is mainly due to two reasons. The first is the inclusion of malnutrition and malaria damages. This is a useful extension, although the Hohmeyer and Gaertner estimates adopted by Meyer and Cooper appear to be huge overestimates in the light of the much more sophisticated work by Rosenzweig and Parry (on malnutrition) and Martens et al. (on malaria). The second reason is the uniform valuation approach taken by Meyer and Cooper. This is the issue where we most fundamentally disagree with the authors.

Uniform Unit Values

Meyer and Cooper frame the issue of uniform valuation in the context of the debate on willingness to pay (WTP) and willingness to accept compensation (WTAC). This is wrong. The choice between WTP and WTAC has no relationship with the question of regionally diversified value estimates, contrary to the suggestion of Meyer and Cooper. WTAC, like WTP, depends on income (even though bids are not constrained by income).A rich person will require a higher monetary compensation than a poor person, because his marginal utility of income is lower (a compensation of, say, $1,000 compensation is less interesting to a rich person than to a poor person). WTAC estimates might lead to higher damages, but they would still differ between regions. WTAC can therefore not be used to justify uniform values at the OECD level. But the concept of uniform values at OECD levels for all (market and non-market) damages is itself flawed. Meyer and Cooper fail to give a good reason for using it other than quoting other authors who have themselves failed to give a good reason. The whole purpose of regional damage analysis is to capture the regional diversity and assess differences in vulnerability. Regions differ in many respects, not the least in price and income levels. Using uniform unit damages defies this. It makes very little sense to estimate the costs of building a sea wall in India at US prices. Even if the US would fund the project, it would still be built in India using local workers and material paid at local rates. The same argument holds for intangible goods and services. Environmental commodities may serve different functions in different regions. To assess local vulnerability, it is the regional value that counts.

The Value of Statistical Lives

The concept of uniform values was conceived in the context of the value of a statistical life (VOSL). In this context, it is sometimes argued that for equity reasons all statistical lives should be valued equally. This may be appealing at first sight, but the case is far less obvious once the difference between VOSL and the 'value of life' as such is understood. Besides, it would point in the direction of using an average uniform value, not the OECD value. We have no problems with using a global average value to assess world damages. In fact, estimates of local environmental damages are commonly based on regionally averaged unit values. This is both convenient and in line with the approach usually taken by national governments. However, as we have pointed out there, using average values does not change the global results of IPCC Chapter 6.

Aggregation

Equity considerations are important in climate change policy, and to the extent WTP/WTAC estimates reflect the unfairness in the income distribution, this has to be corrected for. However, the way to do this is not by tinkering with the value system, but by giving different weights to different regions in the aggregation process. Comparison and aggregation are difficult, and cannot be done in an unambiguous manner. Ethical choices are required. Chapter 6 shows how these can be depicted.

PPP-Correction

The matter of market versus purchasing power parity exchange rates was not corrected because this issue is rather more complicated, although less far-reaching than Meyer and Cooper suggest. To us, there is no 'right' answer to the question of how absolute figures should best be expressed. Damages include both market and non-market impacts, while GDP (corrected or not) is restricted to market transactions. No division by a GDP-related figure therefore produces the 'clean' percentage ratio Meyer and Cooper aspire to. Nevertheless, PPP corrected figures are in preparation to illustrate the significance of this point, and will be published shortly.

Cost-Benefit Analysis

Being a scientific panel, Working Group 3 of the IPCC does not advocate cost benefit analysis as the appropriate tool for decision making, either at the global or the regional level. It does discuss its advantages and disadvantages compared to other tools, such as the precautionary principle. Monetary estimates of the impacts of climate change do facilitate, but do not imply cost-benefit analysis, and are equally useful in other approaches to decision making. It is certainly true that CBA will not replace 'argument, discussion, negotiation and compromise', as Meyer and Cooper say (nor does Chapter 6 or any part of Working Group III suggest any such view). But it is equally true that argument, discussion or negotiation uninformed by data on the costs and benefits involved is unlikely to produce a good compromise.

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