



Centre for
Climate Change
Economics and Policy



Grantham Research Institute on
Climate Change and
the Environment

What we risk and how we should cast the economics and ethics

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THE LONDON SCHOOL
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Robbins on markets, ethics and policy

- “Economics is the science which studies human behaviour as a relationship between given ends and scarce means which have alternative uses.” 1932 (2nd edition 1935). Based on this, his approach has been considered by some to be narrow and concerned only with efficiency – quite wrong.
- “If it is felt that the working of the market results in a distribution of goods which is not equitable, the remedy is to be found, not in suspending the market or in falsifying the system of prices, but rather in direct operation on the level of net incomes and property either by way of taxation or by way of subsidies to persons.”
- “This analysis no doubt is familiar to many of you – like most alleged novelties, it is to be found in that great book *The Economics of Welfare* [Pigou]. It is parallel in type to the analysis which draws our attention to the external economies and diseconomies of production; indeed the indiscriminate benefits and damages which it reveals have been called the external economies and diseconomies of consumption.”
- **Lionel Robbins, 1950, *The economic problem in peace and war: Some reflections on objectives and mechanisms*, McMillan London.**

Five Part Structure

- Part 1: Science – scale, risks and dangers of delay
- Part 2: How we cast the ethics
- Part 3: How we cast the economics
- Part 4: How far are the scale and implications of the risks understood?
- Part 5: Where are we heading?

The science - the building of theory and evidence over two centuries

- Joseph Fourier (1827) recognised that the atmosphere was trapping heat (if it were not, planet would have been much cooler).
- John Tyndall (1861) identified the types of gases responsible for the trapping.
- Svante Arrhenius (1896) gave calculations of the possible effects of doubling GHGs.
- In the 1940s insights from quantum mechanics used in explaining the mechanism of “trapping”; basically, molecules of GHGs have modes of vibration that have frequencies that are the same as some of the photons in the infra-red band of radiation.

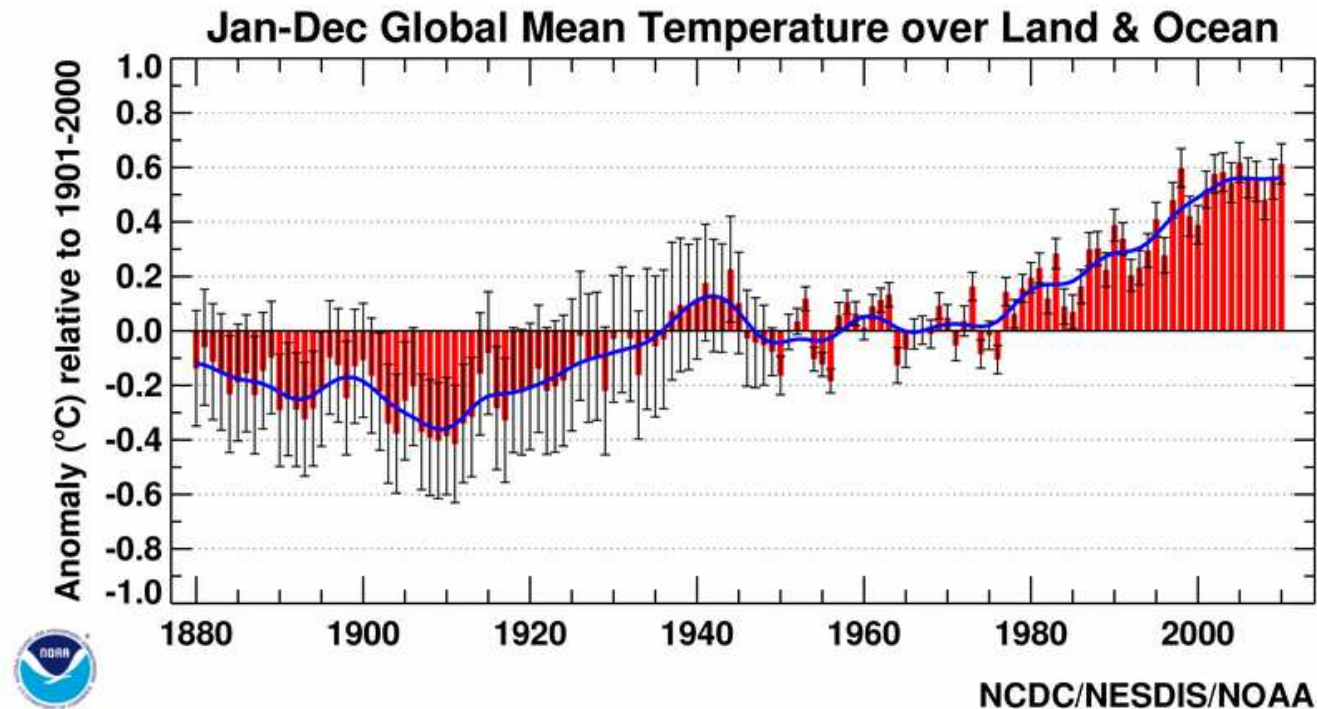
The science - the chain of causation

- Understanding the relevant processes is key to thinking about the ethics, the economics, policy, and the political economy:
 - Human activity to emissions of greenhouse gases;
 - Emissions (**‘flows’**) to increased concentrations (**‘stocks’**). There is a “ratchet-effect” from the **“flow-stock”** process;
 - Increased concentrations to increased temperatures and climate change;
 - Climate change to human impacts.
- All links in the chain subject to uncertainty: this is about managing immense risks.
- **The structure of the science has key implications:**

Scale, risk/uncertainty, lags, publicness.

The science - past temperature

- The Earth has warmed around 0.8°C since around 1900. Similar results from NASA in the USA and Met Office Hadley Centre in the UK. Further confirmed in Berkeley study (BEST) in 2011.



- Estimates of Northern Hemisphere temperature fluctuations for last 2000 years within $\pm 1^{\circ}\text{C}$ of mid-19th century, until the late 20th century rise (IPCC, AR4, WG1 Ch. 6). Little evidence of global temperature outside this range for Holocene period (last 8-9,000 years) but proxy data still limited.

The science - scale and risks (I)

- Greenhouse gas concentrations or stocks have increased from around 285ppm CO₂e in the 1800s to around 445ppm today.
- CO₂ has risen from 280 to 393ppm today and responsible for bulk of radiative forcing - easier to measure directly but other gases are involved. We follow here the 6 Kyoto gases but extending to Montreal gases would add perhaps another 30ppm to the 445ppm.
- We are adding at a rate of over 2.5ppm per year (likely to accelerate with little or weak action). Were adding around 0.5ppm 1930-1950, 1ppm 1950-1970 and 2ppm 1970-1990.
- BAU likely to take us over 750ppm by the end of the century or thereabouts.
- This level of concentration could result in a large probability, perhaps as much as 50%, of an eventual temperature increase of more than 5°C compared with the pre-industrial era.
- This would likely be enormously destructive.

The science - scale and risks (II)

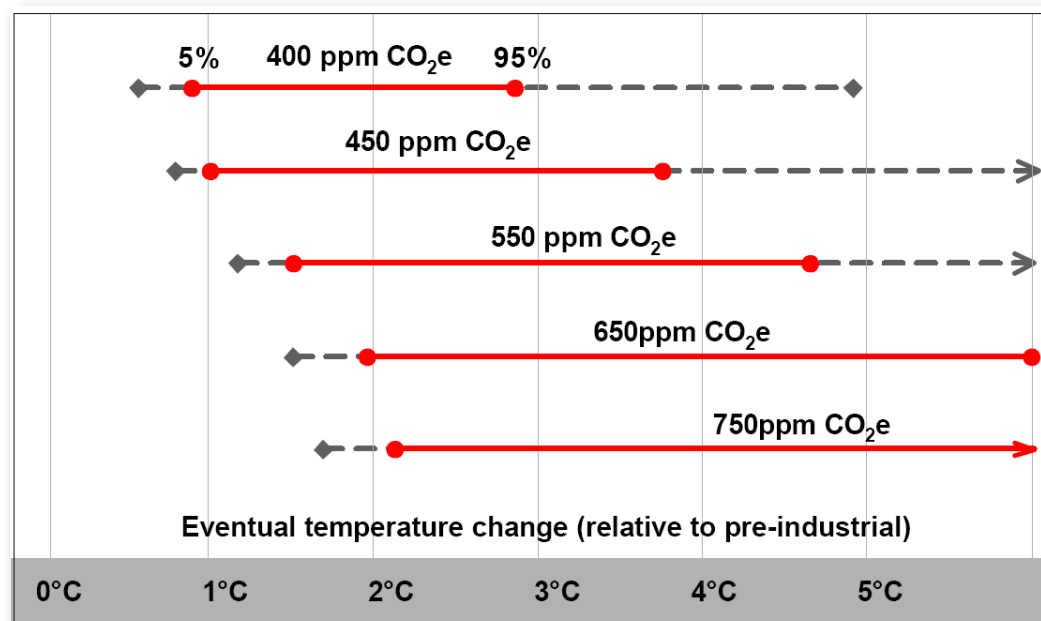
- Physical and human geography would likely be transformed with temperature increases of 5°C or more: most or all of the snows and ice in the world would go, probably Southern Europe would become a desert, and eventually sea-level rise would submerge most of Bangladesh and Florida (see Stern, 2009).
- Deserts, coastlines, rivers, rainfall patterns, the reasons we live where we do, would be redrawn.
- Potential cause of migration of hundreds of millions, perhaps billions, of people around the world: likelihood of severe and sustained conflict.
- The planet has not seen such temperatures for around 30 million years. Humans (as *homo sapiens*) have been here around 250,000 years, and our civilisations here for around only 8,000 or 9,000 years.
- Have not seen 3°C for 3 million years: 450ppm gives around a 20% chance of greater than 3°C.

The science - scale and risks (III)

- Damages from climate change will accelerate as the world gets warmer: are already seeing effects at 0.8°C but that is a small temperature increase relative to what we risk.
- Climate change is largely about **water**: storms, floods, inundations, droughts, desertification, sea level rise.
- Oscillations and trends: former will continue; underlying trend very powerful – must be quantitative.
- Nonlinearities and tipping points, e.g., collapse of Amazon forest or thawing of permafrost releasing methane.
- The potential risks are huge and the associated probabilities are not small (not confined to the “tails” of the distribution).

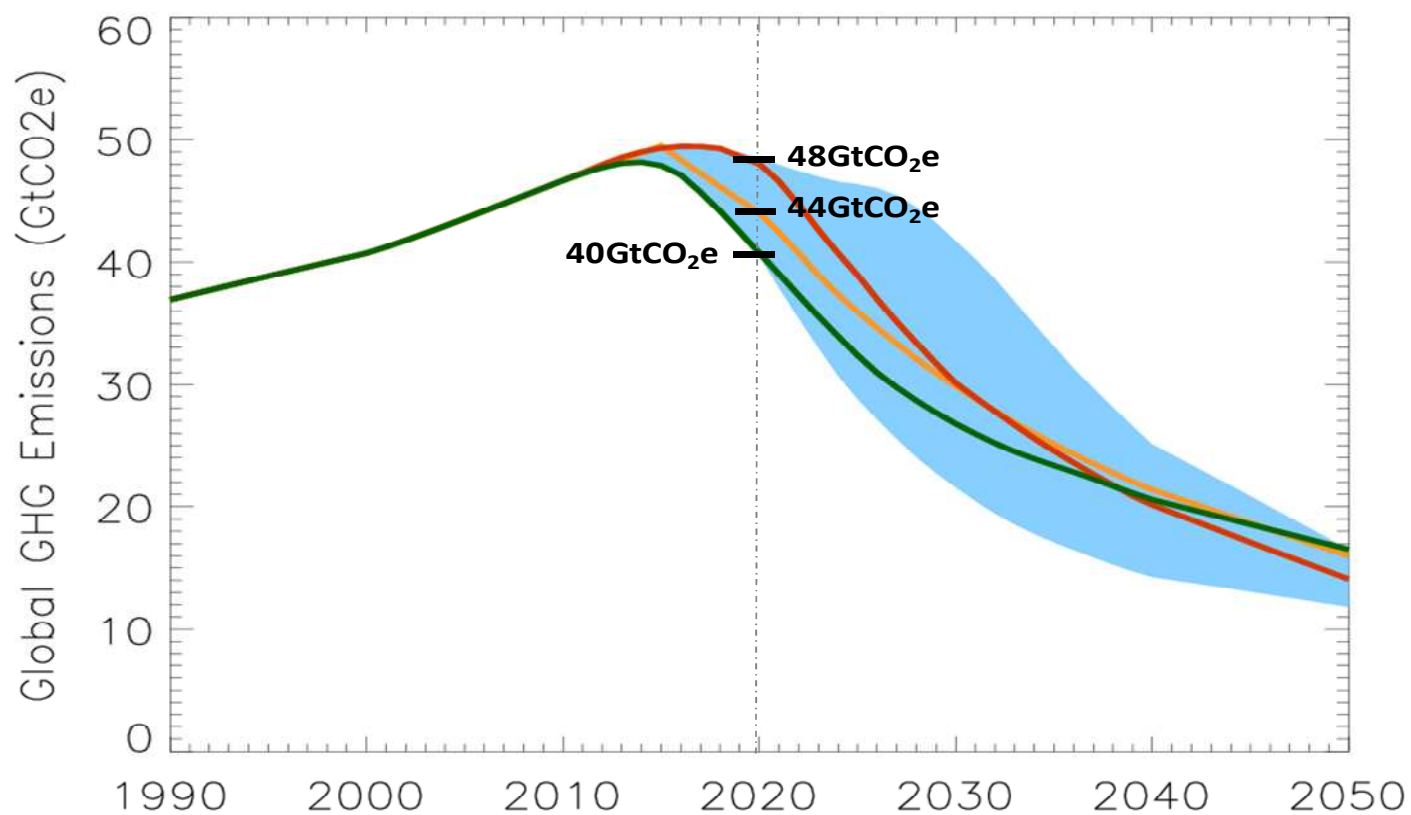
The science - scale and risks (IV)

- *Probability distribution* of possible temperature increases presented as 5-95% ranges.
- As a *rough* approximation, the distribution for **450ppm is centred around 2°C**, 550 around 3°C, 650 around 4°C, and 750 around 5 °C.



Source: Stern Review (2007), Table 1.1

What our targets should be (I)



Source: Bowen and Ranger (2009).

What our targets should be (II)

- Holding below 500ppm CO₂e, and reducing from there, is necessary to give a reasonable (say 50-50) chance of staying below 2°C (around 20% chance of greater than 3°C).
- A plausible emissions path is close to **50Gt** CO₂e in 2010, **44Gt** in 2020, **under 35Gt** in 2030 and **under 20Gt** in 2050. Likely to have to go ‘**well under**’. Clearly necessary to ‘peak’ before 2020.
- Can do a little more earlier and a little less later and vice versa but shape of feasible paths similar, and very costly to catch up if postpone action.
- Can express in terms of remaining “carbon space” as a stock but story is similar.
- 550ppm would give around a 50-50 chance of 3°C (around 25% chance of greater than 4°C).
- A 2°C path (50-50) requires very strong action on emissions over this century and beyond.

The science - lags and publicness

- The potential effects or consequences of climate change appear with **long lags** (in part due to the **flow-stock** process).
- Additional CO₂ casts an influence for many centuries; sea level will go on rising for many centuries after we have stopped adding GHGs to the atmosphere.
- GHG emissions are also '**public**' in the sense that the effect of a kilogram of GHG emissions is independent of who or where are the emitters (emissions are “public bads” in the language of economics).
- The 'publicness' of the causes may tempt people to:
 - leave action to others on the articulated grounds that each individual contribution is small, or
 - decline to act because they do not have confidence that others will act.

The science - dangers of delay (I)

- Uncertainty and the ‘publicness’ of the causes may suggest that delay whilst we **learn more** is the sensible response, rather than early and strong action. **That would be a profound mistake.**
- First, the **flow-stock** process implies a “ratchet effect”. We are already at a difficult starting point in terms of concentrations of GHGs. Twenty years delay adds 50-60ppm. Would make 550 hard to avoid, let alone 450, with consequent risks of 4/5°C much higher (e.g. 25% of $\geq 4^{\circ}\text{C}$).
- Processes to remove GHGs from the atmosphere or prevent solar energy reaching the earth, known as geoengineering, are undeveloped, largely untested and are likely to involve significant risks (see 2009 Royal Society report).
- Such geoengineering could radically change the climate, the seas and the atmosphere in ways which are unpredictable and could be deeply damaging.
- Deeply worrying governance/democracy issues.

The science - dangers of delay (II)

- Second, much of infrastructure and capital investment can result in technological “lock-in”.
- With little action the long life times of much of the relevant high-carbon infrastructure and network investment could imply that the lock-in could last for many decades.
- Delay increases the risk we would need to undertake radical, rapid and expensive decarbonisation in 2 or 3 decades time, which would result in the scrapping of vast amounts of ‘locked-in’ capital.
- To illustrate: China and India delay strong action until 2030 and then very rapid transition consistent with 450ppm post 2030 - would need to scrap between \$US 20-70 billion of coal plant in India (35-140% of current value) and \$US 50-200 billion of coal plant in China (40-70% of current value) (Vivid Economics, 2011).
- Would this be politically possible?

The science - dangers of delay (III)

- IEA World Energy Outlook 2011 - 450ppm scenario.
- Around 80% of energy-related CO₂ emissions permitted to 2035, by 450ppm target, are already locked-in by existing capital stock.
- If no further action to reduce emissions by 2017 this rises to 100% - i.e. no room for anything other than zero-carbon.
- For every **\$1** of investment in cleaner technology that is avoided in the power sector before 2020, an additional **\$4.30** would need to be spent after 2020 to compensate for the increased emissions (for 450ppm).

In denial? (I)

- The scale of risks and the dangers of delay point to strong and urgent action. What could be the case for inaction or wait and see?
 - ‘The risks are small’: This seems hard to sustain given the weight of the **scientific evidence**.
 - ‘Uncertainty means we should wait-and-see’: But the flow-stock process (ratchet effect) and the lock-in of high carbon into capital and infrastructure suggest delay is **dangerous**.
 - ‘We can adapt to whatever comes our way’: That seems **reckless** given the scale of the effects that we risk.
- To present a convincing case for inaction or delay you have to show you are very confident that the risks are small, or the risks of delay are small, or that a magic antidote will be discovered. Or to **care little** about the future.

In denial? (II)

- Remember that the science predicts outcomes with **risk** and **uncertainty**.
- Type I error (false alarm)
 - If we accept the science as giving us a strong signal to act, and the science turns out to have over-estimated risk, then we will have incurred possibly unnecessary costs of action, but we are likely, for example, to have valuable new technologies, cleaner, more efficient and secure energy-infrastructure and will have saved forests and biodiversity.
- Type II error (false negative)
 - If we reject the science, argue that it is misleading and do not act, and then the science turns out to be correct, concentrations will have built to very dangerous levels: it will be extremely difficult to back out because CO₂ is so long lasting.
- Basic common sense, in this case, points strongly to action.

In denial? (III)

- What are methods of those who would undermine the science?
 - Confuse risk/uncertainty with assumption that best guess of impacts may be taken as zero. Fail to distinguish oscillations and trends;
 - Find a handful of erroneous papers and imply that all the other many thousands can be disregarded. Thus fail to ask about implications of striking out any erroneous papers;
 - Fail to recognise compelling refutations of (often crucial) counter-arguments - urban heat islands, conspiratorial interpretations of UEA emails...
- See Oreskes and Conway “Merchants of Doubt” on methods and finance.
- Consult the scientists who assess the science of other fields (Royal Society, US National Academy of Sciences).

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How we cast the ethics (I)

- Ethical discussion must take account of scale, risk, lags, and publicness.
- Issues between generations and across generations. Who are our fellow citizens for these global intertemporal issues?
- Ethics and economics intertwined.
- Cannot bury ethics in some market assumption: must be considered explicitly.

“If informed scrutiny by the public is central to any such social evaluation (as I believe is the case), the implicit values have to be made more explicit, rather than being shielded from scrutiny on the spurious ground that they are part of an “already available” metric that society can immediately use without further ado.”

A. K. Sen (1999, p. 80) Development as Freedom.

How we cast the ethics (II)

- **Relationships across peoples and countries:** rich countries responsible for bulk of past emissions; poor countries are hit earliest and hardest; who should do what and when in responding to climate change?
- **Right to the carbon space?**
- A story of “**equal rights**” to the *per annum* carbon space gets us stuck on the science (ignores history: stocks are key, emissions are flows), on the economics (why allocate a financial asset equally across rich and poor?), and on the ethics (what responsibility for the past?).
- Above would suggest equal allocations per year are not equitable enough.
- Approach is analytically problematic and politically difficult.
- Story better posed in terms of finding new structures for economic development, together with strong support, that both allow the management of climate change and the overcoming of poverty. Better than getting stuck in ill-founded arguments on formulae for the ‘space’.
- Return to these issues in Lecture 3.

How we cast the ethics (III)

- **Relationships between generations:** intertemporal valuation (including discounting), rights and justice in relation to scale of risks to well-being and life itself. Many deep and difficult issues.
- Focus here mostly on ‘discounting in context of public finance in imperfect economies’. Discounting was where main controversy around the Stern Review lay: but that discussion generally embodied narrow views of both ethics and economics, and did not focus enough on scale of dangers.
- Ethical issues much broader than ‘discounting’: ethics should embrace the science: *scale, uncertainty, lags, publicness*. Thus how do we think about the ethics of creating immense risks to those in the future and about acting together to manage them.

How we cast the ethics (IV)

- Consequentialism/utilitarianism is one useful starting point. Also rights-liberty approaches, ideas of justice, virtue ethics, are all highly relevant as ethical perspectives here.
- Justice involves ideas of entitlement, including perhaps the right not to be faced by a hostile environment created by others.
- Public reasoning (à la J.S. Mill) can help understand, share and embrace values and notions of responsible or virtuous behaviour. Social choices/values and individual values.
- Most of the perspectives point the same way, i.e. to strong action on climate change, but some may enshrine rights, codes of behaviours, and public reasoning more strongly.
- Sustainability invokes a right to future generations to be able to “enjoy” at least the prosperity (taking account of its many dimensions) that we enjoy.

How we cast the ethics (V)

- Economics generally adopts the particular, narrow approach of ***standard welfare economics***, a special case of ‘consequentialism’.
- Where the consequentialist approach is followed, apply it broadly, and should go beyond very narrow formulations of values and ethics, which are standard in economics (often narrowed still further to marginal CBA in one-good growth model). “...*it is important to consider a broader range of ethical arguments and frameworks than is standard in economics.*” (Stern Review, 2007).
- **Action to overcome the GHG externality can give a Pareto improvement for all generations.**

How we cast the ethics - discounting (I)

- Suppose we adopt a standard multi-good, multi-period, multi-person welfare economics.
- Discounting is the process of adjusting the value attached to a unit of some good accruing in the future to compare with the value a unit of that good would be given if available today:
 - The relative value is the discount factor and its rate of fall is the discount rate. Will usually vary across time, good and person.
- Discounting is used in cost-benefit analyses to aggregate benefits and costs accruing at different times to one point in time – usually the time is now and the calculation gives the “present value”.
- It is usually a marginal approach considering small changes around a given path. Even high-speed rail or another airport for London likely to be small in relation to whole economy even though big for some people. Climate change a different order of magnitude.

How we cast the ethics - discounting (II)

- Pure time discounting is to give younger people or later people less weight (irrespective of income, etc.) only because some parts of their lives lie in the future. It is discrimination by date of birth. Equal treatment is well founded in standard welfarism/utilitarianism and moral philosophy.
- Apart from uncertainty about existence in the future, arguments in favour of pure time discounting are weak or absent.
- Usually vague appeal to “some people appear to instinctively act this way”: largely assertion without foundation. Sometimes selective quoting (e.g. from David Hume).
- Or claim that some models look to have odd conclusions without it – usually something wrong with the models.

How we cast the ethics - discounting (III)

- The discount factors and the discount rates ***depend on the path*** and the generation: e.g., if future generations are ***assumed*** to be much richer than us, an increment to them can be argued to have a small social value.
- As climate change involves looking at very different future paths it is a mistake to use a marginal method around a given growth path.
- A choice among paths means choosing the implied discount rates not vice versa. Thus discount rates are not separate or exogenous determinants of our choices (apart from pure time discounting).
- Many errors in literature on discounting in context of climate change derive from failure to understand this fundamental point. They arise from ignorance or ignoring of basic public economics combined with failure to recognise that the magnitude of possible effects could put growth into reverse and lead to large-scale loss of life.

How we cast the ethics - discounting (IV)

- Must also take care with the multi-good nature of this problem: different discount rates for consumption and the environment. **Both rates may be negative in bad outcomes**, and former might be positive for a while and the other negative (thus relative valuations of consumption and environment change).
- Some argue that relevant discount rates can be ‘read-off’ from market interest rates or rates of return. Obviously wrong given 2 basic arguments above concerning endogeneity of living standards and many goods (and wrong in other ways too).
- There is no market on which one can ‘read off’ anything similar to a revealed ***collective preference or appropriate rate for 100 years or more.***

How we cast the ethics - discounting (V)

- Further, such markets that exist are full of **imperfections** of information, of taxation, and of ability to bear risk so that rates of interest and return would, in any case, be unreliable guides.
- Even if one persisted with this route one would find that long-run, real (i.e. inflation-adjusted), low-risk rates of interest on consumption or other loans are **around 1.5%**, not the 6% that some analysts have used in context of climate change. It is “riskless rates” that are relevant because uncertainty is dealt with explicitly.
- Cannot “**read-off**” or **infer** (“inverse optimum”) public preferences from models of public policy concerning savings, distribution, or uncertainty. Results are all over the place and critically dependent on underlying model (See Stern 1977 and Atkinson and Brandolini 2010).

How we cast the ethics - discounting (VI)

- For those who like optimum growth theory: some lean heavily on $\eta g + \delta$ and claim they can be confident of the size of η on the basis of happiness measures or degrees of egalitarianism.
- In any case the science undermines the idea of an exogenous underlying growth rate g .
- There is no substitute for facing the direct ethical discussion – see e.g. Broome “Climate Matters”.
- Lack of understanding of basic public economics has lead to an embarrassingly weak discussion of discounting in the literature.
- ***As well as being weak, that discussion has diverted attention from key ethical issues in managing immense risks over long periods including potential large-scale loss of life.***

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How we cast the economic policy responses (I)

- Have seen how the science shapes the ethics. How does it shape the economics? Introduction only here – mostly in Lecture 2.
- The scale, uncertainty, lags and the ‘publicness’ of the problem make the politics and economics of policy very difficult.
- Must be framed in terms of analysis of policies for effective, efficient and equitable risk-management on a great scale and over long periods.
- What should be our goals and policies for managing risks of climate change? How much risk to accept? How big the response? How to create policies to foster change? What are the roles of different players (Lecture 3)?

How we cast the economic policy responses (II)

- Science/ethics suggest narrow CBA based on one-good model of underlying growth can provide only part of the story.
- An attempt to fine-tune such a CBA, e.g. to identify an “optimum emissions path”, may obscure and distract from a broad risk-management approach, which is based on sound economics and transparent ethics, rather than give it more precision.
- How big a risk of 3°C (not seen for 3 million years) or of 4/5°C (not seen for 30 million years) are we willing to take?
- How can we invest, innovate and learn to keep costs of and investments for risk management efficient and equitable and what are the appropriate policies?

How we cast the economic policy responses (III)

- We can achieve 2°C 50-50 chance (<450ppm CO₂e) with strong investment - perhaps 2% or more of world income. Still leaves around 20% chance of greater than 3°C. Not easy to do much better. Both the transition to the low-carbon economy and a low-carbon growth path look attractive.
- It seems that prudent risk management points to strong action. Will learn along the way and find new methods. So perhaps could become more ambitious later.
- Initial portions of paths for 425-500ppm CO₂e may in any case look quite similar. 550, as argued earlier, with 25% chance of going above 4°C, looks very dangerous.
- 2°C or 450ppm path looks sensible on this basis.
- Broad analysis of cost-effective risk management is likely to be more robust and informative than narrow CBA.

Scale and nature of response

- If world emissions are to be cut by factor of close to 2.5 (nearly 50 billion tonnes in 2010 to below 20 in 2050) and world output grows by a factor of 3 then emissions/output must be cut by a factor of 7 or 8.
- Will require strong action in all regions of world and in all economic sectors. Surely a new energy-industrial revolution.
- The transition to low-carbon growth represents a very attractive path: could, if economic history is a guide, stimulate dynamic, innovative and creative growth with large and growing markets for the pioneers.
- Likely to be one of the most dynamic periods in economic history.
- Will need large investments and will involve substantial dislocation.
- The new energy industrial-revolution is explored in lecture 2.

Adaptation, mitigation and development

- Climate change policy involves both mitigation and adaptation. This is not a horse-race between the two. Adaptation to 2°C will be difficult and 3°C very difficult. 4-5-6°C risks being unmanageable without large movements of people and loss of life.
- Managing the unavoidable and avoiding the unmanageable.
- Policy for mitigation and adaptation are interwoven with low-carbon growth and development, particularly for developing countries but also developed.
- Adaptation is essentially development in a more hostile climate. It can be diversionary or disruptive to attempt to separate investments in physical and human capital into 'development' or 'adaptation'.
- Examples include: low-till agriculture; low-carbon/energy efficient infrastructure; halting deforestation. Will help developing countries achieve poverty reduction and development objectives.
- More on the economics in Lecture 2.

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Scale, risks and urgency: communication

- Why is communication so difficult? Difficult to contemplate the *scale* and impacts; difficult to understand *risk and uncertainty*; difficult to see the consequences of our actions because of the *lags* and *publicness* of the problem.
- We see disasters now at 0.8°C which are deeply worrying, but greater than 4°C, temperatures not seen on planet for tens of millions of years. Likely to be far more worrying than narrow calculations and forecasts of (e.g.) impact in one particular sector suggest. Great dangers of movement of people and of conflict.
- *Homo sapiens* is moving into territory way outside its range of experience. This inhibits scientists from describing the possibilities (often look at these in a piecemeal way). Must engage with understanding of risk: scientists should try still harder to describe what a 4-5-6°C world might look like. They are better placed than the rest of us.
- Some attempts to describe possible impacts. See, for example, Royal Society (2011). See Lynas (2007) for a journalist's research and speculation on a warmer planet on basis of trawls of scientific literature.

Understanding the scale: experience/anticipation

- By the time we experience “scale” it is too late.
- The great depression and two world wars: catastrophic consequences of failure to collaborate were clear.
- Radical new international institutions to rebuild the world’s economy and create stability and growth at Bretton Woods, 1944.
- But climate poses much greater test of rationality, anticipation and collaboration: scale, uncertainty, lags, publicness, **again**.
- How do we understand and reflect on preferences over things that are enormous, are hard to describe, uncertain, and where we cannot see directly or identify the consequences of our actions?

Damage and risks beyond climate change

- Floods in Bihar of 2008; a continuing threat for 70% of area in state with population of 100 million. Closely linked with deforestation and poor river management.
- Destruction to environments and roles of planetary boundaries go beyond climate change.
- But through water, forests, biodiversity, and in other ways, they are closely intertwined.
- Loss of forest in Brazil hits climate, disrupts water flows and rainfall, causes soil erosion and destroys biodiversity.
- Should not be thinking only of climate change in discussing sustainability.

Five Part Structure

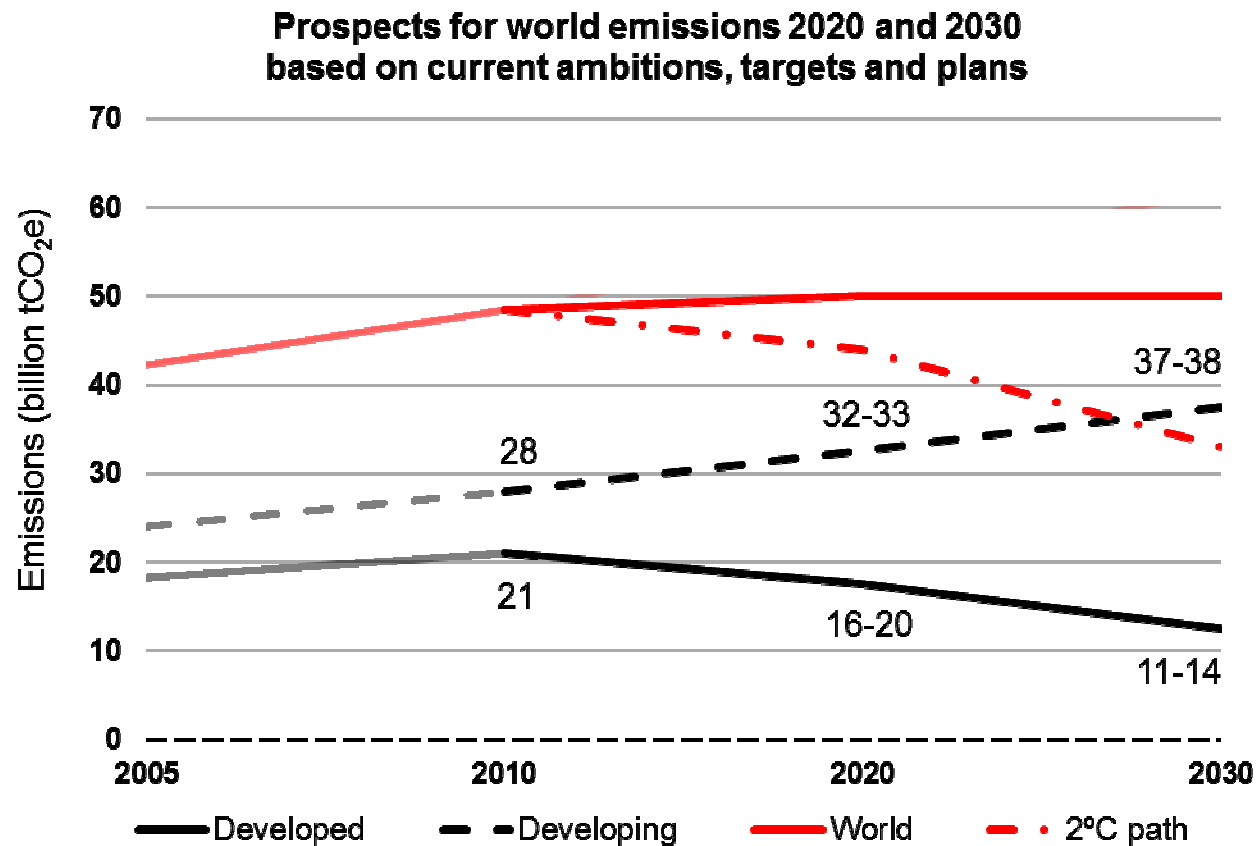
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Where are we heading? (I)

- Public policy requires not only an understanding of mechanisms at work and history, but also on where we are going on current plans. Need to understand our current path to see magnitude of challenge and assess need to change.
- Particularly relevant where there are ratchet effects and lock-in.
- For a problem that is “public” must understand what others are doing and why. Essential to understand other economies, polities and cultures.
- Current commitments to change in decade to 2020 are major in relation to past but far from the scale the problem demands (UNEP, 2011).

Where are we heading? (II)

- Patterns of emissions strongly influenced by a changing world economy. Copenhagen-Cancun plans.



- Current plans look like shaded area; plateauing at 50 at best.

Where are we heading? (III)

- Emissions of developing world are likely to rise strongly over the **coming decade**, possibly by around 4-5 billion (possibly more) tonnes p.a. CO₂e to around 32-33 billion tonnes by 2020.
- China (+3) and India (+1.5) are likely to account for much of the 5 or more billion tonne p.a. increase in next 10 years.
- Developed countries' plans indicate a fall of 2-5 billion tonnes p.a. by 2020 to between 16 and 20 billion tonnes p.a.
- For the **decade 2020-2030** - estimates more speculative and illustrative - the developing world may add another 5-6 billion tonnes p.a. to get to 37-38 billion tonnes in 2030.
- Based on discussion with senior policy makers in China and India, these two countries will account for much of the increase, simply on weight of population numbers and economic growth rates.

Where are we heading? (IV)

- Developed world may be able to reduce another 5 p.a. to get to between 11-14 billion tonnes in 2030.
- But China and India are only 40% of developing world in 2030: rest of Asia, Latin America and Africa likely to go through period of growth. Africa may be approaching 2 billion people by 2030.
- These estimates suggest on current plans we may see, at best, world emissions plateau at around 50 billion tonnes for the next couple of decades (assuming growth in developing countries continues).
- Without intensification of emissions reduction around the world, including technological leap-frogging to low-carbon growth in developing world, even that plateau around 50 may be optimistic (somewhere in shaded area on diagram may be more likely).

Where are we heading? (V)

- The consequences of likely emissions under current (Copenhagen-Cancun) plans to 2020 and on to 2030:
 - Any reasonable chance of 2°C would be lost. Concentrations of greenhouse gases would rise to levels consistent with temperatures (50/50 chance) of 3.5 to 4°C - not seen on the planet for 3 million years. Associated risks of still higher temperatures.
 - Climate impacts and risks will increase further - will need adaptation on a major scale.
 - High-carbon infrastructure lock-in, particularly in context of expanding availability of hydrocarbons and rapid growth in emerging/developing country energy infrastructure. May need to scrap vast amounts of capital.
 - Will we need / is there a role for geoengineering? Need to examine but immensely dangerous.

Where are we heading? (VI)

- To be consistent with an emissions path that resembles 2 degrees (50-50 chance) in 2030 - developing countries need to be around 25-27 billion tonnes p.a. (less than now) and developed countries around 7-8 billion tonnes (would be close to dividing by 3 over 20 years).
- Thus in 2030 developing countries around 3-3.5 tonnes/cap and developed countries around 7-8 tonnes/cap, compared with 4.5-5 and close to 20 now.
- Stronger action in developing countries is possible but will require coordinated, collaborative and rapid action. Strong moral responsibility for and self-interest in long-term support from developed world.
- Have to share an understanding that the two defining challenges of our century are overcoming world poverty and managing climate change.

Where are we heading? (VII)

- There are signs of growing enthusiasm from developing countries around low-carbon growth as they recognise the great risks of climate change and the opportunities in low-carbon for growth, development and overcoming poverty.
- Support for low-carbon growth is growing, e.g. China 12th plan, Korea, Ethiopia, Rwanda (return in lectures 2 and 3).
- A McKinsey (2011) business survey reveals a higher percentage of respondents in China and India believe climate change policy will strengthen over the coming decade, compared with the US and Europe.
- Can the world make the changes? This is the subject of lectures 2 and 3.

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