Estimating the Costs and Benefits of Climate Change Adaptation in Europe

Paul Watkiss
Overview

- Results and emerging findings from selection of EC FP7 Projects
- Economic costs of climate change - headlines and observations
- Considering the costs and benefits of adaptation – it depends!
  - Key issues (uncertainty, framing and objectives)
  - Moving from theory to practice
- And reflections from new approaches
  - Uncertainty and adaptation economic decision support
The Theoretical Framework

Simplified assessment of costs and benefits of adaptation

1) Socio-economic Change
2) Climate Change
3) Benefits of Adaptation

Translating this into practice is less simple

Also not particularly useful for framing adaptation
## Economic Costs of Climate Change

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<th>Vulnerability</th>
<th>Adaptation</th>
<th>Integrated</th>
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<td>Vulnerability indicators and profiles</td>
<td>Integrated assessment modelling</td>
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<td>Hazard-driven risk assessment</td>
<td>Past and present climate risks</td>
<td>Cross-sectoral interactions</td>
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<td>Livelihood analysis</td>
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<td>Narrative methods</td>
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<td>Risk perception including critical thresholds</td>
<td>Combining assessment approaches/methods</td>
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<td>Development/sustainability policy performance</td>
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<td>Relationship of adaptive capacity to sustainable development</td>
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<td>Spatial domains</td>
<td>Top-down</td>
<td>Bottom-up</td>
<td>Linking scales</td>
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<td></td>
<td>Global → Local</td>
<td>Local → Regional</td>
<td>Commonly global/regional</td>
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<tr>
<td></td>
<td>(macro-economic approaches are top-down)</td>
<td></td>
<td>Often grid-based</td>
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<tr>
<td>Scenario types</td>
<td>Exploratory scenarios of climate and other factors (e.g., SRES)</td>
<td>Socio-economic conditions</td>
<td>Exploratory scenarios: exogenous and often endogenous (including feedbacks)</td>
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<td>Normative scenarios (e.g., stabilisation)</td>
<td>Scenarios or inverse methods</td>
<td>Normative pathways</td>
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<td>Baseline adaptation</td>
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<td>Adaptation analogues from history, other locations, other activities</td>
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<tr>
<td>Motivation</td>
<td>Research-driven</td>
<td>Stakeholder-/research-driven</td>
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</tbody>
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Combines scenario based impact assessment, CGE and IAM

Source: IPCC AR4, WGII, Chapter 2, Carter et al 2007
Projected change in global mean temperature (°C) with respect to 1961-1990 for the A1B (red) and E1 (green) emissions scenarios. Results from ENSEMBLES GCMs. Thin lines: individual models. Thick lines: ensemble mean.

Source Christensen, Goodess, Harris, Climatic and Watkiss, 2011
Multi-model analysis (12)

Temperature – RCM output

Source Christensen, Goodess, Harris, Climatic and Watkiss, 2011
Rainfall – RCM output

2080s, A1B
(Wettest)

2080s, A1B
(Driest)

Source Christensen, Goodess, Harris, Climatic and Watkiss, 2011
Models and Sector Analysis

ClimateCost uses existing sector models

- **Coastal** zones (DIVA). Population affected, flood damage, beach erosion, loss wetlands, etc
- **Floods** (LISFLOOD) – flood damage for 5 sectors.
- **Energy** (POLES). Heating and cooling, hydro potential, thermal cooling, water abstraction
- **Health** (LSHTM). Heat and cold related mortality, food borne disease, labour productivity, floods
- **Agriculture** (UPM - PESETA). Crop based models and land productivity - then trade model
- **Ecosystems** (LPJ) – terrestrial carbon and biomes
- **Economy wide modelling** (CGE and IAM) – aggregated values

While comprehensive – still only a subset of impacts – and subset of sectors
Potentially Large Economic Costs

Economic costs of climate change in EU are large. Under M-H scenario (A1B)

- Sector IA – indicates high costs from floods (coastal and river), health, energy (cooling), that cumulatively over hundred €billion / year by 2050 (EU)
- Noting there are also some large economic benefits (e.g. heating demand)
- Rising in later time periods with potential cost discontinuities (tails)
  - IAM (PAGE) = -4% of European GDP by 2100 (with upper value > -10%)

Mitigation can reduce these very significantly

- IAM (PAGE) = -0.5 - 1% of European GDP equivalent by 2100 (E1)
- Sector assessments show large reductions under 2 degrees scenarios
Coastal damage costs A1B and E1, Brown et al, 2011
River flood damage costs A1B, Feyen et al, 2011
Energy cooling costs, Mima et al, 2012

EU Wide Economic Costs of Climate Change
Discussion and implications for adaptation

- Large economic costs but.....
  - People used to bigger numbers these days
- Mitigation reduces sector impacts significantly, but only after 2040
- Need for adaptation in early years
- High costs from climate change only emerge later in the century (post 2050)
  - Issue because of discounting
  - Relatively low cost in short-medium term, i.e. in relation to early adaptation
  - Important in focusing adaptation efficiently
Strong distributional patterns for different risks across Europe

Coasts

Coastal damage costs A1B, Brown et al, 2011
River flood damage costs A1B, Feyen et al, 2011

ClimateCost
River Floods
Strong Gradient North to South for Many Risks

- Cooling demand
- Relative health impacts (heat)
- Agriculture

 Raises issues of solidarity for adaptation

- Would Nordic countries be prepared to pay?

Cooling, A1B, Mima et al, 2012
Agricultural productivity A1B, Iglesias et al, 2011
Costs are uncertain

Alternative scenarios and model outputs

Not necessarily helpful for decision making

Costs range becomes extremely large – CBA breaks down at this point

And not solved by moving to probability

Noting extends beyond climate uncertainty

Change in EAD between the 2080s (2071-2100) and baseline period (1961-1990) for the A1B scenario based on LISFLOOD simulations driven by various regional climate models. Each plate represents the results for one of the 12 model combinations.

Feyen et al, 2011
Uncertainty in impacts and valuation

Further amplified by valuation choice (VSL vs. VOLY)
Costs (and Benefits) of Adaptation

Different aggregation and governance levels, addressing separate policy questions:

- Global level
  - Scale of adaptation and also specific input to finance negotiation discussion

- National level
  - National adaptation financing needs. National response, planning and prioritization

- Regional to local level
  - Design and prioritization of adaptation policies, programs and projects (appraisal)

- Noting that these are different problems with different objectives – and can’t be solved with a one-size-fits-all approach
<table>
<thead>
<tr>
<th>Approach</th>
<th>Description</th>
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<tbody>
<tr>
<td>Economic Integrated Assessment Models (IAM)</td>
<td>Global aggregated economic models that assess damage costs of climate change, and costs and benefits of adaptation. Values in future periods, expressed in $ and equivalent %GDP as well as Present Values (PVs).</td>
</tr>
<tr>
<td>Investment and Financial Flows (IFF)</td>
<td>Financial analysis. Early studies estimate costs of adaptation as percentage increase against future baseline investment expenditure. More recent national studies cost marginal increase needed to reduce climate risks to acceptable levels.</td>
</tr>
<tr>
<td>Computable General Equilibrium (CGE)</td>
<td>Multi-sectoral and macro-economic analysis for economic costs of climate change, and emerging analysis of adaptation.</td>
</tr>
<tr>
<td>Impact assessment - scenario based</td>
<td>Projected future physical impacts and associated welfare costs of climate change derived using climate model outputs and sectoral impact functions/models, complemented by comparison of costs and benefits of selected adaptation options.</td>
</tr>
<tr>
<td>Impact assessment – extreme weather events.</td>
<td>Variation of IA approach above, using historic damage-loss relationships from extreme events applied to future projections of such events. Adaptation costs estimated on basis of replacement expenditures or analysis of response options. Risk based variations include probabilistic analysis and thresholds.</td>
</tr>
<tr>
<td>Impact assessment - econometric based</td>
<td>Variation of IA approaches above. Historical relationships between economic production and climate parameters derived using econometric analysis and applied to future scenarios – that identify cross-sectoral differences to adaptation to current weather sensitivity</td>
</tr>
<tr>
<td>Adaptation assessments</td>
<td>Economic analysis of adaptive management (including adaptive capacity and iterative (dynamic) adaptation pathway).</td>
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</tbody>
</table>
Difficult challenges with Adaptation Economics

- Uncertainty
  - Baselines
  - Climate projections
  - Reversibility, flexibility and adaptive management

- Economic Valuation
  - Time horizon and discount rates
  - Non-monetary costs and benefits
  - Adaptation – mitigation linkages
  - Cross-sectoral linkages
  - Economic wide impacts
  - Hard vs. soft adaptation
  - Ancillary effects
  - Public versus Private
  - Limits of Adaptation

- Equity
  - Distributional effects

Markandya and Watkiss, 2009
Adaptation is very different to mitigation

- **Mitigation**
  - Common goal across all sectors - to reduce GHG
  - Benefits independent of location or technology
  - Common metrics (tCO₂ or $/tCO₂) allow prioritisation across sectors and options

- **Adaptation**
  - Adaptation is local, and is risk, sector, location, aggregation, time specific
  - Addressing large range of different risks and problem types, even within a sector
    - Responding to different climate parameters, different impacts – no single goal
  - Different possible ambition levels or objectives
  - No common metrics of physical benefits (over than money, €)
Costs and Benefits of Adaptation

- Economic literature primarily uses scenario based impact assessment and simplified form of this in IAMs
- Focuses on technical options, where unit costs can be applied
  - e.g. coastal costs per km of dyke, costs of irrigation per ha
- Adaptation options are assessed for one defined scenario at a time, using an if-then framework (predict and optimise). Using this approach:
  - Adaptation can significantly reduce the costs of climate change
  - Adaptation costs are low, and economic benefits high
Costs

- Coastal damage costs A1B, Brown et al, 2011

Benefits

- Ratio of benefits to costs

Coasts

- ClimateCost

Coastal damage costs A1B, Brown et al, 2011
River floods

Benefits - Reduction in Expected Annual Damage in Billion Euro/year

COSTS

Annual Adaptation Cost (Billion Euro/year)

Feyen et al, 2011
Examining the numbers

- Modelled adaptation highly effective – to the point reduces need for mitigation
  - Some early adaptation clearly has low cost / high benefits
  - Some costs would be expected to fall as introduce non-technical options
  - But closer look at the numbers raises some issues of validation, e.g. coasts
  - EU27, estimated annual costs of adaptation of €1 – 2 billion a year EU27
  - But Dutch Delta Commission planning to spend this amount in NL alone
  - MSE barrier in Venice capital cost of €5 billion, next London barrier €10 billion
  - So why do some of the numbers – especially later years - seem low….
What is happening?

- Assume perfect foresight. Predict and optimise to defined outcomes, allow incremental changes without penalty (no uncertainty or mal-adaptation)

- Marginal impact on top of existing protection – no adaptation deficit – linear

- Technical costs, omit policy and transaction costs

- And they have in-built assumptions about objectives and framework

  - e.g. CBA vs. CEA, 1 in 100 vs. 1 in 1000 level of protection – higher levels of protection increases costs (but changes benefits and reduces residual risks)

  - In practice these vary across Europe, and between sectors (mainstreaming)

- If someone presents a cost of adaptation (or a database) – they have already (implicitly) made a decision on framework and objectives
And also...

- Adaptation is already happening in Europe – need to look at the ‘with policies’ scenario, e.g. heat alerts

- And set against a background of strong socio-economic change and autonomous adaptation – what is the rationale for government planned action, and how to act

- In the (good) old days we could ignore these – but not as adaptation becomes real
Uncertainty

- Given uncertainty, adaptation should not optimise to a central projection

- But uncertainty does not mean we don’t need to act

- Number areas where early action needed, economically rationale
  - Building adaptive capacity
  - Win-win, no regret options justified by current climate or ancillary benefits
  - Identifying those long-term issues that require early pro-active intervention including where long life-times or irreversibility

- Moving to greater focus on ‘Adaptation Assessment’ rather than I-A – Use of Iterative Adaptive Management (flexibility, avoiding lock-in)) and economic decision support approaches that address uncertainty (robustness, resilience)
Iterative Adaptive Management (TE2100)

- Iterative adaptive management – also termed adaptation pathways

- No adaptation presentation is complete without a Thames Estuary 2100 slide!

- TE2100 Plan commissioned to provide an overarching strategy for managing the Thames tidal defences - short-, medium- and long-term programme

- Based on a managed adaptive approach to ensure that the right investments are made at the right time.
1 All costs quoted are undiscounted, at 2009 prices and exclude contingencies
2 depends on end-of-century option chosen in 2050

<table>
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<tr>
<th>Estimated Cost</th>
<th>Date (decade commencing)</th>
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<tr>
<td>(£ million)</td>
<td>2020</td>
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<tr>
<td>(i) Transition programme currently under way, and completing in 2013</td>
<td>£86m</td>
</tr>
<tr>
<td>(ii) First 10-year programme of defence works (2013 to 2023)</td>
<td>£449m</td>
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<tr>
<td>(iii) Habitat creation sites 1 &amp; 2 of 4 (2015 to 2026)</td>
<td>£54m</td>
</tr>
<tr>
<td>(iv) Second 10-year programme of defence works (2024 to 2034)</td>
<td>£616m</td>
</tr>
<tr>
<td>(v) Habitat creation sites 3 of 4 (2030 to 2056)</td>
<td>£76m</td>
</tr>
<tr>
<td>(vi) ‘Renewal phase’ defence works 15-year programme (2035 to 2049)</td>
<td>£1,650m</td>
</tr>
<tr>
<td>(vii) Planning and construction of ‘end of century’ works (2050 to 2069)</td>
<td>£1,400m - £1,500m</td>
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<tr>
<td>(viii) Habitat creation site 4 of 4 (2070 to 2090)</td>
<td>£110m</td>
</tr>
<tr>
<td>(ix) Final phase defence works (2070 to 2100)</td>
<td>£2,300m - £3,200m</td>
</tr>
<tr>
<td>(x) Multi-partner actions undertaken throughout the life of the Plan</td>
<td>£2,300m</td>
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New Thames Barrier in service 2070

EA, 2009:2010: Defra; 2010
Adaptation pathways
- Iterative decision making over time

Adaptation as a process and noting interdependencies

Risks

Current effects
Climate variability

Increasing climate signal and rising risks

Possible thresholds

Major climate signal and risks

Future

Policy cycles

Current

Decisions with long planning time

Decisions with long-life time

Short-term

Possible pathways for iterative decision making over time

Long-term

Review
Research
Pilots

Win-win
No regrets
Low cost

Other

Research

Awareness
Education

Monitoring
Training

Evaluation
Decision information
Policy cycle progress

Act now

Delay

Watkiss, 2010
Method for Economics of Climate Resilience

1. Define risk / problem type and consider objectives
2. Identification and classification of options
3. Appraisal of options
4. Prioritisation (risks and sectors)
5. Order of magnitude of adaptation
6. Continuous and ex post evaluation
7. Transfer the CCRA and other information

Watkiss and Hunt, 2011
# Analysis and roles: Temperature related mortality

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<th>Impact assessment</th>
<th>Adaptation assessment</th>
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<td>Climate model output for SRES scenarios</td>
<td>Current variability, near-term risks, long-term</td>
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<tr>
<td>Gridded population data</td>
<td>Current drivers of vulnerability (age, income, public health system) and changes</td>
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<td>Epidemiological functions</td>
<td>Analysis of institutional architecture and governance (responsibility)</td>
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<td>Impacts in future time periods</td>
<td>Non climate drivers and policy</td>
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<td>Adaptation options</td>
<td>Future baseline risk reduction including autonomous adaptation</td>
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<td>Effectiveness in reducing future impacts</td>
<td>Existing adaptation options and influence – heat alert</td>
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<td>Options from capacity building – public health – buildings – ancillary effects</td>
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<td>Analysis of options with decision making under uncertainty</td>
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<td>Stakeholder consultation</td>
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Reviewing TE2100 / Pathways

- TE2100: Project level, single risk with known gradual direction of change
  - Application in other areas proving more complex
  - Very time and resource intensive

- Lessons from the UK, from developing national iterative economics methods

- Application and costing of iterative adaptive management is challenging!
  - Appraisal of large number of integrated options
  - for different (linked) risks evolving differently over time
  - many involving capacity building and soft options
  - grounding this in current policy and effects, and non-climate drivers
  - and taking account of existing early adaptation
Existing tools we use in economic decision support not suited for adaptation

Cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis all problematic, particularly in relation to uncertainty

Looking at new economic decision support tools (impact assessment) to cope with uncertainty

- Real Option Analysis
- Portfolio analysis
- Robust decision making
Real Option Analysis (ROA)

- Assess economic value of delay (the option value) in light of new information that reduce uncertainty, or that builds-in flexibility

- Formal approach has limited application – large irreversible infrastructure where potential for learning
  - But wider application through decision trees & informal analysis

- Challenges: perception - widely mis-cited (TE2100 did not do RO)
  - ROA works well where up-front benefits (adaptation deficit) or long-life times. Formal approach needs probabilities

Cash Flow ($) vs. time

- Capital cost
- Opportunity cost of waiting
- Delayed investment decision point
- New expected gross margin
  - Upper estimate of gross margin
  - Original expected gross margin
  - Lower estimate of gross margin
- Avoided loss

Risk event

- High revenue €175m, net return = €175-100 = €75m
  - Expected net return = 50% x €75m + 50% x -€25m = €25m
- Low revenue €75m, net return = €75-100 = -€25m
  - Expected net return = 50% x €75m + 50% x €0m = €37.5m
- Don’t invest, net return = €0m
Robust Decision Making

- RDM: analytical approach, use qualitative and quantitative information for deep uncertainty – robustness not optimisation

- Formal application computer based, very resource intensive,

- Evaluate how different strategies perform under large ensembles of scenarios reflecting different plausible future conditions (hundreds to thousands to millions).

- Look at key trade-offs among promising strategies

- Allows selection of robust strategies

- Applied in California water supply

Groves et al., 2008b
Portfolio Theory

- Portfolio theory: economic analysis to assemble portfolios of options to maximise economic return subject to given level of risk

  - Evolved from financial markets - portfolios of financial assets that maximise the return on the investments subject to a given level of risk

  - Overall aggregate returns for portfolio that minimise variance and covariance against future scenarios

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Hunt, 2009
Some observations

- While powerful, technically complex approaches to apply (formally)
- Work well only for specific applications – but not all cases
- Large resources involved – and considerable expertise needed
  - Likely to mean niche applications, where large potential costs are involved
- Unlikely to be generally applicable (not possible to download off the web)
- Critical question is whether possible to take the general concepts and simplify for more general application
- And when approaches are useful – which techniques for different problems
## Decision Support Tool

<table>
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<th>Decision Support Tool</th>
<th>Brief Description</th>
<th>Usefulness &amp; limitations in climate adaptation context</th>
<th>Principal References</th>
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</table>
| **Social Cost-Benefit Analysis (CBA)** | CBA values all relevant costs and benefits to government and society of all options, and estimates the net benefits/costs in monetary terms. CBA aims to directly compare costs and benefits, allowing comparisons within and across sectors. | Most useful when:  
- Climate risk probabilities known  
- Climate sensitivity likely to be small compared to total costs/benefits  
- Good quality data exists for major cost/benefit components | The Green Book (2003)  
Metroeconomica (2004)  
Granger et. al. (2010) |
| **Social Cost-Effectiveness Analysis (CEA)** | CEA compares the costs of alternative ways of producing the same or similar outputs, identifying least-cost outcomes. | Most useful when:  
- As for CBA;  
- Agreement on sectoral social objective (e.g. minimise loss of life years from heat-related causes). | Watkiss et. al. (2009)  
Metroeconomica (2004) |
| **Real Options Analysis (ROA)** | ROA extends the principles of CBA to allow for learning about the nature/extent of climate change and its impact on the adaptation option(s) being considered. This is incorporated by estimation of the value associated with providing information that reduces the uncertainty relating to climate risks. | Most useful when:  
- As for CBA;  
- Learning related to climate sensitivities is likely within decision time-frame;  
- Adaptation context includes possibility of need for investment in long lifetime, climate-sensitive, assets. | Green Book Supplementary Guidance (2009); |
| **Portfolio Analysis (PA)** | PA allows an explicit trade-off to be made between the return – measured e.g. in net benefit terms (from CBA) – and the uncertainty of that return – measured by the variance – of alternative combinations (portfolios) of adaptation options, under alternative climate change projections. | Most useful when:  
- As for CBA;  
- A number of adaptation actions are likely to be complementary in reducing climate risks. | Crowe and Parker (2008) |
| **Robust Decision Making (RDM)** | RDM quantifies the trade-offs implied by adopting adaptation options that address possible vulnerabilities under future uncertainty, compared with other criteria such as economic efficiency | Most useful when:  
- Probability distributions of alternative climate, socio-economic and vulnerability futures can be constructed, and data for their characterisation is available. | Groves and Lempert (2007) |
| **Risk-Based Rules (RBR)** | Ranking, (ordinal or cardinal), guided by risk attitude of decision-maker. Includes e.g. Maximin and Minimax Regret rules. | Most useful when:  
- Climate risk probabilities not well established, or do not exist;  
Ranger et. al. (2010) |
Conclusions

- Potentially large but uncertain economic costs from climate change

- In theory, adaptation is a low cost-high benefit approach to tackle these
  
  - But in practice unlikely to be quite as effective

- Costs (and benefits) of adaptation are context specific – it depends

- Greater focus on real adaptation policy - grounding analysis in short-term, alongside multiple drivers, policy

- Because of uncertainty, moving from optimisation to decision making under uncertainty – changes methods and also changes likely choice of options