Paying attention to extreme events -- and monetizing damages

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Topics

- Some history
  - Environmental economics
  - My history
- Damages and extreme events

Economics

- Economics as a discipline, and economists, possesses some foibles.
- Economists are not generally known for their modesty or lack of self-confidence.
- They tend to regard themselves as possessing uniquely powerful insight into human behavior.
- They tend to regard other social sciences, and humanities with condescension if not contempt.
- It isn't hard to dislike economists.

Where economics is wrong (1)

- Theory is held in very high regard.
- Empirical analysis much less so.
- A leading textbook on the use of experiments in economics once commented that, if experimental data turn out to be inconsistent with economic theory, this indicates the experiment must have been badly designed.
- Economic theory relies heavily on assumptions.
- When economists make assertions that are false, this is typically because they are relying on assumptions that are incorrect, albeit highly conventional.

Where economics is wrong (2)

- Economics decided it wanted to be a science, like physics.
- To achieve this, it needed to be shorn of any subjective elements, and any value judgments.
- However, one cannot make policy prescriptions without value judgments (cf David Hume).
- Economics functions by making implicit value judgments.

Economic argumentation

- In economic argumentation, my approach has been:
  - To identify the implicit assumptions and implicit value judgments underlying assertions being made
  - To show how the results would change if those assumptions and value judgments were modified.

Where economics is right (1)

- Economics emphasizes the importance of incentives in motivating individual behavior.
- Economists often assume, incorrectly, that only monetary rewards can constitute incentives.
- My own experience is that non-monetary incentives are often more important than monetary ones, although the latter are also required.
- Monetary incentives may be necessary but not sufficient for motivating change in behavior.

Where economics is right (2)

- Economics emphasizes the importance of trade-offs.
- Most choices involve a trade-off, whether it is expressed in monetary or non-monetary terms.
- Benefit-cost analysis, broadly conceived, is an apt framing for policy -- do the benefits of this action, suitably calculated and suitably weighted, outweigh the costs, suitably calculated and suitably weighted?
  - Whether the calculation and weighting are suitable is where the action lies.
  - This typically involves ethical considerations.

Don't ignore the distribution of benefits and costs

- The essence of the problem with both mitigation and adaptation is that they involve A spending money that yields benefits to B.
- This is commonly obscured because the analysis fails to disaggregate A vs B: it lumps everybody together. That is a mistake.
- How do you persuade A to spend the money?
  - Persuade him that it is also in his interest.
  - Persuade him that it is the right thing to do.
  - Compensate him.

Do all economists believe in economic growth?

- Most economic theorizing is actually framed in terms of a single (representative) individual making choices.
- It is frequently (and erroneously) assumed that the individual cares only for things that money can buy.
- It is often also assumed that there are no (negative) externalities.
- In that set-up, how could growth in per capita income not be welfare improving?

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COMMENTARY

Are the economic costs of stabilising the atmosphere prohibitive?

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Abstract

Macro economic studies of the costs of reducing CO_2 emissions generally estimate the global cost of stabilising the atmospheric concentrations of CO_2 in the range 350–550 ppm in trillions of USD. This creates the impression that the cost of CO_2 reductions is so large that it threatens economic development. But, presented in another way, a completely different picture emerges. There is widespread agreement amongst the more pessimistic macro economic studies that stringent carbon controls are compatible with a significant increase in global and regional economic welfare. Even if the cost of CO_2 abatement rises to 5% of global income per year by the end of this century, this reduction is minor compared with the tenfold increase in global income that is expected. Since income is assumed to grow by a couple of percent per year, the trillion USD cost could also be expressed as a few years delay in achieving an order of magnitude higher income levels. Similar observations can also be made as regards near-term abatement targets such as the Kyoto protocol. A more widespread recognition of the fact that carbon abatement policies will only marginally affect economic growth is likely to increase the willingness to introduce carbon abatement policies.

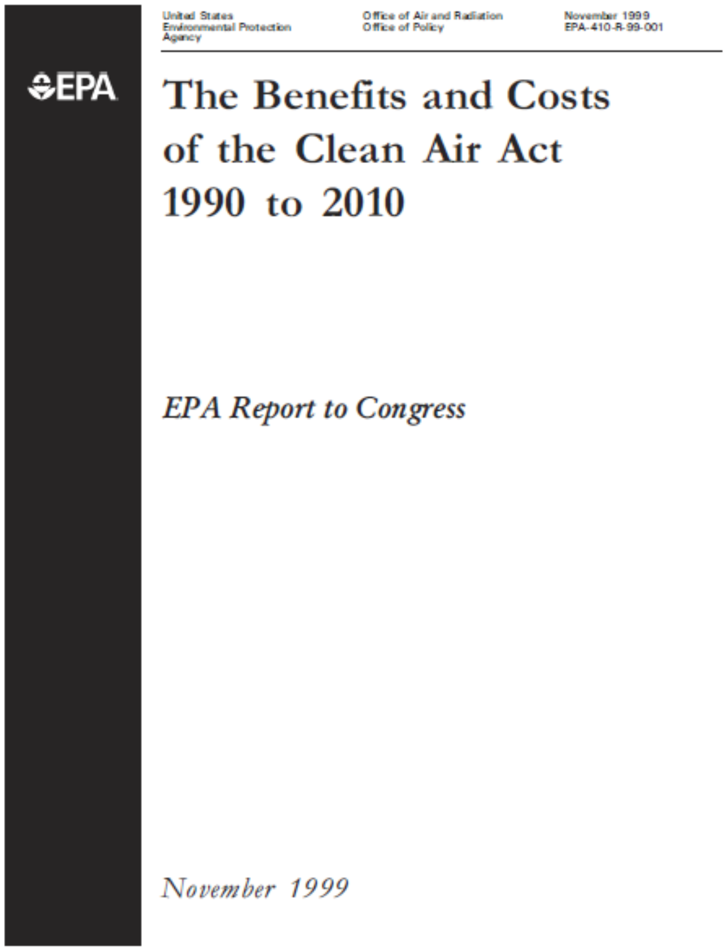
Environmental economics

- Environmental economics arises from the work of the English economist Arthur Pigou, who in 1920 formulated the concept of an *externality*.
- An externality arises when there is a divergence between the private and social cost, or the private and social benefit, of an action.
- People act on the basis of private costs and benefits. The public interest requires consideration of social costs and benefits.
- Hence, in the presence of externalities, individual behavior can generate outcomes not in the public interest.
  - This negates the "invisible hand" argument.

Measuring environmental costs

- In the late 1960s, economists turned their attention to the problem of measuring the external (social) costs associated with pollution.
- The methodology -- known as *non-market valuation* -- developed relatively quickly, essentially during the period 1971-1976.
- The US EPA was a major sponsor, promoting the application of this methodology.
- It became commonplace for a variety of forms of pollution, including water pollution (my dissertation) and air pollution (required for the Clean Air Act).
  - Environmental cost-benefit analysis has been performed (not without some critics) for ~35 years, driven by the underlying necessity of assessing a trade-off.

Non-market valuation widely used by EPA



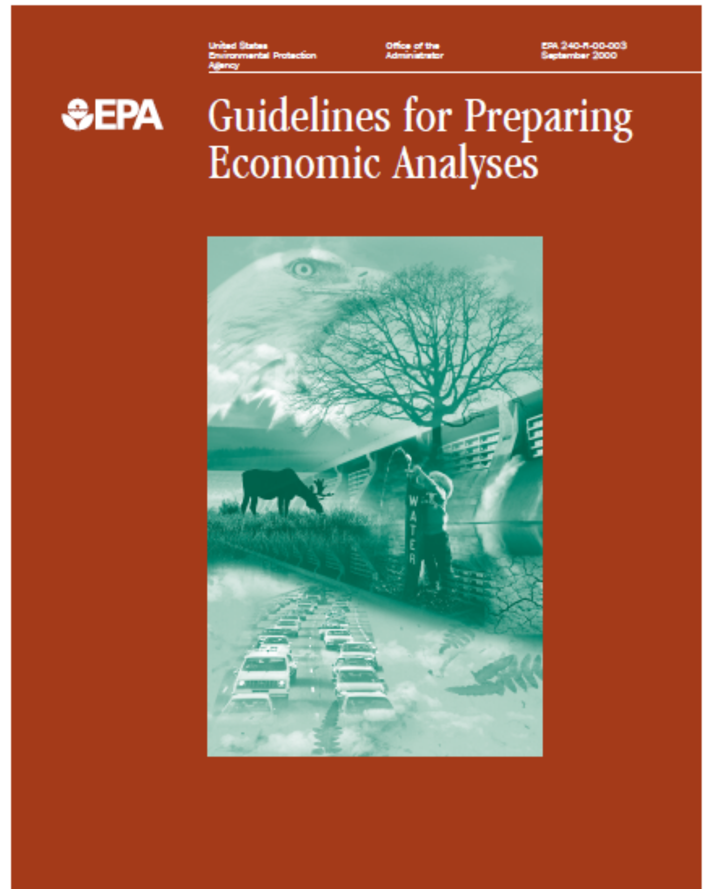
United States Environmental Protection Agency | Office of Air and Radiation Office of Policy | November 1999 EPA-410-R-99-001

EPA

The Benefits and Costs of the Clean Air Act 1990 to 2010

EPA Report to Congress

November 1999



United States Environmental Protection Agency | Office of the Administrator | EPA 240-R-00-003 September 2000

EPA

Guidelines for Preparing Economic Analyses

Climate change

- Conceptually, greenhouse gasses (GHGs) involve an externality, just like carbon monoxide, SO2, mercury or other air pollutants.
- The spatial and temporal scales of the consequences are larger; the moral issues may be more grave.
- The larger scale complicates the empirical analysis.

My career (in part)

- 1968 Enter Economics Ph.D program at Harvard.
- Some environmental economics consulting 1971-1973.
- 1974 Settle on thesis topic (EPA project): economic methodology to value reduction in water pollution at Boston area beaches.
- 1976 Assistant Professor at UC Berkeley
- 1984 Tenured at Berkeley
- 1986 Serendipitously invited to serve as economics staff for California water rights agency
- 1987 Participate as staff in hearings for water rights decision on water diversions from San Francisco BayDelta to Central & Southern California
- 1988 April -- Oil spill in San Francisco Bay; invited to serve as State's economic expert.
- 1988 November -- Draft staff report on water diversions released: pandemonium breaks out; excoriated by water users *and* enviros.
- 1989 March -- Exxon Valdez oil spill; assemble economic expert team for State of Alaska.
- Then, economic expert for governments in various other oil spills
- 1992 Invited to attend RFF conference on greenhouse warming.

- 2002 Asked by Guido Franco to create and direct California Climate Change Center at UC Berkeley for California Energy Commission

Joel Darmstadter and Michael A. Toman (eds) *Assessing Surprises and Nonlinearities in Greenhouse Warming.* RFF Press, 1993

7

Assessing Climate Change Risks: Valuation of Effects

Anthony C. Fisher and W. Michael Hanemann

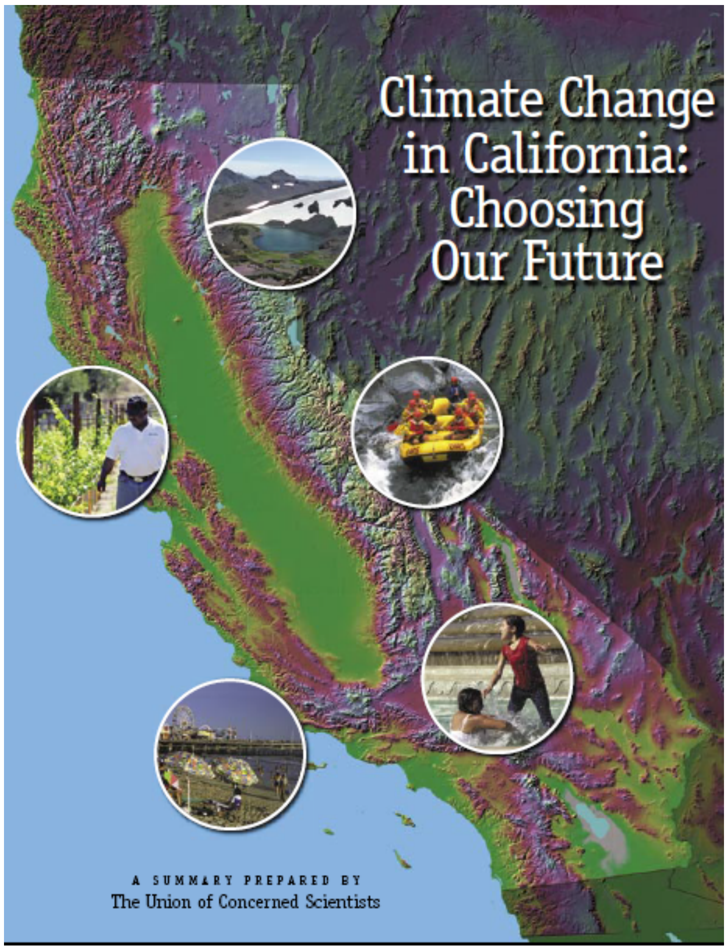
We conclude with two observations. First, since knowledge of the damage functions—in particular of the regions where they are badly behaved—is crucial for policy regarding emissions of greenhouse gases, we would urge support for research that focuses on what happens beyond the doubling usually assumed for concentrations of CO_2. Second, we would urge that more of the economic research be focused on the potentially very large costs of adjustment affecting stocks of physical, human, and natural capital. Most economic analysis—and virtually all of the economic research that has been performed so far on the subject of climate change—is conducted in terms of comparative statics. It deals with economic equilibrium and the shift in equilibrium conditions that can be expected as a result of climate change. By contrast, the issues lying at the heart of climate change concern dynamics and disequilibrium—how long will it take for people to perceive changes in climate and respond to them? Will they refuse to acknowledge such changes when they occur, or will they quickly anticipate them? Will they adapt readily or with difficulty? Are

Guido Franco California Energy Commission

California climate actions

- Initial set of impact studies outsourced to EPRI 2000-2002.
- California Climate Change Center established 2003.
- Collaboration with UCS 2003-2004-2006
- 1st round of the Scenarios Project 2003 - 2006.
- Governor Schwarzenegger announces climate goals June 1, 2005; AB 32 passed August 2006.
- 2nd round of Scenarios Project 2007- 2009.
- 3rd round of Scenarios Project 2010 - 2012.

Collaboration with UCS



Emissions pathways, climate change, and impacts on California

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Contributed by Christopher B. Field, June 23, 2004

The magnitude of future climate change depends substantially on the greenhouse gas emission pathways we choose. Here we explore the implications of the highest and lowest Intergovernmental Panel on Climate Change emissions pathways for climate change and associated impacts in California. Based on climate projections from two state-of-the-art climate models with low and medium sensitivity (Parallel Climate Model and Hadley Centre Climate Model, version 3, respectively), we find that annual temperature increases nearly double from the lower B1 to the higher A1fi emissions scenario before 2100. Three of four simulations also show greater increases in summer temperatures as compared with winter. Extreme heat and the associated impacts on a range of temperature-sensitive sectors are substantially greater under the higher emissions scenario, with some interscenario differences apparent before midcentury. By the end of the century under the B1 scenario, heatwaves and extreme heat in Los Angeles quadruple in frequency while heat-related mortality increases two to three times; alpine/subalpine forests are reduced by 50–75%; and Sierra snowpack is reduced 30–70%. Under A1fi, heatwaves in Los Angeles are six to eight times more frequent, with heat-related excess mortality increasing five to seven times; alpine/subalpine forests are reduced by 75–90%; and snowpack declines 73–90%, with cascading impacts on runoff and streamflow that, combined with projected modest declines in winter precipitation, could fundamentally disrupt California's water rights system. Although interscenario differences in climate impacts and costs of adaptation emerge mainly in the second half of the century, they are strongly dependent on emissions from preceding decades.

California, with its diverse range of climate zones, limited water supply, and economic dependence on climate-sensitive industries such as agriculture, provides a challenging test case to evaluate impacts of regional-scale climate change under alternative emissions pathways. As characterized by the Intergovernmental Panel on Climate Change, demographic, socioeconomic, and technological assumptions underlying long-term emissions scenarios vary widely (1). Previous studies have not systematically examined the difference between projected regional-scale changes in climate and associated impacts across scenarios. Nevertheless, such information is essential to evaluate the potential for and costs of adaptation associated with alternative emissions futures and to inform mitigation policies (2).

Here, we examine a range of potential climate futures that represent uncertainties in both the physical sensitivity of current climate models and divergent greenhouse gas emissions pathways. Two global climate models, the low-sensitivity National Center for Atmospheric Research/Department of Energy Parallel Climate Model (PCM) (3) and the medium-sensitivity U.K. Met Office Hadley Centre Climate Model, version 3 (HadCM3), model (4, 5) are used to calculate climate change resulting from the SRES (Special Report on Emission Scenarios) B1 (lower) and A1fi (higher) emissions scenarios (1). These scenarios bracket a large part of the range of Intergovernmental Panel on Climate Change nonintervention emissions futures with atmospheric concentrations of CO_2 reaching ≈550 ppm (B1) and ≈970 ppm (A1fi) by 2100 (see *Emissions Scenarios* in *Supporting Text*, which is published as supporting information on the PNAS web site). Although the SRES scenarios do not explicitly assume any specific climate mitigation policies, they do serve as useful proxies for assessing the outcome of emissions pathways that could result from different emissions reduction policies. The scenarios at the lower end of the SRES family are comparable to emissions pathways that could be achieved by relatively aggressive emissions reduction policies, whereas those at the higher end are comparable to emissions pathways that would be more likely to occur in the absence of such policies.

Climate Projections

Downscaling Methods. For hydrological and agricultural analyses, HadCM3 and PCM output was statistically downscaled to a 1/8° grid (≈150 km^2) (6) and to individual weather stations (7) for analyses of temperature and precipitation extremes and health impacts. Downscaling to the 1/8° grid used an empirical statistical technique that maps the probability density functions for modelled monthly precipitation and temperature for the climatological period (1961–1990) onto those of gridded historical observed data, so the mean and variability of observations are reproduced by the climate model data. The bias correction and spatial disaggregation technique is one originally developed for adjusting General Circulation Model output for long-range streamflow forecasting (6), later adapted for use in studies examining the hydrologic impacts of climate change (8), and compares favorably to different statistical and dynamic downscaling techniques (9) in the context of hydrologic impact studies.

Station-level downscaling for analyses of temperature and precipitation extremes and health impacts used a deterministic method in which grid-cell values of temperatures and precipi-

Freely available online through the PNAS open access option.

Abbreviations: DJF, December, January, February; HadCM3, Hadley Centre Climate Model, version 3; JJA, June, July, August; PCM, Parallel Climate Model; SRES, Special Report on Emission Scenarios; SWE, snow water equivalent.

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AGCI Workshop

Climate Scenarios and Projections: the Known, the Unknown, and the Unknowable as applied to California

11 March - 14 March 2004

Governor Schwarzenegger
San Francisco, June 1 2005

I say the debate is over. We know the science. We see the threat. And we know the time for action is now.
Global warming and the pollution and burning of fossil fuels that cause it are threats we see here in California and everywhere around the world.

And all of this impacts our water supply, public health, agriculture, coastlines, forestry, and much more.

In decades past when we brought this damage to the world around us we didn't know any better. That was our mistake.
But now we do know better. And if we do not do something about it that will be our injustice.

Climate damages

Three problems now confront us

1. Justifying one climate mitigation target versus another.
2. There is a disconnect between the growing body of research by impact scientists and the impacts presumed in some of the IAMs.
3. It is becoming evident that the bulk of the economic damage is associated with extreme weather events that are currently not well accounted for, least of all in IAMs.

The IPCC process, as currently constitutued, is not helpful in bringing about a solution.

Climate impacts need to be expressed in a monetary equivalent

- Mitigation involves a trade-off of costs and benefits. So does adaptation.
- In both cases, we need a monetary measure of the damages, non-market as well as market, in order to answer the question: Is it worth giving up x% of our income now to accomplish y degree of reduction in warming, or y degree of adaptation to warming?
  - For some, myself included, this is a moral question.
  - But, it is not a categorical imperative for *everybody.*
  - In practice, we cannot avoid making a case that the damages avoided outweigh the costs required.

For this we need a damage function

- The IPCC Fifth AR strongly emphasises the 2^o target.

- In the future we may need to answer the question: What is so bad if the warming is 3^o instead of 2^o? Or 3.5^o? How much more harmful would that be?

- For that we need a mapping translating the degree of warming into damage represented as an equivalent percentage of GDP, or something like that.

Two types of IAM

Many economy-wide models do *not* represent the damages of climate change. They trace the link from economic activity to the emission of GHGs, to changes in global climate, but not the link from that to damages.

There is only a handful of IAMs that include a representation of the impacts of climate change on the economy.

It is those latter models that have been used to calculate estimates of the Social Cost of Carbon.

Tension: IAMs versus reality

CLIMATE VARIABLE TRACKED

The simplified carbon cycle in the IAMs represents only the change in global average, annual temperature, ΔT.

Precipitation and other variables are not covered.

SPATIAL SCALE

The IAMs operate on a highly aggregated spatial scale

FUND 16 groups of countries

RICE 13 groups of countries

DICE, PAGE whole world

While ΔT depends on global emissions, the impacts are spatially very heterogeneous; not really a function of global ΔT.

TEMPORAL SCALE Annual temperature

THE PROBLEM: MITIGATION IS LOCAL; IMPACTS ARE LOCAL.

Aggregation systematically biases down the damage estimate

With convex damage function (increasing marginal damage), aggregation understates damages:

$$E\{D(\Delta T)\} > D(E\{\Delta T\}).$$

A local approximation:

$$E\{D(\Delta T)\} = D(E\{\Delta T\}) + \sigma_{\Delta}^{2} D''(E\{\Delta T\})$$

The larger σ_{Δ}^{2} and the larger D”(.), the more D(E{ΔT}) understates the aggregate damage E{D(ΔT)}.

A disconnect between the impacts reported by WGII, and the damages reflected in the IAM damage functions.

The damage functions in DICE, PAGE and FUND contain no citations to impacts studies conducted after about 2001.

- No citations to economic assessments of impact
- No citations to physical assessments of impact (including IPCC WGII reports)

However, the literature is expanding. A *Web of Knowledge* search on the terms (“climate change” or “global warming”) and “damage” and “economic impacts” returns:

- 39 papers for pre-2000,
- 136 papers for 2000-2009, and
- 209 papers for 2010 through September 2013.

Does that make a difference?

- YES: the more recent literature shows more severe impacts

Changing judgments for DICE (no specific explanation for the changes is provided)

Estimated impacts of warming on global GDP in successive versions of DICE

Version	Reduction in global GDP associated with a warming of		
	2.5°C	3°C	4.5°C
2000	0.5%	1.8%	5%
2007	1.8%	2.5%	6.7%
2010	1.6%	2.4%	5.5%
2013	1.4%	2.0%	4.6%

The 2000 version is based on a sectoral decomposition of estimates.

The sectoral decomposition is abandoned in 2007, except that there is a separate representation of sea level rise damages

There is a larger, institutional problem.

Many of the scientists studying impacts go out of their way to avoid any monetary endpoint.

While there is a large literature covering physical and biological impacts, except for agriculture and forestry only a tiny portion of the literature carries the analysis to the point of measuring an economic value.

Many of the economists working on the damages from climate change are blind to any endpoints not represented in monetary terms.

This disconnect is reflected in the existing IAMs, but extends far beyond them.

It is reflected in the IPCC itself

The sectoral groups in WGII contain no economists.

WGIII contains no representation of impact science.

There is no other institutional forum where the scientists studying impacts sit down with economists capable of translating them into monetary endpoints.

Extreme weather events

It seems likely that, for the next three or four decades at least, most of the economic effects of climate change will be associated with such local extreme events.

- If they occur infrequently, the economic effects will be small.
- If they occur frequently, those effects will be larger.

To model the incidence of local extreme events, one needs a fine spatial scale – with spatial downscaling – and one needs a finer temporal scale than the GCM outputs that have typically been used so far.

- Daily rather than monthly.
- In some cases (e.g., floods, energy demand and supply) hourly.

Extreme events are not captured in existing damage functions used in the IAMs, which are framed around the change in *annual average* (*global*) temperature.

Importance of extreme temperature, especially near-term (Schlenker et al., 2006)

	Proportion of net economic loss to US agriculture due to change in:	
	Precipitation & degree days 8-32C	Degree days over 34C
2020-2049 both emission scenarios 2070-2099 B1 scenario	10-20%	80-90%
2070-2099 A1Fi scenario	40%	60%

An new approach to a damage function

Start with a particular type of impact at a particular location.

The location accounts for Θ percent of the population.

An extreme event occurs Π percent of the time.

Conduct the analysis on two tracks:

If an extreme event occurs.

It is doen't occur ("normal").

Construct a spline damage function. With two segments, say, there are 3 parameters: the two slopes and the switch point.

Use the damage function to calculate the damage with and without the occurrence of an extreme event.

The expected damage from an event, E{D}, is calculated using the probability Π .

The expected damage is extrapolated over space by multiplying E{D} by Θ.

This is done for each type of impact, and then aggregated.

The strategy is to try to identify thresholds beyond which there are significant changes in the slope of the damage function, instead of focusing on evaluating two parameters in a function – a spline function approach.

This requires the judgment of experts

What is the argument of this function?

It may be temperature, or it may be some function of a climate variables, eg a state variable is created, and damage is function of the state variable.

There may be thresholds in both the transformation from climate variables to the state variable, and in the damages as a function of the state variable.

The key is to start with some specific region and try this out. Extend it to other areas later.

To implement this, one needs to assemble panels containing impact scientists and economists to brainstorm sectoral/ regional damage functions.

Bottom line

- Instead of discussing whether monetization of damages is possible, and how it should be done, we should just move ahead and do it, with the right combination of people, recognising that this will be imperfect and will have to be refined and improved subsequently.