LA006: Climate Change

Economics of climate change

8th November 2013

THE UNIVERSITY OF WARWICK

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

- 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

The valuation of economic costs and benefits

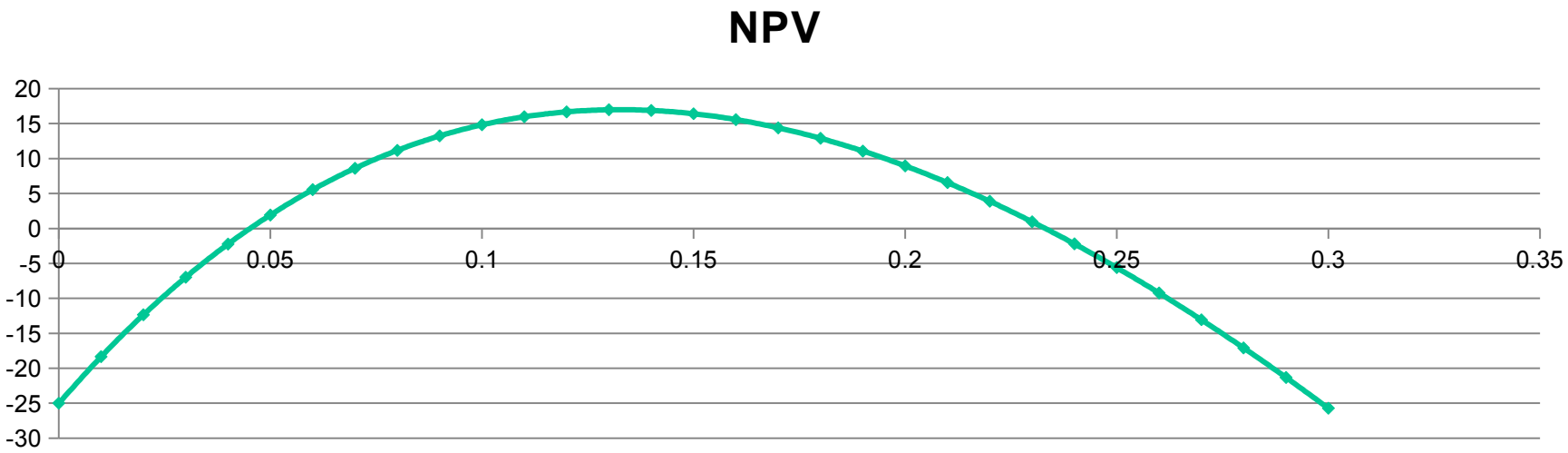
- Cost-benefit and cost-effectiveness
  - *Benefit/cost ratios* (B/C - maximised) require common unit of measurement
    - This is generally *money*; implies existence of efficient markets to 'price' costs, benefits, risks, etc. We will see that this is a strong assumption
  - *Cost effectiveness* (C/V - minimised) (cost per unit of value) allows two units
    - Separates money from 'something' – asks how much it costs to produce a unit of something (e.g. sustainability)
  - Neither captures complexities of distribution, location, time, 'state' (uncertainty)
  - But use of a common metric encourages *engagement*
- Costs, benefits should always be measured in *opportunity terms* - value of using resources in 'next best' way
- Present value – using cost, benefit data in policy:
  - Initiative gives a flow of net value (Benefit – cost) over time (weighted by 'importance' of individuals experiencing costs and benefits): $V_t = B_t - C_t$ (could be positive or negative)
  - Fixing discount rate δ, we can compute *net present value* $NPV = \sum_{t=1}^{\infty} e^{-\delta t} V_t$
  - *Internal rate of return* (IRR) is value of δ for which PV = 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 an initiative 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%



The valuation of economic costs and benefits

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

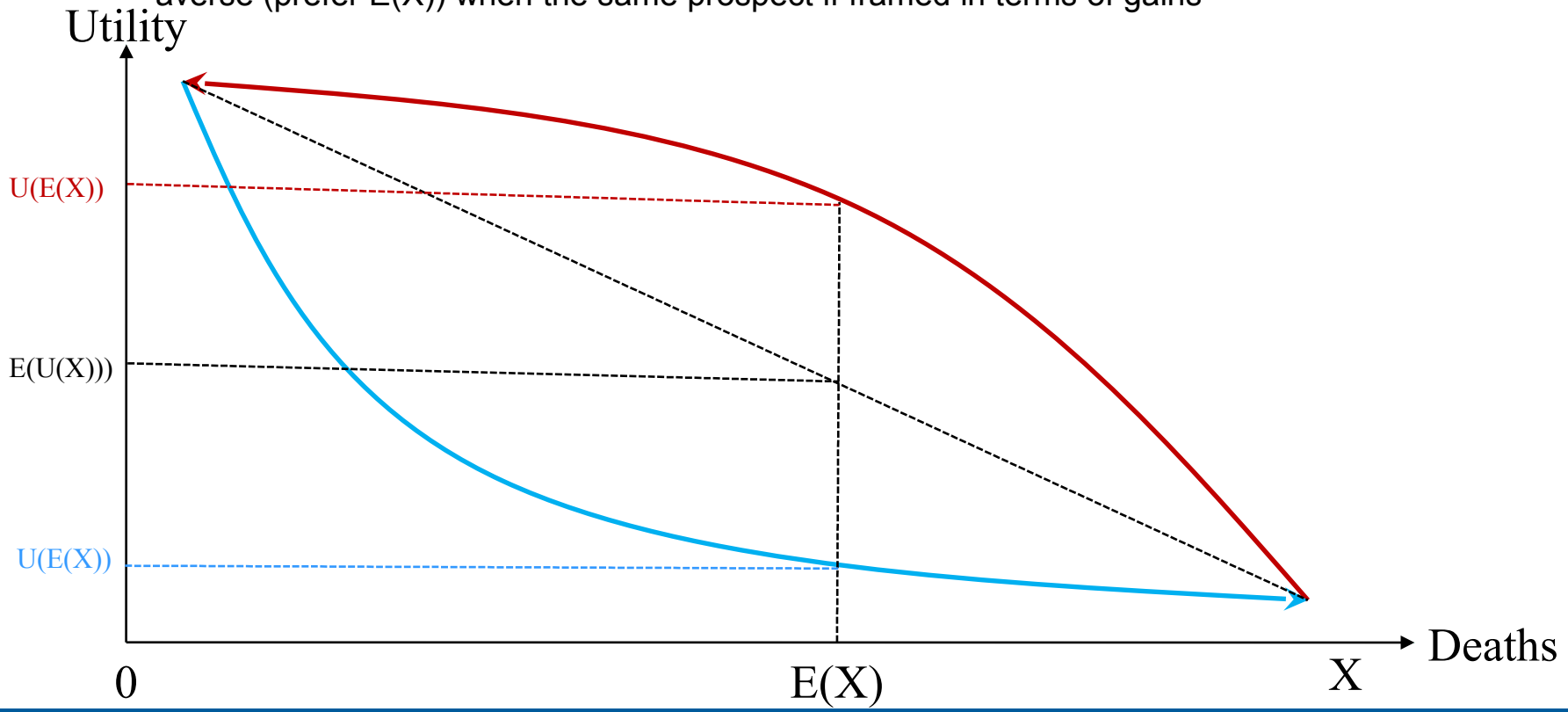
- *Risk* is handled by weighting impacts by likelihood of occurrence (probability, if available)
  - Some risks are unquantifiable (Knightian uncertainty)
  - People may assess risks differently (role of markets, science, discourse and voting)
  - They tend to follow patterns (A may not happen, but if it does then B is more likely) – this non-stationarity is handled by scenarios or stochastic processes: a good example is the stock-flow dynamics of GHG accumulation, and the progress of scientific knowledge
- Differences in time are handled by discounting (differently weighting impacts over time)
  - Time discounting may reflect many psychological factors; myopia, survival probabilities, attention, cost of moving money over time, value of flexibility, intergenerational equity, etc.
  - Discounting is also justified because
    - Increased consumption means lower marginal utility in future
    - Uncertainty: it may not happen or something unexpected may come along to kill or save us
  - Discounting at a constant exponential rate 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.
  - This is often called δ. It may be
    - Negative = more weight on future than present
    - near 0 = indifferent to time
    - Positive more weight on present than future
- Differences in incidence (who is affected) are handled by welfare weights (e.g. η).
  - These may reflect ethical judgements
  - They may also reflect estimates of the 'welfare' severity of impacts
  - They may reflect different abilities to mitigate or avoid impacts

Valuation of economic benefits: reference position

- An individual with utility function V choosing between a reference position R (with income I^R - e.g. status quo ante) and an alternative A (with income I^A) can value the change in two ways:
  - 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 be close except when expenditure on the good in question as % of income or transactions costs are large
  - Typically, WTP is substantially less than half of WTA; in particular, using WTP (which is anchored in today's reality) particularly understates environmental 'goods'
    - WTP is closer to market valuation and more appropriate for valuing environmental gains or improvements
    - WTA is counterfactual and more appropriate for measuring environmental damage or resource loss.
  - This means that 'framing' can strongly influence societal decisions
  - The collective analogues are
    - The 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
    - The Equivalent variation (EV) – how much people harmed by a change would pay to avoid the damage
    - The social decision is whether those who gain can 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 -> 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 if 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.

Modelling economic impacts

- 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* schemes
- 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 measureable 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
  - Some reduction in heating cost

Estimates of damage to US economy

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

Type of Damage	Short-term warming based on doubling CO2 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 + X1	16.0 + Y1
Sea-level rise		35.0
-- 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	X2	Y2
Human life loss	5.8	33.0
Human morbidity	X3	Y3
Migration	0.5	2.8
Increased hurricanes	0.8	6.4
Construction costs	+/- X4	+/- Y4
Loss of leisure activities	1.7	4.0
Water supply costs	7.0	56.0
Urban infrastructure costs	0.1	0.6
Air pollution		
-- Tropospheric ozone	3.5	19.8
-- Other air pollution	X5	Y5
Total	61.1 + X1 + X2 + X3 +/- X4 + X5	335.7 + Y1 + Y2 + Y3 +/- Y4 + Y5

Market impacts

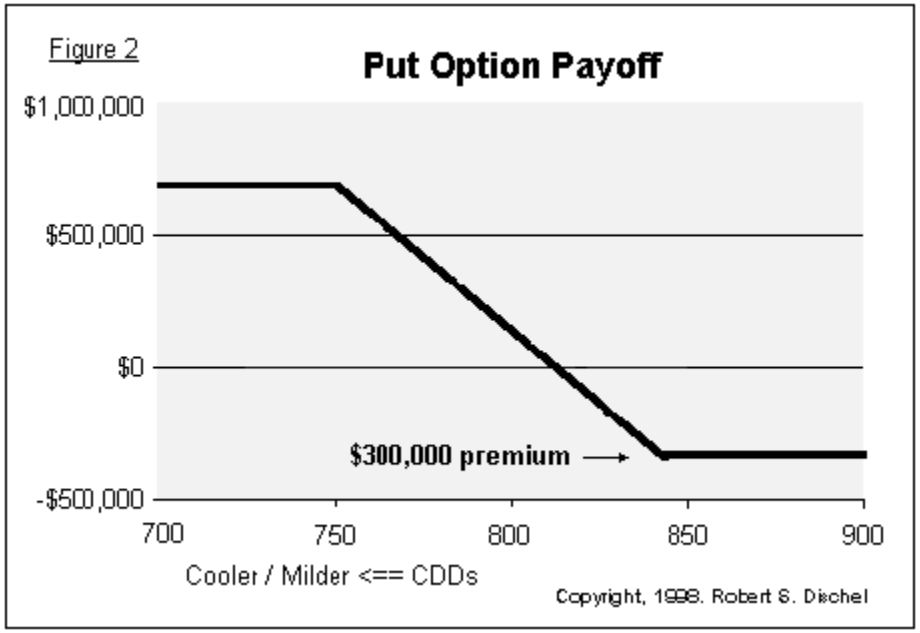
- Individual markets
  - Allocational efficiency – could make everyone better off
  - Technological efficiency – minimise unit (opportunity, societal) cost
  - Dynamic efficiency – incentives to invest, innovate
  - Informational efficiency – elicits, collects, and 'prices' all relevant information
- Mechanisms by which markets are affected
  - Changes in costs and productivity of resources used for supply
  - Changes in demand and 'welfare productivity' of consumption
  - Spillover or general equilibrium effects e.g.
    - Fossil fuels are used for various purposes; some are easier to substitute than others. If price rises too slowly, there will be no incentive to innovate or to substitute until it is too late; if price rises too fast, there will be collapse or lock-in to inappropriate decisions
    - Unexpected consequences – 70's US gas deregulation tried to encourage production (to keep prices down) 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 – the same can happen with 'societal' pricing of eco-friendly innovations (predatory patenting)
    - Classic rebound – rising energy prices spur development of efficient new technologies; this reduces the *relative* cost of energy inputs (compared to others) and makes output cheaper. The resulting increase in demand may lead to net increases in energy use.

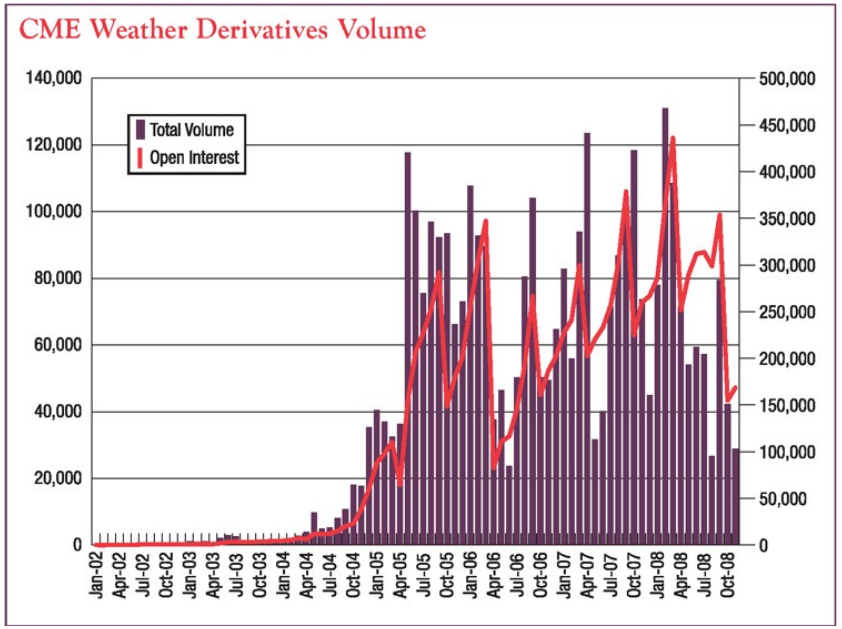
Ancillary markets

- Land,
- Transport
- Communications
- Fertiliser
- Pharma
- Financial instruments
  - Futures markets in climate-sensitive commodities
  - Asset values for climate-affected industries (rebound)
  - Insurance – systemic risk and agency problems (catastrophe bonds, etc.)
  - Microclimate data used for hedging and pricing commodity futures
  - Weather derivatives (next slides)
  - Cat bonds (next slides)

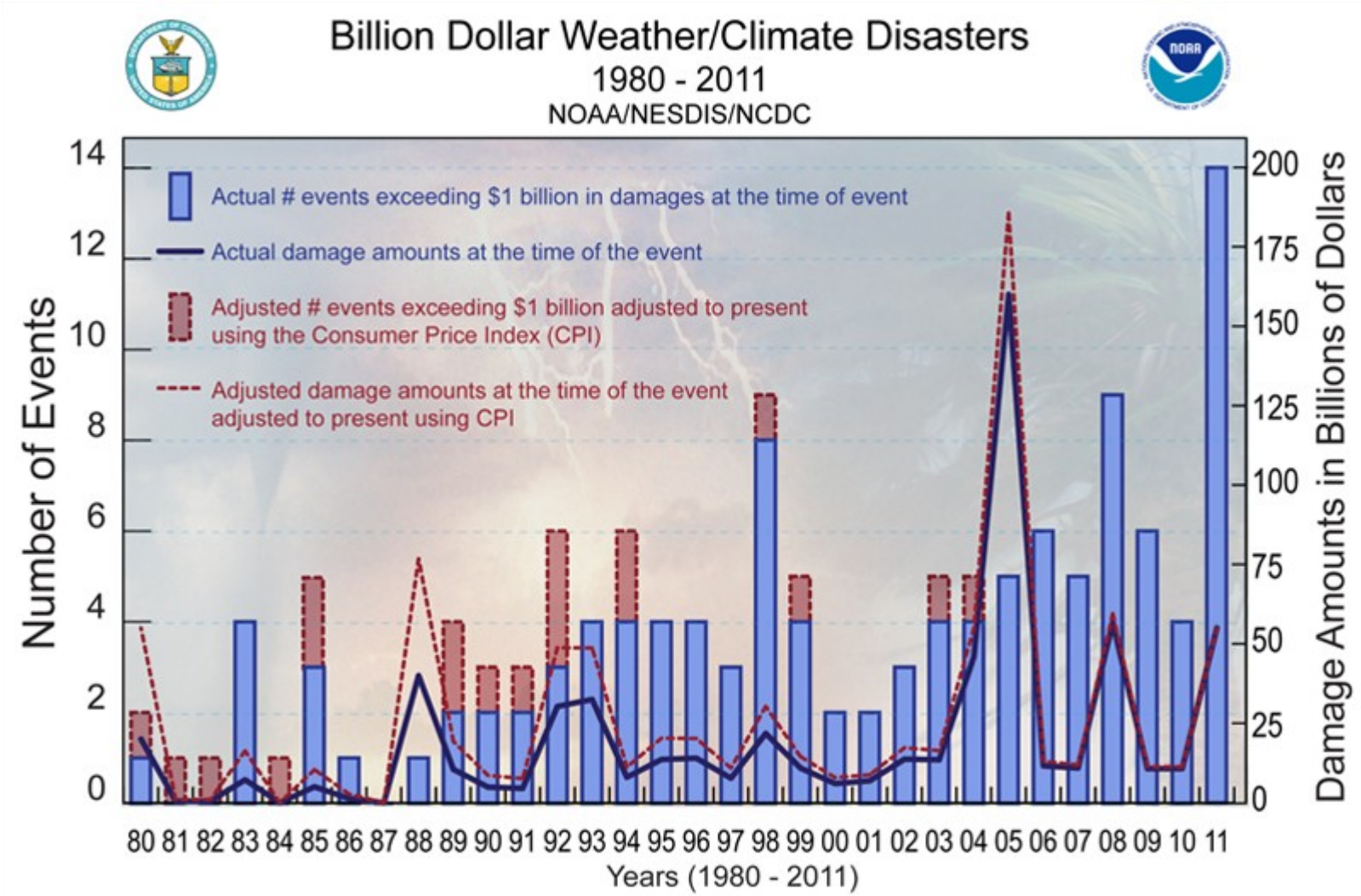
Weather derivatives (since 1997-8 el Niño)

- 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)



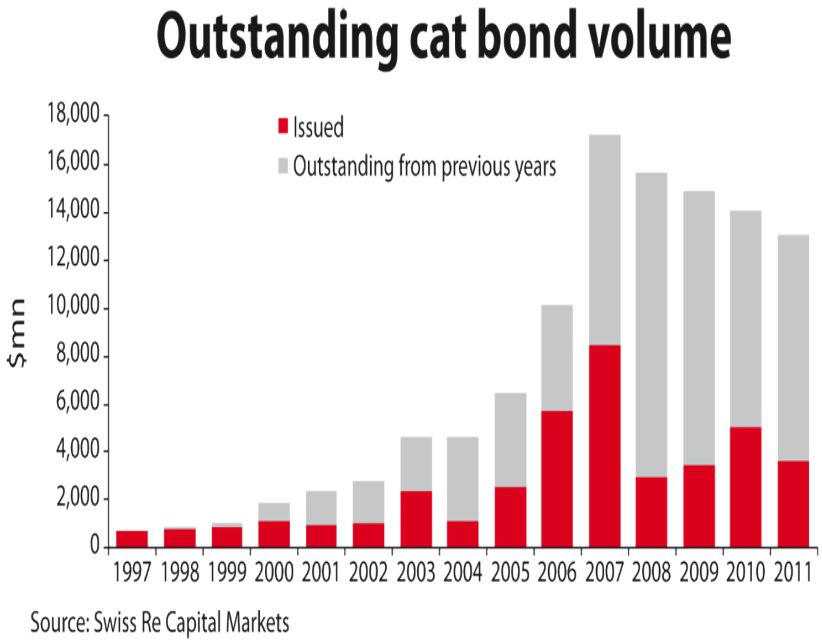


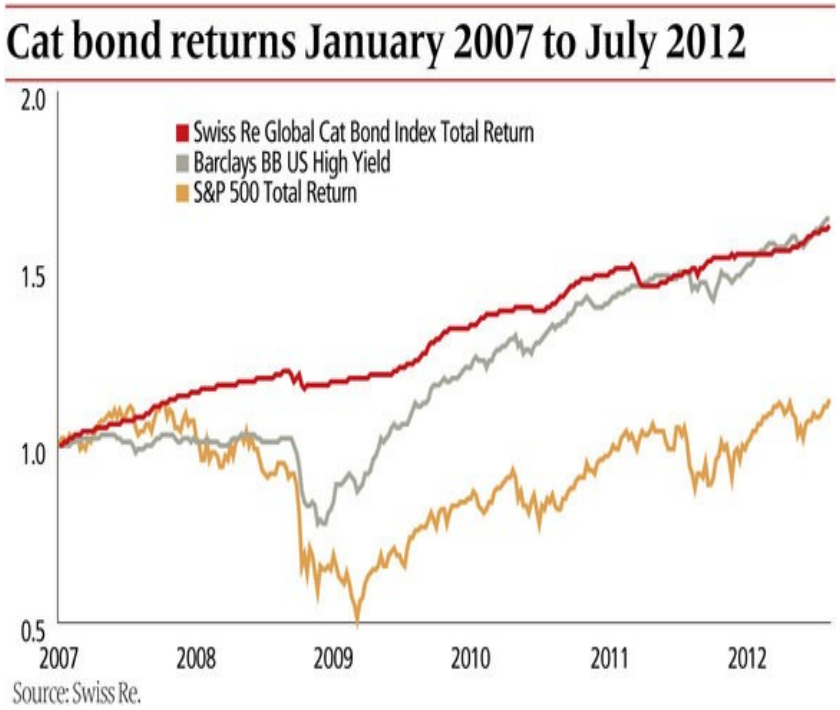
Disasters and Catastrophes



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

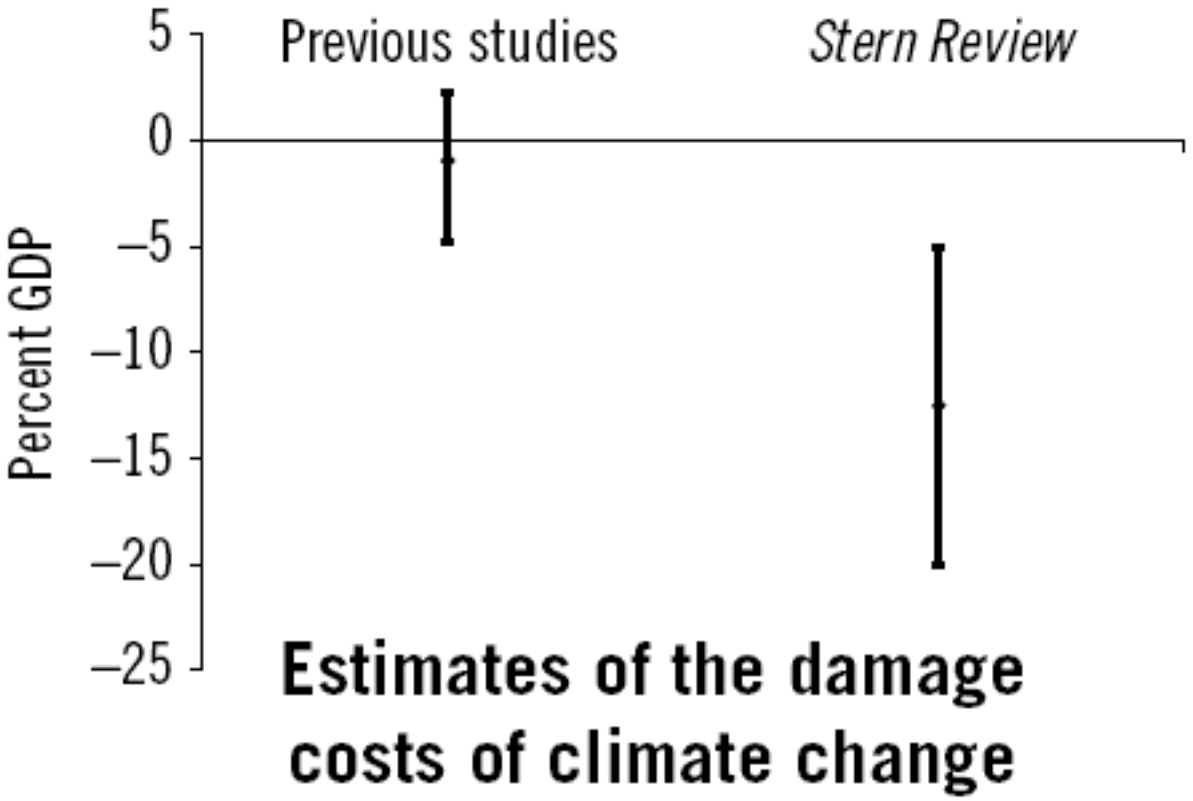




Political economy: the Stern Report

- 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?)
- Concludes that strong, prompt action is necessary on cost-benefit grounds
  - Uses integrated model; attaches positive probability to 5-6% rise
  - Cost-benefit analysis uses discounting at social discount 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 and 550ppm CO2e
  - Stern draws attention to the plight of the poorest – most affected by CC – whose utility is heavily weighted by η.
  - 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 to Stern Report, 1

- Criticised low discount rate (e.g. Arrow, Dasgupta)
  - Is it ethical to use δ above 0? I think it depends on what future generations are able to 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 of Stern argues that high discount factors (e.g. 3%) only work for infinitely-lived representative agent, not overlapping generations.
- Uncertainty
  - Stern replaced uncertain future flows with certainty equivalents (vs. discount shift, real options).
  - Weitzmann said discounting cannot handle tail events (Stern was "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 η=1 (in a static model) - 97.5%!

Economists' reaction to Stern Report, 2

- The related issue of contemporaneous inequality is less discussed, but should be
  - due to persistence of (climate-related) poverty and impact on mobility.
  - Stern later accepted need for higher η but argued that we'd need to address current imbalances to make this consistent.
- Technological advances
  - criticised, but alternatives seem thin on the ground,
  - non-linearity and endogeneity of technological progress, adoption and market impacts.
- Some of the discount discussion compares assumed rate to market rates.
  - Stern's choice was close to return on gilts (government riskless debt);
  - others wanted rates closer to return on 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

Economic instruments for addressing climate change

To be discussed in more detail with the aid of game-theoretic tools next week.

- Marketable discharge rights
- Cap and trade systems
- Labelling and certification
- ‘Green’ consumer markets
- Taxes
- Standards
- Prizes and licensing

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
  - Krahmann (2013) "Green consumer markets in the fight against climate change" *European Security* **22**(2): 230-247, DOI: 10.1080/09662839.2012.727184

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.