

LA006: Climate Change

Economics of climate change

28th November 2014

Preamble

- Economics as a science
 - Platform for engagement
 - Domain of activity and motives
 - Source of models, perspectives and data
 - Control/governance mechanism
- What does economics do for CC science?
 - Tools to measure impacts of CC and of potential policies
 - Drivers in models of human-caused CC
 - Guidelines for ‘mechanism design’ – creating new policies

Preamble

- How markets do and don't work
- The valuation of economic costs and benefits
- The economic impacts of climate change
- Political economy: the Stern Report
- 'Economic' drivers of climate change
- Economic instruments for addressing climate change

How markets do and don't work, 1

- In a market, preferences are linked to actions through the production and sale of goods and service.
- Citizen views are expressed through consumer preferences and regulatory constraints.
 - Consumers are motivated by *preferences* over choices available to them; the strength of our desire for particular goods and services is the price we are willing to pay.
 - This *can* include our valuation of the consequences of producing and using goods (including environmental or climactic changes)
 - But the scale of the impact – and the change we can effect as individuals – are limited by the size of our purchases, the alternatives available and our knowledge and understanding.
- Prices give firms
 - information about what to produce (and how)
 - incentives to get on with producing it.
 - Firms are motivated by profits: *revenues* from selling (which reflect willingness to pay) minus *costs* of producing and marketing them (and others imposed by law and regulation). Costs should represent the value of inputs used in their best alternative use.
 - Both input requirements and opportunity cost reflect technologies and resource availability (ownership)
- Market outcomes also inform governments about e.g.
 - Costs and benefits of interventions (markets as policy instruments)
 - Implicit value of intangibles to citizens

How they *should* work

- Individual markets (one ‘good’ at a time) – ideal markets identify and attain *efficient* outcomes. Efficiency comes in 4 flavours:
 - Allocational – no other arrangement would make *everyone* better off
 - Technological – unit (opportunity, societal) costs are minimised
 - Dynamic – ‘optimal’ incentives to invest, innovate
 - Informational – elicits, collects, and ‘prices’ all relevant information
- Markets are flexible in response to:
 - Changes in costs and productivity of resources used for supply
 - Changes in demand and the ‘welfare productivity’ of consumption
- Markets are linked by spillover or general equilibrium effects e.g.
 - Substitutes and complements – input and consumption mixes can change
 - Unexpected consequences – 70’s US gas deregulation tried to encourage production by pegging the price of a well to the market price when it was tapped; because prices rose faster than interest, this stopped new discovery immediately
 - Fossil fuels used for various purposes; some are easier to substitute than others. Price should not rise too slowly or too fast
 - Classic rebound – rising energy prices encourage efficient new technologies; this reduces the *relative* cost of energy inputs and makes output cheaper. The resulting increase in demand may lead to net increases in energy use.

How and why markets fail

- Fail to do what? Produce efficient outcomes
- To do this, they need (sufficient)
 - A workable and cheap system of property rights (something to trade)
 - Rational individuals
 - Effectively perfect information
 - Complete networks of economic interaction
 - Universal powerlessness (competitiveness)
- Problem 1 – spillovers (externalities) not captured inside the system
 - Imperfect or impossible property rights
- Problem 2 – irrationality ('behavioural' economics)
- Problem 3 – market power
 - Inefficiency is more profitable than efficiency
 - Scarcity brings profit
- Problem 4 – imperfect and incomplete information
 - Incorrect or divergent assessments of risk
 - Uncertainty; 'impossible' or underweighted outcomes
- Problem 5 – incomplete (or unknown) networks
 - Future generations
 - Global imbalances and 'divides'

Setting the benchmark

- To use economic mechanisms effectively and diagnose and address their problems, we need an independent measure of what is 'good'
- Economists (especially in government) use cost-benefit, cost-effectiveness or related tools.
- Cost-benefit and cost-effectiveness
 - Benefit/cost ratios (maximum benefit per unit of cost) require common unit of measurement
 - This is generally *money*, which already implies the existence of efficient markets to aggregate and 'price' costs, benefits, risks, etc.
 - Cost effectiveness (minimum cost per unit of value) allows two units
 - Separates money from 'something else' (e.g. sustainability) and asks how much it costs to produce a unit of something
 - Neither captures distribution, location, time, 'state' (uncertainty)
 - But using a common metric encourages engagement

Economic costs and benefits

- Should always be measured in *opportunity terms* - value of 'next best' use
- Expected Net Present value:
 - A policy gives a flow of (uncertain) net values over time
 - These can be aggregated if we weight them by
 - The 'importance' of individuals experiencing costs and benefits
 - The delay involved in their occurrence (discounting)
 - The likelihood that they will occur
 - *Net present value* = current money equivalent of this flow = weighted sum

Economic costs and benefits for different people

- Differences in incidence (who is affected) are handled by welfare weights (e.g. η). These may reflect
 - Ethical judgements
 - Estimates of the 'welfare' severity of impacts
 - Different abilities to mitigate or avoid impacts
 - What the 'assessor' knows about the preferences of those assessed.

Economic costs and benefits at different times

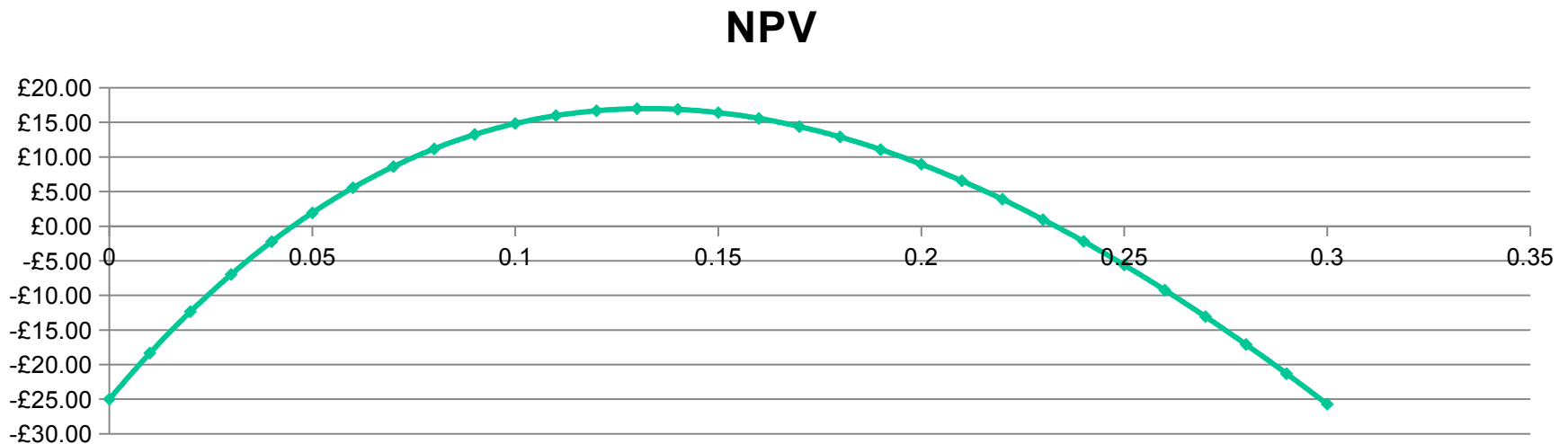
- Discounting is differently weighting impacts at different times
 - It may reflect psychological factors; myopia, survival probabilities, attention, cost of moving money over time, value of flexibility, intergenerational equity, etc.
 - Discounting is also justified by
 - Diminishing marginal utility increased consumption brings less added happiness
 - Unquantifiable uncertainty: what we are expecting may not happen or something unexpected may come along to kill or save us
 - Constant (exponential) discounting is required for *time-consistency* – i.e. that we will actually carry out the actions in period t that we thought we would when planning at period 0.
 - It is represented by a discount factor (δ) or an interest rate (r)
 - Mathematically, the value of an impact t periods into the future as seen from date 0 is $\delta^t = \frac{r}{1+r}$. In practice δ may be
 - Negative = more weight on future than present
 - near 0 = indifferent to time
 - Positive more weight on present than future
 - *Internal rate of return* (IRR) is the value of δ for which $NPV = 0$.
 - Should start with highest IRR projects, continue till budget exhausted or opportunity cost of funds (market rate) is reached
 - But scope of budgeting not obvious and PDV not monotonic

Non-monotone NPV

- Suppose a policy gives alternating costs and benefits

Pd 1	Pd 2	Pd 3	Pd 4
-£925	£1000	£1400	-£1500
Initial stake			Cleanup cost

- IRR = 4.52% or 23.31%



Uncertainty and delay of costs and benefits

Costs and benefits are uncertain and occur to different people at different times

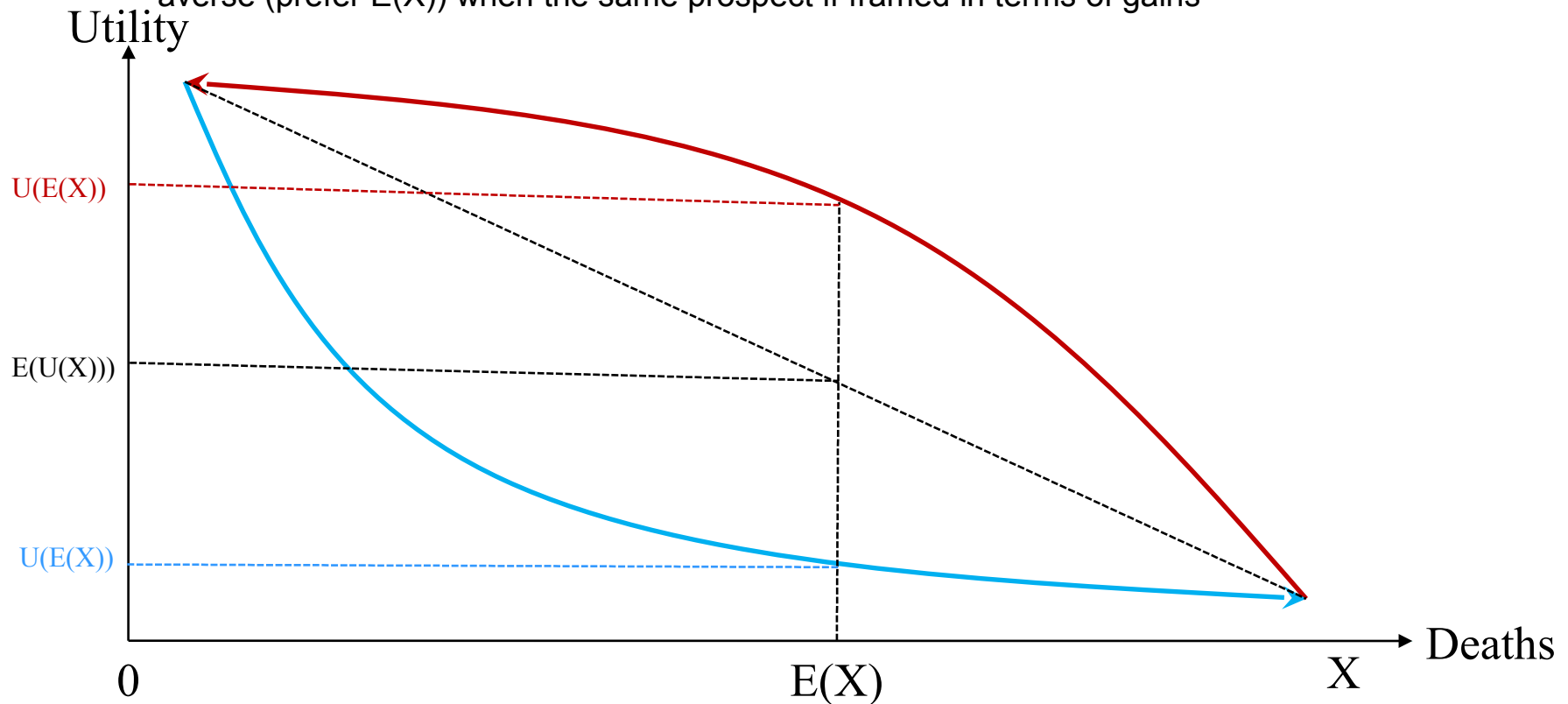
- *Risk* is handled by weighting impacts by likelihood of occurrence (probability, if available)
 - Some risks are unquantifiable (Knightian uncertainty)
 - People may assess risks differently (markets, science, discourse and voting)
 - They may evolve over time (if A happens then B is more likely)
 - non-stationarity handled by scenarios or stochastic processes: examples include stock-flow dynamics of GHG accumulation, progress of scientific knowledge

Valuation of economic benefits: reference position

- Suppose an *individual* with utility function V has a choice of two situations
 - a reference position R (with income I^R - e.g. status quo ante) and
 - an alternative A (with income I^A)
- There are two ways to frame the choice:
 - Willingness-to-pay to attain the alternative - the most the person could pay without being worse off under the alternative: $V(R, I^R) = V(A, I^A - WTP)$
 - Willingness-to-accept in lieu of the alternative – the smallest amount the person would pay in exchange for foregoing the alternative: $V(R, I^R - WTA) = V(A, I^A)$
- Conventional economics suggests WTP and WTA for purchases should be close except when expenditure on the good or transactions costs are relatively large
- Typically, WTP is substantially less than half of WTA ; in particular, using WTP (anchored in today's reality) particularly understates environmental 'goods'
 - WTP is closer to market valuation and more appropriate for valuing environmental gains
 - WTA is counterfactual and more appropriate for measuring environmental damage
- Conclusion: 'framing' can strongly influence societal decisions
- The *collective* analogues are
 - Compensating variation (CV) – the transfer necessary following a change (e.g. with higher pollution) to leave a person or society as well off as they were before the change
 - Equivalent variation (EV) – how much people harmed by a change would pay to avoid the damage
 - Social decision: can those who gain afford to compensate those who lose – as in a market

WTP vs. WTA – why the disparity?

- One reason – diminishing returns
 - If the starting point is “X people will die” then the first few lives saved bring substantial utility – as $X \rightarrow 0$, the ‘problem’ is not so serious and marginal utility drops.
 - If the starting point is no deaths, the first few are shocking and bring a big loss of utility; as we approach X, we become inured to the problem
 - The conclusion: we are risk-seeking (prefer lottery) when confronted with potential losses and risk-averse (prefer $E(X)$) when the same prospect is framed in terms of gains



Eliciting preferences

- How can we measure counterfactual benefits and costs?
 - Revealed preferences (RP): extrapolate from observed behaviour (e.g. price premia for living or working in unpolluted environments, wage differentials for jobs that involve different levels of environmental risk)
 - Stated preferences (SP): surveys, choice experiments, etc.
 - Market outcomes: responses to e.g. carbon or pollution taxes, prices of discharge rights, returns to investment/innovation in abatement technology
 - Political outcomes: willingness to vote for green taxes; price- and information elasticity of demand and energy use; response to public assessments (e.g. the numbers in Stern)
- How stable are the estimates?
 - Not very: Valuations derived from SP studies (e.g. asking people whether they'd be willing to have a £5 surcharge on utility bills if the money were spent on CCS or emissions reduction yields much higher values than RP measures (paying £5 to make a plane journey 'carbon neutral')
 - Even with 'green' pricing of energy, the premium paid for a high-rated appliance greatly exceeds the monetary savings or the (larger) environmental benefits arising from using less energy (evaluated using high-end estimates)
- What drives the disparities?
 - Many 'behavioural factors' such as self-interest bias, expressive vs. instrumental actions, choosing for one vs. choosing for all, 'merit good' framing, status (conspicuous virtue), etc.

Climate change as a 'public good'

- A classification of commodities
 - Excludability – can people be prevented from enjoying a good or protected from suffering a bad? (Can we use markets to find, pay for and allocate “optimal” amount?)
 - Externalities – is the welfare of ‘third parties’ enhanced or reduced by production and consumption? (do all costs and benefits have a voice? Do we add up quantities or values?)

Excludability\Externality	Positive	Neutral	Negative
Excludable	Network	Club good	Private good
Not excludable	Productive commons	Pure public	Congestible

Approaches

- Internalise externalities via *property rights*
- Create equivalent mechanism via *liability rules*
- Develop *collective rights* and obligations
- Create *novel mechanisms*

Where do economic effects come from?

All parts of the matrix:

1. Human economic activities (private goods) result in GHG emission flows (non-excludable?)
 2. These flows accumulate into stocks, no matter where they arise (global pure public good) following carbon cycle and related mechanisms
 3. The GHG stock traps heat and produces warming (congestible good)
 4. Warming produces climate change
 5. Climate change affects people and other living organisms and systems, primarily via water (drought, flood, sea level, absorption of radiation) – the problem is global, but many manifestations are local (club goods)
 6. Scientific and socio-political responses (network) to evidence of these problems may slow the process or help us cope, but a productive commons change in values is needed. Little gains may kill us.
- Each of these steps can be modelled, but each is uncertain
 - Some steps (esp. 2-4 and 6) involve time lags – thus probabilities and discounting
 - **The issues are similar to those of conventional economics; why the problem?**

The economic impacts of climate change

- Scientifically measurable and economically significant negative impacts:
 - Loss of land area due to sea level rises (certain and storm-related)
 - Change in nature of land area (deforestation, loss of agricultural land, diminished productivity of land for different uses)
 - Change in resilience and robustness of economic activities (variations in agricultural output and quality due to yields, disease, etc.)
 - Loss of 'genetic capital' such as biodiversity (Pharma), ecological webs, ecosystem services
 - Disruption of water supplies (quantity, timing, quality) to agriculture, industries and dwellings
 - Positive feedbacks with energy use (air conditioning, heating) and agriculture (biofuels)
 - Health and productivity (heat waves, extreme weather, tropical (and other) disease)
- Some positive effects (at least for some):
 - Localised agricultural benefits (CO₂ fertilisation of crops)
 - Some reduction in heating cost

Aggregate economic effect

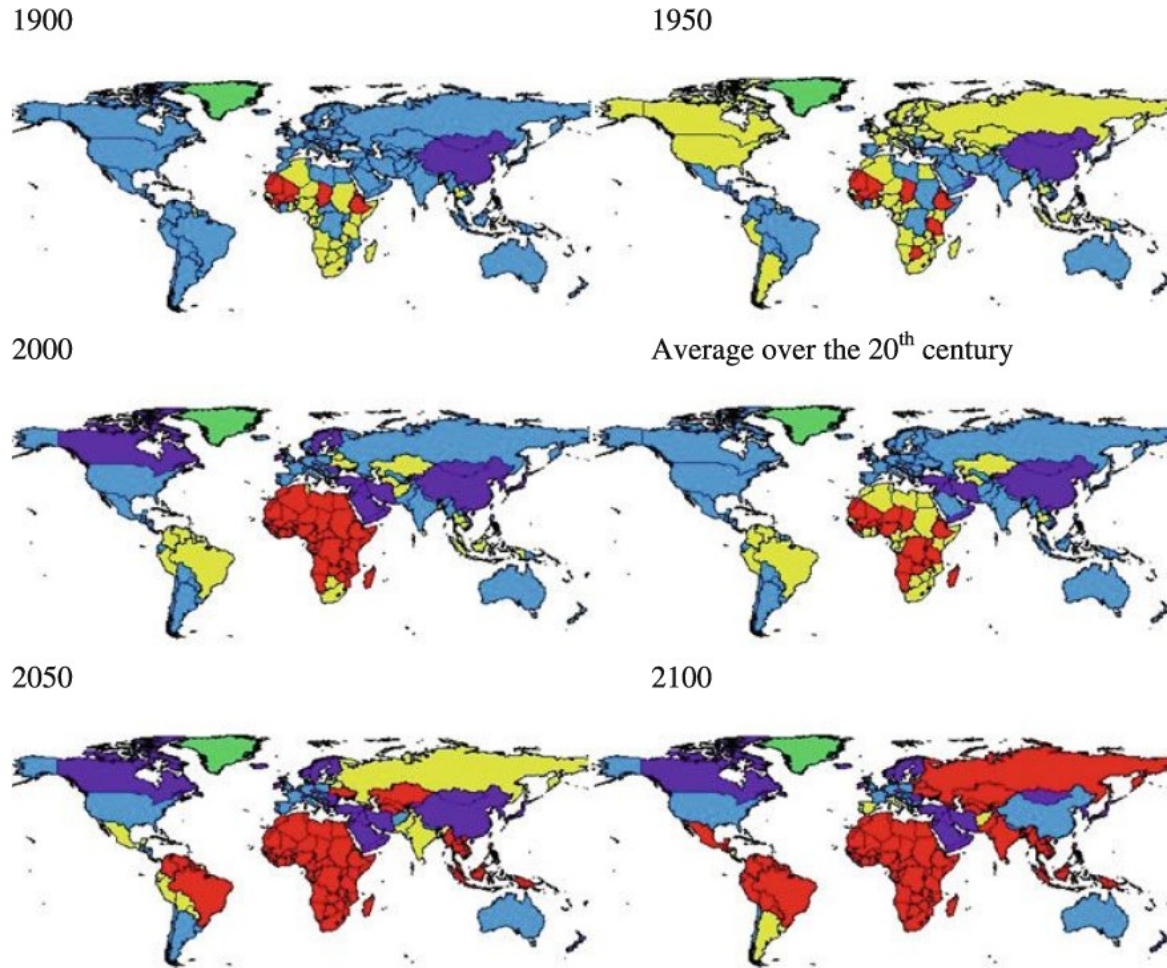


Fig. 5 The national total economic impact of climate change in three selected years and averaged over the 20th century; *purple*: impact > 1 % GDP; *blue*: impact > 0 % GDP; *yellow*: impact < 0 % GDP; *red*: impact < -1 % GDP; *green*: no data

Estimates of damage

Table 1. Estimates of Annual Damages to the U.S. Economy from Global Climate Change (billions of 1990 dollars)

OVERALL COSTS				
	Losses 2010, Bln PPP corrected USD	Losses 2010, % of GDP	Net Losses, % of GDP 2010	Net Losses, % of GDP 2030
Climate	696	0.9%	0.8%	2.1%
Carbon	542	0.7%	0.7%	1.2%
World	1,238	1.7%	1.6%	3.2%

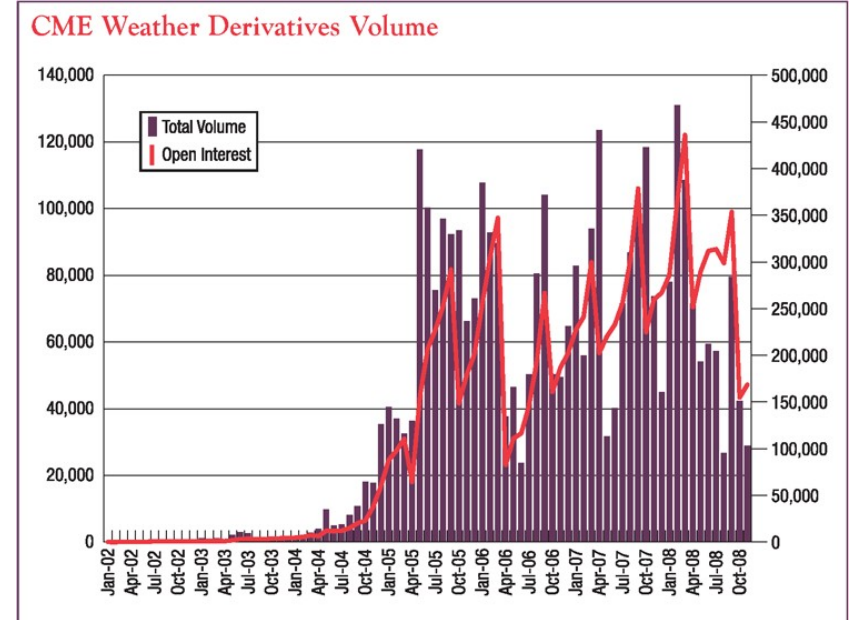
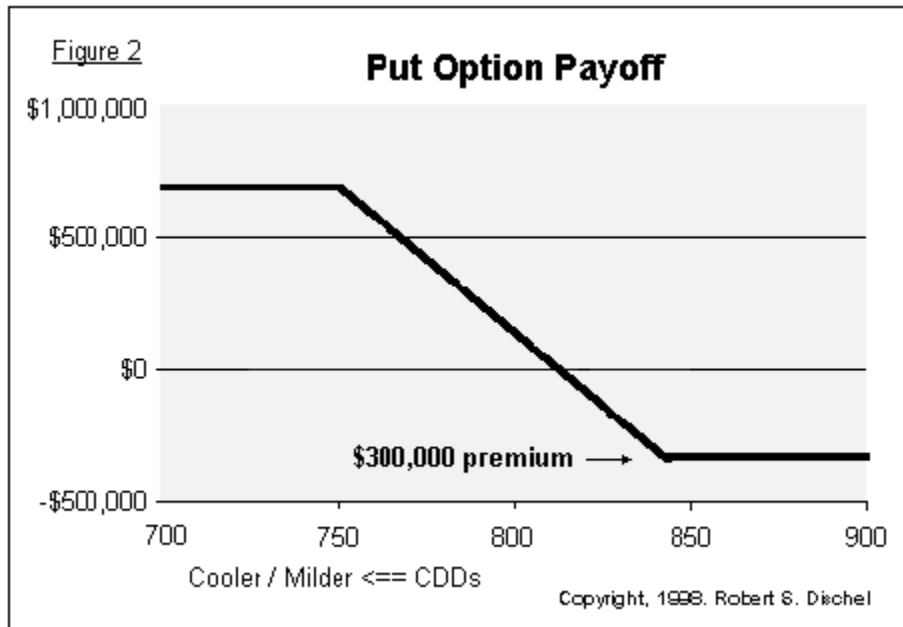
Type of Damage	Short-term warming based on doubling CO ₂ levels (+2.5 degrees C)	Very long-term warming (+10 degrees C)
Agriculture	17.5	95.0
Forest loss	3.3	7.0
Species extinctions	4.0 + X ₁	16.0 + Y ₁
<i>Sea-level rise</i>		
– Building dikes, levees	1.2	
– Wetlands loss	4.1	
– Drylands loss	1.7	
Electricity requirements	11.2	64.1
Non-electric heating	-1.3	-4.0
Human amenity	X ₂	Y ₂
Human life loss	5.8	33.0
Human morbidity	X ₃	Y ₃
Migration	0.5	2.8
Increased hurricanes	0.8	6.4
Construction costs	+/- X ₄	+/- Y ₄
Loss of leisure activities	1.7	4.0
Water supply costs	7.0	56.0
Urban infrastructure costs	0.1	0.6
<i>Air pollution</i>		
– Tropospheric ozone	3.5	19.8
– Other air pollution	X ₅	Y ₅
Total	61.1 + X ₁ + X ₂ + X ₃ +/- X ₄ + X ₅	335.7 + Y ₁ + Y ₂ + Y ₃ +/- Y ₄ + Y ₅

Where in the economy can these be seen?

- Sectoral markets can 'price' environmental damage and stimulate or retard efforts to tackle the problem
- They can also tilt the playing field
 - in favour of mitigation or adaptation
 - Stimulate or distort loss & damage alternative mechanisms
- Some affected markets:
 - Land
 - Transport
 - Communications
 - Fertiliser
 - Pharmaceuticals
- Financial instruments
 - Futures markets in climate-sensitive commodities
 - Asset values for climate-affected industries (rebound)
 - Microclimate data used for hedging and pricing commodity futures
 - Weather derivatives (next slides)
 - Insurance – Cat bonds (next slides)

Weather derivatives (since 1997-8 el Niño)

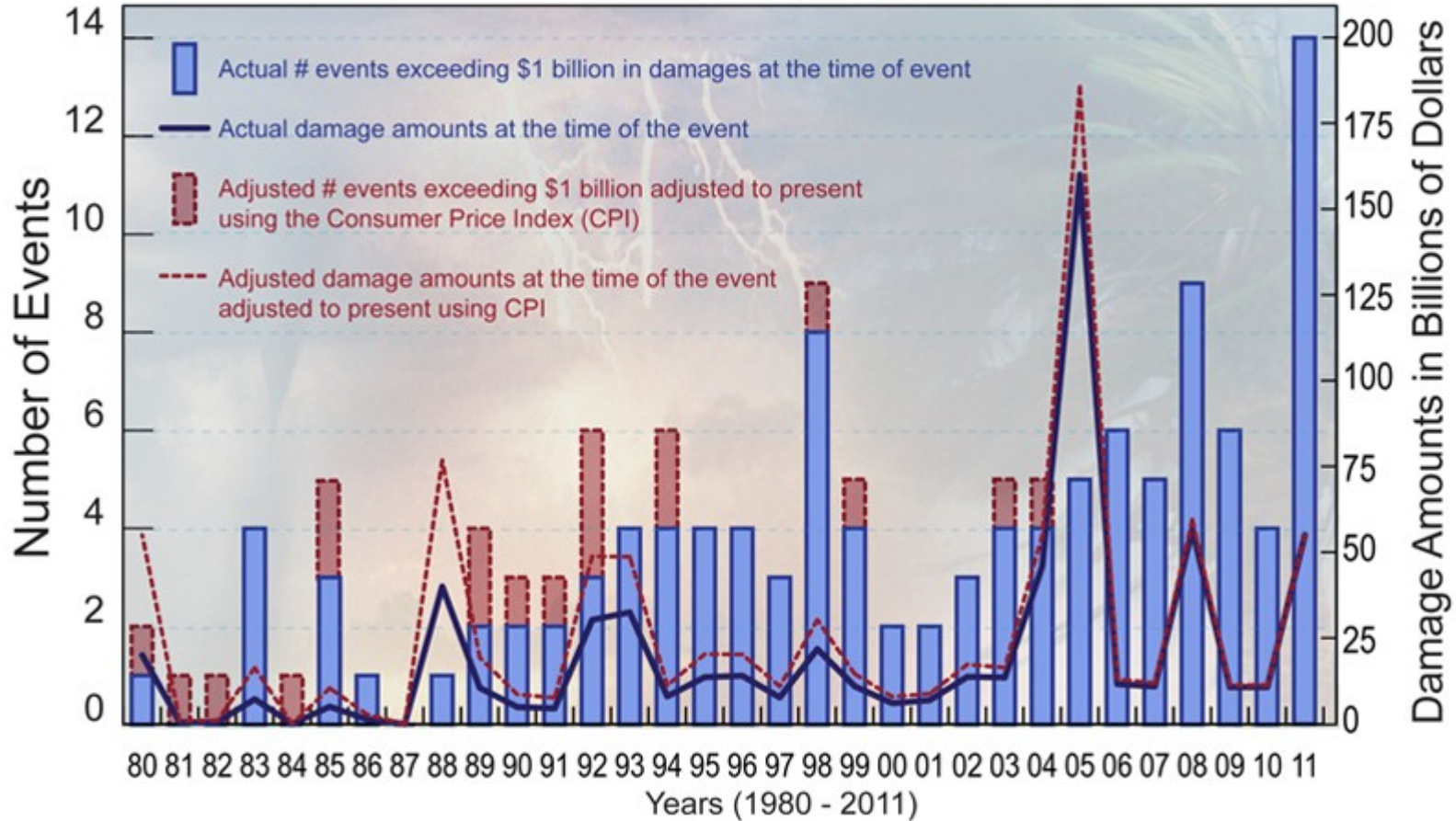
- How are they structured? (very complex, e.g. calendar-month futures (swap) contracts on heating degree days (HDD) and cooling degree days (CDD) as well as options on futures)
- Do they help in hedging climate risks? (varies widely by crop, region)
- Can they help value climate impacts? (yes)
- Do they work as 'predictive markets'? (not obviously)
- Who uses them? (mainly utilities, increasingly transport, agriculture; preferred to power/fuel positions due to availability of long time series)



Disasters and Catastrophes



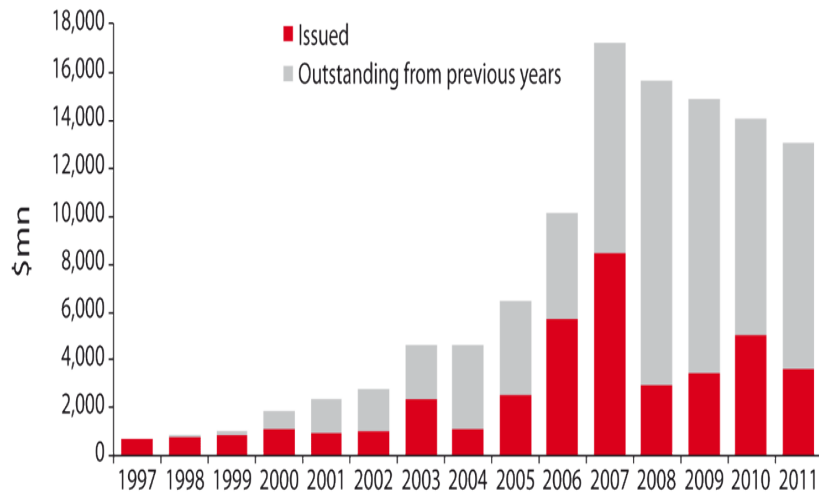
Billion Dollar Weather/Climate Disasters
1980 - 2011
NOAA/NESDIS/NCDC



Cat bonds

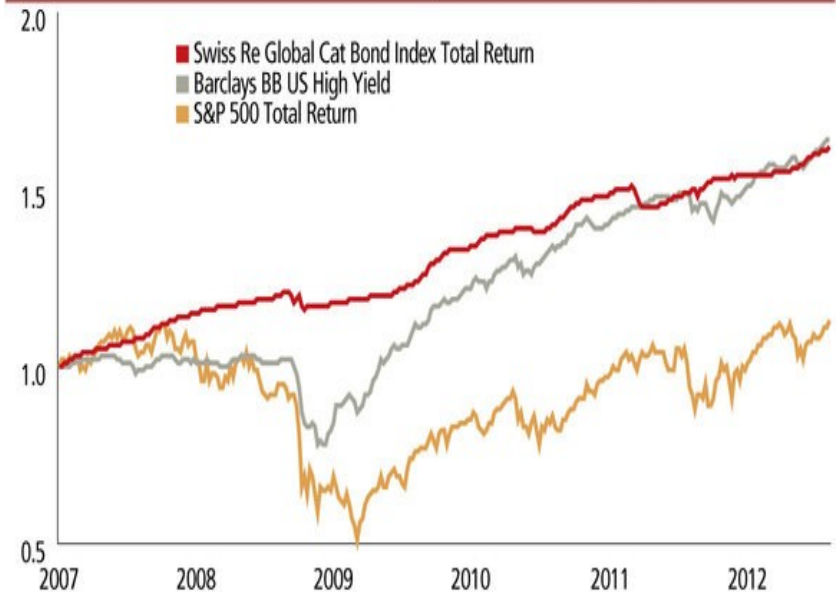
- High-yield debt, usually insurance linked
- Meant to raise money in case of a catastrophe such as a hurricane or earthquake.
- If the issuer suffers a loss from a pre-specified catastrophe, their obligation to pay interest and/or repay principal is deferred or forgiven
- Not closely linked with stock market or economic conditions; good diversification
- May create correlated (systemic) risk as CC advances

Outstanding cat bond volume



Source: Swiss Re Capital Markets

Cat bond returns January 2007 to July 2012

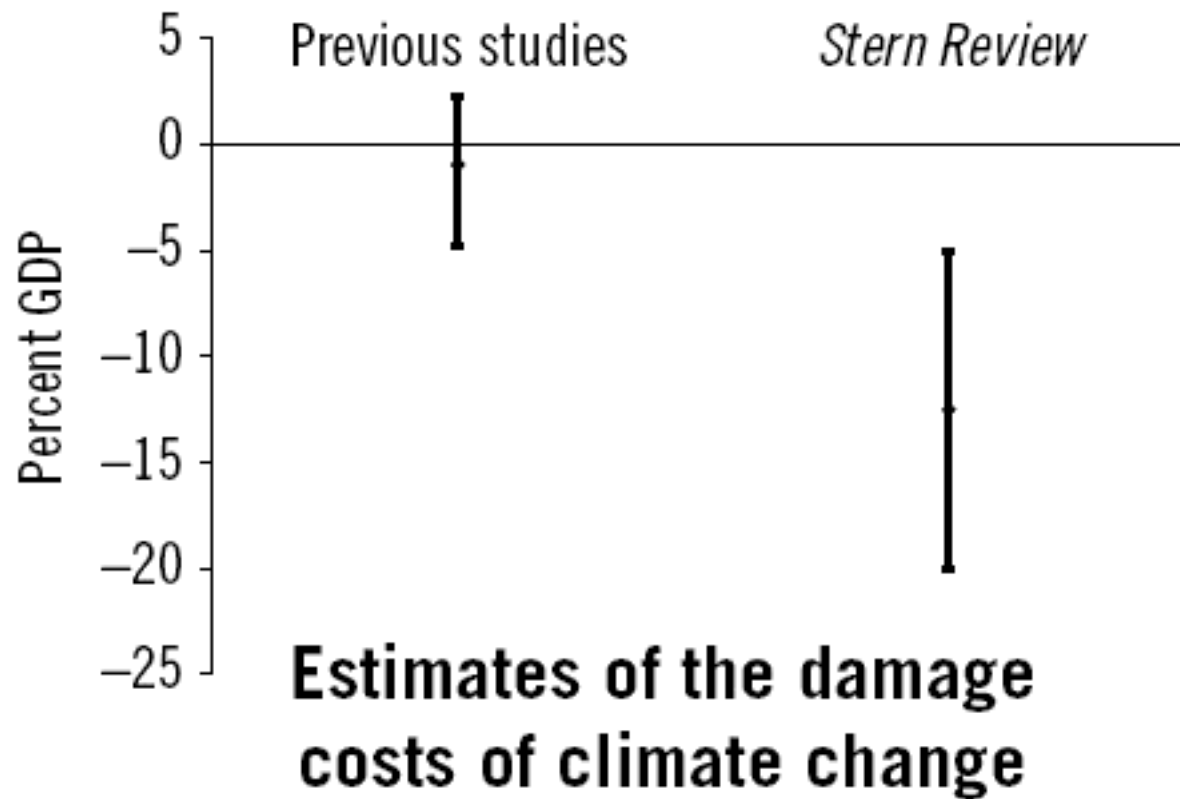


Source: Swiss Re.

Political economy: the Stern Report

- 700 pages; most widely cited and discussed report of its kind
- Lays out basic economics and carefully develops modelling strategy
- Regards CC as the largest 'market failure' ever seen (failure to do what?)
- Calls for strong, prompt action on cost-benefit grounds
 - Integrated model; attaches positive probability to 5-6% rise
 - Cost-benefit analysis discounts at social rate $s = \delta + \eta g$ - *psychological discounting (close to 0) + equity factor (marginal utility) * consumption growth rate* = 1.4% that looked low at the time □
 - Inaction will cost 5% of global GDP per year in perpetuity (NPV = 5%/interest rate); adding indirect effects brings this to more than 20%, which can be saved by investing 1% of GDP per year to stabilise at 500 - 550ppm CO₂e
 - Plight of the poorest – most affected by CC – highlighted by η weighting.
 - Transition to low-carbon economy will challenge competitiveness (of leading countries) but allow possibilities for growth
 - Policy must involve pricing carbon (via trading, taxes or regulation) – this should be globalised for consistency, with carbon finance for poorer countries.
 - Not all effects can be avoided; adaptation is necessary.

Stern vs. the rest



Economists' reaction, 1

- Criticised low discount rate (e.g. Arrow, Dasgupta)
 - Is it ethical to use δ above 0? Depends on what future generations can do; more freedom of action means discount future more steeply (they can look after themselves)
 - Is there a case for treating the far future differently due to feedback, lock-in and endogeneity?
 - Results very sensitive to this ambiguous parameter
 - Defence: high discount factors (e.g. 3%) only work for infinitely-lived representative agents, not overlapping generations.
- Uncertainty
 - Replaced uncertain future with certainty equivalents (vs. discount shift, real options).
 - Weitzmann said discounting cannot handle tail events (“right for the wrong reasons”).
- Inequality
 - We can think of η as measuring aversion to inequality;
 - Dasgupta argues that the assumed value (1) largely ignores inequality (over time).
 - He also computes savings rate implied by $\eta=1$ (in a static model) - 97.5%!

Economists' reaction, 2

- The related issue of contemporaneous inequality needs more discussion
 - Persistence of (climate-related) poverty and its impact on mobility.
 - Stern later accepted need for higher η but argued that we'd need to address current imbalances to make this consistent.
- Assumptions regarding technological advances
 - criticised, but alternatives seem thin on the ground,
 - non-linearity and endogeneity of technological progress, adoption and market impacts.
- Some discount debate compares assumed rate to market rates.
 - Stern's choice was close to return on gilts (government riskless debt);
 - others wanted rates closer to weighted average cost of capital (WACC).
 - These are now converging – was Stern right after all?

‘Economic’ drivers of climate change

- Profit motive and the value of ecosystem assets and services
- Global economic cycles (the recession and the environment)
- The informational (in)efficiency of asset markets
- Specific incentives
- The growth imperative

Economic instruments for addressing climate change

Should be discussed using game-theoretic tools.

- Marketable discharge rights
- Cap and trade systems
- Labelling and certification
- 'Green' consumer markets
- Taxes
- Standards
- Prizes and licensing
- New business models favouring sustainability

Readings, 1

- Basic environmental economics:
 - Backgrounder from encyclopaedia of Earth : <http://www.eoearth.org/view/article/151943/>
 - Goulder's [article on environmental economics](#), New Palgrave Dictionary of Economics
- Specific aspects of economics in relation to CC:
 - Brekke & Johansson-Stenman (2008) “The behavioural economics of climate change” *Oxford Review of Economic Policy* **24**(2): 280–297.
 - Russel & Benson (2013) “Green budgeting in an age of austerity: a transatlantic comparative perspective” *Environmental Politics*, DOI: 10.1080/09644016.2013.775727 at: <http://dx.doi.org/10.1080/09644016.2013.775727>
 - Bowen & Rydge (2011) “Climate-change policy in the United Kingdom” (No. 886). OECD Publishing.
 - Fitzroy, Franz-Vasdeki & Papyrakis (2012) “Climate Change Policy and Subjective Well-Being” *Environmental Policy and Governance* **22**: 205-216.
 - Horowitz and Maconnell (2002) “A review of WTP/WTA studies” *Journal of Environmental Economics and Management* **44**: 426-447.
 - Zeng (2000) “Weather Derivatives and Weather Insurance: Concept, Application, and Analysis” *Bulletin of the American Meteorological Society* **81**(9): 2075-2082.

Readings, 2

- The Stern review and reactions:
 - Stern's 2008 AER piece based on his University of Chicago lecture – esp. Sections II (valuation and modelling) and III (Policy)
 - Heal (2008) "Climate economics: A meta-review and some suggestions" NBER WP 13927
 - Partha Dasgupta's comments
 - Nordhaus, W (2007) "The Stern Review on the Economics of Climate Change"
 - Marty Weitzman's "review of the review"
 - Ken Arrow's "Global Climate Change: A Challenge to Policy" *The Economists' Voice* 4(3) 2007
 - Tom Schelling's "Climate Change: The Uncertainties, the Certainties and What They Imply About Action" *The Economists' Voice* 4(3) 2007
- Possible solutions:
 - Crampton and Stoft "How to Fix the Inefficiency of Global Cap and Trade" (The Economists' Voice. Volume 9, Issue 1, ISSN (Online) 1553-3832, DOI: 10.1515/1553-3832.1787, April 2012)
 - Bowen and Rydge (2011) "Climate-change policy in the United Kingdom" No. 886. OECD Publishing
 - Krahmman (2013) "Green consumer markets in the fight against climate change"

Multiple choice questions for discussion

- Is climate change a global pure public good?
 - Yes – not excludable, no externality
 - No, it is possible to insulate some people (or generations) from some effects
 - No, it only affects some parts of the world
- How (and how much) should we discount the future?
 - Same amount for each time period = social rate of discount
 - Same amount for all time periods = market rate of interest
 - Not at all
 - Different amounts for different strategies
- Are markets capable of pricing environmental risk
 - Yes, but only for specific sectors
 - No, due to incomplete information
 - No, because the most-affected parties are not born yet
 - Yes, because catastrophe bonds and weather derivatives capture the most important aspects
- Will carbon trading schemes implement the efficient level of emissions?
 - Yes, they will internalise externalities
 - Depends on how they are allocated and who can trade them
 - No, they will become sources of monopoly power and will not be enforced.