ipcc
INTERGOVERNMENTAL PANEL ON climate change

CLIMATE CHANGE 2014

Mitigation of Climate Change

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Working Group III contribution to the
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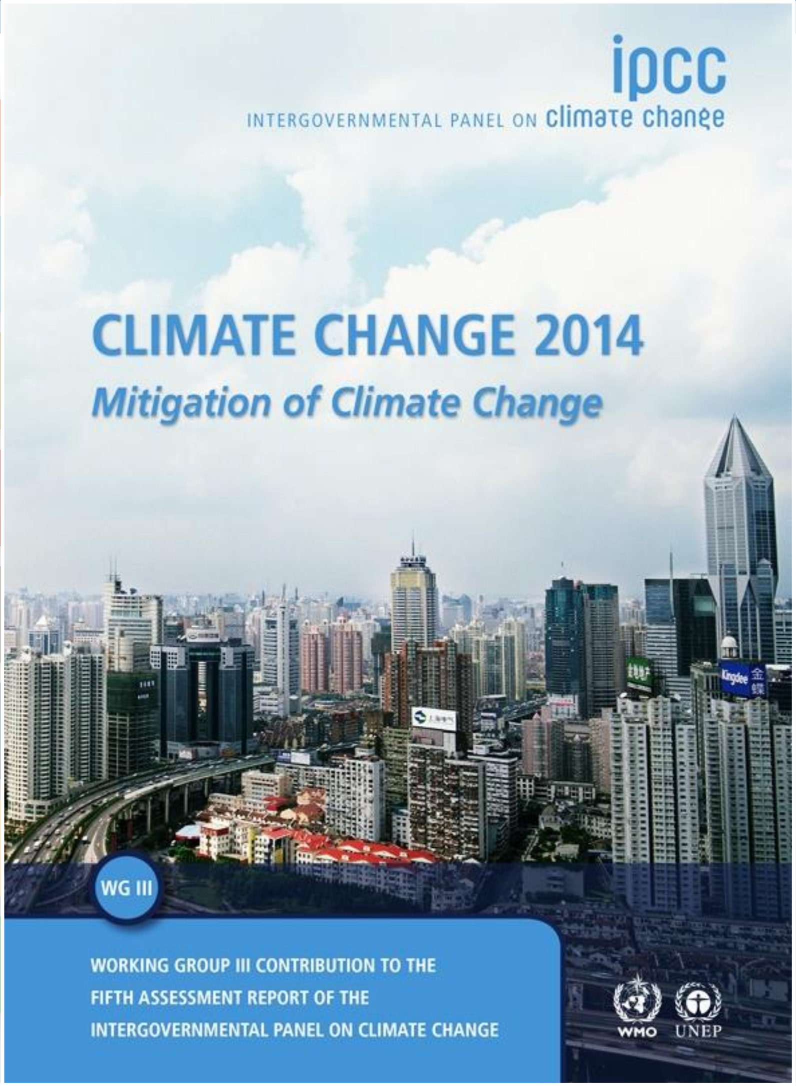
WMO UNEP

IPCC reports are the result of extensive work of many scientists from around the world.

- 1 Summary for Policymakers
- 1 Technical Summary
- 16 Chapters
- 235 Authors
- 900 Reviewers
- More than 2000 pages
- Close to 10,000 references
- More than 38,000 comments



Chapter 3

- Chapter 3 is a framing chapter, providing background information on the ethics and economics of climate change.
- The writing committee contained some philosophers as well as some economists.
- With regard to economics, it mainly explains and summarizes concepts employed in later chapters; it has a few substantive conclusions.
- With regard to ethics, it provides a framework for thinking about the ethical issues raised by mitigation and adaptation policy, also with a few substantive conclusions.

Economic evaluation can be given a foundation in ethics if distributional weights are applied.

- Social, economic and ethical analyses may be used to inform value judgments and may take into account values of various sorts, including human wellbeing, cultural values and non-human values.
- Ethical theories based on social welfare functions imply that distributional weights, which take account of the different value of money to different people, should be applied to monetary measures of benefits and harms in order to reach normative conclusions.
- Few empirical applications of economic valuation to climate change have been well-founded, in terms of using distributional weights.

The use of a temporal discount rate has a crucial impact on the evaluation of mitigation policies and measures.

- The literature provides significant guidance on the social discount rate for consumption, which is in effect inter-temporal distributional weighting.
- An appropriate social risk-free discount rate for consumption is between one and three times the anticipated growth rate in real per capita consumption.
- A consensus of the literature suggests that a declining risk-free rate be used over long time horizons.
- Ultimately, however, these are normative choices.

Metrics discussed in Chapter 3

- Greenhouse gas emission metrics (exchange rates)
- The Social Cost of Carbon (SCC)

Exchange rates between different GHGs are sensitive to choice of emission metric. There are numerous alternatives.

Name of metric		Impact function	Atmospheric background	Time dimension	Reference
GWP	Global Warming Potential	RF	Constant	Constant temporal weighting over fixed time horizon	IPCC (1990)
GWP-LA	Global Warming Potential (discounting)	RF	Constant, average of future conditions	Exponential discounting	Lashof and Ahuja (1990)
GTP-H	Global Temperature Change Potential (fixed time horizon)	ΔT	Constant	Evaluation at a fixed time T after emission	Fuglestvedt et al., (2010), Shine et al. (2005)
GTP(t)	Time-dependent global temperature change potential	ΔT	Time-varying	Evaluation at a fixed end point time in the future	Shine et al. (2007)
CETP	Cost Effective Temperature Potential	ΔT	Exogenous scenario	complex function of time when climate threshold is reached	Johannson (2012)
MGTP	Mean Global Temperature Change Potential	ΔT	Time-varying	Constant temporal weighting over fixed time horizon	Gillet and Mathews (2010), Peters et al (2011a)
GCP	Global Cost Potential	Infinite damage above climate target	Time-varying	Exponential discounting	Manne and Richels (2001)
GDamP	Global Damage Potential	D(ΔT)	Time-varying	Exponential discounting	Kandlikar (1996), Hammit et al. (1996a)

Exchange rates between different GHGs are sensitive to choice of emission metric.

- In WGIII AR5 , most quantities of GHG emissions are expressed in CO_2-equivalent emissions that are calculated based on GWP_{100}.
- Unless otherwise stated, GWP values for different gases are taken from the Second Assessment Report (SAR).
- Although GWP values have been updated several times since, the SAR values are widely used in policy settings, as well as in many national and international emission accounting systems.
- Modelling studies show that the changes in GWP_{100} values from SAR to AR4 have little impact on the optimal mitigation strategy at the global level. [see 6.3.2.5, Annex II.9.1]

Exchange rates between different GHGs are sensitive to choice of emission metric.

- The choice of an emission metric depends on the potential application and involves value judgments.
- There is no consensus as to which metric is “best”.
- In terms of aggregate mitigation costs, the Global Warming Potential with a 100 year horizon performs similarly to other metrics (such as global temperature change); however various metrics differ considerably in regional and industry level difference.

Exchange rates between different GHGs are sensitive to choice of emission metric.

- An alternative to a single metric for all gases is to adopt a 'multi-basket' approach in which gases are grouped according to their contributions to short and long term climate change.
- This may solve some problems associated with using a single metric, but the question remains of what relative importance to attach to reducing emissions in the different groups.

The Social Cost of Carbon (SCC)

- The Social Cost of Carbon is the increase in the present value of the damages occurring from now into the future as the result of a one tonne increase in emissions of carbon (or CO_2) today.

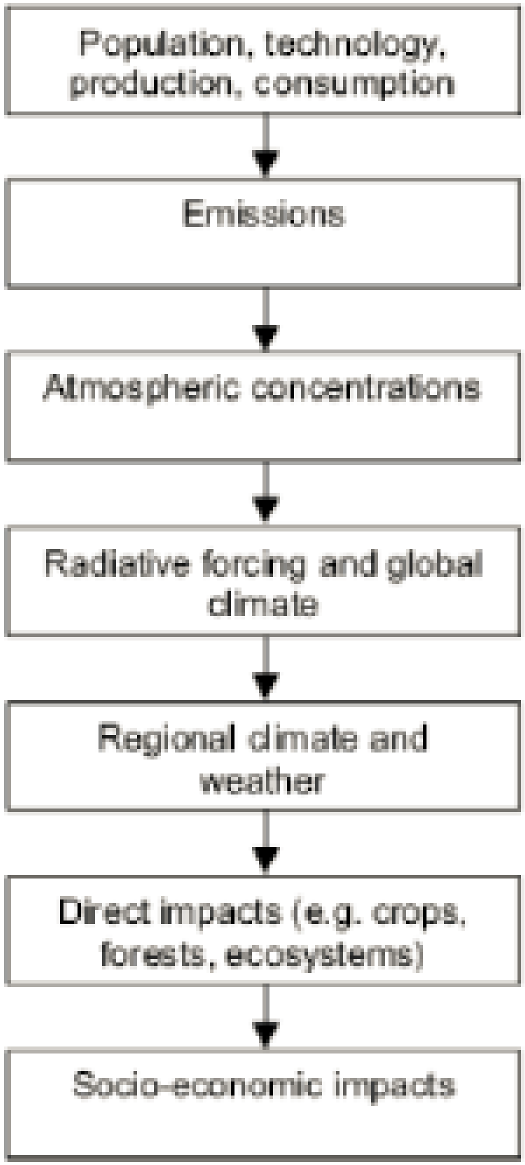
- The Social Cost of Carbon is measured using an *Integrated Assessment Model* containing a *damage function*.

Integrated Assessment Models (IAMs)

- IAMs link:
  - Economic production.
  - The generation of GHG emissions from production.
  - The change in global average annual temperature, ΔT, (via a simplified representation of the global carbon cycle).
  - The economic value of the damage (reduction in GDP) resulting from the change ΔT (via a damage function).

IAMs

- The models translate economic activity to the emission of GHGs, to change in global average annual temperature, to impacts on human wellbeing, to changes in economic activity.



Two types of IAMs

- 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 (SCC).

The main IAMs used to calculate the social cost of carbon

- Three IAMS have received most attention in this literature, all developed in the 1990s.
  - DICE, first published in Nordhaus (1993), and its regionally disaggregated sibling RICE, first published in Nordhaus and Yang (1996)
  - PAGE, first published in Hope et al. (1993)
  - FUND, first published in Tol (1995)
- The models have undergone various refinements and updates. While the details have changed, their general structure has stayed same.

Tension: IAMs versus reality

CLIMATE VARIABLE TRACKED

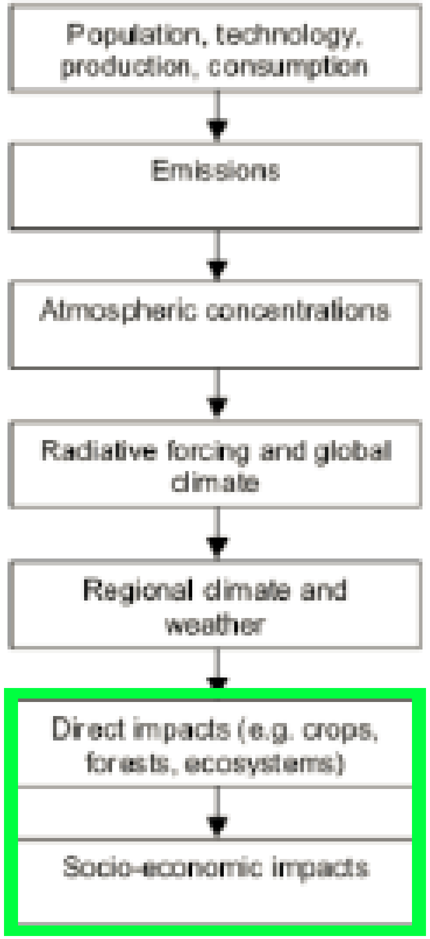
- The simplified carbon cycle in the IAMs represents only the change in global average, annual temperature, ΔT.
- Precipitation and other variables are not covered.

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.

The Damage Function

- The damage function serves as a summary representation of the economic impact of climate change in Integrated Assessment Models (IAMs) and other analyses.
- It maps from temperature change to equivalent reduction in GNP.
- It gives the "bottom line."



The damage function and the social cost of carbon

- Damages at a point in time depend on ΔT at that time, $D(\Delta T_t)$.
- ΔT_t depends on the trajectory of previous emissions $(E_0, \ldots, E_t)$.
- The discounted present value of damages is the present value of damages occurring from now into the future

$$PVD \equiv \int_0^\infty D(\Delta T_t)\,dt$$

- The Social Cost of Carbon (SCC) is the derivative of PVD with respect to a small change in emissions at $t = 0$, E_0.

Factors that influence the estimate of the SCC

The estimate of the SCC depends heavily on:

- The discount rate used to calculate the present value of damages
- The assumed trajectory of emissions used to generate a time path of ΔT_t
- The damage function used to translate ΔT_t into $D(\Delta T_t)$.

Issues regarding the IAM damage functions

- What damages are included?
- How are they included?
  - What are they expressed as a function of?
- How is the damage function calibrated
- What gets left out in this representation?

Representation of damages

- The monetized damages (the willingness to pay to avoid damages) is expressed as a percentage, D_t, of GDP in t.
- The mapping from ΔT_t to D_t is represented by a simple reduced-form equation, calibrated to damages estimated at some benchmark temperature change, ΔT^*.
- The percentage damage in year t is given by:

$$D_t = a[\Delta T_t / \Delta T^*]^b$$

- At the benchmark ΔT^*, $D_t = a$.
- The coefficient b is set at b=2 in DICE
  - In PAGE, b is a random variable taking values 1,2 or 3.
  - FUND has a more complex structure, and b is set at more specific values.

Model parameterization

- There are essentially two parameters, a and b.
- Their values are set based on the judgment of the model builder.
- They are based on more-than-heroic extrapolations from a handful of impact estimates for particular locations – often the US – to other regions and, in many cases, to the whole world.
- The estimates used originally came from the 1990s. The model builders have done some limited updating.

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

- The damage functions in DICE, PAGE and FUND contain no citations to studies conducted after 2001.
- However the economic literature on impacts has grown since then:
  - 39 papers published pre-2000
  - 136 papers published 2000-2009
  - 209 papers published 2010-September 2013
- Could that make a difference?
  - YES: the recent literature shows more severe impacts

In the last decade, the literature has identified further concerns regarding the IAM damage functions

- Is the *level* of the function correct? Some categories of damage may be omitted or underestimated
  - With a convex function, the spatial aggregation systematically understates damages
- Is the *curvature* correct?
  - The non-economic impacts literature is now paying attention to higher levels of warming, tipping points and extreme events.
- Is the *mathematical structure* correct?
  - The economic impact in a given year typically depends on the level of warming in that year. Thus impacts are assumed to be (a) reversible, and (b) independent of the prior trajectory of warming.

In the last decade, the literature has identified further concerns regarding the IAM damage functions

- The damages are represented as proportional to that year's output, in a multiplicative formulation.
  - It turns out that an additive formulation leads to a higher estimate of SCC.
- In some cases, the damages involve destruction of capital, and should be proportional to capital stock
  - Physical capital
  - Human capital
  - Natural capital
- To the extent that damaged capital is not replaced immediately, the damage can linger and persist for some years.

In the last decade, the literature has identified further concerns regarding the IAM damage functions

- The models confound a preference for consumption smoothing with risk aversion for variation in consumption. When those are parameterized *separately*, this raises the estimate of SCC.
- There is no allowance for risk aversion with respect to local impacts (fire, floods, drought). But the local populations exposed to these risks are likely to be willing to pay a risk premium to lower those risks.
- If parameter uncertainty is correctly introduced into the IAMs, it raises the SCC.

Some conclusions from Chapter 3

Impacts from climate change are both market and non-market. Market effects (where market prices and quantities are observed) include impacts of storm damage on infrastructure, tourism, and increased energy demand. Non-market effects include many ecological impacts, as well as changed cultural values, none of which are generally captured through market prices. The economic measure of the value of either kind of impact is 'willingness-to-pay' to avoid damage, which can be estimated using methods of revealed preference and stated preference. [3.9]

Some conclusions, continued

Impacts of extreme events may be more important economically than impacts of average climate change *(high confidence)*. Risks associated with the entire probability distribution of outcomes in terms of climate response [WGI] and climate impacts [WGII] are relevant to the assessment of mitigation. Impacts from more extreme climate change may be more important economically (in terms of the expected value of impacts) than impacts of average climate change, particularly if the damage from extreme climate change increases more rapidly than the probability of such change declines. This is important in economic analysis, where the *expected* benefit of mitigation may be traded off against mitigation costs. [3.9.2]

Some conclusions, continued

Damage functions in existing Integrated Assessment Models (IAMs) are of low reliability *(high confidence)*. The economic assessments of damages from climate change as embodied in the damage functions used by some existing IAMs (though not in the analysis embodied in WGIII) are highly stylized with a weak empirical foundation. The empirical literature on monetized impacts is growing but remains limited and often geographically narrow. This suggests that such damage functions should be used with caution and that there may be significant value in undertaking research to improve the precision of damage estimates. [3.9, 3.12]

Our general conclusion is that the reliability of damage functions in current IAMs is low. Users should be cautious in relying on them for policy analysis: some damages are omitted, and some estimates may not reflect the most recent information on physical impacts; the empirical basis of estimates is sparse and not necessarily up-to-date; and adaptation is difficult to properly represent.