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Potential costs and benefits of adaptation options: A review of existing literature

Technical paper

Summary

Building on recent reviews on the costs and benefits of adaptation, this technical paper analyses the general methodological issues for estimating the costs and benefits of adaptation options, reviews new studies on the economics of adaptation in light of these methodological issues, and discusses the strengths and weaknesses of the studies and methods.

Key findings from the paper include: the benefits of adopting multiple methods and approaches, including non-monetary ones, in accordance with the objectives of the assessment and the types of adaptation options to be assessed; the need for further methodology development, including in relation to the treatment of uncertainty, economic valuation and equity; and the continued lack of detailed analyses of the costs and benefits of adaptation, including in a form that is relevant to decisions on public funding.

Parties may use the information contained in this technical paper as they consider implementing adaptation action under the Convention, including in the work under the Nairobi work programme, and particularly on its work area on socio-economic information. In addition, improved understanding and capacity for addressing the costs and benefits of adaptation is an important pillar in implementing enhanced action on adaptation at all levels.

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I. Executive summary

A. Introduction

1. The Subsidiary Body for Scientific and Technological Advice (SBSTA), at its twenty-eighth session, requested the secretariat, in the context of the Nairobi work programme on impacts, vulnerability and adaptation to climate change and under its work area on socio-economic information, to prepare a technical paper reviewing the existing literature on the potential costs and benefits of adaptation options. The aim of this technical paper is to review and analyse methodological issues and evidence related to the costs and benefits of adaptation options. Parties may also use the information contained in this technical paper as they consider implementing enhanced action on adaptation, including their consideration of financial needs assessments.

2. Over the past few years, a number of studies (IPCC, 2007; Agrawala and Fankhauser, 2008) have reviewed the literature on the costs and benefits of adaptation and revealed that there is generally a low level of knowledge in this area. This lack of knowledge, particularly for developing countries, has led to several new studies being commissioned on the economics of adaptation. This technical paper does not seek to repeat the content of earlier reviews. It provides a synthesis of the new studies, taking into account the new insights that these provide. The paper aims to:

(a) Raise awareness of the latest studies;

(b) Investigate key methodological issues that these studies reveal;

(c) Discuss the approaches and methods used, what each of these provide, and the applications and outputs for which they are relevant;

(d) Discuss the strengths and weaknesses of the studies and methods;

(e) Consider the evidence base in light of the new studies.

3. The primary focus of the paper is on planned adaptation at the national level, that is to say adaptation that requires some level of organizational or policy intervention, and defined broadly here as 'national-level' policy. It is primarily, but not exclusively, focused on the public sector. It is to be noted that planned adaptation does not just relate to technical or 'hard' options, but also includes 'soft' non-technical measures that may influence socio-economic behaviour.

4. The paper investigates the costs of adaptation, defined as the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs. It also investigates the benefits of adaptation, defined as the avoided damage costs or the accrued benefits following the implementation of adaptation measures. For both of these aspects, this paper considers the economic costs and benefits of adaptation, considering the wider costs and benefits to society as a whole, rather than financial ones alone. Finally, it discusses the potential for consideration of residual impacts, noting that adaptation reduces the impacts of climate change, but does not remove them entirely.

B. Review of methodological issues

5. Existing studies of the costs of adaptation fall into two broad groups: those that adopt an aggregate level analysis and those using a more disaggregated approach. The aggregated approach is more basic and relies on a number of assumptions that are difficult to substantiate. The disaggregated approach provides better estimates at the sectoral level; but when implementing this approach, one faces considerable uncertainty relating to future developments in the economy and

likely impacts from climate change. It is difficult to obtain reliable data at an adequate geographical resolution to allow accurate assessment of the adaptation options.

6. In a financial or economic evaluation, the standard approach would be to compare the costs of options against the benefits and choose only those where the benefits exceed the costs. This type of cost-benefit framework is widely applied to public expenditure allocations, but it is not the only criterion that is used. In the context of adaptation, the broad conclusion is that cost-benefit analyses are limited in their application. There are issues relating to the valuation of non-monetary impacts (e.g. lives lost) that make it difficult to rely exclusively on that approach. In some cases, more can be achieved by using a cost-effectiveness approach, i.e. selecting the options that have the lowest cost for achieving a given physical target of supplying key services. In others, a risk-based approach, in which policies that achieve an acceptable risk level at least are selected, may be more appropriate. Finally, for others a multi-criteria methodology may be adopted. In all cases, distributional effects have to be taken into account and it must be ensured that adaptation does above all benefit the most vulnerable communities and groups. Furthermore, while working at a sectoral level, inter-sectoral linkages need to be recognized and taken into consideration.

7. Although most adaptation policies will not be based on a pure cost-benefit assessment, it has been shown that an analysis of the costs and benefits, even if it is incomplete, provides important and useful information to the decision maker. Methods that completely ignore such assessments are unlikely to be useful to those who have to allocate scarce public funds for adaptation. For this reason, it is recommended that a careful assessment of costs of options is included in any study of adaptation options and that measurable benefits of these options are also reported.

8. The evaluation of adaptation options should also bear in mind other key factors. These include issues relating to both uncertainty and equity. On uncertainty, the ranges of possible values for the physical impacts as well as for the economic costs associated with those impacts have to be taken into account. Estimates of the costs and benefits of adaptation cannot be presented as single values but have to be provided as ranges. Furthermore, decisions on actions have to incorporate an element of risk aversion. The issue of equity is crucial because the impacts of climate change often disproportionately affect the most vulnerable communities and groups and they need to be protected even if the costs of doing so appear to exceed the benefits.

9. A number of other important factors have also been highlighted. The first is the role of public and private adaptation. The two are closely linked; public adaptation has to be undertaken in the light of the actions of private individuals and their reaction to public measures. Second, an exclusive focus on hard options, involving engineering solutions, should be avoided, and softer options, involving information, education and the use of insurance markets and other such instruments, need to be accorded due importance. Third, it is important to keep options open and to design the programmes so they can be modified in the light of new information.

C. Literature review on the costs and benefits of adaptation options

10. While the key focus of this paper is on national-level assessment, three aggregation levels have been assessed: global studies, national studies and a brief selection of local studies. A number of studies have been reviewed for each of these levels. A key aim has been to choose studies which demonstrate a variety of methods for the assessment of climate change and adaptation. The review has then assessed the approaches and methods used, their applications and outputs and their strengths and weaknesses. Where possible it has also compared the studies.

1. Global studies

11. Table 1 shows the global studies reviewed.

Table 1. Overview of reviewed global studies

Study	Method	Report focus
UNFCCC (2007) Investment and financial flows relevant to the development of an effective and appropriate international response to Climate Change	I&FF	Estimates additional investment and financial flows needed for adaptation globally in 2030
World Bank (2009) The costs to developing countries of adapting to climate change. Global report of the 'Economics of Adaptation to Climate Change' project	Impact/ I&FF	Estimates the costs of adaptation in developing countries from 2010 through to 2050
Hope (2009) The costs and benefits of adaptation (in Parry, 2009)	IAM	Investigates the global economic benefits of adaptation, and cost-benefit ratios for a business as usual and a stabilization scenario
De Bruin et al (2009) Economic aspects of adaptation to climate change: Integrated assessment modelling of adaptation costs and benefits	IAM	Investigates 'optimal' balances between investments in mitigating and adapting to climate change vs. accepting (future) damages
Carrarro et al (2009) Analysis of adaptation as a response to climate change. Copenhagen consensus on climate change	IAM	Investigates integrated analysis of both optimal mitigation and adaptation at the global and regional level

Abbreviations: IAM = Integrated Assessment Models, I&FF = Investment and Financial Flow analysis.

12. In broad terms, there are two main categories of global studies:

(a) Investment and Financial Flow (I&FF) analyses and other similar aggregated assessments; and

(b) Economic Integrated Assessment Models (IAM).

13. These use different types of analysis and provide different outputs, and thus are not directly comparable. The IAMs use a more explicit economic framework, and have been used to assess the global costs and benefits of adaptation over long time-scales, including comparison against mitigation. The UNFCCC (2007) and the World Bank Economics of Adaptation to Climate Change (EACC) (2009) studies focus on the costs of adaptation, but only provide short-term results and do not estimate the economic benefits of adaptation or residual damages.

14. They report broadly similar estimates of USD 30–90 billion per year for developing countries by 2030. However, the critique by Parry et al (2009) on such estimates concludes that these are significant underestimates, potentially by a factor of two to three for the sectors covered, and higher still if other sectors such as ecosystem services are included. The critique also reports a number of constraints and issues with these rapid assessments. The convergence of the current estimates must therefore be treated with some caution and thus the global-level level estimates should not be considered as definitive.

15. The global studies are evaluated in terms of their treatment of methodological issues relating to uncertainty, economic valuation and equity. At this aggregation level, the consideration of uncertainty is limited, although more recent studies have started to account for some uncertainty, such as in climate projections. Similarly, the global studies provide only partial coverage of the issues raised in terms of economic valuation and efficiency.

16. There are still major gaps in the following areas: non-monetary benefits; mitigation and adaptation linkages; cross-sectoral and wider economic effects; and the limits of adaptation. Furthermore, they mostly focus on hard adaptation. The studies have also been evaluated in terms of their consideration of equity. It is extremely difficult to consider vulnerability and distributional effects on a global scale (other than broadly between regions and countries), and none of the studies have considered these effects in their quantitative analysis or in their prioritization of adaptation options, though most highlight that distributional effects are a potential concern.

17. The global studies to date have all been rapid estimates. They are therefore incomplete and preliminary, although they have been useful in providing initial information on adaptation, especially in the absence of detailed disaggregated analysis. A clear priority is to shift to a more comprehensive analysis, taking into account the results of current national-level studies.

2. National studies

18. At the national level, there are a growing number of studies, particularly in developing countries. There is a much greater range of approaches to study the costs, and sometimes the benefits, of adaptation. These include I&FF and IAM methods similar to those used in global studies, but also the use of computable general equilibrium (CGE) models and sectoral impact assessment modelling. There are other possible methods that can be used for national-level assessments at this aggregation level, notably vulnerability and adaptation assessments, but these do not lend themselves as easily to economic assessments. The studies reviewed are shown in table 2 below.

Table 2. Overview of reviewed national studies

Study	Type of study	Report focus
National adaptation programmes of action (NAPAs)	NAPA	Identify and cost priority activities for adaptation that focus on urgent and immediate needs
UNDP (2009) Methodology for the assessment of investment and financial flows to address climate change	I&FF guidance, emerging studies	Guidebook for conducting national investment and financial flows analysis for mitigation and adaptation to climate change
ADB (2009) The economics of climate change in South-East Asia: A regional review	IAM plus qualitative adaptation	Economic costs of climate change, costs and benefits of adaptation and low carbon growth for South-East Asia
Galindo (2009) The economics of climate change in Mexico/the economics of climate change in Brazil	Sector impact assessment plus CGE	Economic costs of climate change, costs and benefits of adaptation and low carbon growth for Mexico/Brazil
SEI (2009) The economics of climate change in East Africa.	IAM, I&FF, sector impact assessment	Economic costs of climate change, costs and benefits of adaptation and low carbon growth for East Africa
Metroeconomica et al (2006) Climate change impacts and adaptation: Cross-regional research programme to quantify the cost of future impacts.	Sector impact assessment	Economic costs of climate change, costs and benefits of adaptation for the United Kingdom
Swedish Commission on Climate and Vulnerability (2007) Facing climate change - threats and opportunities	Sector impact assessment, CGE, I&FF type analysis	Impacts and opportunities for Sweden, assessing economic costs of climate change and the potential costs of adaptation
Van Ierland et al (2006) Qualitative assessment of climate change adaptation options and some estimates of adaptation costs. Netherlands: ARK/Routeplanner project.	Multi-criteria analysis and review of costs and benefits	Assessment of adaptation options for climate change in the Netherlands in connection to spatial planning

Abbreviations: ADB = Asian Development Bank, ARK = Dutch National Programme for Spatial Adaptation to Climate Change (Nationaal Programma Adaptatie Ruimte en Klimaat), CGE = computable general equilibrium, IAM = Integrated Assessment Models, I&FF = Investment and Financial Flow analysis, SEI = Stockholm Environment Institute, UNDP = United Nations Development Programme.

19. These studies include different time frames and metrics and their results are not easily comparable. Nonetheless, many of them report large costs of adaptation, which implies that the estimated global costs of adaptation may be too low.

20. The general consideration of the costs and benefits of adaptation options, even at a national level, is limited. Most studies focus on the costs of adaptation and do not even assess the benefits of adaptation, or residual impacts, even in qualitative terms. Moreover, the use of benefits and costs data in analyses, or to determine priorities, has been limited. This is partly caused by difficulties in collecting the data and in estimating economic benefits. In terms of the evidence that is currently available, the key finding is that there is still a small number of detailed assessments of the costs and benefits of adaptation. When such estimates do exist, they are concentrated in areas such as coastal zones and agriculture, as found in the previous (Agrawala and Fankhauser, 2008) review. However, more studies will be completed in 2010.

21. The national studies have also been evaluated in terms of their treatment of methodological concerns relating to uncertainty, economic valuation and equity. This review has found that the consideration of uncertainty is still limited, even at this aggregation level. Some studies have shifted to a more explicit consideration of uncertainty, although the majority still use single projections of climate and socio-economics. Moreover, there is limited consideration of the issues associated with reversibility, flexibility and adaptive management. While many studies now recognize these are issues, they have not found a way to include this in their quantitative assessment.

22. The national studies fare better when viewed in terms of economic valuation and efficiency. There is a growing focus on non-monetary aspects, although there is still limited focus on ecosystems and associated services. There is also a greater consideration of mitigation and adaptation, though the explicit linkages between the two are limited to one or two studies in one or two sectors. The national studies do have a greater focus on soft adaptation, at least when considering various options. There are also examples of wider economic assessments, through the use of CGE models. However, the analysis of cross-sectoral linkages, private adaptation, ancillary effects and the limits of adaptation are generally still omitted from these assessments.

23. Finally, the national studies have been evaluated in terms of their consideration of equity. Even at this aggregation level, the consideration of equity and distributional effects is difficult and none of the studies address this issue comprehensively. While many studies identify the issue, the focus on economics has tended to shift the analysis away from equity considerations, in contrast to non-economic vulnerability and adaptation assessments. This remains a key issue to address in future analyses.

3. Sub-national and local studies

24. The final areas of investigation have been at the sub-national and local level, and only a small selection of case studies has been included. These case studies demonstrate that it is often easier to address some of the methodological challenges of adaptation at this spatial scale. For example, there are examples of greater consideration of soft and hard options, analysis of ancillary effects and more sophisticated methods for evaluating options, taking advantage of the flexibility of the timing of additional investments (using real option values). Moreover, where studies have addressed these issues, different policies emerge, such as a greater focus on soft options as being more efficient, or the introduction of monitoring programmes to consider longer-term risks.

25. Such studies need to be replicated to give a more accurate picture of the appropriate adaptation measures at national - and consequently global - levels, and of the associated costs. It is also highlighted that one way to improve national level assessments might be to undertake local case studies alongside**,** or as part of, national-level analysis. Although these approaches are promising,

more economic studies are required before adequate information is available for use in wider policy decisions related to adaptation.

D. Discussion and conclusions

26. This paper has outlined the methodological challenges faced when calculating the costs and benefits of adaptation options. It has compared these against a selection of recent studies on the economics of adaptation. This review has shown that significant gaps still remain and that there is considerable scope for advancing the economic assessment of adaptation options. A number of challenges remain which need to be overcome in order to address these key issues. The study has investigated these challenges and makes some initial recommendations for future priorities.

27. The study has considered the different approaches used in the studies. It is clear that all the methods have strengths and weaknesses. These strengths and weaknesses are determined by:

(a) The type of adaptation being assessed, i.e. short-term priorities including adaptive capacity-building, or consideration of longer-term concerns;

(b) The objectives of the study, in particular whether the study was an initial analysis to identify the scale of the adaptation issue and raise awareness, or whether its aim was to set in place national adaptation plans.

28. The analysis of methodological issues used in recent studies highlights the need for methodological development to properly address the costs and benefits of adaptation options. The key challenges are related to uncertainty, economic valuation and equity.

29. From these findings, a clear recommendation emerges. There are potential benefits in adopting multiple methods and approaches in an analysis of the costs and benefits of adaptation options, as linking these together would provide a greater evidence base. Indeed, it is almost impossible to see how one single approach could capture all of the complex methodological issues raised, or address different types of adaptation and/or different objectives.

30. It is also clear that knowledge is still evolving and that there are a large number of research priorities that need to be investigated. One of the key findings of this study is that there is still a lack of a careful and detailed analysis of the economic costs and benefits of adaptation, information from which estimates of the public funding needs can be developed. However, this does not detract from the need for national-level assessments to shift to a more explicit consideration and analysis of the costs and benefits of adaptation options, whether through formal or semi-formal economic analysis.

31. Clarity on methodological issues in the assessment of costs and benefits of adaptation is essential for informed adaptation planning and decision-making. As the global community, guided by the Bali Action Plan and the negotiations of the Conference of the Parties at its fifteenth session in Copenhagen, embarks on enhanced action on adaptation that incorporates provisions for the short, medium and long term at different levels, enhancing understanding of the costs and benefits of adaptation emerges as an even more important pillar in support of such efforts.

II. Introduction

A. Mandate

32. The SBSTA, at its twenty-eighth session, requested the secretariat, in the context of the Nairobi work programme and under its work area on socio-economic information, to prepare a technical paper reviewing the existing literature on the potential costs and benefits of adaptation options. This technical paper is complemented by submissions by Parties and organizations on efforts undertaken, including methods used to assess the costs and benefits of adaptation options, and

their views on lessons learned, good practices, gaps and needs, in addition to a synthesis report based on the submissions and other relevant sources, and by an upcoming technical workshop on costs and benefits of adaptation options to take place before June 2010.[1]

B. Objectives

33. The aim of the Nairobi work programme is to assist all countries, in particular developing countries, including LDCs and SIDS, to improve their understanding and assessment of the impacts of climate change and to make informed decisions on practical adaptation actions and measures. Within this context, the aim of this technical paper is to review and analyse methodological issues and evidence related to the costs and benefits of adaptation options.

34. The paper does not aim to repeat earlier literature reviews but to provide a synthesis of new and emerging studies, to analyse the new insights that they provide and to use this information in context of the objectives of the Nairobi work programme. Furthermore, Parties may use the information contained in this technical paper as they consider implementing enhanced action on adaptation, particularly within the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA), including their consideration of financial needs assessments.

35. In particular, the aim of this paper is to:

(a) Raise awareness of the latest studies;

(b) Investigate key methodological issues of relevance that these studies may address;

(c) Discuss the approaches and methods used, what each of these provides (as opposed to what is needed) and consider the applications and outputs for which they are relevant;

(d) Discuss the strengths and weaknesses of the studies and methods;

(e) Consider the evidence base in light of the new studies.

36. This paper does not suggest new estimates of the costs or benefits of adaptation; nor is it meant to provide tools or guidance for undertaking assessments. Instead, the focus is to explore methodological issues and evaluate how well these are covered in the current generation of studies. Part of this process will be to explore whether different studies can be compared and whether or not they provide valid results. This paper focuses on the near to medium term, and on 'moderate' climate change; it does not attempt to address adaptation associated with the long term and higher temperature changes.

C. Background

1. The role of information on the costs and benefits in adaptation planning and implementation

37. Adaptation as defined by the Intergovernmental Panel on Climate Change (IPCC) is an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". There are multiple types of adaptation, including anticipatory, reactive, autonomous and planned adaptation.

[1] FCCC/SBSTA/2008/6, paragraphs 50–54.

38. The focus of this paper is on planned adaptation, i.e. on adaptation that requires some level of organizational or policy intervention.[2] However, such planned adaptation does not just relate to hard technical options; it also includes socio-institutional issues and adaptive capacity-building, as part of 'soft' non-technical measures that may influence behaviour and individuals. The paper focuses on the public sector, although it does not entirely ignore the private sector; some sectors or activities that are publicly run in some countries are privately run in others. A more representative definition of the form of planned adaptation considered here is therefore national-level policy, irrespective of who implements or encourages this adaptation.

39. It is useful to supply the information needed on the costs and benefits of adaptation options within an adaptation decision framework. Different frameworks have been developed and applied to assessing climate change impacts, vulnerability and adaptation and to supporting adaptation decision making (Carter et al., 2007). For example, UNDP developed an Adaptation Policy Framework (Lim et al., 2005), within which one of the key steps in formulating an adaptation strategy is to consider costs, alongside impacts and barriers. Other adaptation frameworks such as the United Kingdom Climate Impacts Programme (UKCIP) Risk-Uncertainty-Decision-Making Framework (Willows and Connell, 2003) outline a more explicit consideration of the costs and benefits of adaptation as part of the appraisal of adaptation options, highlighting the economic valuation of costs and benefits. Their guidance was accompanied by detailed costing methodologies for adaptation (Boyd and Hunt, 2004).

40. In both the UNDP and the UKCIP frameworks and in other adaptation decision frameworks (see Table 2 of Lu, 2009 for a summary), the consideration of costs and benefits forms part of the appraisal process for adaptation strategies or options, whether this is at a national level or for a local project. The frameworks recognize that, for any given adaptation decision, there is a number of options or choices that could be implemented. The preferred option can be selected using the appraisal process. The information on the costs and benefits is used in this appraisal process, allowing decision makers to make informed decisions between options, allowing trade-offs and/or providing a means to justify decisions. Neither the UNDP nor the UKCIP guidance documents recommend the use of a single approach for such decisions; instead suggesting a variety of approaches for which information on costs and benefits could be developed, including cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis. The earliest analysis comparing the application of these different approaches to the context of prioritized adaptation action can be found in the annotated guidelines for the preparation of NAPAs (LEG, 2002).

41. These frameworks tend to concentrate on planned adaptation at the project and programme level. However, there is a much wider set of aggregation levels where information on the costs and benefits of adaptation is potentially relevant, addressing different objectives. These include:

(a) The global level, where information on the costs and benefits of adaptation can raise awareness on adaptation and its scale, as well as provide input to the discussion on the needed financial resources;

(b) The national level, where the information on costs and benefits is relevant for assessing national adaptation financing needs, and for the allocation of funds to allow efficient, effective and equitable adaptation strategies, including national planning and prioritization;

(c) The sub-national or local level, where the information on the costs and benefits of

[2] While the focus is on planned adaptation, autonomous adaptation still needs to be taken into account, noting that, in practice, the distinction between the two is often blurred. Sometimes planned adaptation will be introduced on top of a base of autonomous adaptation, whereas at other times, the two will coexist. In other cases, where the autonomous responses lead to detrimental effects or externalities on other areas, those autonomous responses may necessitate a planned adaptation response.

adaptation can aid in the design and prioritization of adaptation policies, programmes and projects, and can be used as input into decision making and the appraisal process.

2. Overview of definitions of adaptation costs and benefits

42. The IPCC Fourth Assessment Report (AR4) defines adaptation costs as "the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs", while the definition for adaptation benefits is "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures". This paper concentrates on the economic costs of adaptation options, rather than the financial costs of adaptation options. There is a very important difference between the two:

(a) Financial costs typically work within the budgetary framework of the adaptation strategy or intervention under consideration;

(b) Economic costs consider the wider costs and benefits to society as a whole. This is different to a financial framework. They require the consideration of all costs and benefits, such as social costs and benefits, for example through assessing distributional effects. There are also other differences between the frameworks, for example in regard to whether they include or exclude different elements, such as domestic taxes and charges, or net or gross revenues.

43. If the economic benefits of adaptation options outweigh the costs, then there are net benefits. If not, then this potentially leads to maladaptation. While adaptation reduces impacts, it does not remove them completely; hence there will be residual damages, which also carry an economic cost.[3]

44. A number of challenges exist in the analysis of the costs and benefits of adaptation options and which will be discussed in the paper. While mitigation has common physical, non-monetary units of benefits (e.g. 1 tonne of greenhouse gases (GHG) emissions abated) which allow for a direct comparison of relative costs (e.g. USD/tCO_2 abated), adaptation has no such metric. Instead, the physical and economic benefits of adaptation vary by sector, location and technology. Moreover, adaptation benefits are often not easy to monetize, as they include non-market sectors, for example ecosystem services.

45. There are different objectives of adaptation options: they can aim at avoiding all damages, or return levels of welfare back to pre-climate change levels; or at maintaining current levels of risk or reducing them cost-effectively within budgets or to pre-defined acceptable levels. In practice, objectives vary between regions, countries and communities and there will be trade-offs between adopting all possible measures on the one hand, and living with the risks on the other (Horrocks et al, 2005).

3. Overview of existing literature

46. The current literature on the costs and benefits of adaptation concentrates on essentially two kinds of methodologies: those that start at the macro or aggregate level and those that start at a more disaggregated level and work up to an overall estimate.

47. A number of studies (World Bank, 2006; Stern 2007; UNDP 2007) clearly used an aggregate approach in which the authors started with an estimate of the level of 'climate sensitive' investment in each country and applied a 'mark-up' to account for the additional costs of climate change. The estimates are basic and of course depend on the percentage of investment that is considered climate sensitive and what mark-up is applied (typically 10–20 per cent). Using this method, the initial

[3] Annex II outlines a stylized framework for costs and benefits of adaptation options.

estimate in the World Bank study was in the range of USD 9–41 billion per year. By taking slightly lower values for the same parameters, the Stern Report reported estimates of USD 4–37 billion, and by further varying the two parameters, the UNDP 2007 Human Development Report reported figures of USD 5–67 billion annually.

48. An example of a more disaggregated approach, which adopts a sector-by-sector approach at the impacts of climate change and then calculates the required investments to deal with those impacts is the Oxfam (2007) study, which examined national adaptation programmes of action (NAPAs) and non-governmental organization (NGO) programmes, combining the data from these programmes to calculate a global estimate. The 2007 UNFCCC study also adopted a more disaggregated methodology, at least for some sectors. It consisted of six sub-studies covering agriculture, forestry and fisheries; water supply; human health; coastal zones; infrastructure; and ecosystems.

49. Over the past few years, a number of reviews have surveyed the literature on the costs and benefits of adaptation. These reviews have generally revealed that a low level of knowledge exists in this area; for example, the IPCC AR4 reported that the literature on adaptation costs and benefits was "quite limited and fragmented" (Adger et al, 2007). A review of existing global, national and local studies was presented in the Organisation for Economic Co-operation (OECD) study on the 'Empirical estimates of adaptation costs and benefits' (Agrawala and Fankhauser, 2008). In considering these different aggregation levels, the study adopted a sectoral focus. The authors found that, while a relatively large amount of information was available, it was very unevenly distributed. They found that there was considerable data available for coastal zones and on the benefits of adaptation strategies in agriculture, although limited information on costs. Outside of these areas there was much less coverage. The review also reported that the evidence base was strongest in OECD regions and that there was much less coverage in developing countries. This lack of evidence, particularly for developing countries, led to several new studies being commissioned on the economics of adaptation. These are to be published in late 2009 and early 2010 and are evaluated in Chapter 4.

50. There have also been several reviews of the methodological issues with the economics of adaptation, for example, the European Environmental Agency report (EEA, 2007) 'Costs of inaction and costs of adaptation' (2007) and the above OECD report. Both these studies emphasize that the costs and benefits of adaptation is a complex and evolving subject area, with many specific challenges.

III. Review of methodological issues

A. Introduction

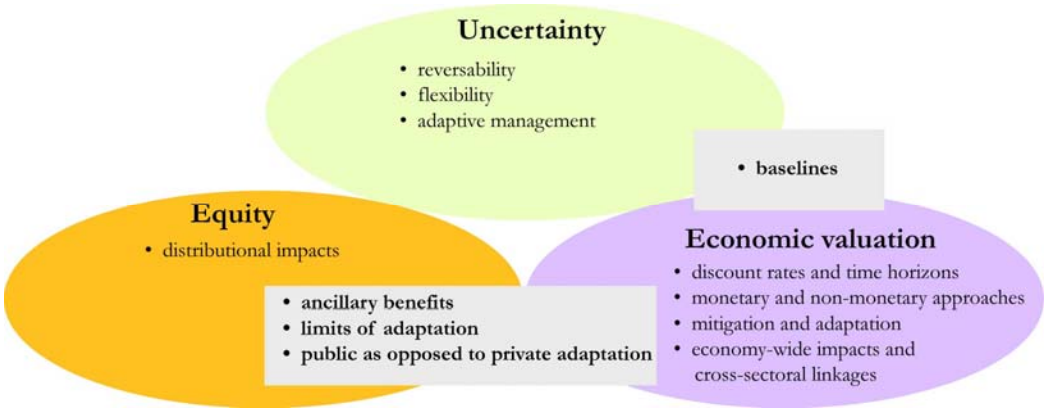
51. This chapter provides a background to the main methodological issues that arise when analyzing the costs and benefits of adaptation options. It does not address all the methodological issues of the economics of climate change adaptation, but rather provides a context for the review of the specific studies. The chapter does not make specific recommendations on how the issues should be addressed but rather presents the different viewpoints. The current estimates of the costs of adaptation are produced using two main methodologies: those that start at the macro or aggregate level and those that start at a more disaggregated level and work up to an overall estimate.

B. Overview of methodological issues

52. The literature on the costs and benefits of adaptation raises a number of methodological issues, which can be grouped under the broad themes of uncertainty, economic valuation and equity, as shown in figure 1. It is important to note that some issues fall under more than one theme:

Baselines are items relating to both uncertainty and economic valuation, while ancillary benefits, limits of adaptation and public as opposed to private adaptation fall under both equity and economic valuation.

Figure 1. Main methodological themes concerning costs and benefits of adaptation



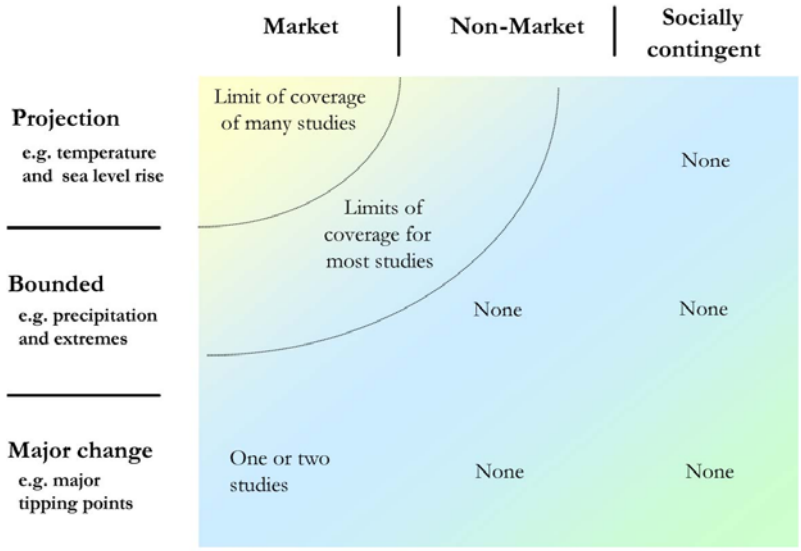
1. Uncertainty

General issues

53. Many of the issues related to baselines and to the appropriate design of adaptation policy are linked to uncertainty about future climate change impacts and future socio-economic development. Even under a given scenario of future emissions, the range of possible impacts is large. The IPCC AR4 offers possible outcomes associated with different increases in temperature. For a 2°C increase, the decrease in water availability is estimated at 20–30 per cent, the declines in crop yields in tropical regions at 5–10 per cent, and 15–40 per cent of species would face extinction (Parry et al, 2007). When different emission scenarios and the different climate models used to make projections of temperature change are taken into account, the resulting wide range of potential increases in global mean temperatures implies that the aforementioned estimates can increase. Uncertainties associated with the valuation of the impacts should be combined with the uncertainty of the magnitude of the physical impacts. The valuation of impacts is not a precise science and therefore the ranges of estimates of impacts are similar to those for physical impacts.

54. In addition, the incomplete coverage of climate change risks and impacts needs to be taken into account. As shown in figure 2, coverage of non-market impacts and 'socially contingent' impacts, for example collective responses by communities to changes in their environment, such as large scale migration, is significantly lacking in the literature. This gives the analysis an additional element of uncertainty, suggesting that the measurements only show a small proportion of possible impacts, and that the actual impacts are likely to be much greater.

Figure 2. Coverage of economic costs of climate change



Source: Watkiss P and Downing TE. 2008. The social cost of carbon: valuation estimates and their use in UK policy. *Integrated Assessment*. 8(1)

55. This means that the estimation of the potential effects of climate change, and the resulting adaptation action required to address the effects, is highly complex, and the available literature on adaptation costs and benefits does not adequately address this problem. Estimates are often based on addressing a given impact, not on selecting the action that will provide the best response to a range of possible outcomes. Some work has been undertaken using 'robust strategies' which yield satisfactory performance under a range of possible outcomes, and has been applied to freshwater management and flood management (Groves and Lempert, 2007; Dessai, 2005). However, there has been limited application of these methods, and these studies do not fully incorporate economic aspects into the decision-making elements that address robustness. Additional effort is required across all areas (both sectorally and cross-sectorally) to ensure that the adaptation measures cover both the 'likely' outcome and a range of other possible outcomes.

Baselines

56. One of the most difficult, and arguably one of the most important, aspects of estimating the cost of adaptation is the definition of the baseline. Ideally, the baseline should define what would happen to the key variables in the absence of climate change. Since one is looking forward several years the analysis has to predict levels of development and social changes in periods up to 2030 and beyond.

57. An example of the problems that arise when defining the baseline, using health as the variable, is shown here. When estimating future disease burdens in the absence of climate change, improvements in the health conditions of the population have to be considered. Typically, environmental diseases such as diarrhoea and vector borne diseases such as malaria decline as the quality and level of the water supply and sanitation improve. It is necessary to make allowance for these improvements, but there are significant uncertainties as to the level of improvement that will occur.

58. When drawing the baseline, it is important to bear in mind that not all plans will always be fully accomplished, or that outcomes may vary. This can be addressed through uncertainty or sensitivity analyses. One can assume, for example, that the Millennium Development Goals will be met, making adequate water supply and sanitation widely-available. The costs of meeting these

goals would not be included in the estimation of the adaptation costs, as they are primarily associated with development. However, if one takes the view that the improvements in water supply and sanitation provide greater resilience against future climate change, then all or part of the expenditure could be included in the adaptation budget.

59. Given the number of uncertainties, some researchers have proposed the use of multiple baselines when estimating the costs of adaptation and evaluating adaptation options. In Chapter 4, there are examples of the way in which multiple baselines have been used when calculating the benefits of adaptation measures and in then selecting the measure that fulfils the requirements of the stakeholders involved when faced with a range of possible outcomes.

Reversibility, flexibility and adaptive management

60. The knowledge base for the possible impacts of climate change is both uncertain and changing over time. Hence adaptation measures must be designed so that they are able to be modified in the light of new information. This is particularly important for adaptation options that have longer-term implications, or for measures that will have a long life span, such as infrastructure. Schemes should be reversible and their parameters as flexible as possible.

61. One way in which flexibility and reversibility can be evaluated in a cost-benefit or cost-effectiveness assessment is through the attachment of an option value to the potential for modification or change in the design of an instrument. This method has recently been outlined in supplementary guidance for cost-benefit analysis for climate change from the United Kingdom of Great Britain and Northern Ireland (UK: Her Majesty's Treasury, 2009). This approach involves attaching an option value in a given year to any scheme that could be modified in that year in the light of new information on the impacts of climate change. This option value would reflect the savings in costs of reducing future impacts when compared with a base value if a full commitment had to be made today. This approach is clearly more relevant when dealing with investments that have a long asset life. Committing to a given response capability for the next 100 years is very risky when the nature of the threat could change significantly over that time.

62. To date, however, the use of option values in adaptation policy evaluation is only an idea, and has not yet been put into practice. Although options markets exist for instruments related to mitigation (Golub and Markandya, 2009), such values have not yet been applied to adaptation.

2. Economic valuation

General issues

63. Adaptation interventions are often evaluated in the context of a financial assessment, based on a cost-benefit analysis (CBA). CBA is designed to show whether the total advantages (benefits) of a project or policy intervention exceed the disadvantages (costs). This essentially involves calculating in monetary terms all of the costs and benefits. An adaptation option would represent a good investment if the aggregate benefits exceed the aggregate costs. Although CBA is important when designing economic policy, other criteria are also considered when making a decision. This is because CBA, in its simple form, does not cover all aspects: it ignores the distribution of the costs and benefits of adaptation options and it fails to account for those costs and benefits that cannot be reflected in monetary terms, such as ecological impacts and impacts on health, as well as concerns that influence welfare, such as peace and security.

64. For these reasons CBA is only one input into the decision-making process, and other approaches are often used as a complement or a substitute. These include cost-effectiveness analysis, multi-criteria analysis (MCA) and other approaches.

65. The aim of the cost effectiveness analysis (CEA) is to find the least costly option or options for meeting selected physical targets. In contrast to CBA, the benefits are measured in units other than money. Moreover, the output (or benefit) of the option is the same or similar for all options considered. It can be used to identify the highest level of a physical benefit given available resources (e.g. delivering the maximum reduction in risk exposure subject to a budget constraint), as well as the least-cost method of reaching a prescribed target (e.g. the supply of a given quantity of potable water).

66. Multi-criteria analysis (MCA) has been developed to account for the fact that some effects cannot be measured, or cannot be costed. With multi-criteria analysis, a number of objectives are identified and each objective is given a weighting. Using this weighting, an overall score for each policy option is obtained, and the option with the highest score is selected. Over the last 30 years, the use of multi-criteria analysis to aid decision making, where there are multiple competing criteria, has increased. MCA essentially involves defining a framework to integrate different decision criteria in a quantitative analysis without assigning monetary values to all factors.

67. There is a number of factors that determine how the assessment of the costs and benefits of adaptation options are incorporated into an adaptation cost framework. These include:

(a) Discount rates and time horizons;

(b) The combination of monetary and non-monetary evaluations and limits for use in cost-benefit analyses;

(c) Economy-wide impacts;

(d) Hard as opposed to soft adaptation options;

(e) Cross-sector linkages;

(f) Ancillary benefits;

(g) Public as opposed to private adaptation;

(h) Adaptation-mitigation linkages.

Discount rates and time horizons

68. When costs are incurred at one point in time and the benefits occur at another, it is standard practice to discount costs and benefits in future periods by applying an appropriate rate in order to estimate the present values of these future costs and benefits. In the case of climate change, the issue is particularly important because the impacts of today's emissions will continue to be felt for a long time. Moreover, in many regions, the major impacts are not expected until the second part of this century. Discounting has been particularly controversial in the context of mitigation, because it implies that decisions on how much to spend to reduce GHGs depends on whether any future impacts are discounted. There is, however, no consensus on what discount rates to apply. The rates proposed by the major studies range from 1.4 per cent (Stern, 2007) and 1.5 per cent (Cline, 1992) to 6 per cent (Nordhaus, 1994). The higher the discount rate, the more future impacts are discounted and the less emission reductions are justified in cost-benefit terms (Please note that this is only one methodological approach for assessing the level of policy ambition).

69. The question of discounting is not as critical for adaptation as it is for mitigation, but it can nevertheless be relevant. The timing of an adaptation decision will depend on the delay between investment and the delivery of services. For example, the design of new roads or sewer systems being planned today might need to consider future climatic conditions The question of the discount

rate that should be applied arises when considering alternative investment profiles under an adaptation programme. Some studies apply existing rates relevant to the country or organization under consideration, whereas others apply a range of discount rates to investigate how this alters the analysis and results.

70. Another question that arises is how far ahead one should plan when making adaptation decisions. In the case of infrastructure, the time horizon is mainly determined by the life of the investment. Dams or roads that have a life of 50–70 years should be designed taking into account the expected impacts of climate change over that period. Similarly, in the case of ecosystem adaptation, it is necessary to consider relatively long periods, as changes are expected to occur over several decades. On the other hand, plans for adapting to health impacts or farming systems can initially take a short- to medium-term view, which can be extended to cover longer periods if necessary. This is because different time horizons exist for different sectors and areas and it is not easy or appropriate to enforce a single horizon for all sectors.

The combination of monetary and non-monetary valuations and limits for use in cost-benefit analysis

71. Assessment of the economic benefits of adaptation has focused on valuing the reduction in damages in monetary terms. However, not all impacts can be valued in monetary terms (e.g. the valuation of loss of life). In view of this it has been argued that adaptation decisions should use other metrics or combine a measure of net benefits with an estimate of impacts in physical terms. The following sections describe some of the alternative metrics that are potentially useful in making decisions relating to adaptation options, by sector:

1. Health

72. It is possible to calculate the benefits of adaptation policies in this sector through the direct valuation of mortality and morbidity, although such assessments are considered controversial. In order to avoid valuation of possible changes in mortality and morbidity (especially the former) and to aggregate the impacts, health economists work in terms of life years lost or disability-adjusted life years lost (DALYs). For climate change, it is possible to estimate impacts at the national level using these calculations (Markandya and Chiabai, 2009). For example, the World Health Organization (WHO) Global Burden of Disease assessment (McMichael et al, 2004) used a range of climate related health effects (cardio-vascular diseases; vector borne diseases, such as malaria; and food and waterborne diseases, such as diarrhoea). This type of approach uses a cost-effectiveness, rather than a cost-benefit, framework. In most countries there are clear guidelines on acceptable values for this measure of cost-effectiveness (e.g. around EUR 12,000 for Value of Life Year (VOLY) in the United Kingdom).

73. The criterion in the previous paragraph can be used to evaluate policies related to the reduction of deaths or illnesses from, for example, thermal stresses. A study by Ebi et al (2004) provided an estimate of the cost of the Heat Health Warning Systems (HHWS) which were adopted in 1995 in Philadelphia, United States, to alert the population and reduce heat-related health impacts during heatwaves. In the study, Ebi estimated that 117 deaths among the elderly were avoided using the alert system over the period 1995–1998. The costs of the system for the same period have been estimated at approximately USD 210,000, based on the costs of extra staff needed to run the system.[4] The resulting additional annual cost per life saved is around USD 1,795. Compared with the 'value of a life lost' used in government programmes in the United States (around USD 4 million for persons over 65), this is a very low figure and would clearly justify the programme.

[4] The system was constructed based on the pre-existing weather forecasting service and using the pre-existing emergency medical services.

2. Sea-level rise

74. Sea-level rise has a wide range of potential effects, which complicates comparison with a single common metric (as for health above). The recent OECD review assessing the economic benefits of climate change policies proposes a wide range of possible approaches, using different exposure-, impact- or valuation-based metrics.

75. Analysis of sea-level rise can be performed using monetary valuation of the benefits of protective measures or ameliorative responses. As identified by Agrawala and Fankhauser (2008), there are many studies on the costs and benefits of adaptation in coastal zones. However, national-level studies use a wider range of approaches and, in many regions, a cost-effectiveness approach based on acceptable levels of risk is adopted.

76. From studying the potential effects of sea-level rise, it is also clear that some impacts do not lend themselves to such valuation, such as land values, including those not captured in market prices, which are usually the basis of the models that determine adaptation to sea-level rise. Examples of these values include watershed protection and public recreational use. Some of these values (which are called externalities) can be measured in monetary terms; they can be calculated and incorporated when carrying out the cost-benefit analysis. Other values, such as biodiversity or cultural or religious importance cannot be easily measured in monetary terms. An alternative approach for handling these values is to impose a 'sustainability constraint' on the design of the protection system, so that when measures are selected on cost-benefit grounds, there is an additional requirement that those values be protected (Barbier, Markandya and Pearce, 1990). It is important to note that sustainability constraints must be imposed with care. It has to be a decision made on clear, well-documented grounds.

3. Freshwater systems

77. Water is a critical sector with many cross-sectoral linkages. It is location-specific and detailed analysis of adaptation measures should take place at the river basin level. In some regions, projections of future water demand and supply are available for the next 30 years or longer. Using these estimates, it is possible to estimate potential changes in supply as a result of a range of climatic and socio-economic projections. For those areas where water scarcity is projected to increase (e.g. many arid and semi-arid regions), this will often create a gap between demand and supply compared with the baseline situation.

78. The design of adaptation measures can use cost-benefit analysis (e.g. Callaway et al, 2007) although this can be difficult and it is also possible to use cost-effectiveness analysis. Although the use of water can be calculated for different purposes, there are many social and other considerations that make it difficult to make water allocation decisions based solely on willingness to pay. Indeed, the pricing of water is an extremely controversial issue. An alternative method can consist of ranking different measures that address the gap between demand and supply, based on the cost per cubic meter of water provided.

79. The main issue relating to non-monetary metrics in the water sector is that of water quality. Water quality is not included in the simple cost-effectiveness measure and yet it can be important. Measures to address quality can possibly be addressed in terms of the cost of meeting given standards for different uses. If, as a result of climate change, additional actions are needed to meet these quality standards, the first step would be to identify the least costly actions that would help reach desired baseline standard.

4. Extreme events

80. Climate change could potentially lead to changes in extreme events, which are best

characterized in terms of increased frequency, duration or intensity of such events, with the potential to cause loss of life, damage to property and other direct and indirect effects. Adaptation can help reduce the risks and/or reduce the consequences of these events.

81. The impacts, i.e. the costs, of the direct effects of extreme events can be valued in economic terms, it is also possible to assess benefits from adaptation in this way, particularly for some categories such as flood risks. However, it is often problematic to value all of the consequences of such events in cost-benefit terms, fortunately other metrics are available. A common approach is to use defined or acceptable levels of risks within a cost-effectiveness framework. A variation on this approach is to set expected losses from such events at an agreed level (such as the current level of losses) and to undertake adaptation measures at the lowest cost possible, so as to not exceed that level. This bypasses the cost-benefit decision-making methodology, but the action can be justified on the grounds that public concern for losses from extreme events is sufficiently high to warrant the adoption of an absolute standard.

82. These methods of assessing extreme events could encounter problems relating to consistency, as mortality and morbidity effects are assessed differently from the other health impacts of climate change.

5. Agriculture

83. As identified by Agrawala and Fankhauser (2008), there is a large amount literature available on the economic benefits of adaptation in the agriculture sector. For example, Rosenzweig and Tubiello (2007) produced a set of metrics, comprising variables that can be easily extracted from current models and used to obtain consistent and comparable information on climate change impacts and benefits in both monetary and non-monetary terms.

84. Adaptation options in the agriculture sector can involve investment in infrastructure (e.g. irrigation); investment in research and development (R&D) for new cultivars etc.; and support for farmers to adapt to new crops or new areas of activity. Decisions to invest in infrastructure can be subjected to cost-benefit analysis, and R&D investments are often driven by the need to adapt to climate change. *Ex post* studies of the benefits of research often reveal very high rates of return on total investment in this area, and one can expect the same for research connected to adaptation.[5]

85. In practice, support for farmers will mainly be driven by a combination of cost-benefit analysis and the necessity to provide sustainable livelihoods for poor farmers, meaning that distributional considerations will be very important. The principal issues that arise relate to the economy-wide effects of the climatic changes for which adaptation strategies must be designed, and the uncertainties regarding future effects.

6. Ecosystems and biodiversity

86. The literature on adaptation costs and benefits is limited and fragmented and does not focus on biodiversity or ecosystem services (Parry et al, 2007; Stern, 2007). To improve the quality of these estimates, it is necessary to focus on species and ecosystem targets rather than monetary costs and benefits. Losses due to the absence of additional measures can be identified and targets set to ensure the sustainability of the relevant ecosystems. The effect of different adaptation actions in reducing these losses can then be estimated and the least expensive actions can be used. It could be argued that targets are not justifiable, but, for most impacts, such a case is very difficult to make on cost-benefit grounds.

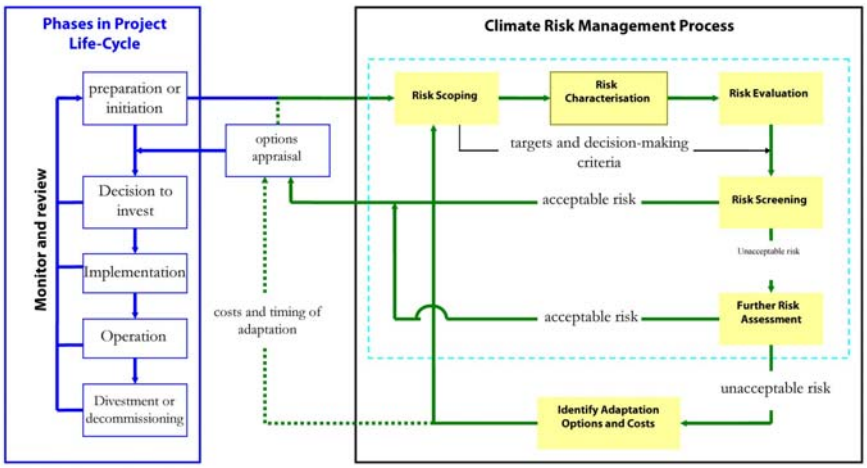
[5] Published estimates of rates of return on R&D and extension investments in the developing world average 43 per cent per year (World Bank, 2008).

87. While most studies provide loss estimates at a high level of aggregation, impacts of climate change should be estimated at a level where actions can be taken**,** such as the local level. It is also important to note that the estimation of the effect of climate change on ecosystems is difficult and, taking into account this uncertainty, there has been a shift towards more flexible adaptive management in this sector.

7. Infrastructure

88. Future infrastructure investments should screen for the potential risks from climate change, which may require the introduction of measures to enhance future resilience. This 'climate proofing' of future investments may be a major requirement for all investments in roads, rail systems, hydropower plants, etc. It is possible to apply cost-benefit analysis to such investment, especially when this type of analysis is already widely-used within a sector; however, there are alternatives, as shown in figure 3.

Figure 3. Framework for managing climate variability for infrastructure at the project level



89. On the right-hand side of figure 3, there is an analysis of a proposed climate risk management process for development projects. This example is based on standard approaches to characterizing and managing risk (Department of Environment, Transport and the Regions, 2000) rather than cost-benefit analysis. Essentially, each project is evaluated for climate risk. If the risk is deemed acceptable, the options are appraised as before. If, however, the risk is considered unacceptable, further modifications are made until the risk is reduced to an acceptable level, at the lowest possible cost. There is no general metric that can be applied here; the rule is defined in terms of acceptable risk and the use of a least-cost analysis to identify the measures that meet the defined level of risk.

8. Other sectors

90. Other sectors, such as tourism, fisheries, marine activities etc. are also likely to be affected by climate change, in some cases positively. Therefore, actions to reduce negative effects and to enhance positive ones will be required. However, in such cases, it is difficult to establish a definitive rule for selecting adaptation options. The impacts of such measures can be quantified in terms of net value added to the sector or sectors concerned, compared with the same situation with no adaptation. These benefits are compared to the costs in the same way as for all project and policy assessments (using economy-wide tools where appropriate).

9. Summary

91. For adaptation, the use of cost-benefit analysis can be limited, both because of the partial availability of data on the costs and benefits of adaptation options and because it should consider the distribution of impacts, especially on the particularly vulnerable. Subject to this qualification, it can be applied to decisions in some sectors for certain types of adaptation options (e.g. technical measures for flood prevention), or in sectors where there is a major private sector involvement.

92. On the other hand, cost-effectiveness criteria are more likely to be of use for health, freshwater systems, extreme weather events and biodiversity and ecosystem services. When cost-effectiveness analysis is applied, it is done in conjunction with standards of acceptable risk or acceptable cost per unit of impact removed. In the case of infrastructure, there may be some limited application of cost-benefit analysis, but adaptation design can also be based on meeting demands and not exceeding acceptable risk at the lowest possible cost.

93. Finally, there is a scope for the use of MCA in those areas where the monetary benefits are only a part of the criteria used. It should be noted, however, that even if multi-criteria analysis is applied, information on the monetary costs and benefits can still be one of the criteria used. Likewise, even if a cost-effectiveness approach is taken, careful documenting of the different kinds of costs and selection of the metric for measuring success is vital.

Economy-wide impacts and cross-sector linkages

94. Although most decisions regarding adaptation have to be taken at the sectoral level and involve assessing impacts on a local scale, many of these impacts are influenced by the wider economy, or even by global market events resulting from and in response to climate change. In the case of agriculture, for example, the appropriate response at a local scale will depend on the expected changes in prices of agricultural commodities in the local markets, and those prices will be influenced by shifts in commodity prices in sub-national, national and even global markets. Therefore, adaptation decisions have to be embedded in a framework that can potentially take into account economy-wide impacts.

95. However, the estimation of such impacts requires models at the national and global level where effects have to be analysed in the wider context of price fluctuations for agricultural commodities as a result of changes in yields worldwide. Economy-wide models have been used extensively for this purpose (Fisher et al, 2005; Randhir and Hertel, 1999; Juliá and Duchin, 2007). However, the highly-aggregated nature of these models, and the complexity and range of uncertainty around climate and socio-economic change, as well as the yield-impact relationships, imply that they cannot predict future changes, only providing a context for possible outcomes.

96. Apart from providing input to decisions on the parameters of national and global economies, an economy-wide analysis can provide context for the linkages between sectors, as examining a sector individually may be insufficient. If, for example, adaptation to sea-level rise is considered in isolation, decisions on protection will be taken on the basis of the direct costs of providing protective barriers compared with the savings from less damage to the immediate affected areas. Yet a decision not to protect an area based on this trade-off may be misleading if the loss in that area has repercussions for neighbourhoods that are linked economically and socially to the affected area. The loss of jobs and increases in prices of commodities supplied from the affected coastal areas may have consequences across the rest of the economy. Furthermore, if all regions are affected by the same impacts, there will be implications for the trade and flow of certain goods and services (e.g. tourism). These impacts could vary across regions and countries, implying that different adaptation options that are beneficial to multiple sectors would be required.

97. Full economy-wide impacts can be analysed using computable general equilibrium (CGE) models[6] that specify links across the economy. Although general equilibrium effects of this kind merit consideration, it is important not to overstate the case for using CGE models to analyse most adaptation options. In general, the severe impacts will be those arising from the local impacts of climate change, and the measures will have dominant effects on the affected communities. In most cases, therefore, a partial analysis of local effects is sufficient when it is performed in the context of the national and global changes explained above. Such partial analysis may, however, need to take account of linkages across sectors at the local level, so, for example, health effects are related to the water sector and agricultural effects are related to sea-level rise. It is not necessary to use CGE models to address these linkages, so long as each policy group is aware of the impacts of other sectors on its sector (and vice versa).

98. Examples of some linkages that should be taken into account when designing comprehensive adaptation options:

(a) The health implications of water shortages, extreme events and food insecurity;

(b) The effects of saltwater intrusion from sea-level rise on freshwater resources; and the potential for aquaculture and the role of wetland ecosystems in addressing sea level rise;

(c) The design and maintenance of coastal protection and associated infrastructure services to allow for changes in tourism demand;

(d) The change in water demand for irrigation and its impacts on infrastructure investment. Groundwater resource use may have infrastructure implications;

(e) The changes in the demand for energy following changes in agricultural practices;

(f) The impacts on tourism from changes in ecosystems;

(g) The design criteria of energy systems (e.g. dams) to address primary changes in water availability and secondary changes from other sectoral demand changes.

Ancillary benefits

99. As noted in the EEA (2007) report, adaptation to climate change often has benefits beyond a reduction of residual damages of climate change. One important benefit of many adaptation measures is that they also reduce vulnerability with respect to current climate variability, meaning that. the reduction of damages caused by current climate variability is an ancillary benefit of adaptation to climate change.

100. The selection of adaptation measures should of course take into account any such benefits. Where cost-benefit approaches are adopted, these benefits can be seen as positive but, as noted, a simple cost-benefit approach is rarely possible for adaptation options, and indeed many ancillary benefits are difficult to quantify in economic terms.

101. Where a cost-effectiveness approach is adopted, the ancillary benefits that are in the same units as the main benefits can be easily included. For example, if the ancillary benefits are a reduction in DALYS through health improvements arising from a reduction of local pollutants, these can be included in the calculation of the costs per DALY. It is more problematic when the ancillary

[6] Annex III provides additional information on CGE models.

benefits cover other areas[7] and especially when they are more diffuse (e.g. promoting wider educational or developmental goals). In such cases, or when a risk-based approach is adopted, the additional benefits have to be treated qualitatively or within a different decision-making framework, such as multi-criteria analysis.

102. An important dimension of ancillary benefits is related to the distribution of these benefits. These benefits sometimes accrue to the more vulnerable sectors and groups of the population. Current climate variability often affects the poorer groups of society (and poorer societies in general) more than it does the richer groups, as the richer are more able to protect themselves against such variability. For these reasons, the evaluation of ancillary impacts should emphasize any benefits to vulnerable communities.

Hard as opposed to soft adaptation options

103. When designing adaptation measures, the tendency is often to focus on the 'hard' engineering solutions and not to give enough attention to the 'soft' options involving policies and instruments that are designed to change behaviour. The soft adaptation options that are often overlooked include adaptive capacity-building at the local and national level, so that public and private agents are informed about the possible impacts, the range of options available to deal with them, approaches to evaluate the options and possible sources of finance for implementing the options. Furthermore, because such aspects of adaptation policy are not adequately covered by cost-benefit analysis, they have to be evaluated separately when creating the package of measures.

Adaptation-mitigation linkages

104. The IPCC AR4 (Klein et al, 2007) addresses the inter-relationships between adaptation and mitigation, and identifies four key areas:

(a) Adaptation actions that have consequences for mitigation;

(b) Mitigation actions that have consequences for adaptation;

(c) Decisions that include trade-offs or synergies between adaptation and mitigation;

(d) Processes that have consequences for both adaptation and mitigation.

105. The level of adaptation needed will depend on the extent of the success in mitigating GHG emissions. Therefore, future plans for adaptation have to be made in light of different scenarios for possible future emission reductions. Since the extent of future reductions is unknown, plans can only be drawn up based on a conservative estimate of likely future emission reductions; however, this significantly increases the resources needed, which underscores the concepts on flexibility and option values.

106. Theoretically, the choice of mitigation and adaptation expenditures can be made jointly, so that the total net benefits from the joint programme are maximized. In practice, however, this is extremely difficult and, furthermore, many argue that it is not appropriate, given current levels of knowledge. The adaptation costs available at a level of aggregation high enough to be analysed in a global model that includes mitigation do not cover the sector details discussed in this section. Nor does such an analysis pick up on the non-monetary aspects of adaptation options or the various critical issues of distribution and poverty. The exercise provided in IAMs such as AD-RICE or

[7] If the ancillary benefits can be measured in monetary terms and a cost-effectiveness analysis is being applied, these benefits can be treated as negative costs and subtracted from the total cost to give a net cost that can be applied to the main measure.

PAGE2002 on the design of mitigation-adaptation strategies therefore remains illustrative. Details of such models are presented in the next chapter.

107. There are, however, some linkages between mitigation and adaptation that are worth noting and possibly addressing. The first is when adaptation affects GHG emissions. There are some adaptation options which can increase energy demand, which in turn will cause GHG emissions to increase. This could arise, for example from increased irrigation or infrastructure construction or the increased need for air conditioning to address heat stress. One way to deal with such demands would be to include the costs of emissions, based on the implicit or explicit price of carbon, in the costs of adaptation. The second is the link between mitigation measures and adaptation. An example would be carbon capture and storage projects, where, in future extreme events, sites could be affected by changes, implying that climate risks would have to be considered and addressed in the design of such storage facilities and sites. The natural implication of this linkage is that the costs of mitigation options should include any necessary adaptation measures that will be needed.

108. Finally, there are some processes that have implications for both adaptation and mitigation. Development of new housing or industrial sites, or the creation of new systems of transport will have implications in terms of the GHG emissions and the need to adapt the programmes to the consequences of climate change. The GHG linkages can be addressed by pricing carbon in the appraisal of the programmes, while the link to adaptation can be considered by including a complementary set of adaptation measures. The costs of these measures should also be included in the appraisal of alternative versions of the programmes.

Public as opposed to private adaptation

109. As noted in the introduction, adaptation measures are taken by both the public and private sectors. Many studies of adaptation do not include private adaptation. While there are good reasons for separating private and public adaptation (e.g. the fact that public adaptation has national budgetary implications, whereas private adaptation mostly does not) it is important to know how much private adaptation will take place and, even more importantly, to design the public adaptation measures in such a way that the combination of the two is as effective as possible. It is important to recognize that individuals will respond to future climate variability, and their response will depend on the public actions that are taken. These public actions should therefore account for this interaction.

110. An example of how private actions could significantly affect current and future climate variability is through insurance. If climate variability is expected to increase with climate change, individuals or the private sector may seek to insure themselves against this changing risk of extreme events, as well as undertaking other measures to reduce the impacts on themselves. This is a cost-effective way to adapt to the increased variability as long as the insurance markets are able to take the risk in a competitive market, and the individuals are able to afford the costs of insurance and other adaptation measures and do not discount future impacts too highly or under-adapt because of the 'Samaritan's Dilemma'.[8] The public sector can play a role in this by:

(a) Providing limited insurance cover when private insurers are unable to provide it (but only when this is caused by market failure and not because the risk is too high);

[8] The Samaritan's Dilemma is the tendency for under-insurance by those who expect external help in the event of adversity: those supplying the help would wish to limit its extent by committing to relatively low support –
but their benevolence implies that they cannot do so credibly.

(b) Acting to correct market failures that result in the private sector undertaking too little insurance, such as applying too high a discount rate or acting in expectation of the 'Samaritan's Dilemma';

(c) Subsidizing poor households that are unable to afford the insurance or offering them alternative livelihoods in the light of the increased costs of climate variability. Thus the public sector measures have to be designed taking into account the possible actions of individuals.

111. In the light of the above, the public sector infrastructure measures should not be based on assuming no private adaptation, nor should they assume that the public sector has to take full responsibility for the consequences of climate impacts. Given the increased risks of flooding, for example, individuals may choose to relocate and take personal measures in response.

112. If, however, public investments offer protection that assumes that no private adaptation will take place, individuals and companies may not adapt, and the overall costs of responding to the change in risk will be much higher than it would be if individual behavioural changes were taken into account. Part of the adjustment individuals and companies will make is in response to higher insurance premiums, or even refusal by insurance companies to offer protection against some events in certain locations. If the government measures consist of essentially underwriting all the risks that the private sector will not cover, the costs of meeting a given 'expected consequence' target could be very high.

113. The public sector may also need to act when the private sector actions are inappropriate (e.g. in the case of 'maladaptation'). An example of such adaptation would be farmers responding to drought conditions by exploiting groundwater unsustainably (a phenomenon reported by Parry et al, 2007, p. 196). In these circumstances, the public sector needs to control this resource while simultaneously developing an alternative way of handling the water shortages.

114. Finally, there are circumstances where the private and public sectors need to act together to plan adaptation actions. A simple case would be when the public sector provides information on climatic variability to the private sector in a timely manner so it can take the necessary actions. More complex cases are ones where national governments may work together in order to pool risk, which they then manage in conjunction with private sector insurers.[9]

Limits of adaptation

115. The extent to which communities can adapt to climate change is limited, both in the narrow sense of preserving existing land use and existing social and economic activity, and in the wider sense of modifying ecosystems so they continue to provide services. From a narrow economic perspective, some limits can be seen more as situations where continued use of a natural resource in any form becomes too expensive to be worthwhile. When this is the case, for example in the case of low-lying areas and some island states, and where there may be no feasible level of protection that can save them, adaptation could then consist of relocation of the current population. Such cases can be considered as extreme situations where the marginal value of reduction in damages is very small compared to the costs of making the reductions.

[9] Examples are included in the technical paper on mechanisms to manage financial risks from direct impacts of climate change in developing countries (FCCC/TP/2008/9).

3. Equity

General issues

116. In all cost-benefit analyses, there is a gap if the prospective winners and losers from the proposed actions are not identified. As a rule, the damages caused by climate change disproportionately affect vulnerable populations, many of whom are poor. The costs of planned adaptation, on the other hand, are borne partly by national governments, spreading the burden across taxpayers in the country, or by global funds, in which case the burden is borne by the international community. Thus there is a significant distributional impact arising from most adaptation actions in favour of the less well-off, which has to be taken into account.

117. Even if the net benefits of adaptation turn out to be negative, this does not imply that the actions should not be taken, as they may have significant benefits to vulnerable households and individuals. Indeed this is often the case for many countries located in tropical regions: the potential benefits of low-cost adaptation measures such as changes in planting dates, crop mixes, and cultivars do not turn out to be sufficient to offset the significant climate change damages (Rosenzweig and Parry, 1994; Butt et al, 2006). Programmes in such circumstances should be assessed in light of the net benefits as well as the distribution of those benefits, especially to the poor.

118. The distributional aspect of net benefits can be handled alongside the estimation of these benefits in a number of ways. One is to give weights to different costs and benefits according to who receives the benefits and who bears the cost. Methods for calculating the weights and for conducting a 'social' cost-benefit analysis were described in some detail by Dasgupta (1972) and Little and Mirrlees (1974). Both show how distributional considerations can be incorporated into cost-benefit analysis through the use of 'shadow' wages and prices, which are another way of representing the weights to be applied to different costs and benefits. An example of how the weights may be calculated based on government preferences for income redistribution was provided by Stern (1977). The difficulty with applying weights is that, in practice, there is little agreement on what they should be. The problem is even more difficult than usual when the stakeholders involved are spread globally and not just within one country. Recent project appraisal using cost-benefit methods has, therefore, rarely applied income or other redistribution weights.

119. An alternative approach is to present the distributional impacts of adaptation options alongside the aggregate costs and benefits and let the decision be taken by the policymakers. Performing a multi-criteria analysis which includes among its components indicators of the net aggregate benefits and a summary indicator of the distributional effects can aid policymakers in this endeavour. This method of dealing with two of the key dimensions of policy selection is more popular than using distributional weights.

C. Discussion and conclusions

120. This chapter has reviewed the methodological aspects of the costs and benefits of adaptation. It began by noting that existing studies fall into two broad groups: those starting with an aggregate level analysis and those using a more disaggregated approach. The aggregate approach is necessarily more basic and relies on a number of assumptions that are difficult to substantiate. The disaggregated approach provides better estimates at the sectoral level but is restricted by uncertainty relating to future developments in the economy as well as to the likely impacts from climate variability. Reliable data at a high enough geographical resolution to allow accurate assessment of the adaptation measures are difficult to obtain.

121. The broad conclusion is that cost-benefit methods are limited in their application. There are issues relating to the valuation of non-monetary impacts (e.g. lives lost or effects on ecosystems) that make it difficult to rely exclusively on that approach. In some cases, more can be achieved by taking

a cost-effectiveness approach). In others, a risk-based approach, in which policies that achieve an acceptable risk level are selected, may be more appropriate. Finally, for others a multi-criteria methodology may be adopted. In all cases it is important to take into account distributional considerations and ensure that adaptation does not increase hardship for the particularly vulnerable. And while it is often necessary to work at a sectoral level, it is important to recognize and to allow for inter-sectoral linkages.

122. Although many adaptation policies will not be based on a pure cost-benefit assessment, it has been shown that information on the costs and benefits, even if it is incomplete, provides important and useful information to the decision maker. Methods that completely ignore these aspects of policies are not likely to be useful to those who have to allocate scarce public funds for adaptation. For this reason it is recommended that a careful assessment of the costs of options is included in any approach that is adopted and, whenever possible, any measurable benefits of these options are also reported.

123. The selection of instruments for adaptation should also be mindful of a number of key factors, including:

(a) The role of public and private adaptation. The two are interlinked as public adaptation has to be undertaken in the light of the possible actions of private individuals and their possible reactions to public measures;

(b) The need to avoid focusing solely on hard options, involving engineering solutions, and give at least equal importance to soft options, involving information, capacity-building, education and the use of insurance markets and other such instruments;

(c) Keeping options open and designing the programmes so they can be modified when new information arises. Typically, soft options are more adaptable in this regard, thus making them preferable to hard options in some cases.

124. The sections above highlight the considerable challenges that remain in addressing the costs and benefits of adaptation. The next chapter investigates how the current generation of adaptation studies have addressed these issues.

IV. Literature review on the costs and benefits of adaptation options

A. Introduction

125. This chapter reviews recent empirical evidence on the costs and benefits of adaptation in relation to the methodological issues identified in Chapter 3, focusing on the approach of these studies to uncertainty, economic valuation and equity. It discusses the approaches and methods used in the case studies, their applications and outputs, and comments on their strengths and weaknesses. It also considers whether the studies are comparable, and provides some initial conclusions.

126. Although the focus is on national-level assessment, the review also covers global studies, and some local and sub-national sectoral studies. A number of case studies are investigated for each of these levels. These have been chosen to demonstrate a broad mix of methods for the assessment of climate change and adaptation. An individual study can include a mix of approaches for climate change and for adaptation assessment, sometimes utilizing a number of techniques concurrently.

B. Review of global level case studies

127. Since the publication of the IPCC AR4 (2007), a number of new studies have focused on global adaptation. These use a broad range of methodological approaches and provide estimates of the costs, and sometimes the benefits, of adaptation. Although these studies are highly-aggregated

and have high uncertainty, they are useful in that they provide initial information on adaptation costs, especially in the absence of detailed disaggregated analysis. In very broad terms, there are two main types of global studies:

(a) I&FF analysis and other similar aggregated assessments;

(b) Economic IAMs.

128. Both study types use different approaches and produce different outputs. In summary, they can include:

(a) The total global costs of adaptation, often expressed as the cost (in United States dollars) of adaptation needed in a specific future year, most commonly 2030. However some studies include estimates through to 2050 or even longer, or for a specific rise in temperature or stabilization scenarios. Both I&FF and IAM assessments can produce these types of estimates, although I&FF studies contain greater regional and sectoral break-down. These estimated adaptation costs are sometimes expressed as an equivalent percent of gross domestic product (GDP);

(b) The present value (PV) of adaptation costs (or costs and benefits), aggregated over time for each year and discounted back to the present day. This allows a comparison of the costs and benefits of adaptation and cost-benefit analysis. Such studies can reveal the potential net economic benefits of adaptation. This type of analysis is undertaken in economic IAMs;

(c) The marginal economic costs and benefits of adaptation over time, which allows an analysis of the optimal adaptation policy and potentially of the optimal balance between mitigation and adaptation policy. Currently, this type of analysis is highly uncertain, but can be used to provide exploratory analysis. This type of analysis is undertaken in economic IAMs.

1. Investment and Financial Flow analysis and other aggregated approaches

129. In the absence of global estimates of the costs and benefits of adaptation, alternative approaches have emerged. These focus on the likely costs of planned adaptation, based on simple and highly-aggregated approximations. They do not consider the benefits of adaptation and thus do not work within a full economic framework. These studies are often referred to as I&FF analyses, as many of them focus on the costs of 'climate-proofing' future investment, or more accurately, the costs of enhancing climate resilience[10] or implementing anticipatory adaptation. These studies estimate future adaptation costs up to 2030.

130. Until recently, there were six large-scale assessments which had estimated the global costs of adaptation. These were reviewed by an OECD study (Agrawala and Fankhauser, 2008); a summary of the estimated costs from these studies is presented in the table 3 below.

[10] It is important to note that the term 'climate-proofing' can be somewhat misleading. First, it is not possible to reduce all climate risks or impacts to zero (i.e. to make economies 'climate proof') as there will often be residual impacts or risks after adaptation. Secondly, even if it were possible to do this, it would not be economically rational. There would be many cases where costs would exceed benefits, meaning current economies are not 'climate proof'. The term 'enhancing climate resilience' is considered more appropriate.

Table 3. Previous estimates of the annual costs of adaptation for developing countries
(*billions of United States dollars*)

Study	Costs	Time frame	Sectors
World Bank (2006)	9–41	Present	Unspecified
Stern Review (2007)	4–37	Present	Unspecified
Oxfam (2007)	At least 50	Present	Unspecified
UNDP (2007)	86–109	2015	Unspecified
UNFCCC (2007)	28–67	2030	Agriculture, forestry, fisheries, water supply, health, coastal zones, infrastructure

Source: Adapted from Agrawala S and Fankhauser S. 2008. *Economic Aspects of Adaptation to Climate Change. Costs, Benefits and Policy Instruments*. Paris: OECD. Table 2.6.

131. The six studies were all rapid aggregated assessments, undertaken within a similar period. They use slightly different approaches, but most are built around some form of I&FF approach. As reported by Agrawala and Fankhauser, many share common or linked methods and they cannot be treated as independent lines of evidence. The estimates generally increase over time.

132. The simplest of these studies (World Bank, 2006; Stern, 2007; UNDP, 2007) consider the possible cost of enhancing the resilience of future investments or financial flows for developing countries, for example in relation to official development assistance (ODA). The studies first consider the sensitivity of investment, estimating the proportion of investments (as a percentage) that are at risk from future climate change. They then estimate (as a percentage) the increase in investment or 'mark-up' needed, to 'climate-proof" or increase resilience against future climate change. The estimates are approximate and depend upon the percentage of investment that is assumed to be climate sensitive and the 'mark-up' that is applied. The UNDP study also estimated the costs of strengthening social protection programmes and scaling up aid in other key areas, whereas the Oxfam study (2007) adopted a different approach, scaling up estimates based on both the NAPAs and NGO programmes.

133. These early studies only provide an estimate of the potential order of magnitude of adaptation costs. More detailed I&FF guidance has been developed for use at a national level (see section IV.C.3 below).

134. The final study in the table (UNFCCC, 2007) adopted a more detailed approach, disaggregating the analysis by sector and world region. It estimated the potential increase in global investment flows at USD 50 to USD 170 billion/year by 2030, of which USD 30 to USD 70 billion/year was anticipated from developing countries (Non-Annex I Parties). Overall, the global value corresponds to 0.2–0.8 per cent of global investment flows or 0.06–0.21 per cent of projected GDP in 2030.

135. The advantage of these six studies is that they are less data intensive than other methods. They provide estimates of potential adaptation costs in the absence of other information. The main disadvantages of these studies are:

(a) The high level of aggregation in the estimation of sector-level investments, which are obtained from a low empirical base of climate sensitivity and the mark-up. The investment flows are so large that even small changes in this mark-up can significantly change the estimates;

(b) The lack of accounting for climate-proofing existing stocks (to the extent that they need to be climate proofed faster than they depreciate);

(c) The lack of accounting for non-investment expenditures especially in the areas of health and agriculture;

(d) The lack of consideration of the additional investment needed to address current climate variability.

136. Moreover, these studies do not estimate the benefits of adaptation. They do not consider future climate projections and, in general, they do not address a number of the methodological issues raised in Chapter 3. These issues are investigated further in the global synthesis in section IV.B.4 below.

137. The recent International Institute for Environment Development (IIED)/Grantham study (Parry et al, 2009) included a critique of the UNFCCC study and the other aggregated estimates above. It highlighted a number of deficiencies which need to be addressed in the future. The study also made a number of comments on the specific sectoral damages. The main conclusion from the review is that the global estimates above are likely to be substantially underestimated, because:

(a) Some sectors were excluded (ecosystems, energy, mining. manufacturing, retailing and tourism);

(b) Some sectors were only partially covered or potential costs were underestimated;

(c) Residual damages, (i.e. the economic costs that remain after adaptation) are not included. While these are not part of the adaptation costs, they are part of the wider economic framework presented in Chapter 2.

138. For these reasons, Parry et al (IIED/Grantham, 2009) suggested that the UNFCCC estimate was likely to be an underestimate by a factor of between 2 and 3 for the sectors included. They also indicated that the total underestimate could be much higher if other sectors were considered. The report also assesses the scope of the analysis (whether all relevant impacts and countries are covered), the depth of analysis, and the costing of measures (whether all relevant costs are included), all of which could lead to underestimates. However, it also highlights the focus on hard adaptation, and suggests that a lack of cost-effectiveness might lead to overestimates.

139. The study also raised the issue of the adaptation deficit and the low levels of assumed current investment in developing countries. The report argued that applying a 'climate mark-up' to infrastructure is not appropriate when current investment flows are well below what they should be. This is highlighted by the situation in some parts of the world, notably Africa, where low levels of investment have led to a current adaptation deficit, meaning that current levels of investment are not considered to be adequate, leading to high current vulnerability to climate variability and extremes. This partly explains why impacts from climate change are expected to be greatest in low- and middle- income countries (IPCC, 2007). The adaptation deficit was not included in the UNFCCC estimate, although it is unclear whether managing the deficit should be considered as adaptation to climate change or whether it is really a part of development, since the current deficit is not attributable to future climate change.

2. Economic integrated assessment models

140. An alternative set of global aggregated estimates of the costs and benefits of adaptation have been produced from economic IAMs.[11] These models can provide estimates at the global and continental level for a wide range of metrics. They have also been used in regional and national assessments.

141. The first study reviewed (Hope, 2009, reported in Parry et al, 2009) used the PAGE model. Using the global costs of adaptation and assumptions from the Stern Review[12], the analysis found a

[11] Annex III provides additional information on IAM.
[12] A 0.1 per cent pure time preference rate.

mean benefit:cost ratio for adaptation of 60 in the business-as-usual A2 scenario and 20 in a '450ppm' stabilization scenario. Adaptation reduced the mean net present value of impacts over the next two centuries by about 28 per cent in the A2 scenario, although 72 per cent of the impacts (residual impacts) remain even after adaptation. Adaptation was more effective in the '450ppm' scenario, over the whole time horizon, reducing the mean impacts by about 33 per cent. Under the A2 scenario, the mean cost of adaptation in 2060 would be USD 90 billion (USD 0.09 trillion), with a 5–95 per cent range of approximately USD 58–132 billion and generated a mean benefit of approximately USD 800 billion, giving a mean net benefit of approximately USD700 billion and a mean benefit:cost ratio of nearly 10:1.

142. The parameterization in the model assumes constant annual costs of adaptation in each year after 2020 (USD 90 billion for each year), but the relative benefits vary over time, with mean benefits of about USD 60 billion in 2020, USD 260 billion in 2040, USD 2200 billion in 2080 and USD 5400 billion in 2100.[13] Under the '450 ppm' scenario, annual adaptation (at USD 90 billion/year) led to mean benefits in 2060 of USD 700 billion, that is to say a mean benefit of USD 600 billion and a benefit:cost ratio of nearly 8:1.

143. The second study (de Bruin et al, 2009) used the AD-RICE model to investigate 'optimal' balances between investments to mitigate climate change, investments to adapt to climate change and estimations of future residual damages. They found that the higher the current value of damages, the more important mitigation is as a policy option in comparison to adaptation. The comparison between adaptation and mitigation therefore depends on the assumptions in the model and especially on the discount rate and the estimated level of future damages. Their policy simulations also suggest that to combat climate change in an efficient way, short term optimal policies would consist of a mixture of substantial investments in adaptation measures, coupled with investments in mitigation, even though the latter will only decrease damages in the longer term.

144. The final study (Carraro et al, 2009) carried out an integrated analysis of both optimal mitigation (carbon cutting) and adaptation at the global and regional level. Adaptation responses were split into three different categories: reactive adaptation (undertaken in response to climate change damage), proactive or anticipatory adaptation (undertaken before damage occurs), and investments in innovation for adaptation purposes. The size, timing, relative contribution to climate damage reduction, and the benefit:cost ratios of each of these strategies was assessed for the world as a whole, and for developed and developing countries in both a cooperative and a non-cooperative setting.

145. The study also takes into account the role of price signals and markets using two scenarios. The first is that of policy-driven adaptation, together with carbon cuts. The second assumes that markets also autonomously contribute to reducing some damages. The study concludes that adaptation is an effective means of reducing climate-related damages. The benefit:cost ratios of adaptation expenditure are larger than 1 in all scenarios, and for high and low climate damages and discount rates. Nonetheless, benefit:cost ratios, and consequently global welfare, are even higher when adaptation and mitigation are implemented jointly. Although the study does quantify a trade-off between adaptation and mitigation, it also considers them strategic complements that contribute to a better control of climate damages.

146. Unlike the I&FF studies discussed above. the key advantage of these models is that they utilize an economic framework to study adaptation options, and therefore include consideration of

[13] The mean benefit is less than the mean cost in 2020 because of the parameterization in the model. However, investment in 2020 provides benefits in later years. A more targeted adaptation policy, with slightly lower amounts in 2020, and greater amounts in 2040 and future years, could bring an even higher mean net present value.

costs, benefits and residual damages. Therefore, IAMs can provide a wide range of outputs, providing direct information on the costs and benefits of adaptation and influence the various choices and assumptions. They can also provide outputs for aggregated economic costs and benefits for future time periods and present values, allowing the analysis of costs and benefits. Finally, they allow quick analysis of a large number of possible scenarios, allowing uncertainty assessment, (e.g. the Monte Carlo analysis in the PAGE model). In all of the above areas, the IAMs provide insights that could not be produced by any other approaches.

147. The disadvantages of these models are that they are technically complex and the linkages and the parameterization may not be entirely transparent or independently validated. The model results are strongly dependent on input assumptions and on the structure of the model. They are strongly influenced by the sectors and impacts in the models and anything that is left out of a model can be as important as what is included. There are concerns expressed over the impact damage functions in the models (Warren et al, 2006; Stanton et al, 2009; Ackerman et al, 2009), especially on how well they reflect the most recent literature; uncertainty; and non-linear, threshold or high impact events. The estimates are also sometimes criticized for the choice of discount rate or the approach used to aggregate (global) estimates between regions (equity weights), although these criticisms also apply to any economic study of climate change.

148. A number of reviews (Lorenzoni and Adger, 2006; Patt et al, 2009) highlight concerns about the highly aggregated and highly theoretical consideration of adaptation in the models, the lack of technological detail or description of adaptation strategies, and the use of older literature for functions. They also emphasize assumptions that autonomous adaptation has effectively zero cost, whilst planned adaptation estimates are potentially over-optimistic as the models adopt a predict-and-provide rational and optimal decision model. However, many of these criticisms are a reflection of the state of knowledge in the underlying literature, although it is of concern when these elements or limitations are not made clear. Concerns have also been raised over whether it is possible or appropriate to consider adaptation and mitigation as direct global substitutes, especially given the paucity of information on the costs and benefits of adaptation (Klein et al, 2007).

3. The World Bank Economics of Adaptation to Climate Change Study

149. The final, and most recent, global study is the World Bank *"Economics of Adaptation to Climate Change (EACC) Study"* (2009). The study was launched soon after the Bali Climate Change Conference in 2007 and the global summary and draft consultation report were published in late 2009 (thus the evaluation below is preliminary). A second report based on seven country case studies[14] will be produced by spring 2010. The global report estimates the costs of adaptation in developing countries through to 2050. The EACC study has some similarities to the previous global studies, but is also significant better because it adopts a more explicit economic framework and uses country-specific data sets. The approach is summarized below:

(a) The study first produced socio-economic development baselines for each sector, establishing a growth path for GDP, population, etc. in the absence of climate change. It then determined sector-level performance indicators (such as stock of infrastructure assets, level of nutrition, etc.);

(b) This growth path was compared with and without climate change, using two alternative future climate model projections for an A2 SRES scenario. These

[14] Bangladesh, Plurinational State of Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Viet Nam. The country studies are aimed to help decision-makers in developing countries better understand, assess the risks posed by climate change and better design strategies to adapt to climate change, in particular by maintaining the focus in the most vulnerable communities.

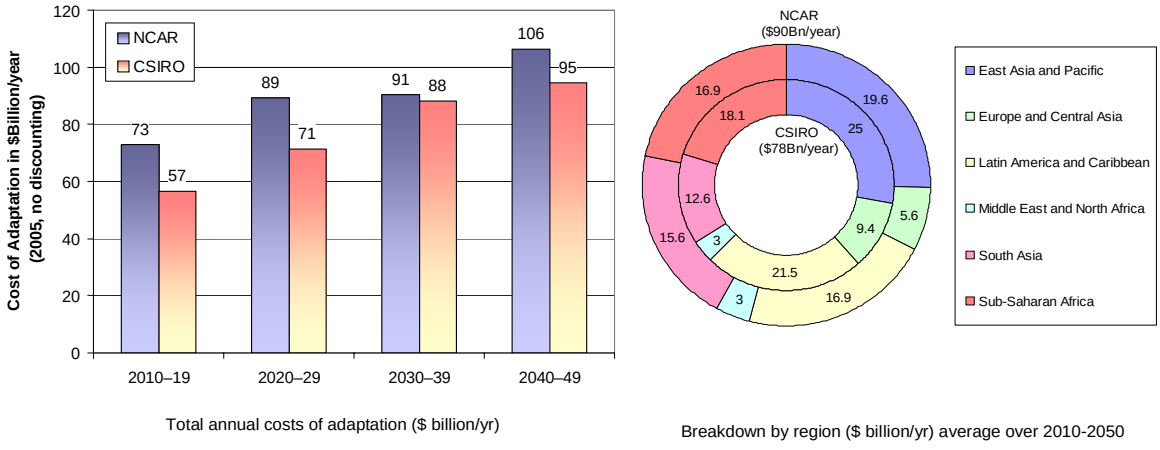
characterize two possible extreme climatic projections, with minimum and maximum temperature and the 'wettest' and 'driest' precipitation outcomes. The study then assessed the effects of climate change on infrastructure; coastal zones; water supply and flood protection; agriculture; fisheries; human health; and forestry. Future climate was imposed upon future development levels allowing for the increase in development and increased adaptive capacity over time;

(c) It then defined and assessed the costs of adaptation, defining them as the costs of initiatives that were needed to restore welfare to levels similar to those before climate change occurred, along the projected development baseline. Since costs are estimated by sector, sectoral proxies for welfare were identified (e.g. the level of services for infrastructure, number of malnourished children, per capita calorie consumption for agriculture, etc). The exception is coastal zones, where costs of adaptation were defined as the cost of measures to establish the optimal level of protection plus residual damage, using the DIVA model.

150. The study focused on planned (public sector) costs of adaptation. However, it took into account autonomous adaptation in some sectors, for example, for natural- and human-induced mobility of forests, adjustments in farm-level behaviour and adjustment through trade for agriculture. For ease of analysis, it favoured hard options involving engineering solutions over soft options based on policy changes and social capital mobilization, except in the study of extreme weather events, where the emphasis was on investment in human resources, particularly those of women (education).

151. One additional problem that was encountered was related to aggregation. In some cases, climate change reduced expenditure requirements, for example, reduced demand for electricity (from reduced heating) or lower water requirements. This implies that there are negative costs of adaptation, and raises the question of whether to offset potential benefits of climate change against the costs of adaptation across sectors or to do so across countries. The study examined three aggregation methods in order to address this question: gross (no netting of costs), net (benefits are netted across sectors and countries) and X-sums (positive and negative items are netted within individual countries but not across countries). The results of X-sums aggregation are shown in figure 4 below.

Figure 4. Total and regional annual costs (X-sums*) of adaptation



Source: World Bank. 2009. *The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates. The Global Report of the Economics of Adaptation to Climate Change Study*. Consultation Draft.

*Note: The X-sums net positive and negative items within countries but not across countries and include aggregate costs for a country as long as the net cost across sectors is positive for the country.

152. Under the relatively drier scenario referred to in paragraph 150 (b), the global costs of adaptation (using the X-sums approach) are estimated at USD 75 billion per year, while under the

scenario that assumes a future wetter climate it is USD 100 billion. Costs increase over time, although they are higher under the wetter scenario and vary by region and by sector with the projection. The study reports that the costs of adaptation are of the same order of magnitude as the current ODA.

153. The potential strength of the study lies in the more advanced framework and analysis compared to the previous I&FF studies. It includes a more explicit consideration of development baselines, the effects of climate change by sector, the level of disaggregation and the dynamic application of functional relationships over time. It also studies uncertainty more explicitly, using the range of climate projections. However, as the report recognizes, adaptation costs are still calculated as though decision makers know with certainty the form the future climate will take (when, in reality, the current climate knowledge does not permit even probabilistic statements about country-level climate outcomes). It also highlights that, in a world where decision makers hedge against a range of outcomes, the costs of adaptation could potentially be higher.

154. The analysis covers similar sectors to the previous UNFCCC study (2007) and also assesses extreme events (and, interestingly, includes the costs of educating women for reducing disaster damages), but omits the sectors identified by Parry et al (2009): ecosystems, energy, mining, manufacturing, retailing and tourism. The study itself does identify other methodological gaps, stating that there was no consideration of innovation and technical change; local-level impacts, particularly the effect on more vulnerable groups; or the distributional consequences of adaptation.

4. Synthesis of global case studies

155. The case studies show the emerging information on the economics of adaptation at the global scale. The studies use a range of methodological approaches, outlined in table 4 below. Overall, the IAMs and the recent EACC study use a more explicit economic framework than the earlier I&FF methods and the UNFCCC study, since the latter does not consider the economic benefits of adaptation or residual damages.

Table 4. Analysis of the methodological framing of the different global studies.

Issues	Investment and Financial Flow analysis	Integrated Assessment Models	World Bank (2009)
Focus	These have a financial focus, rather than an economic one, considering only the costs of adaptation. No benefits or residual impacts are estimated.	These have a strong economic focus, working with costs and benefits of adaptation and residual impacts.	Economic focus is limited to costs of adaptation. There is no consideration of benefits or residual impacts, as adaptation returns welfare to pre-climate levels.
Outputs	Costs of adaptation (USD/year) in a future period, e.g. 2030.	Varied. It can include costs and benefits in any future year, present values, benefit:cost ratios and optimization runs.	Costs of adaptation (USD/year) for future periods up to 2050.
Models/ tools	Usually no models are used, though the UNFCCC (2007) study did use the DIVA model for the coastal analysis.	Economic Integrated assessment models, e.g. PAGE, AD-RICE.	Use of a number of models, e.g. IFPRI IMPACT model for agriculture, DIVA model for coastal areas.
Orientation and coverage	The studies usually have a broad sectoral orientation. UNFCCC covers agriculture, coastal, health, infrastructure and water.	The models have very aggregated assessment. For example 'all sectors', or just 'market' and 'non-market' sectors.	Agriculture, coastal, fisheries, health, infrastructure, water, extreme events.
Geographical scale/ level of disaggregation	The aggregation level is generally at continental scale and has high transferability, with vulnerability and mark-ups applied equally to all sectors in all regions.	The aggregation level is at global or continental scale and has very high transferability within regions.	The aggregation level is at the sub-continental level, though climate analysis uses country data. High transferability for functions and adaptation cost relationships.

156. The studies are not directly comparable, as they also consider different time frames and report different outputs and metrics. However, the I&FF UNFCCC (2007) and the World Bank (2009) studies do estimate the total costs of adaptation, broken down by sector, and are compared in table 5 below.

Table 5. Comparison of annual adaptation costs by sector
(*billions of United States dollars*)

Sector	UNFCCC (2007)	World Bank (2009)*	
		Wettest climate scenario	Driest climate scenario
Infrastructure	2–41	29.5	13.5
Coastal zones	5	30.1	29.6
Water supply and flood protection	9	13.7	19.2
Agriculture, forestry, fisheries	7	7.6	7.3
Human health	5	2.0	1.6
Extreme weather events	–	6.7	6.5
Total	**28-67**	**89.6**	**77.7**

Source: Adapted from UNFCCC. 2007. *Investment and financial flows relevant to the development of an effective and appropriate international response to Climate Change*. United Nations Framework Convention on Climate Change and World Bank. 2009. *The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates. The Global Report of the Economics of Adaptation to Climate Change Study*. Consultation Draft.
* The World Bank figures cited are the X-sums values.

157. These two studies provide broadly similar estimates of the global costs of adaptation, at least for the upper end of estimates provided by UNFCCC. The higher costs from the EACC study mainly arise because of the large increase (six fold) in the adaptation costs in coastal zones.[15] There are also higher costs for water supply and flood protection in the EACC study, though the estimates for infrastructure are lower than the UNFCCC upper value.

158. However, great care must be taken in interpreting any convergence of the total cost estimates:

(a) First, the Parry et al (2009) study reports costs that are two to three times higher than these two studies for the sectors covered above. It also notes that the global costs of adaptation will be higher still if other sectors such as ecosystems were considered, or if the costs of addressing the adaptation deficit were included.

(b) Second, there are many similar assumptions or constraints within these assessments. The coverage of sectors is similar and is partial. Moreover, in some sectors, adaptation costs are based on similar approaches, notably in the case of coasts, where the studies use the same model.

(c) Third, they are bound by similar methodological aspects. They generally assume optimal adaptation, with perfect foresight and do not take account of the additional costs for hedging against the range of outcomes or of maladaptation. All of the studies focus on hard adaptation and contain limited consideration of institutional and organizational adaptation, adaptive capacity-building and other soft options.

(d) All of these studies have been rapid assessments. There has been little chance as yet to validate the estimates against sector- and national-level analysis. This is a key next step that is covered in the next section.

[15] Both studies actually use the same model (DIVA) for analysis: the difference is caused by changes in the range of potential sea-level rise and the inclusion of residual damages.

159. Therefore, the apparent convergence of the estimates should not be interpreted as providing any definitive confidence on the likely costs of adaptation, or even a consensus on the bounded estimates. It is stressed that estimating these aggregate global values is extremely challenging, because of the high uncertainty with climate change and its potential impacts, and the complex methodological issues associated with costing adaptation that were discussed in the previous chapter. The studies are discussed in relation to the methodological aspects of uncertainty, economic valuation and equity below.

Uncertainty

160. In table 6 below, the global studies are evaluated with regard to the uncertainty issues raised in the previous chapter.

Table 6. Analysis of uncertainty within the different global studies

Issues	Investment and Financial Flow analysis	Integrated Assessment Models	World Bank (2009)
Uncertainty	Almost no uncertainty analysis included. Results are usually reported as central estimates or as a central range.	Some models include uncertainty analysis, with use of Monte Carlo analysis in PAGE (uncertainty analysis across parameters and distributions of results).	Considers uncertainty in climate projections, but not development paths or impact analysis. Some sensitivity analysis undertaken, which found some countries facing very large variability in costs.
Baselines	There are no explicit baselines or socio-economic projections, though some assessments study possible change in financial flows over time.	The models include baseline of SRES economic and population growth, etc. Some models include autonomous adaptation within functional relationships.	Works with a development baseline and considers the additional effects of climate change. Limited autonomous adaptation in some sectors.
Climate projections	No climate projections are used in the analysis.	Models include future climate modules that project climate.	Two future projections from downscaled outputs of two global climate models
Reversibility, flexibility and adaptive management	These aspects are not included in analysis.	These aspects are not included in analysis. Adaptation is considered as an optimal response with perfect foresight.	The study recognizes the concept but does not include it in the analysis, emphasizing that the need to hedge could increase costs.

Abbreviations: SRES = Special Report on Emissions Scenarios.

161. The studies vary, but a key conclusion is that all studies partially address uncertainty. In summary:

(a) The consideration of future baselines and development is taken into account in the IAM and the EACC study, although there is no real uncertainty analysis of socio-economic development, which can be as important as future climate in determining economic effects and thus adaptation responses;

(b) The I&FF approaches and the UNFCCC study do not utilize climate projections, and so do not address the uncertainty in future climate change. This uncertainty is also omitted in many of the IAMs, though it is partially considered when Monte Carlo analysis is used. The EACC study uses the bounded range of the outputs from the global models;

(c) None of the studies address the issues of uncertainty and flexibility in options, though it is particularly difficult to address these aspects at this highly-aggregated scale. The issue is recognized as a key concern, notably in the EACC study, but this does not translate through to the analytical approach.

Economic valuation

162. The global studies are considered with regard to the issues of economic valuation and efficiency in table 7 below.

Table 7. Analysis of economic valuation within the different global studies

Issues	Investment and Financial Flow analysis	Integrated Assessment Models	World Bank (2009)
Time horizon and discount rates	Time horizon is 2030. Results are reported as annual cost (not annualized equivalent), without discounting.	Time horizon up to 2100 or 2200. The discount rate is user defined. Some studies use uncertainty analysis with range of rates.	Time horizon is 2050. Results are presented in 2005 prices no discounting.
Non-monetary costs and benefits	Benefits are not assessed explicitly in these approaches	Included in the assessment of overall or non-market functions, though very aggregated and partial coverage	Focus on market sectors, though the study considers health and some ecosystem services (production).
Adaptation – mitigation linkages	UNFCCC, 2007 consider mitigation and adaptation but not the linkages between the two	Mitigation and adaptation considered (and in some models traded-off), but this is at an extremely high aggregation level.	There is no direct consideration of linkages between mitigation and adaptation.
Cross-sectoral linkages	There is no cross-sectoral comparison included.	There is no cross-sectoral comparison included.	There is no cross-sectoral comparison included.
Economic wide impacts	Wider economic effects are not included in analysis	Varies with model. Some IAMs are explicitly built around CGE analysis and so include directly.	Wider economic effects are not included in analysis
Hard as opposed to soft adaptation	These studies focus on hard technical adaptation.	Highly theoretical, though generally hard adaptation.	Generally hard adaptation, though some examples of soft adaptation options in health, agriculture, and fisheries as well as education for extreme weather events.
Ancillary effects	These are not included, although there is some qualitative discussion in some sectors.	These are not considered.	These are not considered.
Public as opposed to private adaptation	These studies have a focus on public planned adaptation. Some discussion of private sector.	These studies focus on public planned adaptation.	These studies have a focus on public planned adaptation. Some discussion of private sector.
Limits of adaptation	Not included, though less relevant caused by short-term focus.	Functions can have limits for adaptation, but highly theoretical.	Not included.

Abbreviations: CGE = Computable general equilibrium.

163. To summarize:

(a) The studies cover a wide range of time horizons, but only the IAMs involve the discounting of future costs and benefits of adaptation;

(b) None of the studies include significant coverage of non-monetary benefits. These are included as part of an aggregated assessment in the IAMs and assessed for 'productive' ecosystem services in the EACC study;

(c) The UNFCCC and IAM studies both consider mitigation and adaptation, but there is no direct assessment of the linkages between the two (i.e. the effect of adaptation on GHG emissions, or the need to make mitigation climate resilient);

(d) There is no consideration of cross-sectoral linkages or wider economic effects in any of the assessments. Similarly there is no consideration of ancillary effects;

(e) All of the studies focus more on hard adaptation for the public sector, although there are some exceptions, including the consideration of agricultural R&D in the UNFCCC study and education in the EACC study for adaptation to extreme events;

(f) The studies do not consider the limits of adaptation, other than through a highly theoretical form in the IAM assessments.

Equity

164. Finally, the studies have been reviewed in terms of their consideration of equity. It is extremely difficult to consider local vulnerability and distributional effects at the global level, and none of the studies have considered these effects in quantitative analysis, although they all highlight that this could be a concern. The IAM and World Bank EACC studies do consider aggregated equity issues between countries. Some IAM assessments take into account more negative impacts that will arise in developing countries through the use distributional or equity weighting when aggregating (and this also translates through to the analysis of adaptation). The World Bank study raised a different distributional issue in relation to adding up positive and negative effects within or between countries, showing that the allocation rule had a significant impact on the overall results.

C. Review of national level case studies

165. At the national level, information on the costs and benefits of adaptation options can raise awareness of the scale of the issue. It is also relevant for assessing national financing requirements and for considering efficient, effective and equitable adaptation options, national planning and priorities. However, assessing the costs and benefits of adaptation, even at the national level, is very challenging.

166. The previous review material, such as the IPCC AR4 and the OECD review (Agrawala and Fankhauser, 2008), identified existing national-level studies and analyses. However, many new national studies have emerged since these reviews, including a number of economic studies in developing countries and new methodological guidelines for adaptation costing. The new studies include:

(a) The latest NAPAs;

(b) The UNFCCC NEEDS project;

(c) The UNDP methodology for the assessment of investment and financial flows to address climate change;

(d) The Regional Economics of Climate Change Studies (RECCs);

(e) Recent national level assessments that estimate adaptation costs, or costs and benefits.

167. These studies adopt a diverse range of methodological approaches, which improve the information on the costs, and sometimes the benefits, of adaptation options. The methods used include:

(a) Bottom-up impact assessment;

(b) I&FF analysis;

(c) IAM analysis;

(d) CGE models;

(e) Other forms of vulnerability or adaptation assessment.

168. These methods provide different types of information and different outputs. The studies are described below and examined with regard to the methodological issues discussed in the previous chapter.

1. National adaptation programmes of action

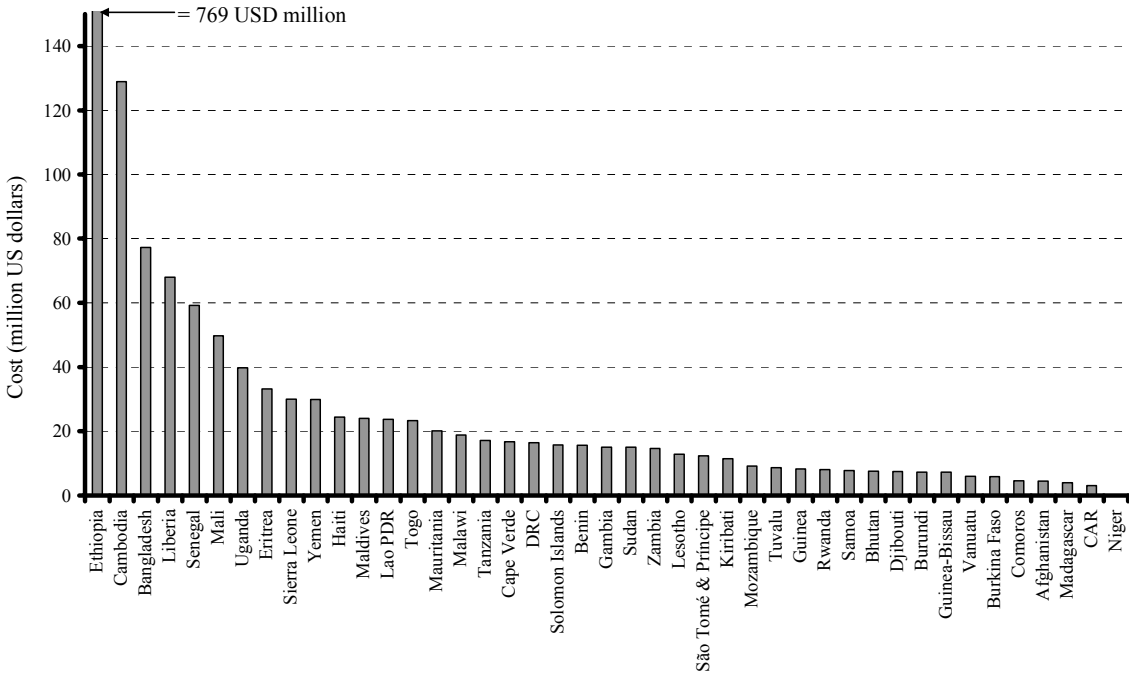
169. The NAPAs provide a process for LDC Parties to identify priority activities for adaptation to the adverse effects of climate change. They contain a ranked list of priority adaptation activities that focuses on urgent and immediate needs (i.e. those for which further delay could increase vulnerability or lead to increased costs at a later stage). In line with their preparation guidelines (Decision 28/CP.7), the NAPAs contain an estimation of the financial and other costs involved. This information is designed to facilitate the development of proposals for implementation. The NAPAs were reviewed in a number of studies, including by Osman-Elasha and Downing (2007) and Agrawala and Fankhauser (2008).

170. As of September 2009, out of the 49 LDC Parties, 43 have submitted their NAPA to the UNFCCC secretariat. Within these submitted NAPAs, a total of 433 urgent and immediate adaptation projects were identified. These projects fall under the following sectors/areas: agriculture and food security, water resources, coastal zones and marine ecosystems, terrestrial ecosystems, early warning and disaster management, health, energy, tourism, and education and capacity building. Total estimated funding required to implement these priorities are around USD 1.66 billion (see figure 5), though most projects run over several years, so this is not an annual cost.

171. It is stressed that these projects only respond to urgent and immediate needs, and that the total amount was based on the cost of implementing the identified projects, thus they do not reflect the full costs of addressing the current adaptation deficit. There is little information on how these costs were calculated, although many appear to be based on and scaled up from historic or ongoing projects.

172. The NAPA guidelines also sets out key stages in the overall process, which include participatory rapid integrated vulnerability assessment, the identification of adaptation options, and the ranking of projects and activities to address priority adaptation needs. The methods recommended, therefore, strongly focus on vulnerability assessment and participatory methods. The selection and prioritization of projects was undertaken taking a number of approaches into account. The annotated guidelines highlighted the potential for cost-effectiveness analysis, cost-benefit analysis and multi-criteria analysis (LEG, 2002), although the latter was most commonly used.

Figure 5. Total NAPA project costs by country



Abbreviations: Lao PDR = Lao People's Democratic Republic, DRC = Democratic Republic of Congo, CAR = Central African Republic.

173. The primary strength of the NAPAs is that they identify urgent needs, based on participation and consultation with stakeholders and assessed at a local or community level. They therefore provide a better reflection of local issues and capture elements that would be missed by many aggregated national studies. They also consider vulnerability and livelihoods and include better consideration of potential distributional effects. However, they focus only on the most urgent adaptation issues and do not investigate longer-term issues (although it is important to note that this was not within their remit). The costing of projects was also undertaken in an ad hoc way. Finally, they usually do not quantify the benefits of projects in physical or economic terms, although they do include qualitative assessment through multi-criteria analysis.

2. The UNFCCC National Economic, Environment and Development Study for Climate Change Project (Financial Needs Assessment)

174. The NEEDS for Climate Change Project[16] was launched by the UNFCCC secretariat in early 2009. It provides technical assistance to Parties for financial needs assessments. The main objectives of the NEEDS project are to assist countries:

(a) To select key sectors for climate change mitigation and adaptation measures based on priorities identified in the second national communications and the national development plan(s) of the Parties to serve as the basis for the financial needs assessments;

[16] <http://unfccc.int/2807.php>. The project was launched in response to a mandate issued by the Subsidiary Body for Implementation at its twenty-eighth meeting, for the secretariat to provide, upon request, information to non-Annex I Parties on the assessment of financing needs to implement mitigation and adaptation measures.

(b) To assess financing needs required to address mitigation and adaptation measures in selected key sectors and to identify appropriate financial and regulatory instruments to support them;

(c) To raise awareness and facilitate informed consensus among government agencies on policy actions required to mobilize finance and investment.

175. Ten countries have joined the project (Costa Rica, Egypt, Ghana, Indonesia, Lebanon, Maldives, Mali, Nigeria, Pakistan and the Philippines). However, there has not been sufficient published material to formally review these studies. The project is highlighted for consideration as part of the future evidence base.

3. UNDP methodology for the assessment of investment and financial flows to address climate change

176. The UNDP global project "*Capacity Development for Policy Makers to Address Climate Change*", launched May 2008, has recently produced a methodology guidebook for conducting national I&FF analysis. The guidebook underwent an in-depth peer review process that included sectoral experts, developing country users, regional centres of excellence, and international agencies. The guidance is aimed at I&FF assessments of mitigation and adaptation measures to address climate change, for selected key sectors.[17]

177. It is a more detailed, bottom-up application of the I&FF approach outlined in section IV.B above and constitutes a significant methodological advance from the global studies. It seeks to strengthen policy-making capacity in participating countries for longer-term financial decision making and policy development (regarding investment shifts and/or additional capital needed to address climate change), but also to enable those countries to estimate the magnitude of national efforts required to address climate change.

178. The analysis is focused on assessing changes to investments in physical assets and programmatic measures (I&FF) that account for national circumstances, capacities and resources. Investments include both domestic and foreign funds, private and public funds, and range from household investments in appliances to corporate and governmental investments in infrastructure. Once the scope of a sector is clearly defined and historical I&FF data is compiled, the relevant investment and financial flows for that sector are projected for two future scenarios:

(a) A baseline scenario which reflects a continuation of current policies and plans (i.e. a future in which no new measures are taken to address climate change – a 'business-as-usual' scenario);

(b) A climate change scenario, in which new mitigation or new adaptation measures are taken.

179. Both scenarios are then compared in order to determine the changes in investments needed for the sector. The overall approach is split into nine distinct steps. The guidebook provides flexible accounting rules and does not dictate the choice of models or approaches. For example, for an I&FF analysis of adaptation, models can be used to develop and define the climate change scenario. Otherwise, a sectoral plan, a projection of trends, the current situation or some combination of these can be used, including prior work on climate change (e.g. National Communications, Technology Needs Assessments, NAPAs, GHG mitigation assessments, vulnerability assessments). Sector-

[17] <http://www.undpcc.org/content/inv_flows-en.aspx>. The methodology guidebook is available in English, French, Spanish and Russian.

specific guidance is produced for adaptation in the forestry, agriculture, water management, public health, biodiversity, fisheries, tourism and coastal sectors.

180. 20 countries[18] are currently conducting an I&FF assessment using the guidance, for mitigation and/or adaptation, in specific sectors, with technical backstopping provided by five regional centres of excellence. Since countries are still conducting their I&FF assessments, no published material from these studies was available at the time of this report, although they are highlighted for consideration as part of the future evidence base.

181. The strength of the guidance lies in the provision of a strong and rigorous analytical framework and flexible accounting rules that will allow countries to move beyond the costing approach used in the NAPAs. It is also methodologically advanced in comparison to the global-level I&FF assessments described earlier. It has a strong focus on building baseline estimates combined with future policy and a more robust analytical method for assessing and presenting cost estimates. It can combine data from climate projections and model outputs to help develop a more accurate assessment of investment needs, (i.e. merging the I&FF analysis with more traditional vulnerability or impact-based approaches).

182. The I&FF assessment does not consider the full economic framework; rather it is a complementary approach that primarily works within a financial framework to assess how investments and financial flows within a sector have to be adjusted to implement adaptation options. The UNDP methodology need not be used as an alternative but can rather build on the outputs of a NAPA, a National Communication, etc., to analyze ways of how to actually implement identified adaptation options.

183. In line with the scope of the project, there is no explicit consideration of the benefits of adaptation, although countries are encouraged to report such benefits qualitatively, and no consideration of the costs of residual impacts. A number of other issues are potentially relevant. There may be attribution issues when differentiating between development and climate adaptation, especially since adaptation options often also facilitate development goals. There is also little explicit consideration of uncertainty in the guidance, either in relation to the range of climate projections or the range of adaptation options.

184. The recommendation to focus on 2030 removes some consideration of climate change over longer time periods that may be particularly important for long-lived infrastructure investment.[19] In addition to this, the I&FF approach often involves an assessment of the sensitivity of individual investments to climate change and the increase in costs that are needed, which may involve ad hoc estimates unless this is linked to more detailed sectoral analysis.

4. The Regional Economics of Climate Change Studies (RECCs)[20]

185. A set of regional studies assessing the economics of climate change have been updated through the Regional Economics of Climate Change Studies (RECCS), which are commonly referred to as ‘mini-Sterns’, as many of them were inspired by the publication of the Stern Review and have a regional or national focus rather than a global one. The aim of these studies is to explore alternative

[18] These include Algeria, Bangladesh, Plurinational State of Bolivia, Colombia, Costa Rica, Dominican Republic, Ecuador, Gambia, Honduras, Liberia, Namibia, Nepal, Nicaragua, Niger, Paraguay, Peru, St Lucia, Togo, Turkmenistan and Uruguay.

[19] The year 2030 was proposed because it aligned with typical sector development plans, while the 20–30 year timeframe was still considered a reasonable period over which to analyze alternative investment decisions.

[20] Regional assessment methodologies are included in this section since they are implemented through national assessments that are aggregated to the regional level.

mitigation scenarios (low carbon growth), the likely economic impacts of climate change and the costs and benefits of adaptation options.

186. Studies are being undertaken in South-East Asia, Mexico, Brazil, Central America, South America, the Caribbean and East Africa. The studies are stand-alone assessments, undertaken by different teams. They use different methodological approaches and assumptions, including the application of IAMs, other aggregated approaches and bottom-up analysis. This variety of approaches provides useful information that allows a comparison of the studies with regard to the methodological issues outlined in the previous chapter. A number of the published or draft final studies are discussed below.

The economics of climate change in South-East Asia

187. The Economics of Climate Change in South-East Asia study (Asian Development Bank (ADB), 2009) focused on Indonesia, the Philippines, Thailand, and Viet Nam. The study is divided into three parts: an impact assessment, an adaptation analysis and a low carbon growth analysis. The study was undertaken in three phases, starting with a introductory analysis and literature review, followed by regional, national and policymaker consultations and climate change modelling for key sectors.

188. The climate change modelling was based on an integrated climate assessment modelling framework, which analysed climate modelling and sectoral impact assessments (but not economics or adaptation). This was complemented by the use of the PAGE2002 economic IAM, which was used to estimate the economic impacts of climate change in monetary terms under different policy scenarios. The results showed large economic costs across market and non-market sectors, potentially equivalent to a loss of 6.7 per cent of combined GDP by 2100 under the reference scenario (A2). These are much higher in relative terms than the global average (almost twice the world average of 2.6 per cent). The model also assessed how these economic costs changed under stabilization scenarios that reduced CO_2 concentrations to between 450–550 ppm, finding that this would significantly reduce the potential losses in the four countries, to 4.6 per cent at 550 ppm and 3.4 per cent at 450 ppm by 2100 (compared with 6.7 per under the 'business as usual' scenario).

189. The study assessed adaptation options in detail, analysing existing adaptation and future reactive and proactive options through sectoral assessment for agriculture, water management (including flood and drought risk), coastal zone management, safeguarding forests and health (vector borne diseases). It outlined adaptation priorities across these sectors, but did not provide estimates of the level of adaptation needed, the costs of adaptation or the potential quantitative or economic benefits. Instead, the PAGE model was used to perform an indicative cost-benefit analysis of adaptation by comparing the cost associated with different levels of adaptation efforts with benefits from avoided climate change impacts.

190. The results showed that, for each of the four countries, the cost of adaptation for agricultural and coastal sectors (mainly the construction of sea walls and development of drought- and heat-resistant crops) would, on average, be approximately USD 5 billion per year by 2020, and that this investment had a high benefit:cost ratio. By 2060, the annual benefit of avoided damage from climate change from adaptation was estimated to exceed the annual cost (anticipatory adaptation in earlier years provides benefits in later years). By 2100, benefits could account for 1.9 per cent of GDP, compared to the cost of adaptation (0.2 per cent of GDP). However, the analysis also shows that adaptation alone is not sufficient, because of the high residual costs of higher emissions, and therefore global mitigation is needed to complement adaptation efforts.

191. The use of IAM models such as PAGE for assessing adaptation – and their strengths and weaknesses – was discussed in the global IAM section above. The application of these models down

to the regional and national levels reveals many of the potential issues and concerns outlined earlier, but the advantage is that they can produce indicative economic estimates and work with a variety of economic metrics.

192. The study concluded that South-East Asia required extensive adaptation measures. It recognized that adaptation requires adaptive capacity-building, the use of technical and non-technical measures in climate-sensitive sectors and, related to this, the need to include adaptation in development planning (especially for sustainable development, poverty reduction and disaster risk management).

Economics of Climate Change in Mexico and Brazil

193. The Economics of Climate Change in Mexico study (Galindo, 2009) also covered three themes: the economic costs of climate change, low carbon growth and the costs and benefits of adaptation. The study assessed the potential economic costs, including the agriculture, water services, land use change, biodiversity, tourism, infrastructure and public health sectors, while recognizing the significant impacts in sectors where valuation was not possible (e.g. loss of biodiversity).

194. In general, the study found that the economic costs of climatic impacts by 2100 were at least three times greater than the costs of mitigating emissions by 50 per cent. For example, in one of the scenarios considered, it was found that with an annual discount rate of 4 per cent, climatic impacts account for, on average, 6.21 per cent of current GDP while the costs of mitigating emissions by 50 per cent represent 0.70 per cent and 2.21per cent of GDP, at a cost of USD 10 and USD 30 per ton of carbon, respectively.

195. It also concluded that the economic costs of climate change for Mexico were potentially very high with a temperature rise of more than 2–3°C. It also found that adaptation could reduce the economic costs, but that adaptation was insufficient once certain climatic thresholds have been crossed (limits of adaptation).

196. The aim of the Economics of Climate Change in Brazil study is to assess the economic impacts of different scenarios of climate change, identify cost-effective mitigation actions, identify adaptation strategies in selected sectors and assess the costs and benefits of adaptation. Other aims are related to biofuels and opportunities avoided because of deforestation.

197. At the time of writing, the results had not yet been published, but information is available on the methodological approach. The study includes future climate model projections. These are then linked to expected environmental, economic and social impacts of climate change under different scenarios. The study uses thematic and sectoral bottom-up models (partial equilibrium), with an impact function to assess impacts and possible responses to climate change for water resources; agricultural production; land-use standards; energy; biodiversity and ecosystem services; and coastal zones. Adaptation measures are discussed for agriculture, energy and coastal zones. The costs of measures and the benefits generated are compared to the extent possible in relation to the reduction in damage.

198. A CGE model was chosen as it could be consistently integrated with the other models in the study, noticeably the models of demand and supply of energy, land use and agricultural productivity. It also analyses the impacts of adaptation policies in Brazil, and how they interact with other macroeconomic factors.

199. The study recognizes the methodological challenges involved in adaptation. It also highlights the need to integrate climate change into environmental and development policies, while

advancing investment in no-regrets actions, that is, development actions that simultaneously increase resilience to climate change.

Economics of climate change in East Africa

200. The final RECCS considered is the East African study (Stockholm Environment Institute, 2009) which focuses on Burundi, Kenya and Rwanda and also includes an overall East African regional assessment, covering the economic costs of climate change, the cost and benefits of adaptation and low carbon growth.

201. The study adopted a different approach to the other RECCs, adopting three aggregation levels and suites of methods and models:

(a) The first was a top-down aggregated economic analysis, using IAMs to estimate the economic costs of climate change and adaptation, complemented by a simple I&FF scaling assessment to study the costs of adaptation;

(b) The second was a bottom-up impact assessment, considering a wide range of climate projection outputs and performing a selection of sectoral impact assessments at the national level to estimate physical impacts and economic costs, and where possible the costs and benefits of adaptation;

(c) The final aggregation level was at a local level, using case studies to test the validity of the national assessments or to provide information on vulnerability and the non-formal economy for both impacts and adaptation, focusing on areas that would otherwise be missed by an aggregate or economic assessment.

202. The study reports that economic costs of climate variability to East Africa from periodic floods and droughts (extreme events) are likely to be significant, and that climate change will create additional stress and further economic costs. While it stresses that these economic costs are uncertain, the aggregated economic IAM analysis estimates that the economic costs to East Africa are likely to be higher (in relative terms) than to other world regions, because of higher vulnerability and lower adaptive capacity. For example, estimated total costs (market and non-market central values) are equivalent to approximately 2.5 per cent of GDP each year by 2030 in Kenya, with this figure rising in future years.

203. The sectoral assessments used a suite of models, such as the DIVA and the Water Evaluation And Planning system (WEAP), to estimate the economic costs from sea-level rise and coastal zones and the additional health burdens (malaria) and found these to be potentially high. However, in other sectors, it found the economic estimates varied widely with climate and socio-economic projections. The study mapped the potential effects on ecosystem services, including non-productive systems, but did not quantify or value the effects. It also undertook sensitivity analysis to explore the potential effects of socio-economic growth and future climate extremes on the economic costs of droughts and floods.

204. The bottom-up analysis indicated that the aggregated estimates were plausible values within the bounded range of projected changes. A number of case studies were used to check against the national-level analysis (e.g. a case study on Mombassa to complement national analysis) and to allow consideration of local vulnerability.

205. A similar approach was undertaken for assessing the potential costs and benefits of adaptation. Some simple scaling analysis was performed using an I&FF framework to calculate the possible regional adaptation costs. This was then tested through a selection of sectoral bottom-up assessments, using the national sectoral impact assessment, and other sector-specific I&FF analysis.

The study found that the costs of adaptation varied widely across the projections, and that the boundaries of adaptation in relation to the deficit (development) and future adaptation also varied.

206. The advantage of this type of approach is that it allows assessment at different aggregation levels using both top-down and bottom-up assessment, combined with local narratives from case studies. This can provide alternative outputs which are often useful to different end-users and objectives, but also provide a means to validate different aggregation levels. Given sufficient time, this can be extended as part of an iterative framework, where the disaggregated parts of the study are used as an input in the aggregated assessment. The challenge of such approaches is to ensure consistency in the resources and time generally required for assessment.

5. Other national studies

207. There is now a large number of national climate change studies and a growing number of national adaptation assessments. These provide a potentially rich source of information on the costs and benefits of adaptation. Most of these have been undertaken for developed countries, but they provide useful information on methods and analytical approaches. It is not possible to comprehensively report or even summarize all of this information here. A summary of a selection of the existing information is outlined in the box below, and a selection of case studies has been used in the following sections, focusing on recent national studies that demonstrate different approaches.

Box National level adaptation economics

Across Europe, there has been a large number of national climate change studies. This includes a significant number of detailed studies which assess the potential impacts of climate change (though not their economic costs), for example in Portugal (Santos et al, 2002) and Spain (Moreno et al, 2005). These studies also consider potential adaptation options. More detailed assessment of the impacts (including some economic costs), and a greater focus on adaptation can be seen in later studies, notably in Finland with the FINADAPT study (Carter, 2007), although even this study does not quantify the costs or benefits of adaptation. More recently there has been a number of national (or national-level) studies that have performed more analysis on the costs and benefits of adaptation. This includes studies of the Alps (Agrawala, 2007) and national-level work by studies in the United Kingdom, Sweden and the Netherlands (see case studies below).

There is also a large number of national adaptation initiatives now in place, many of which seek to progress information on the costs and benefits of adaptation over the next few years. There has also been considerable pan-European work. Earlier studies such as ACACIA (Parry, 2000) and A-Team (Schröter et al, 2004) assessed adaptation qualitatively. More recent studies (such as the PESETA[21], or ADAM[22]) have sought to extend the research to include an economic analysis, undertaking economic impact assessment and attempting to also assess the costs and benefits of adaptation, though this has been narrowly focused on specific sectors (e.g. coasts and energy). More comprehensive analysis on the economics of adaptation is now underway (e.g. ClimateCost[23]).

There is a strong base of evidence on adaptation in North America, particularly in Canada which has been one of the main countries improving vulnerability, impact and adaptation studies. It has performed a series of national-level assessments (1998; 2004; 2007), specific work on the costs of adaptation (Dore and Burton, 2001), and there is a large body of sector- or regional-based analysis, including studies on the Northwest Territories, on vulnerability to permafrost degradation, including the costs of adaptation, transportation and tourism in the Great Lakes; and many other sectors (Lemmen et al, 2008).

[21] <http://peseta.jrc.es/index.htm>.
[22] Information on the ADAM project (Adaptation and Mitigation Strategies: supporting European climate policy) is available at <http://www.adamproject.eu/>.
[23] <www.climatecost.eu>.

Box (continued)

There is also considerable information at state level in the United States, particularly for New York and California. As highlighted in the earlier sections, a large number of ongoing studies is due to be published in the near future for Central America and South America.

There is a very large body of adaptation work in Australia, reflecting the high potential vulnerability of the country (Parry et al, 2007). The Garnaut Review (2007) examined the impacts of climate change on the Australian economy. It also considered adaptation in a number of sectors, although costs and benefits of adaptation were not estimated.

In **Asia**, there have been several studies of the risks of sea-level rise, including the costs of adaptation and country-level adaptation strategies, with examples in Bangladesh (Smith et al, 1998), Singapore (Ng and Mendelsohn, 2005), the Pacific (World Bank, 2000) and case studies on climate-proofing case against extreme events in the Cook Islands and Federated States of Micronesia (ADB, 2005). There are plans for even more detailed assessment, for example the ADB-World Bank-Japan Bank for International Cooperation Initiative on Climate Impact and Adaptation in Asian Coastal Cities, which is implementing studies on several coastal mega cities including Bangkok, Ho Chi Minh, Jakarta, Karachi, Kolkata, and Manila. There is also a large number of studies scheduled to report in the next year (see sections above) including the NEEDS and UNDP studies and several studies on river management and flooding, such as the *Scenario Analysis Technology for River Basin Flood Risk Management in the Taihu Basin* report, which is part of the China Foresight study.

In Africa, there are several studies on coasts and agriculture. Examples include the analysis of the costs of coastal protection at the continental level (Niang-Diop et al, 2006; Nicholls et al, 2009), and the national level (Agrawala et al, 2004). There has also been extensive work on agriculture, with the World Bank "*Climate Change and Agriculture in Africa"* study at the Centre for Environmental Economics and Policy in Africa (CEEPA)[24], which has included analysis in eleven countries. Cost-benefit analyses of adaptation options were undertaken for the Berg river (see discussion below) and for cereal production in Gambia as part of the Assessments of Impacts and Adaptation to Climate Change (AIACC) project (Njie et al, 2006).

United Kingdom Cross Regional research on Climate Change Impacts and Adaptation

208. The Department for Environment, Food and Rural Affairs (Defra) Cross Regional research project (Metroeconomica, 2006) focused on the economic valuation of impacts of climate change, quantifying and valuing potential economic costs using a bottom-up impact assessment approach. The study considered a large number of sectoral assessments, covering priority impacts for health; transport; the built environment and cultural heritage; agriculture; biodiversity; water resources;, tourism;, and energy, for four socio-economic and climate scenarios, over three separate time periods (2020s, 2050s, 2080s). It then considered adaptation, working to identify options within an economic framework, though the coverage across sectors was mostly focused (in economic terms) on floods and water demand.

209. For floods, the report assessed an earlier study (Evans et al, 2004). This study was itself a major national-level analysis and assessed the economic costs of climate change in detail, assessing the people at risk and the average annual damage from coastal, river, and intra-urban flooding, for four socio-economic scenarios. It presented the results as the combined effects of socio-economic and climate change and included future growth. One of the key findings of the study was that socio-economic change was as important as climate change to future damage levels. The study also reported that annual losses would increase under every scenario by the 2080s, from less than 1 billion pounds sterling (GBP) under the Local Stewardship scenario (Medium-Low), to around

[24] <http://www.ceepa.co.za/Climate_Change/index.html>.

GBP 7 billion in the 2080s (World Markets / High emissions), which is equivalent to 0.1–0.4 per cent of GDP.

210. The study also assessed the economic benefits of adaptation, concluding that an integrated portfolio of responses could reduce the risks of river and coastal flooding from the worst-case scenario of GBP 20 billion worth of damage per year, down to approximately GBP 2 billion in the 2080s, although it was also noted that this figure would still be double the current damage figure. It did not directly compare adaptation benefits against costs, and instead estimated the total investment needed for adaptation over time at between GBP 22 billion and GBP 75 billion of new engineering by the 2080s (total costs over 80 years, not annual costs). The study highlighted the lower costs of adopting an integrated approach, as opposed to just building higher defences.

211. For the water sector, a more explicit economic analysis was adopted for at-risk regions. The report used pre-existing studies of water resource zones, existing water infrastructure and the 30-year average household water deficit over time. It extended these studies to estimate the economic losses to households for foregone water use because of the anticipated water deficit up to 2100 using a revealed preference approach. The report then assessed the cost of addressing this water deficit, using information on the range of options available for managing the public water supply, including options that reduced demand and options that increased supply, and by constructing indicative cost-yield curves to investigate how to eliminate the household water deficit at minimum cost. By approximating the willingness-to-pay of households for each additional unit of water along their demand curves, the study estimated the cost of the water deficit to households, and then estimated the economic losses to households associated with foregone water use in adaptation. Using this data, the report subsequently estimated the net benefits of adaptation (i.e. the net benefits of eliminating the predicted household water shortfalls).

212. The results show initial economic impacts from climate change up to the 2080s of between GBP 41 million and GBP 388 million per year for one region alone (depending on scenario). The costs of largely (but not entirely) eliminating these deficits through adaptation was estimated at GBP 6 million to GBP 39 million per year for the same period.

213. The study also considered the costs of private adaptation, in relation to increased air conditioning to address cooling demand (quantified and valued), summer tourism movements and farm-level adaptation.

214. The key advantage of these impact assessment-based approaches is that they facilitate the analysis of physical impacts and monetary valuation and thus the analysis of the costs and benefits of adaptation. They therefore work within the economic framework outlined in Chapter 2. Any assessment that extends to cost-benefit analysis goes beyond the relative ranking of activities to allow a consideration of the absolute justification for adaptation (i.e. whether benefits exceed costs).

215. However, there is often less emphasis placed on cross-sectoral impacts and linkages, and use of a common metric may result in less focus on non-monetary impacts. Moreover, in many studies, it has proved difficult to estimate the physical and economic benefits of adaptation, thus making the comparison of costs and benefits outside of one or two sectors, such as flooding, difficult. Finally, these impact-driven assessments are often of limited use for shaping actual adaptation policy because of the insufficient consideration of short-term policy issues (they tend to focus on the long-term), insufficient knowledge at the scale relevant for adaptation decisions, insufficient consideration of the full diversity of adaptation options (including soft options) and insufficient consideration of the factors determining the adaptation process itself, including adaptive capacity and the policy context for adaptation (Füssel and Klein, 2006).

Sweden facing climate change - threats and opportunities (2007)

216. The Swedish Commission on Climate and Vulnerability (2007) assessed the potential effects (impacts and opportunities) for Sweden, assessing the associated economic costs of climate change (as increased aggregate incomes or costs) and the potential costs of adaptation over the period 2010–2100. The analysis included study of costs related to floods; landslides; erosion and hydropower, including to the road network); agriculture; forestry and reindeer herding; drinking-water supply and fisheries; health; building structures; heating and cooling needs; and wind and storms. It considered a number of scenarios, reporting that the costs in the 'High' scenario corresponded to a loss of approximately two-thirds of a year's gross production, measured against current gross national product (2,600 billion Swedish krona (SEK) in 2006) during this period, although it also reported that earnings would increase by approximately the same amount. However, the study also highlighted that the costs and benefits would have a different distribution across individuals and geographic areas).

217. The study also assessed adaptation options. With the exception of the road sector (for which a direct comparison of the costs and benefits of adaptation was performed), the analysis estimated the likely investment needs for adaptation over time, but did not assess adaptation benefits. In this respect it is similar in nature to a detailed national I&FF analysis, although it linked this assessment directly to a national-level assessment of climate change. The assessment considered the short- and long-term investment needed over the period 2010–2100, although for some sectors only the initial (immediate) cost of preventive measures was presented. There is no summary of the total investment needed across the economy. However, a wide range of national investment costs were estimated, including preventative and adaptation measures for the transport sector, national infrastructure (communication and electricity), coastal zones, buildings (including protection against landslides and roofs and façade maintenance), energy (dams, heating and cooling demand, district heating), water supply and water treatment, agriculture and forestry (including reindeer herding) and for increased visitor pressures.

218. The study emphasizes that action costs are usually easier to calculate than damage costs. In the limited areas where a cost-benefit assessment was carried out (road and rail sectors, rainwater and waste water systems, as well as measures against landslides in certain areas), the study found it was socio-economically beneficial to implement preventive measures rather than waiting until the damage occurs. In most cases, preventive measures can be implemented in conjunction with new investments and regular maintenance. In this way, considerable additional costs can be avoided. The report also states that, for many sectors, it was not possible to analyse whether it was cost-effective to implement preventive measures now or better to wait. In many cases, however, the action costs were found to be lower than the damage costs, particularly if measures were implemented at the same time as ongoing maintenance work.

Netherlands: Adaptation, Spatial Planning and Climate/Routeplanner

219. The Netherlands has developed a national adaptation agenda through its national programme *"Adaptation, Spatial Planning and Climate"* (ARK), the aim of which is to provide a systematic assessment of potential adaptation options to respond to climate change in the Netherlands in connection to spatial planning. The analysis was performed by the "Routeplanner" group.[25] As part of this, a detailed analysis of adaptation options was carried out (van Ierland et al, 2006). This analysis considered the direct and indirect effects of the options for and costs and benefits of adaptation. Following a review, the project constructed a database of adaptation options and the associated effects. It then identified evaluation criteria for a qualitative assessment of adaptation options and performed a multi-criteria analysis of scoring and weighting in order to rank these

[25] <http://www.klimaatvoorruimte.nl>.

options through expert workshops. It also compiled an inventory of the incremental costs and benefits of adaptation options, in order to assess the order of magnitude related to decision-making and to identify any gaps in knowledge.

220. The options were scored against five criteria, which are listed below. This is of particular interest, because it covers some of the methodological challenges raised in the previous chapter. The criteria used were:

(a) The importance of an option, reflecting the level of necessity for implementation. Significant options can reduce major risks and/or preserve essential function. In principle, significant options generate substantial benefits, though potentially at high costs;

(b) The urgency of the option, relating to the need to implement the adaptation option immediately compared to the possibility of deferring the action to a later point in time. Long-lasting investments and conservation of the existing situation require early planning, and therefore a long period of waiting will render the option redundant (e.g. raising awareness), much more costly (e.g. large infrastructure projects) or impossible (e.g. conserving nature);

(c) No-regret options, which are those for which non-climate related benefits, such as improved air quality, will exceed the costs of implementation; they will therefore be beneficial irrespective of future climate change. They are worthwhile (in terms of economic and environmental benefits exceeding cost), irrespective of any benefits of avoided climate damages;

(d) Ancillary benefit options, which are specifically designed to reduce climate-change related vulnerability while also producing benefits that are not related to climate change. Ancillary benefits thus concern external effects which have a positive impact on policy goals unrelated to climate change policy;

(e) Mitigation linkages, as certain adaptation options will also induce a reduction of GHG emissions, and thus score very high on mitigation effect (i.e. are complementary to mitigation policies).

221. This approach was used to rank adaptation options for each sector (agriculture, nature, water, energy and transport, housing and infrastructure, health and recreation, and tourism). It was noted that the scoring is based on subjective expert judgement.

222. The study also attempted to produce information on the costs and benefits of various adaptation options. However, the project team observed that reliable information on costs and benefits was still lacking in many cases, and that there was an urgent need for more detailed studies and for the design of the best options to cope with climate change. Where data were available, estimates were generally presented as the net present value of the costs and benefits of adaptation.

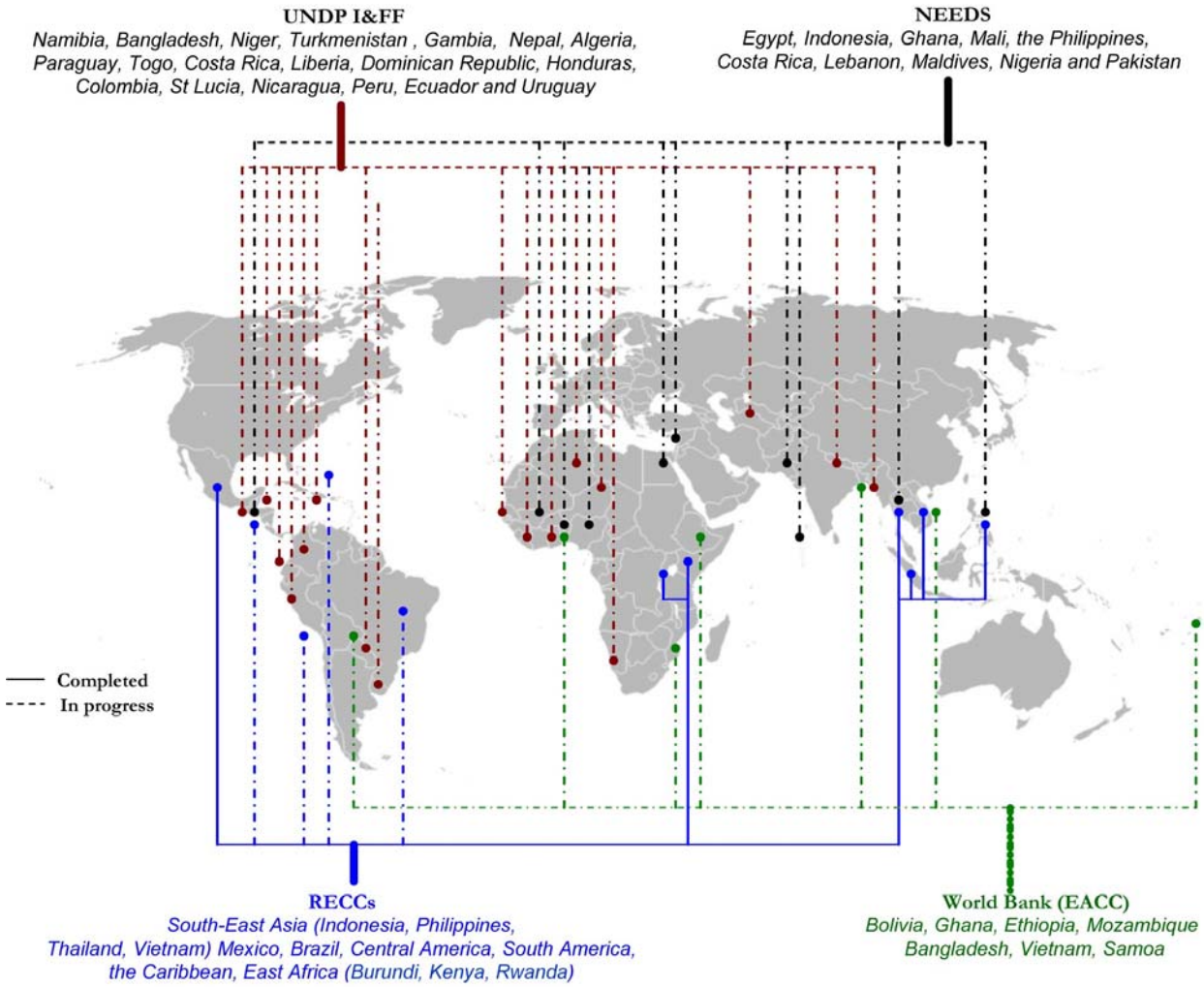
223. The advantage of this study and of multi-criteria analysis frameworks in general is that they allow consideration of quantitative and qualitative data together (i.e. monetary and non-monetary effects). In cases where only qualitative data exist, different options can be assigned a score. Relative weightings are then given to different categories, usually through stakeholder workshops or expert opinion. They also allow consideration of many of other methodological issues (uncertainty, ancillary effects, mitigation linkages, etc.) in the selection of options. However, the approach also has a number of limitations, notably the subjectivity of the weighting and ranking (which are often formed based on the views of a small number of experts) and the fact that it is a complex and time-consuming process. It can also only provide a relative ranking, rather than providing absolute

assessment (though it is possible to include the outcomes of a cost-benefit analysis within a multi-criteria analysis, allowing a wider overall analysis).

6. Synthesis of national case studies

224. The studies above provide recent information on the economics of adaptation at the national scale. At the present time, there is still a relatively small information base. However, a key finding is that a large number of studies will be completed over the next two years. The four main groups of national studies (NEEDS, UNDP I&FF, EACC and RECCs) will provide a wide geographical coverage of economic studies on adaptation in developing countries. In some cases, countries are being included in more than one initiative, which will allow a direct comparison of approaches. The geographical spread is shown in figure 6 below.

Figure 6. Coverage of forthcoming studies of the economics of adaptation



225. Therefore while a lot of information on adaptation cost is not yet available at the current time (November, 2009), there is a limited amount available: of the studies shown in the map above, only four have been published. A more in depth review will be possible once all the studies are completed and a key recommendation is that this review process be repeated in the near future using this wider evidence base.

226. The information from the published studies has been complemented with examples from developed countries, to allow consideration of a range of methods, presented in table 8 below. These studies cover different time frames and metrics in order to investigate different aspects, meaning their results are not comparable. The focus on economics does lead more studies to focus on economic modelling techniques (IAM, CGE) and impact assessment-based approaches. It has been more difficult to find explicit economic assessments that work within a framework of vulnerability or adaptation assessment.

Table 8. Analysis of the approach and framework adopted by the national studies considered

Study	Approach and framework
NAPAs	The NAPAs use a financial cost analysis, rather than an economic analysis. The focus is on immediate needs. There is no quantified analysis of the benefits of adaptation or residual impacts after adaptation. Multicriteria analysis is often used to prioritize vulnerabilities and adaptive responses.
UNDP I&FF	The guidance adopts a financial, rather than an economic analysis, assessing future I&F flows and the additional costs needed for adaptation. The exact approach will vary between studies, but there is less or no focus on the economic benefits of adaptation (and comparison against costs) or the residual impacts after adaptation.
South East Asia RECC	This study uses a more complete economic framework. It includes analysis of the impacts of climate change and a qualitative analysis of adaptation by sector, and complements this with a highly aggregated economic analysis using an economic IAM, which provides the analysis of costs and benefits.
Brazil RECC	This study uses a more complete economic framework. The study used climate projection, bottom-up sector models (partial equilibrium) and CGE modelling. The costs of measures and the benefits generated are compared as far as possible.
East Africa RECC	This study uses an economic framework with multiple lines of evidence including an aggregated economic analysis (IAM and I&FF), an impact assessment for economic costs, the costs of adaptation and, for a few sectors, the economic benefits, plus local case studies to validate and complement this information.
UK Cross regional study	This study uses an economic framework using bottom-up impact assessment and adaptation analysis for the physical impacts and economic costs of climate change, and for a small number of sectors, the economic costs and benefits of adaptation.
Swedish Commission	This study uses an economic framework, undertaking impact assessment of climate change impacts and economic costs. The analysis of adaptation is largely based on adaptation financing needs (similar to a national I&FF), with no quantification of the benefits of adaptation or residual effects.
Netherlands ARK/ Routeplanner	This study uses an economic framework. For screening options, the study adopted a multi-criteria framework, which allowed consideration of many of the methodological aspects. The study also estimated costs and economic benefits (and present values) for a selection of options.

Abbreviations: ARK = Dutch National Programme for Spatial Adaptation to Climate Change (Nationaal Programma Adaptatie Ruimte en Klimaat), CGE = computable general equilibrium, IAM = Integrated Assessment Models, I&FF = Investment and Financial Flow analysis, NAPA = National adaptation programme of action, RECC = Regional economics of climate change, UNDP = United Nations Development Programme.

227. The studies adopt different approaches and report different metrics for a variety of time periods. Moreover, none of the studies have provided a detailed systematic comparison of the costs of adaptation, and even fewer have been able to estimate the economic benefits of adaptation, which emphasizes the challenges involved in such studies. This makes it very difficult to directly compare the estimates between the studies, though some broad conclusions can be drawn. First, the studies confirm that the relative economic costs of climate change (as a percentage of GDP) will be greater in developing countries, reinforcing the need for adaptation. Second, many of the studies potentially imply high adaptation costs at a national level for just a single sector (tens to hundreds of millions of

USD per year, in the case of East Africa, and billions of USD per year, e.g. for energy adaptation, in Brazil). These potentially suggest that the global costs of adaptation presented in the previous section, which were around USD 100 billion per year in 2030 for all countries and all sectors, may be low. As more national studies are completed, further clarification on this will be possible.

228. Therefore, a key recommendation is that once the full suite of new national studies have been completed, a comparison exercise should be undertaken to investigate whether there is a gap between the global estimates of the costs of adaptation and the amount proposed from aggregation across national studies.

229. The specific methodological approach, outputs and orientation for each study is presented in the tables 9 and 10 below.

Table 9. Analysis of the methodological framing of the national studies considered

Issues	NAPAs	UNDP I&FF	South-East Asia RECC	Brazil RECC	East Africa RECC	UK cross-regional	Swedish Comm.	Netherlands ARK
Outputs	Project lists and total costs.	Estimated changes in investments for the sector.	Benefits of adaptation (benefit:cost ratio).	Costs of adaptation (agriculture and energy)	Costs of adaptation and in some sectors costs and benefits.	Costs of adaptation in some sectors and economic benefits in two.	Adaptation investment needed over time for short- and long-term.	Ranking, plus some information on costs and benefits (PV).
Models/Tools	No models.	Models can be used within the framework to provide a more detailed analysis.	Integrated assessment models for climate /impacts. PAGE02 for economics.	Suite of models. Economic Forecasting Equilibrium System.	Suite of models including PAGE and FUND IAM plus sector based models (DIVA, WEAP).	Sectoral models.	Sectoral models and GCM though adaptation based on engineering analysis	Database and expert elicitation (workshops).
Orientation (sector/other) and coverage	Usually sectoral orientation, though also cross-sectoral coverage.	Sectoral guidance for forestry, agriculture, water, health, biodiversity, fisheries, tourism and coastal zones.	Qualitative analysis covers agriculture, water, coastal zone, forests and health.	Macro-economic plus energy, agriculture, land use, ecosystem services and coastal zones.	Health, agriculture, water, coastal zones, built environment, and ecosystem services.	Health, transport, built environment & cultural heritage, agriculture, biodiversity, water resources, tourism, and energy.	Infrastructure, agriculture, forestry, livestock, drinking water, fisheries, health, built environment, and extreme events.	Agriculture, nature, water, energy & transport, housing & infrastructure, health, recreation and tourism.
Geographical scale/ level of disaggregation.	National or large sub-region, down to project level.	National.	Regional group for South-East Asia in IAM.	National, with disaggregated data and regional consideration.	Different aggregation and analysis at regional, country and local level.	National, with regional disaggregation.	National, with high disaggregated analysis for impacts.	National.

Abbreviations: ARK = Dutch National Programme for Spatial Adaptation to Climate Change (Nationaal Programma Adaptatie Ruimte en Klimaat), CGE = computable general equilibrium, GCM = general circulation model, IAM = Integrated Assessment Models, I&FF = Investment and Financial Flow analysis, NAPAs = national adaptation programmes of action, PV = present value, RECC = Regional economics of climate change, UNDP = United Nations Development Programme

Table 10. Analysis of uncertainty within the national studies considered

Issues	NAPAs	UNDP I&FF	South-East Asia RECC	Brazil RECC	East-Africa RECC	UK cross-regional	Swedish Commission	Netherlands ARK
Uncertainty	No uncertainty analysis.	Consideration of uncertainty is not part of the core guidance.	Represented by PAGE Monte Carlo analysis.	Not explicitly considered. Note extra uncertainty with projections of trade patterns in CGE.	High consideration across project.	Limited, working with central climate-SRES scenarios.	Low consideration of uncertainty (single outcomes).	Partly captured through the urgency of the option.
Baselines	Focused on current situation.	Future baseline including existing policies/ plans.	Considers future baselines under A1F and B2 scenarios.	Considers future baselines under two SRES scenarios.	Consistent with country projections for development.	Climate and socio-economic for four scenarios.	Future baselines developed.	
Climate projections	Climate projections inform choice of projects.	Climate projections are a prerequisite to conduct the assessment.	Separate projections for region using integrated assessment models.	Two scenarios from HadRM3P from the regional climate modelling system PRECIS.	Historical trend analysis plus eight downscaled global model projections (CCE) for two scenarios.	Four climate projections (UKCIP02) linked to the four socio-economic scenarios.	Used in impacts modelling but not adaptation assessment.	
Reversibility, flexibility and adaptive management	Not included, as focus on short-term needs.	Not included, especially post 2030 linkage.	Not included.	Not included.	Discussion included.	Not included.		Analysis of no-regret characteristics, as part of MCA.

Abbreviations: ARK = Dutch National Programme for Spatial Adaptation to Climate Change (Nationaal Programma Adaptatie Ruimte en Klimaat), CGE = computable general equilibrium, IAM = Integrated Assessment Models, I&FF = Investment and Financial Flow analysis, MCA = Multi-criteria analyis, NAPAs = national adaptation programmes of action, RECC = Regional economics of climate change, SRES = Special Report on Emissions Scenarios, UNDP = United Nations Development Programme

230. Tables 9 and 10 show a wide variation in approaches, models used, and outputs. They highlight that these national studies are also subject to some of the same concerns that were raised for the global studies. While some of the studies provide good coverage across the main sectors, nearly all studies omit ecosystem services, manufacturing and retailing. The studies are discussed in relation to uncertainty, economic valuation and equity below.

Uncertainty

231. Table 11 below show an assessment of the national studies in relation to the uncertainty issues raised in the previous chapter. Although the studies vary, a key conclusion is that the studies only partially address uncertainty. Many of the studies (though not all) still do not fully reflect the range of uncertainty in the climate projections, as they only use single projections. While the development of future baselines is considered in all studies, single future projections are usually used. Finally, there remains little explicit consideration of the issues associated with reversibility, flexibility and adaptive management. Some studies do recognize these issues, but none discuss these issues within their analytical assessment.

Economic valuation

232. A summary of the analysis of the national studies in relation to economic valuation and efficiency is given below:

(a) The studies use a wide range of time horizons and different economic metrics. The I&FF studies focus on 2030, while most other studies concentrate on the period up to 2050 or 2100. A number of studies do assess adaptation in present value terms and use discounting;

(b) While most studies assess (and even value) health, there is much less coverage of other non-monetary benefits. Some studies do attempt to assess potential effects on ecosystems and associated services, although this is not reflected by any economic costs, except for productive services;

(c) Many of the studies consider mitigation and adaptation, as these are joint studies analysing both. Almost none consider the effect of adaptation on GHG emissions, or the need to make mitigation climate-resilient, other than a few limited studies in the energy sector, some qualitative discussion and multi-criteria analysis scoring;

(d) There are almost no cross-sectoral linkages assessed, with most studies adopting a sector-specific analysis. A number of studies do, however, include wider economic analysis through the use of CGE analysis. Sometimes these use the outputs from other parts of the study. In one case these models are used to perform the central part of the analysis;

(e) There is a greater consideration of soft adaptation in many studies, although when cost estimates are compiled, these still focus on hard engineering options. All of these studies focus on public planned adaptation;

(f) Ancillary effects are generally excluded from all studies, although they are included as a scoring option in the multi-criteria analysis;

(g) The studies do not consider the limits of adaptation, other than through a highly theoretical form in the IAM assessments, and some qualitative discussion in a number of other studies.

Equity

233. Finally, the studies have been evaluated in terms of their consideration of equity. Even at the national level, the consideration of equity and distributional effects is difficult. The greatest focus on vulnerable groups is probably captured by the NAPAs. In all other studies, the focus on economics has tended to shift the analysis away from equity considerations. Distributional effects are described as a potential concern, with some studies identifying regional areas that might be at greater risk, or highlighting issues of livelihoods and inequalities, but these effects are not explicitly included in quantification or in prioritization of adaptation options. No studies consider the use of equity or distributional weights.

234. This lack of a distributional context contrasts with vulnerability assessments, which concentrate on distributional issues. These assessments can be seen as the opposite of many of the economic and impact assessment-based approaches. Instead of starting with climatic projections, vulnerability assessments start with the indicators of current vulnerability, both non-climate and climate-related, and then add in climate and socio-economic trend data to determine how these indicators might change in the future (from both climatic and non-climatic risks).

235. Vulnerability assessments also investigate adaptive capacity, generally focused at a national level on indicators such as income, education and health as well as sector-specific indicators. They therefore provide information for wider development plans and strategies through ensuring that all risks, both climatic or non-climatic, are considered. This has the advantage of identifying social groups that are susceptible to climate change on a more disaggregated basis and leads to a much stronger focus on inequalities and distributional effects. They also have a greater focus on short-term adaptation needs. However, there are no recognized procedures for quantifying many outputs, and most importantly here, there are no obvious ways to link vulnerability assessments to economic valuation.

Table 11. Analysis of economic valuation within the national studies considered

Issues	NAPAs	UNDP IFF	South-East Asia RECC	Brazil RECC	East-Africa RECC	UK cross-regional	Swedish Comm.	Nether. ARK
Time horizon and discount rates	Immediate and urgent needs only, no discounting.	2030. Discount using two country rates (public, private).	2100. Discounting in IAM CBA analysis.	2011–2041, 2041–2070 and 2071–2100.	Multiple. Short-term policy and through to 2070. No discounting.	3 time horizons, 2020s, 2050s, 2080s No discounting.	2100, in30 year sections.	2050 (and beyond).
Non-monetary costs and benefits	No explicit consideration of benefits, but qualitatively in ranking.	Physical or monetary benefits included qualitatively.	Included as non-market sectors in IAM, though partial / highly theoretical.	Some consideration of non-market effects.	Health, plus qualitative mapping of ecosystem services.	Some coverage through health and biodiversity, but partial.	Coverage of health and productive ecosystem services	Included where possible.
Adaptation – mitigation linkages	Not a focus.	Linkages are considered qualitatively.	Low carbon growth considered.	Low carbon growth considered and some linkages with forestry.	Low carbon growth considered, qualitative links described.	Not included (except energy).	Considers mitigation and adaptation but not linkages.	Directly included in MCA and screening for mitigation.
Cross-sectoral linkages	Cross-sectoral projects included.	No cross-sectoral analysis included.	Not included.	N.A.	Not included.	Not included.	N.A.	N.A.
Economy-wide impacts	Not included.	Not included.	Not included.	Macroeconomic analysis using CGE model.	Not included.	Not included.	Some CGE for impacts, but not for adaptation.	Not included.
Hard as opposed to soft adaptation	Mixture of both.	Can include both.	Qualitative analysis considers both.	Focus on hard adaptation.	Includes soft and hard including adaptive capacity.	Primarily focused on hard adaptation.	More focus on hard engineered adaptation.	Consider soft and hard adaptation.
Ancillary effects	Qualitative in relation to project goals.	Encourages qualitative assessment.	Not quantified, but some discussion.	Not quantified, but some discussion.	Not quantified, but some discussion.	Not quantified, but some discussion.	Not quantified, but some discussion.	MCA screens ancillary benefits to other sectors.
Public as opposed to private	Focus on public planned adaptation.	Focus on public planned adaptation.	Focus on public planned adaptation.	Focus on public planned adaptation.	Focus on public planned adaptation.	Focus on public planned adaptation.	Focus on public planned adaptation.	Focus on public planned adaptation.
Limits of Adaptation	Not included, as focus on short-term.	Not included, though short-term focus.	Included in IAM functions but theoretical.	Not included.	Some limited discussion.	Not included.	Not included.	Not included.

Abbreviations: ARK = Dutch National Programme for Spatial Adaptation to Climate Change (Nationaal Programma Adaptatie Ruimte en Klimaat), CBA = Cost Benefit Analysis, CGE = computable general equilibrium, IAM = Integrated Assessment Models, I&FF = Investment and Financial Flow analysis, MCA = Multi-criteria analyis, NAPAs = national adaptation programmes of action, RECC = Regional economics of climate change, UNDP = United Nations Development Programme

D. Review of sub-national and local case studies

236. The final set of studies relate to the sub-national and local level. At this level, the information on the costs and benefits of adaptation can allow the design and prioritization of adaptation policies, programmes and projects and are an important input into the decision-making and appraisal process.

237. There is a large number of regional and local adaptation studies, though a much smaller number focus on economic matters. Nonetheless, a small set of case studies is included to illustrate how local studies have addressed some of the challenging methodological aspects identified in Chapter 3. These comprise:

(a) The Climate's Long-term Impacts on Metro Boston (CLIMB) study;

(b) The work in the Berg river in South Africa (Callaway et al, 2007);

(c) The Economics of Climate Adaptation (ECA) *"Shaping Climate-resilient Development: a framework for decision-making"*;

(d) The ADB study on Climate proofing case studies in the Cook Islands and Federated States of Micronesia;

(e) The Environment Agency Thames Estuary 2100 study (TE2100).

1. CLIMB: Climate's Long-term Impacts on Metro Boston

238. The study by Kirshen et al (2004) in the metropolitan area of Boston is one of the more comprehensive local studies to include the quantification of impacts and adaptation. It focused on transportation, water resources, coastal and river flooding, energy and health, using a dynamic analytical modelling tool, with a geographic information system (GIS) incorporating socio-economic change. The analysis examined two general circulation model (GCM) climate scenarios and used various sensitivity analyses for the time period up to 2100. It also includes explicit consideration of hard as opposed to soft adaptation.

239. The study investigated the overall monetary and environmental costs for three adaptive strategies. The first strategy assumed no adaptation, except rebuilding after flood damage. The second assumed limited pre-emptive actions, mostly focused on hard adaptation. The final scenario assumed pre-emptive strategies with a greater focus on soft pre-emptive actions. Overall, the study concluded that failure to take any adaptation action was the most ineffective and expensive response, whilst, investment in pre-emptive and precautionary soft measures is generally more cost-effective and would significantly reduce the cost of climate change and lower the costs of adaptation.

240. Economic values were estimated for river flooding. The estimated total losses throughout metropolitan Boston from river flooding were estimated to exceed USD 57 billion by 2100 assuming no adaptive steps are taken, of which USD 26 billion was attributed to climate change. Under the proactive adaptation strategy, the costs of damages caused by climate change were estimated to fall to USD 9 billion. Impacts for also estimated for other sectors, including energy use, health and increased average annual morbidity and mortality effects, and local and regional water supply systems. The study is unusual as it compares hard, defence-based options with soft, accommodating, pre-emptive approaches – the latter largely comprising no-regret options that are considered more cost-effective.

2. The Berg River

241. One of the most comprehensive formal economic assessments of the costs and benefits of adaptation was undertaken for the Berg River Basin in South Africa (Callaway et al, 2007). The study is particularly interesting because it outlines a methodology for incorporating development, climate and ancillary effects into the cost-benefit assessment of projects. Although the main purpose of the hydrologic-economic model was to estimate the costs and benefits of optimal development, the framework was also extended to assess climate change. It considered water management/adaptation options, studying both structural (water storage capacity through the construction of a dam) and institutional options (establishment of an efficient water market) for increasing water supply.

242. The study effectively demonstrated the framework of Fankhauser (1998), which stresses that the costs of adaptation have to be measured against current adaptive measures; and that many adaptive measures may have climate change as well as non-climate change-related benefits. The study assessed the economic benefits and costs associated with expanding future water demand for this development project. It then assessed the possible economic costs and benefits from this project in a changed future climate (which was not explicitly planned for, i.e. a development project that did not take climate change into account). Finally, it also examined costs and benefits when climate change was explicitly factored into the project, taking into account the resulting more or less severe climate. In undertaking the analysis it therefore adopts some methodological criteria to separate the effects of development from the effects of climate change on economic welfare in the reference case(s) used in the analysis. The study also distinguishes between the net benefits of adapting to development and the net benefits of adapting to climate change.

243. From a cost-benefit perspective (Callaway et al, 2007), the construction of the Berg River Dam at capacity levels that were optimal for the climate scenarios were justified on the basis of economic efficiency. However, the implementation of an efficient system of water markets, with or without the construction of the Berg River Dam, resulted in the highest net returns under all climate and urban demand scenarios. Nevertheless, the analysis of the costs of caution and precaution did not provide any unambiguous results that would allow one to determine if it would be less costly to anticipate climate change or plan cautiously.

3. Shaping Climate-resilient Development a framework for decision-making study

244. The Economics of Climate Adaptation working group (ECA) (2009)[26] has developed a framework for decision making for climate resilient development. This method assesses the current expected annual loss from existing climate patterns and includes a projection of how future economic growth is at risk from climate change impacts and an assessment of the incremental loss that could occur over a twenty-year period under a range of climate change scenarios. It then uses cost-benefit analysis to evaluate adaptation options to the expected risks.

245. The approach was tested in eight local/regional (sub-national) case studies in China (drought and agriculture in North and North-eastern China), Guyana (flood risk in Georgetown), India (drought risk and agriculture in Maharashtra), Mali (climatic zone shift and agriculture in Mopti), Samoa (sea level rise), the United Republic of Tanzania (drought on hydro power and health in the Central region,), the United Kingdom (coastal flood risk in Hull), and the United States of America (flood risk to South Florida). The assessments were built around broad metrics of economic loss, such as GDP, asset value and agricultural production.

[26] A partnership between the Global Environment Facility, McKinsey & Company, Swiss Re, the Rockefeller Foundation, ClimateWorks Foundation, the European Commission, and Standard Chartered Bank.

246. The study found that significant economic value was at risk. If current development trends continue to 2030, the locations studied were estimated to lose between 1 and 12 percent of GDP as a result of existing climate patterns. With climate change, this was estimated to increase, with a scenario of high climate change increasing current losses by up to 200 percent by 2030. It also found that adaptation was potentially very effective in reducing potential losses, and that, in principle, portfolios of measures could efficiently reduce between 40 and 68 percent of the loss expected to 2030 (i.e. such that economic benefits outweighed costs).

4. Climate Proofing: A Risk-based Approach to Adaptation

247. This ADB project undertook six case studies in the Cook Islands and the Federated States of Micronesia to investigate adaptation to current and future climate risks (ADB, 2005). It adopted a risk-based approach to adaptation, considering national development planning, sector programmes and project activities. The approach combines the likelihood and consequence components of climate-related impacts and can assess risks for both current and anticipated conditions, with the option of examining either specific events or an integration of those events over time. This risk-based approach also facilitates an objective and more quantitative approach, including cost-benefit analyses that result in the evaluation of the incremental costs and benefits of adaptation and assists in prioritizing adaptation options. The focus was to demonstrate how and why reducing climate-related risks is an integral part of sustainable development.

248. The analysis considered increasing resilience (climate proofing) for a coastal community in Pohnpei; a road infrastructure project in Kosrae; infrastructure, human health and environment components of the Federated States of Micronesia National Strategic Development Plan; the design of the breakwater for the newly developed Western Basin in Rarotonga, a community inland from Avatiu Harbour; and the Cook Islands National Development Strategy.

249. The study found that, for infrastructure projects, it is possible to avoid most of the costs of damages attributable to climate change, and that, if the actions are considered during the design stage of the project, it is possible to do this cost-effectively. Implementation of specific risk-reduction measures at project and local levels can be facilitated if land-use planning and associated regulations and permit procedures for structure, infrastructure and community development projects incorporate requirements that are designed to reduce risks related to current and future climate extremes and variations.

5. Thames Estuary 2100

250. The TE2100 project[27] has developed a tidal flood risk management plan for London and the Thames estuary which was developed in order to determine the appropriate level of flood protection (adaptation) needed for the next 100 years in view of a changing climate and the varying socio-economic scenarios. It considered a wide range of options, including the construction of a new downstream Thames Barrier. The remarkable element of this project is the consideration of uncertainty, flexibility and adaptive management, which is demonstrated though the use of both pipeline/portfolio analysis and real-option analysis.

251. A key feature has been the view that options for managing flood risk over the next hundred years are strongly governed by the impact that future climate change and sea-level rise will have in the future and on the current uncertainty over how great these impacts might be. A number of future scenarios were adopted based upon varying emission trends over the next 100 years. Adaptation options were developed, even for severe climate change.

[27] <http://www.environment-agency.gov.uk/homeandleisure/floods/104695.aspx>.

252. An adaptation methodology was also developed to help decision makers decide when they needed to make decisions, and what decisions to make. This works through the identification of thresholds when action is needed and best estimates of the dates when thresholds will be reached. The options were designed to implement the incremental changes that apply to all scenarios first, leaving major irreversible decisions for as far as possible into the future, in order to make best use of the information available. The project includes a monitoring and evaluation strategy. If monitoring reveals that climate change is happening more quickly (or slowly) than predicted, the implications for decision points are established. The strategy can then be reappraised in light of the new information, and options can be brought forward (or put back).

253. The study also included real-option analysis, which provides an economic framework to incorporate the uncertainty of climate change and the value of flexibility into decision making. For example, designing an activity with the flexibility to upgrade in the future provides an option to deal with more (or less) severe climate change. The approach therefore recognizes that information about uncertainty will change over time (e.g. from learning or research) and can alter future decisions (whilst not detracting from performance). The study conducted a cost-benefit analysis of all the options. Multi-criteria analysis was also used to articulate a comprehensive range of impacts for inclusion in the analysis, allowing indirect and ancillary impacts to be included in the decision-making process.

6. Synthesis of sub-national and local case studies

254. The sub-national and local case studies provide a more detailed analysis of the costs and benefits of adaptation. The case studies also demonstrate that it is easier to address the methodological challenges identified in Chapter 3 at this spatial scale, at least in relation to specific issues. For example:

(a) The consideration of soft adaptation is easier at this scale, as demonstrated in the CLIMB study. This study also showed the potential benefits of these approaches as being more effective and efficient;

(b) The consideration of development as opposed to adaptation, and of current as opposed to future risks, is easier, which also makes it easier to build ancillary effects into the analysis, as demonstrated by the Berg river study;

(c) The analysis of major long-term risks, uncertainty and flexibility can be built into adaptation responses, as with major flood risk for London TE2100. This also highlights the need for alternative approaches to capture these effects in economic analysis with portfolio/pathway analysis and the consideration of real options.

255. There are three particularly relevant findings/recommendations from this brief review, at least in the context of the main study focus at national level:

(a) One way to improve national-level assessments would be to undertake local case studies alongside (or as part of) any national-level analysis, in order to capture these specific issues. This might, for example, include a focus on particularly vulnerable areas that are likely to have high distributional effects, or to investigate uncertainty and flexibility for major infrastructure (e.g. major cities);

(b) It would be useful to undertake a wider review of local studies and assess them more explicitly against all the methodological issues raised in Chapter 2. A wider review of local case studies, particularly focusing on different approaches, would be useful to test the finding above (that these methodological issues can best be addressed at the local spatial scale) for uncertainty, economic efficiency and equity. There is also a need for a

greater number of such studies to be performed, in order to investigate how potential applications vary with location and local issues;

(c) It would be useful to investigate whether it is possible to apply the methods and lessons from these local studies, or elements of thereof, to national-level assessments.

E. Discussion and conclusions

256. This chapter has reviewed the information on the costs and benefits of adaptation at different aggregation levels. It has considered the approaches and methods used in a number of global, national and local case studies, their application and outputs and commented on their strengths and weaknesses. A number of the studies reviewed are ongoing and only methodological aspects related to these could be presented.

257. At the global level, the study has found a wide range of studies, which work with different frameworks and metrics. Many of these are not associated with an explicit economic framework, and those that do are highly theoretical in nature. However, some studies provide directly comparable estimates of the costs of adaptation.

258. These global studies have been compared in terms of uncertainty, economic valuation and equity. At this level, the consideration of uncertainty is limited. While later studies have started to recognize and partially account for this, the implications of uncertainty on the costs and benefits of adaptation are not yet included in analysis. Similarly, the global studies only partially cover the issues raised in terms of economic valuation and efficiency. There are still major gaps in the following areas: non-monetary benefits; mitigation and adaptation linkages; cross-sectoral and wider economic effects; and the limits of adaptation. Furthermore, they are focused on hard adaptation. Finally, the studies have been evaluated in terms of their consideration of equity. It is extremely difficult to consider local vulnerability and distributional effects at the global level. None of the studies have considered such effects in their quantitative analysis or in their prioritization of adaptation, although they all recognize that distributional effects could be a concern.

259. At the national level, a growing number of studies have been identified. However, the results of a large number of studies are expected over the next six months. A key recommendation is that this review should be repeated in the near future, once this wider evidence base is available, and that the new review should compare and aggregate the national-level studies against the global estimates to investigate the validity of these global estimates.

260. The national studies have also been discussed in relation to uncertainty, economic valuation and equity. This review has found that the consideration of uncertainty is still limited. Some studies have moved to a more explicit consideration of uncertainty, but many others still work with single projections of climate and socio-economic development. Moreover, there remains little explicit consideration of the issues associated with reversibility, flexibility and adaptive management; many studies now recognize that these are issues, but have not found a way to account for this in quantitative assessment.

261. The national studies fare better when discussed in terms of economic valuation and efficiency. There is a growing focus on non-monetary aspects, although there is still limited focus on ecosystems and associated services. There is also a greater consideration of mitigation and adaptation, though the consideration of explicit linkages is limited to one or two studies and mainly to one or two sectors. The national studies also focus more on soft adaptation, at least when considering various options. There are also examples of wider economic assessments through the use of CGE models. However, the analysis of cross-sectoral linkages, private adaptation, ancillary effects and the limits of adaptation are generally still omitted from these assessments.

262. The national studies have been evaluated in terms of their consideration of equity. Even at this aggregation level, the consideration of equity and distributional effects is difficult and none of the studies address this issue comprehensively. While many studies identify the issue, the focus on economics has tended to shift the analysis away from equity considerations, in contrast to (non-economic) vulnerability and adaptation assessments. This remains a key issue to address in future analysis.

263. The final areas of investigation have been at the local and sub-national level. Only a small selection of case studies has been included here. These case studies demonstrate that it is easier to address the methodological challenges at this spatial scale. A number of recommendations are made following this local review. First, one way to improve national-level assessments would be to undertake local case studies alongside (or as part of) national-level analysis, in order to capture these specific issues. Second, it would be useful to undertake a wider review of local studies and assess them more explicitly in terms of the methodological issues raised in Chapter 3. Third, there is a need for a greater number of such studies to be undertaken, in order to investigate how potential applications vary with location and local issues. It would be useful to investigate whether it is possible to take the methods and lessons from these local studies and apply them to national-level assessments.

V. Discussion, conclusions and future priorities

264. This report has outlined the methodological challenges (Chapter 3) with the costs and benefits of adaptation. It has also discussed these issues in relation to a selection of recent studies (Chapter 4). This discussion has highlighted the existence of important evidence gaps and that there is considerable scope for improving the economic assessment of adaptation. This chapter presents a summary of the methods used, drawing on the national studies, and discusses the key challenges that remain. It also outlines selection of future priorities, primarily in the context of national-level assessment.

A. Overview of approaches and methods

265. The case studies reveal a wide range of approaches towards the costs and benefits of adaptation, though, in all cases, there remains only a modest coverage against an economic framework. At the global level, many of the available studies are associated with different frameworks and metrics. The I&FF studies do not work with an explicit economic framework and they do not consider the benefits of adaptation or residual damages. Similarly, the World Bank EACC study removes the need to consider benefits or residual damages by assuming adaptation returns welfare back to pre-climate levels. The IAM studies do have a strong economic focus, but they are highly aggregated, and the consideration of adaptation is therefore theoretical.

266. The national studies have also not fully followed the economic framework. Most studies assess some adaptation costs; however, the economic benefits of adaptation are rarely considered, outside of one or two sectors (notably coastal zones) and are rarely compared directly to costs. This partly reflects the lack of available data and information on benefits. A wider range of methods has been adopted at the national scale. This includes IAM models and national-level I&FF methods, as used at the global scale, but also the use of CGE models and sectoral impact assessment (scenario) modelling. All of these have strengths and weaknesses. There are also examples of consideration of costs and benefits (at least at a national level), cost-effectiveness, risk management and multi-criteria analysis. It is noted that the focus on economics in the national studies has led to consideration of methods that more easily align to, or are extensions of, existing economic assessments. The study has not found national-level examples of vulnerability or adaptation assessments that have a strong economic component.

267. The focus of vulnerability assessments on current variability and the place it holds within the local- and national-level decision-making processes suggests that this aspect needs to considered in future economic studies. Similarly, adaptation assessments adopt a different approach to the national

scenario-based climate change impact assessment approaches often considered above (which consider risks and existing adaptation options, and then treat adaptation as an output). In contrast, adaptation assessments consider risks over a range of policy and planning horizons for specific activities and regions. They often focus on risk management by examining adaptive capacity and the adaptation measures required to improve the resilience or robustness of a system exposed to climate change.

268. When local studies are included, a much wider range of methods are involved, including more explicit cost-benefit analysis, cost-effectiveness and risk management analysis, as well as portfolio analysis. In assessing how these existing studies might aid future assessments, it is useful to consider the strengths and weaknesses of the approaches and studies. To do this, it is necessary to consider two elements. First, the type of adaptation that one is trying to assess and, second, the objectives of the study.

269. When considering the type of adaptation, it is important to emphasize that different adaptation options have different characteristics, which facilitate analysis through different approaches. For example, assuming that early adaptation priorities could include the need to build adaptive capacity, the implementation of no-regret measures and the investigation and management of longer-term issues, there is a number of different approaches/tools that will be suited to assessing each of these elements. As an example, while cost-benefit analysis may be applicable for some no-regret options, it will be less suited to the analysis of adaptive capacity. Table 12 below (adapted from Hunt and Watkiss, 2009) explores these issues and maps the strengths of different approaches (from Carter et al, 2007) for these the different adaptation types.

Table 12. Indicative mapping of the suitability of methods for assessing different adaptation priorities in an economic context

	Adaptation type		
Options for assessing adaptation	**Adaptive capacity**	**No regrets**	**Longer-term priorities**
Formal cost-benefit analysis	✓	✓✓	✓✓
Non-formalized cost-benefit analysis	✓✓	✓✓✓	✓✓
Cost-effectiveness analysis	✓	✓	✓✓✓
Multi-criteria analysis	✓✓	✓✓	
Portfolio theory	✓	✓	✓✓✓
Pathway analysis			✓✓✓
Adaptive capacity assessment	✓✓✓		
Risk management methods		✓✓	✓✓✓
Scenario-based approaches		✓	✓✓
Technological assessments		✓	✓✓
Normative policy assessments	✓	✓	✓
Identifying learning in individuals/organisations	✓✓	✓	✓
Participatory techniques	✓✓	✓	✓
Social learning	✓✓	✓	✓

Source: Adapted from Hunt and Watkiss. 2009. A greater number of ticks represents a potentially greater suitability.

270. An over-reliance on one approach is likely to provide partial (and misleading) information. The authors conclude that it is necessary to use a combination of approaches to develop adaptation in an economic context.

271. For the second point (the objectives of the study), the most applicable methods and tools will depend on a country's position in the adaptation policy cycle. For most countries, national adaptation

studies are at an early stage and the focus is on information gathering and raising awareness, as a precursor to embarking on adaptation. Most of the national studies considered in Chapter 4 are at this stage. The methods used across the national studies all provide valuable information for raising awareness and identifying issues. In contrast, some countries are more advanced in the adaptation policy cycle and have already completed this phase. They already have a good level of awareness and knowledge base and, in many cases, are starting to implement some adaptation measures and policies at a range of aggregation levels. In such cases, a different type of national study and information is needed, which focuses on the incorporation of adaptation in national policy, the allocation resources so as to allow efficient, effective and equitable response strategies and on national planning and prioritization within a context of multi-level governance. In this case, some of the methods used in the existing national studies are less useful. The focus is on more immediate priorities and on greater levels of detail.

272. The strengths and weaknesses of the various approaches for assessing adaptation costs and benefits are considered in table 13 below. This includes a variety of approaches, decision methods and tools. Each has strengths and weaknesses and may be more or less suited to different types of studies. For example, global aggregated models are useful for framing the indicative costs of adaptation, but cannot provide information that is of practical use in national adaptation strategies. However, no individual approach can, on its own, adequately address all of the methodological aspects identified in this paper.

273. This leads to two key points. First, the study objectives and the position in the policy cycle will determine the most appropriate approaches and methods to use. Second, for the analysis of the costs and benefits of adaptation, there are potential benefits in adopting multiple methods and models and then linking these together to provide a greater evidence base. Indeed, it is almost impossible to see how one single approach can capture all of the complex methodological issues raised.

274. Two other issues raised in this paper are coverage and geographical scale. While the sectoral coverage of studies is improving, it is still partial. The consideration of non-market sectors is discussed later. However, gaps still remain for some market sectors in most studies, whether at a global (as identified in Parry et al, 2009) or a national level. Similarly the coverage of the effects of climate change (and adaptation) also remains partial and although most studies now consider the effects of extreme events, they still focus on a limited number of climatic parameters overall.

275. While adaptation is local in nature and local agents are critical for the implementation of adaptation, there is still a need for a coherent national policy that sets a framework, which filters down to the local level (as with any national and sectoral policy) in a way that enables appropriate local-scale action. Very few of the studies have addressed these multi-level aspects and governance issues, and this is a major challenge. Moreover, in order to address adaptation, a principal requirement should be that output can be used in a disaggregated way for the appropriate geographical scale. Some national assessments have used a local case study approach to gain insight into some local considerations, which is a reasonable start, although greater investigation of this issue is warranted.

B. Key methodological challenges

276. This paper has discussed the methodological issues in relation to a selection of recent studies. In summary, while individual studies cover most methodological aspects, no individual study extends beyond a few areas. This highlights the need for wider methodological analysis to properly address the costs and benefits of adaptation. A discussion by key theme is summarized below.

Table 13. Indicative assessment of the range of approaches and methods for costs and benefits of adaptation options

Approach	Description/outputs	Examples	Advantages (able to provide/capture or suitable for)	Issues (unable to provide/capture or unsuitable for)
Economic Integrated Assessment Models	Aggregated economic models. Full economic framework.	– Global studies (e.g. Hope et al, 2009); – Regional or country studies (e.g. ADB South-East Asia RECC).	– Headline values for raising awareness; – Wide range of outputs; – Cost and benefit values as well as benefit to cost ratio for a specific future year; – Some theoretical global level analysis of trade-offs with mitigation; – Long-term into the future (e.g. beyond 2100).	– Impacts and adaptation in any realistic form; – Vulnerability to climate variability; – Short term analysis; – Uncertainty or equity; – Detailed national planning.
Investment and Financial Flows (I&FF)	Costs of adaptation, estimated as change in investments with climate change against future baseline.	– Global studies (e.g. UNFCCC, 2007); – National Studies (e.g. UNDP I&FF).	– Estimates of costs of adaptation in immediate policy time-scale around current and future baseline; – Rigorous and robust analysis of costs; – Application, even without detailed analysis of climate change.	– Direct linkage with climate change or adaptation; – Future climate conditions, benefits of adaptation or residual damages; – Sufficient treatment of uncertainty or equity; – Economic valuation.
Computable General Equilibrium models (GCE)	Wider economic analysis. Range of outputs including macro-economic.	– National level (e.g. Brazil RECC).	– Cross-sectoral linkages and existing socio-economic conditions; – Global trade effects; – Analysis of wider effects on economy.	– Non-market effects; – Sufficient treatment of uncertainty or equity; – Detailed national planning.
Impact assessment (scenario based assessment)	Impacts of climate, costs of adaptation and sometimes benefits, often with sectoral models. Provides physical effects and economic values.	– National level (e.g. Defra cross-regional, Swedish Vulnerability, East Africa RECC).	– Country and sector specific context for wide range of impacts; – Some representation of uncertainty; – I&FF, risk, cost-effectiveness analysis or cost-benefit analysis; – More relevant information for national prioritization and potential adaptation.	– Current or near-term impacts and adaptation; – Cross-sectoral, economy-wide effects; – Consistency across sectoral approaches; – Application with limited resources; – Sufficient treatment of equity.
Cost-benefit analysis	Benefits and costs of adaptation are expressed in monetary terms. Present values can be estimated and benefit: cost ratios.	– Global (IAMs); – Local (e.g. Berg river).	– Absolute justification for decision (rather than relative information); – Comparison between different aspects using a common metric (USD); – Representation to economic framework; – Consideration of some economic valuation aspects.	– Information on economic benefits of adaptation (except one or two sectors); – Sufficient treatment of methodological issues (uncertainty or equity); – Non-monetary aspects.
Portfolio analysis / real options	Optimize decisions across a portfolio rather than individually.	– Local (e.g. EA (2008) Thames Estuary 2100).	– Framework to incorporate uncertainty and the value of flexibility in adaptation decision making; – Application in conjunction with other frameworks including CEA, CBA or MCA framework.	– Near- or medium-term aspects; – Scaling up to national level; – Sufficient treatment of equity; – Sufficient exploration of many aspects of economic valuation.

Table 13 (continued)

Multi-criteria analysis	MCA allows consideration of quantitative and qualitative data together using multiple indicators (i.e. monetised and non-monetised effects).	– Netherlands ARK/ Routeplanner	– Consideration of qualitative, quantitative and economic information together, and also wider criteria (methodological issues such as ancillary, mitigation linkages, etc.) in selection of options; – Inclusion of the outcomes of CBA within a MCA, or link to other methods, e.g. portfolio analysis.	– Objective scoring and ranking; – Application with time and resource constraints; – Absolute assessment.
Vulnerability assessment	Focuses on existing socio- and economic vulnerabilities, inequalities and adaptive capacity, then considers climate change.	– No strong economic examples, though large number of vulnerability assessments produced.	– Analysis centred within existing socio-economic conditions and decision-making structures; – Distributional and equity issues; – Assessment of adaptive capacity and identification of groups least able to adapt.	– Common metrics for prioritization; – Framing in economic terms; – Treatment of economic valuation aspects.
Adaptation assessments	Consider risks over a range of policy/ planning horizons. Often focus on risk management and adaptation measures to improve the resilience of a system.	– No real economic examples; – Emerging number of adaptation assessments.	– Focus on immediate adaptation policy needs and decision making under uncertainty; – Greater consideration of the full diversity of adaptation options (including soft options) and factors determining the adaptation process itself, including adaptive capacity and the policy context for adaptation.	– Economic assessment.
Cost-effectiveness analysis	Identifies least-cost method of reaching a prescribed target or risk reduction level (can also work within available resources).	– Included within sectoral assessment of many national studies, e.g. coastal and river flood risks.	– Assessment between options, using units other than money (thus good for effects that difficult to value); – Application within the context of routine risks (e.g. health effects) as well as major risks, threshold effects and limits of adaptation.	– Absolute analysis; – Common metrics; – Multi-attribute analysis; – Easy or objective selection of thresholds or target risk levels; – Sufficient treatment of uncertainty or equity.
Risk management	Assess current risks to climate variability and extremes with projected future changes, then decision support tools to assess adaptation.	– Climate Proofing: A Risk-based Approach to Adaptation (ADB).	– Treatment of uncertainty, particularly for variability, often with probabilistic approach to likelihoods of occurrence; – Application with CBA but more commonly used with CEA, notably in relation to extremes, major risks and limits of adaptation.	– Application with limited resources.

Abbreviations: ARK = Dutch National Programme for Spatial Adaptation to Climate Change (Nationaal Programma Adaptatie Ruimte en Klimaat), CBA = Cost Benefit Analysis, CGE = computable general equilibrium, IAM = Integrated Assessment Models, I&FF = Investment and Financial Flow analysis, MCA = Multi-criteria analyis, NAPAs = national adaptation programmes of action, RECC = Regional economics of climate change, UNDP = United Nations Development Programme

1. Uncertainty

277. Chapter 3 highlights the high uncertainty involved in climate change. The recognition of this raises complex challenges and causes a shift in thinking away from adaptation to future central projections to a framework of decision-making in relation to uncertainty. This is recognized in most adaptation assessments, but still not fully recognized in economic analysis. Key uncertainty challenges are highlighted below

278. Baselines: The methodological review in chapter 3 outlines that one of the most difficult and most important aspects of the estimation of the costs of adaptation is the definition of the baseline. It highlights the potential use of multiple baselines when estimating the costs of adaptation and evaluating adaptation policy. The review of national studies in Chapter 4 reports that the majority of national studies use with a future baseline that includes socio-economic growth. However, very few consider multiple baselines or undertake even basic sensitivity analysis for key parameters or assumptions. This remains an important challenge for future studies. Although introducing uncertainty into baselines will increase the analytical complexity, some basic sensitivity analysis would be good practice in future studies. A more complex baseline issue arises over future vulnerability and adaptive capacity; for example, the baseline for the future burden of disease (in the absence of climate change) should allow for improvements in the health conditions of the population over time, thus changing the level of vulnerability (including adaptive capacity). A limited number of the studies take these effects into account. The studies also give little consideration to how autonomous adaptation might change future baselines. A final baseline issue arises from the need to distinguish between development and adaptation, across the current and future climate. The studies adopt different approaches for this, leading to different results. This is likely to be a key aspect for future funding and requires further analysis.

279. Climate projections: Another key uncertainty highlighted in the methodological review relates to climate projections. The projections of future temperature vary widely between models for a single future socio-economic scenario. The projections for precipitation change can often vary widely, with some models showing increases and some decreases for a given location. Some national studies still ignore this uncertainty and use a single future projection for each given socio-economic scenario. However, recent studies have addressed this issue by sampling across the range of projections or analysing the range of model outputs. This increases the analysis needed and leads to more complex outputs, but it is a more robust approach. Some challenges remain, notably the need to include this consideration of uncertainty in studies (such as I&FF studies) which focus on the costs of adaptation.

280. Other aspects of uncertainty, particularly the benefits of adaptation: In addition to the uncertainty related to baselines and projections, additional uncertainty is introduced when assessing the potential impacts and economic costs of climate change or the potential benefits of adaptation. This wider uncertainty is rarely captured in the studies, with only a few examples where alternative impact relationships are used (mostly for agriculture). A particular problem is that it is very difficult to validate the functional form of adaptation benefits: there is usually no ex post data and information from current extremes or analogues (from other regions) can only be considered to be estimates. Another issue relates to the high levels of transferability (geographical or aggregation level) in most studies, in relation to impact and adaptation functions. Greater focus and research is needed in this area, as well as more realistic bounded estimates of the range of climate effects and adaptation outcomes.

281. Reversibility, flexibility and adaptive management: Chapter 3 outlines the need to design some adaptation measures that can be modified in the light of new information in the future. It highlights the concepts of reversibility and flexibility, particularly for adaptation responses that have longer-term considerations. The case study review shows that many studies now recognize this. The local case study of the London TE2100 project demonstrates a methodological approach (portfolio analysis and real

options) to consider such issues. However, there many challenges remain for such approaches at the national scale. A qualitative example is the scoring criteria used in multi-criteria analysis in the Netherlands ARK/Routeplanner study, which assessed options on the basis of their no-regret characteristics. Other similar frameworks (e.g. Hallegatte, 2009) have suggested criteria for the reversibility of an option. This remains a key area of future focus in national-level assessments.

2. Economic valuation

282. This paper outlines the numerous economic valuation challenges related to adaptation. It is clear that many require further study.

283. Time horizon and discount rates: The methodological review outlines the issue of discount rates, noting that there is no consensus in this area. Many of the national studies avoid this issue by reporting estimates as a percentage of GDP or by only reporting costs or benefits in current prices for a future year. In cases where discounting is used to estimate present values, different rates are used. However, many studies now report across a range of discount rates, to investigate how this affects the results. This avoids the potential issues with a single rate and is considered good practice. The studies also consider a wide range of time horizons, with some studies extending to 2030 and others to 2100. This raises the question of whether it is better to focus on the short or the long term. A focus on the immediate time horizon will be more relevant for policy and can consider current vulnerability. In many ways the use of an immediate time horizon is more appropriate for the adaptation process. However, the artificial truncation of climate effects in the near term will omit the consideration of reversibility and flexibility outlined above and can lead to maladaptation as future options are removed (e.g. only considering sea-level rise to 2030 will miss the key aspects in infrastructure lifetimes and emphasizes the need for flexibility). In practice, the best approach is to take account of both time frames, through an integrated and linked assessment. This can focus on immediate priorities for capacity-building and no-regret options for the short-term, but also allow consideration of the potential issues that have longer-term consequences.

284. Non-monetary costs and benefits: The methodological review reports that not all impacts can be valued in monetary terms and that the valuation of some impacts in this way is not widely accepted. However, it also demonstrates that it is still possible to consider these non-monetary aspects as part of sectoral assessment. A comparison of the national studies shows that the focus remains on market sectors, with the only non-market sector that is widely covered being health. Other than agriculture, forestry and fisheries (provisioning services), there is rarely any analysis of biodiversity and ecosystem services, even in quantitative terms, though these are extremely important in the economies of many developed countries.

285. Adaptation and mitigation linkages: The methodological review in Chapter 3 identifies the inter-relationships between adaptation and mitigation. It also identifies some linkages between the two that may be worth noting and possibly addressing. While many of the studies reviewed consider adaptation and mitigation as part of a single study, almost none look at the linkages between the two. There are only examples in the energy sector (e.g. the effects of climate change on hydro generation for supply and demand of air conditioning in East Africa and effects on hydroelectricity generation in Brazil). This is an area that is likely to become a larger issue in future years and is recommended as an area of specific consideration.

286. Cross-sectoral linkages: The methodological review notes the need to account for indirect and cross-sectoral linkages in designing adaptation and maps out a selection of cross-sectoral effects in a matrix. A discussion of this matrix in relation to the studies shows an extremely low coverage. The lack of cross-sectoral effects partly arises because national studies are oriented by sector, for example agriculture or health. Maintaining this focus is necessary given it guides Government policy and

encourages the development of adaptation methods, as well as reflecting the underlying literature. However, this does not foster cross-sectoral analysis. As a minimum, the mapping of indirect and cross-sectoral effects is good practice. An additional way to encourage this is to add horizontal themes alongside any sectoral grouping, for example by considering end-users (e.g. household), cross-sectoral themes such as land-use, or considering geographical areas. It is also possible to analyse these indirect and cross-sectoral effects (e.g. with integrated assessment, as well as CGEs).

287. Economy wide impacts: The methodological review emphasizes that adaptation decisions have to be embedded in a framework that potentially accounts for economy-wide impacts. The national studies show an example of such an analysis in the use of CGE models in the Brazil RECC. These capture information that is not included in other studies, though there is high uncertainty with the use of these models for climate change effects in the longer term.

288. Hard as opposed to soft adaptation: As the methodological review notes, there is often a tendency for studies to focus on hard engineering solutions and not to give enough consideration of the soft options, such as policies and instruments that are designed to change behaviour. This is certainly the case in the national studies reviewed, although this is not surprising. These options are the easiest to cost and are also easy to attribute to climate change. However, all studies recognize the importance of soft options, and studies such as the CLIMB assessment demonstrate that they can be more efficient. There is a need for national studies to include these softer options and particularly to include them in economic assessment. Some challenges remain, notably that soft adaptation measures often have a large overlap with development and therefore attribution can be more complex. There is also a need to include adaptive capacity in assessments, which enable social and institutional learning, and are a necessary pre-cursor step to delivering successful adaptation outcomes. In economic terms, more work is needed to demonstrate the economic benefits of enhanced adaptive capacity, for example through research into the value of information and organizational economics.

289. Ancillary effects: The methodological review outlines that adaptation often has benefits beyond a reduction of residual damages of climate change, whether reducing vulnerability with respect to current climate variability or providing other ancillary benefits. As Chapter 4 shows, with the exception of local studies (e.g. the Berg river) and the scoring of ancillary benefits of adaptation options in the Netherlands ARK/Routeplanner multi-criteria analysis, there are no examples in the adaption assessments studied where ancillary effects are considered. While these effects are likely to be more relevant as adaptation moves down to the sectoral and project level, their omission is important. The consideration of ancillary effects remains a key methodological challenge and will be particularly important as adaptation is incorporated into sectoral policy.

290. Public as opposed to private: The methodological review notes that adaptation measures are taken by both the public and private sectors. The national studies do not include private adaptation, outside of a few areas such, such as agriculture. It is important to know how much private adaptation will take place and to design public adaptation measures in such a way that the combination of the two is effective. This is highlighted as an important consideration for future studies.

291. Limits of adaptation: The methodological review discusses the potential limits to adaptation. Outside of the theoretical consideration in the economic IAMs, this is not an area that has been covered in any detail in the national-level assessments.

3. Equity

292. The methodological review outlines the problems related to distributional impacts and equity. It also notes a number of ways that these issues can be addressed. The first possible approach, of giving weights to different costs and benefits, is captured at a very aggregated level in some IAM assessments, although there are no examples of such approaches been using in the national studies reviewed in this

paper. The second approach, of presenting the distributional impacts of the measures alongside costs and benefits, is potentially easier to include in analysis. However, while the national studies reviewed in Chapter 4 recognize the distributional effects of impacts and adaptation, this recognition is not reflected in the assessments. As noted earlier, the focus on economics has tended to shift the analysis away from equity considerations, in contrast to non-economic vulnerability and adaptation assessments. This remains a key issue to address in future analyses.

C. Future priorities

293. The previous sections outline the key issues related to the assessment of the costs and benefits of adaptation. It is clear that our knowledge is still evolving and there are a number of research priorities that need to be investigated. However, this does not detract from the need for national-level assessments to start shift to a more explicit consideration and analysis of the costs and benefits of adaptation, whether through formal or semi-formal economic analysis.

294. The global studies to date have all been rapid estimates. They are therefore incomplete and preliminary, although they have been useful in providing initial information on adaptation, especially in the absence of detailed disaggregated analysis. A clear priority is to shift to a more comprehensive analysis, taking into account the results of current national-level studies.

295. A broader set of national studies is underway. At the time of writing (late 2009), there is still a relatively small information base on the economic costs and benefits of adaptation, and much of this is still concentrated on a few sectors (notably coastal zone and agriculture), but the evidence will increase dramatically over the next year. These various national studies adopt different frameworks and produce different outputs and their results will often not be comparable. However, they will provide a significant increase in knowledge.

296. In light of these findings, the paper has identified a number of future priorities for consideration:

(a) The national-level review undertaken for this technical paper should be repeated in the near future, once all the studies from the current programmes have been published. The combined coverage of the UNFCCC NEEDS, the UNDP I&FF, the RECC and the World Bank EACC studies will include over 50 countries across all continents. Together these will provide the evidence base for a thorough review and evaluation. Furthermore, it would be extremely useful to aggregate and compare the adaptation costs from these studies with the global estimates (elaborated in section IV.B above) to test the latter's validity;

(b) It would be useful to perform broader review of local studies and assess them more thoroughly in relation to the methodological issues highlighted in this paper, especially since these local studies are often the most appropriate spatial scale for adaptation and are better able to address specific methodological challenges. It is also highlighted that there is a need for a more studies to be performed in order to investigate how potential applications vary with location. Finally, it would be useful to investigate whether it is possible to take the methods and lessons from these local studies and apply them to national-level assessments;

(c) Further work is needed on the methodological framing of economic studies of adaptation, particularly as the focus moves from raising awareness to practical adaptation policy. A key element is for the economics studies to incorporate the positive elements of vulnerability assessment, adaptation assessments, and distributional aspects and to develop a more complete adaptation policy focus;

(d) Finally, while individual studies cover most methodological aspects, no individual study extends beyond a few areas. This highlights the need for further work on all the methodological issues discussed in this paper. There is also a need for more practical studies to build the evidence base and to provide good practice examples.

Annex I

List of references

Ackerman F, DeCanio SJ, Howarth RB and Sheeran K. 2009. Limitations of integrated assessment models of climate change. *Climatic Change*. 95(3–4): pp.297–315.

Adger WN, Agrawala S, Mirza MMQ, Conde C, O'Brien KL, Pulhin J, Pulwarty R, Smit B and Takahashi K. 2007. Assessment of adaptation practices, options, constraints and capacity. *In*: ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanson (eds.). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. pp.717–743.

Agrawala S (ed.). 2007. *Climate Change in the European Alps: Adapting Winter Tourism and Natural Hazards Management*. Paris: OECD publications.

Agrawala S and Fankhauser S (eds.). 2008. *Economic Aspects of Adaptation to Climate Change. Costs, Benefits and Policy Instruments*. Paris: OECD.

Agrawala S, Moehner A, El Raey M, Conway D, van Aalst M, Hagenstad M and Smith J. 2004. *Development and Climate Change in Egypt: Focus on Coastal Resources and the Nile.* COM/ENV/EPOC/DCD/DAC(2004)1/FINA. OECD.

Asian Development Bank. 2005. *Climate Proofing: A Risk-based Approach to Adaptation*. Asian Development Bank.

Asian Development Bank. 2009. *The Economics of Climate Change in Southeast Asia: A Regional Review*. Available at <http://www.adb.org/documents/books/economics-climate-change-sea/default.asp>.

Barbier EB, Markandya A and Pearce DW. 1990. Sustainable agricultural development and project appraisal. *European Review of Agricultural Economics*. 17(2): pp.181–196.

Bell ML, Hobbs BF, Elliott EM, Ellis H and Robinson Z. 2000. An evaluation of multicriteria decision-making methods in integrated assessment of climate policy. *In*: YY Haimes and RE Steuer (eds.). *Research and Practice in Multiple Criteria Decision Making*. Berlin: Springer. pp.228–237.

Bigano A, Francesco B, Roson R and Tol RSJ. 2006. *Economy-Wide Estimates of the Implications of Climate Change: A Joint Analysis for Sea Level Rise and Tourism*. FEEM Working Paper No. 135. Available at <http://ssrn.com/abstract=944480>.

Bosello F and Roberto R. 2007. *Estimating a Climate Change Damage Function through General Equilibrium Modeling*. Department of Economics, University Ca' Foscari of Venice. Research Paper No. 08-07. Available at <http://ssrn.com/abstract=1000839>.

Boyd R and Hunt A (Metroeconomica). 2004. *Costing the Impacts of Climate Change in the UK: Overview Guidelines*. UK Climate Impacts Programme Technical Report. Available at <http://www.ukcip.org.uk/images/stories/Pub_pdfs/Costings%20overview.pdf>.

Butt TA, McCarl BA and Kergna AO. 2006. Policies for reducing agricultural sector vulnerability to climate change in Mali. *Climate Policy*. 5(5): pp.583–598.

Callaway JM, Louw DB, Nkomo JC, Hellmuth ME and Sparks DA. 2007. *The Berg River Dynamic Spatial Equilibrium Model: A New Tool for Assessing the Benefits and Costs of Alternatives for Coping With Water Demand Growth, Climate Variability, and Climate Change in the Western Cape*. AIACC Working Paper No. 31. Available at <http://www.aiaccproject.org/working_papers/Working%20Papers/AIACC_WP31_Callaway.pdf>.

Carraro C, Bosello F and De Cian E. 2009. *Analysis of Adaptation as a Response to Climate Change*. Copenhagen Consensus on Climate Change. Available at <http://fixtheclimate.com/uploads/tx_templavoila/AP_Adaptation_Bosello_Carraro_De_Cian_v.3.0.pdf>.

Carter TR (ed.). 2007. *Assessing the Adaptive Capacity of the Finnish Environment and Society under a Changing Climate: FINADAPT*. Available at <http://www.ymparisto.fi/default.asp?contentid=56105&lan=en>.

Carter TR, Jones RN, Lu X, Bhadwal S, Conde C, Mearns LO, O'Neill BC, Rounsevell MDA and Zurek MB. 2007. New assessment methods and the characterisation of future conditions. *In*: ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanson (eds.). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. pp.133–171.

Cline WR. 1992. *The Economics of Global Warming*. Washington, D.C: Institute for International Economics.

Dasgupta P. 1972. A comparative analysis of the UNIDO Guidelines and the OECD Manual. *Bulletin of the Oxford Institute of Economics and Statistics*. 34(1): pp.33–51.

de Bruin K, Dellink R and Agrawala S. 2009. *Economic Aspects of Adaptation to Climate Change: Integrated Assessment Modelling of Adaptation Costs and Benefits*. OECD Environment Working Paper No. 6. Available at <http://www.olis.oecd.org/olis/2009doc.nsf/LinkTo/NT00000F3E/USDFILE/JT03261837.PDF>.

Department of the Environment, Transport and the Regions (United Kingdom). 2000. *Guidelines for Environmental Risk Assessment and Management – Revised Departmental Guidance*. London: Stationary Office Books.

Dessai S and van der Sluijs J. 2007. *Uncertainty and Climate Change Adaptation – A Scoping Study*. Available at <http://www.nusap.net/downloads/reports/ucca_scoping_study.pdf>.

Dessai S. 2005. Robust Adaptation Decisions amid Climate Change Uncertainties. PhD Thesis. Available at <http://www.uea.ac.uk/~e120782/thesis.pdf>.

Dickinson T. 2007. *The Compendium of Adaptation Models for Climate Change: First Edition*. Environment Canada. Available at <http://www.preventionweb.net/files/2287_CompendiumofAdaptationModelsforCC.pdf>.

Dore MHI and Burton I. 2001. *The Costs of Adaptation to Climate Change in Canada: A Stratified Estimate by Sectors and Regions—Social Infrastructure*. Final report submitted to the Climate Change Impacts and Adaptation Program, Natural Resources Canada. Available at <http://adaptation.nrcan.gc.ca/projdb/pdf/79a_e.pdf>.

Downing T, Anthoff D, Butterfield R, Ceronsky M, Grubb M, Guo J, Hepburn C, Hope C, Hunt A, Li A, Markandya A, Moss S, Nyong A, Tol RSJ and Watkiss P. 2005. *Social Cost of Carbon: A Closer Look at Uncertainty*. Available at <http://www.decc.gov.uk/media/viewfile.ashx?filepath=what we do/a low carbon uk/carbon valuation/social_cost/sei-scc-report.pdf&filetype=4>.

Ebi KL, Teisberg TJ, Kalkstein LS, Robinson L and Weiher RF. 2004. Heat watch/warning systems save lives: estimated cost and benefits for Philadelphia 1995-98. *Bulletin of the American Meteorological Society*. 85(8): pp.1067–1073.

Economics of Climate Adaptation Working Group. 2009. *Shaping Climate-Resilient Development: A Framework for Decision-Making Study*. Available at <http://www.rockfound.org/initiatives/climate/shaping_climate%20res_dev.pdf>.

European Environment Agency. 2007. *Climate Change: the Cost of Inaction and the Cost of Adaptation.* Technical Report. Available at <http://reports.eea.europa.eu/technical_report_2007_13/en>.

Evans EP, Ashley RM, Hall J, Penning-Rowsell EC, Saul AJ, Sayers P, Thorne CR and Watkinson AR. 2004. *Foresight. Future Flooding. Scientific Summary: Volume I Future Risks and Their Drivers*. Office of Science and Technology, London. Available at <http://www.foresight.gov.uk/OurWork/CompletedProjects/Flood/Docs/Volume1/ContentsVol1.asp>.

Evans EP, Simm JD, Thorne CR, Arnell NW, Ashley RM, Hess TM, Lane SN et al. 2008. *An Update of the Foresight Future Flooding 2004 Qualitative Risk Analysis*. Cabinet Office, London. Available at <http://archive.cabinetoffice.gov.uk/pittreview/_/media/assets/www.cabinetoffice.gov.uk/flooding_review/evidence/foresight_report%20pdf.pdf>.

Fankhauser S. 1998. *The Cost of Adapting to Climate Change*. Working Paper No. 16, Global Environment Facility, Washington, DC.

Fankhauser S. 2006. *The Economics of Adaptation*. Supporting Research commissioned as part of the Stern Review. Available at <http://www.hm-treasury.gov.uk/media/5/B/stern_review_supporting_technical_material_sam_fankhauser_231006.pdf>.

Fischer G, Shah M, Tubiello FN and van Velhuizen H. 2005. Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080. *Philosophical Transactions of the Royal Society B*. 360: pp.2067–2083.

Füssel HM and Klein RJT. 2006. Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change*. 75(3): pp.301–329.

Galindo LM (ed). 2009. *The Economics of Climate Change in Mexico*. English Synopsis. Available at <http://www.semarnat.gob.mx/queessemarnat/politica_ambiental/cambioclimatico/Documents/Economics%20of%20climate%20change%20in%20Mexico.pdf>.

Garnaut R. 2008. *The Garnaut Climate Change Review*. Available at <http://www.garnautreview.org.au/CA25734E0016A131/pages/draft-report>.

Golub AA and Markandya A. 2009. *Modeling Environment-Improving Technological Innovations under Uncertainty*. New York NY: Routledge.

Groves DG and Lempert RJ. 2007. A new analytic method for finding policy-relevant scenarios. *Global Environmental Change*. 17(1): pp.73–85.

Hallegatte S. 2009. Strategies to adapt to an uncertain climate change. *Global Environmental Change*. 19(2): pp.240–247.

Hope C. 2006. The marginal impact of CO_2 from PAGE 2002: an integrated assessment model incorporating the IPCC's five reasons for concern. *Integrated Assessment*. 6(1): pp.19–56.

Hope C. 2009. The costs and benefits of adaptation. *In*: ML Parry, N Arnell, P Berry, D Dodman, S Fankhauser, C Hope, S Kovats, N Nicholls, D Satterthwaite, R Tiffin and T Wheeler. *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*. London: International Institute for Environment and Development and Grantham Institute for Climate Change. pp 100–111.

Horrocks L, Mayhew J, Hunt A, Downing T, Butterfield R and Watkiss P. 2005. *Objective Setting for Climate Change Adaptation Policy*. Available at <http://www.ukcip.org.uk/images/stories/Tools_pdfs/Objective_setting.pdf>.

Hunt A and Watkiss P. 2009. Identification and analysis of options. *In:* P Watkiss, H Hunt and L Horrocks. 2009. *Scoping Study for a National Climate Change Risk Assessment and Cost-Benefit Analysis*. Final Report. Metroeconomica, AEA group, and Paul Watkiss Associates, published by UK Defra. pp: 57–72. Available at <http://randd.defra.gov.uk/Document.aspx?Document=GA0208_7996_SCO.pdf>.

Juliá R and Duchin F. 2007. World trade as the adjustment mechanism of agriculture to climate change. *Climatic Change*. 82(3–4): pp.393–409.

Kirshen PH, Ruth M, Anderson W, Lakshmanan TR, Chapra S, Chudyk W, Edgers L, Gute D, Sanayei M and Vogel R. 2004. *Climate's long-term impacts on metro Boston (CLIMB)*. Final Report to the US EPA. Available at <http://www.publicpolicy.umd.edu/faculty/ruth/CLIMB_full_report.pdf>.

Klein RJT, Huq S, Denton F, Downing TE, Richels RG, Robinson JB and Toth FL. 2007. Inter-relationships between adaptation and mitigation. *In*: ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanson (eds.). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. pp.745–777.

Lahdelma R, Salminen P and Hokkanen J. 2000. Using multicriteria methods in environmental planning and management. *Environmental Management*. 26(6): pp.595–605.

Least Developed Countries Expert Group. 2002. *Annotated Guidelines for the Preparation of Aational Adaptation Programmes of Action*. United Nations Framework Convention on Climate Change. Available at <http://unfccc.int/files/cooperation_and_support/ldc/application/pdf/annguide.pdf>.

Least Developed Countries Expert Group. 2009. *Support needed to fully implement national adaptation programmes of action (NAPAs)*. Available at <www.unfccc.int/ldc>.

Lemmen DS,Warren FJ, Lacroix J and Bush E (eds.). 2008. From Impacts to Adaptation: Canada in a Changing Climate 2007. Government of Canada: Natural Resources Canada. Available at <http://adaptation.nrcan.gc.ca/assess/2007/toc_e.php>.

Lempert RJ and Collins MT. 2007. Managing the risk of uncertain thresholds responses: comparison of robust, optimum, and precautionary approaches. *Risk Analysis*. 27(4): pp.1009–1026.

Lempert RJ and Schlesinger ME. 2000. Robust strategies for abating climate change. *Climatic Change*. 45(3/4): pp.387–401.

Lempert RJ, Groves DG, Popper SW and Bankes SC. 2006. A general, analytic method for generating robust strategies and narrative scenarios. *Management Science*. 52(4): pp.514–528.

Lim B, Spanger-Siegfried E, Burton I, Malone E and Huq S (eds.). 2005. *Adaptation Policy Frameworks (APF) for Climate Change: Developing Strategies, Policies and Measures*. Available at <http://www.undp.org/climatechange/adapt/apf.html>.

Little IMD and Mirrlees JA. 1974. *Project Appraisal and Planning for Developing Countries*. London: Heinemann.

Lorenzoni I and Adger N. 2006. Critique of treatment of adaptation costs in Page and fund models. *In*: R Warren, C Hope, M Mastrandrea, R Tol, N Adger and I Lorenzoni. *Spotlighting the Impacts Functions in Integrated Assessment. Research Report Prepared for the Stern Review on the Economics of Climate Change.* Tyndall Centre for Climate Change Research Working Paper 91: pp.72–74.

Lu X. 2009. Applying Climate Information for Adaptation Decision-Making. National Communications Support Programme, UNDP. <http://ncsp.undp.org/docs/1005.pdf>.

Markandya A and Chiabai A. 2009. Valuing climate change impacts on human health: empirical evidence from the literature. *International Journal of Environmental Research and Public Health*. 6(2): pp.759–786.

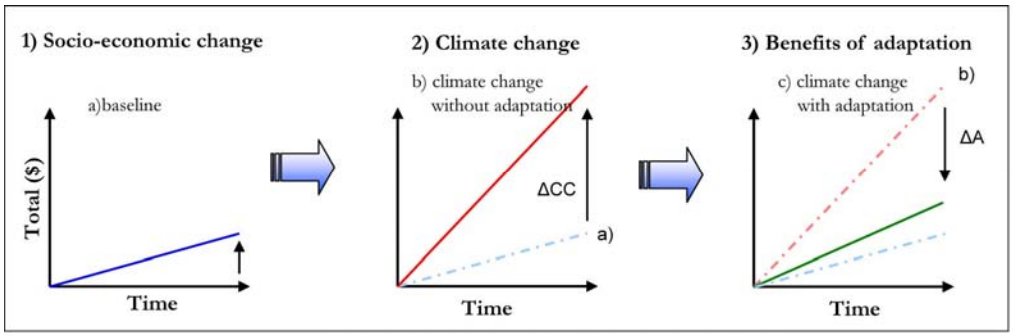
Martinez–Alier J, Munda G and O'Neill J. 1998. Weak comparability of values as a foundation for ecological economics. *Ecological Economics*. 26(3): pp.277–286.

Annex II

Stylized framework for costs and benefits of adaptation and the challenges involved

The basic definitions of costs and benefits of adaptation are often used to present a high level framework for adaptation costs and benefits, shown in the figure below.

Figure 7. Outline and steps of a stylized framework for assessing adaptation benefits



Source: Adapted from Boyd R and Hunt A. 2004. *Costing the Impacts of Climate Change in the UK: Overview Guidelines*. UK Climate Impacts Programme Technical Report.

The figure shows a simple schematic of the economic costs (vertical axis) against time (horizontal axis) and outlines three steps for assessing costs and benefits:

(a) The economic costs are first estimated for the **f**uture baseline conditions, marked as (a). This estimate is needed because future impacts are strongly influenced by socio-economic change, caused by population growth, increased wealth, land-use change, etc. Failure to account for these changes allows the assumption that climate change will take place in a world similar to that of today. It is important to note that these changes will occur even in the absence of climate change. Previous studies show that socio-economic change can be as important as climate change in determining economic costs;

(b) The additional impact of climate change (ΔCC) is added in order to show the total combined effects of socio-economic change and climate change impacts, which are marked as (b). In some cases, socio-economic and/or climate change may lead to economic benefits, not just economic costs;

(c) Adaptation reduces the impacts of these changes, as shown by line (c). The resulting reduction (ΔA) provides the economic benefits of adaptation and this can be compared with the costs of adaptation. Note that adaptation reduces impacts, but it does not remove them completely. The line (c) represents the residual damages (economic costs) after adaptation.

However, the simple framework face several problems in practice:

(a) The future baseline (a) is not a business as usual scenario based on historic data. It is a complex projection involving future development, socio-economic trends, etc.;

(b) Unlike mitigation, which has a common goal to reduce GHG emissions, there is **a** wide range of potential impacts that adaptation policy has to take into account. The impacts shown by (b) may arise from a variety of climate changes (average temperature, seasonal

changes, frequency and intensity of extreme events, etc.) acting individually or together, and varying strongly in time period and geographical location. The benefits (ΔA) will thus also differ. There are also issues when aggregating economic costs (and adaptation benefits) across effects, sectors and space and time;

(c) It is often difficult to define or attribute adaptation benefits (ΔA), because of confounding factors, the lack of ex-post data to demonstrate benefits and the difficulty in distinguishing whether an action (or how much of the action) should be classified as development as opposed to adaptation or assigned to current or future climate;

(d) Studies which focus only on the costs of adaptation omit the residual costs in c). This is often overlooked in discussions on adaptation, however both cost components, i.e. costs of adaptation options and costs residual damage, should be considered clearly;

(e) There are major spatial and temporal issues. The impact of climate change (ΔCC) requires a dynamic adaptation response, rather than a single static one. Unlike the representation in the figure, the change in costs, and the level of benefits, is unlikely to be linear. The rate of change will be significant and there will often be thresholds of effects including potential limits of adaptation.

Annex III

Additional information on assessment methodologies

A. Computable general equilibrium models

General equilibrium approaches, and CGEs, allow for linkages between all sectors of the economy. These economic modelling approaches quantitatively represent and trace through the consequences of inter-linkages between economic sectors and thus the effects from one sector on all others. They can therefore consider the entire economic system and consider how direct (first-order) effects of climate change have indirect (second-order) effects and how these in turn may exacerbate or reduce the size of first-order impacts. They can be used to study the national level in detail as well as to assess the effects on countries or regions as part of a larger global system. They are primarily used to study the economic impacts of climate change, although examples have recently been produced where they have been applied to adaptation. This has been through two approaches.

The first approach analysed the changes in absolute and relative prices from climate change impacts and the wider economic implications as a form of autonomous adaptation, in relation to adaptation of a market-based economic system. Adjustments in the size of capital stock resulting from climate impacts are included in this aspect of autonomous adaptation by Sgobbi and Carraro (2008), who modelled climate change impacts over a number of economic sectors in Italy. The second approach studies the economic impacts of forms of planned adaptation. This has mostly been applied to sea-level rise, where hard coastal defences, such as sea-walls and dykes, are recorded. Hard defences are particularly well-suited to macro-economic modelling since costs are relatively easy to identify and adaptation responses are likely to be sizeable, quantifiable and expressed through changes in market output. In such models, these adaptation costs are reported as investments in the economy; their effectiveness is determined by the degree to which they are assumed to crowd out other productive investment (Bosello et al, 2007).

The strengths of these models are that they assess wider economic effects that cannot be assessed by other approaches. However, such models lack a detailed sectoral representation and they are heavily dependent on the assumptions and calibration made, requiring knowledge of the detailed structure of the economy, a substantial data inventory and a high degree of sophistication. They do not easily capture non-market effects. A key challenge is their use for future time periods, because of the need to consider the economic linkages and factors, and they are not really applicable for longer-term assessments because of these uncertainties. Furthermore, the adaptation that can be included is limited by whether it can be expressed in market terms. Both climate change and adaptation are represented through aggregate functional forms and such models provide aggregate outputs which are not applicable for detailed or local scales.

B. Economic Integrated Assessment Models

Integrated assessment is a generic term used to describe the integration of different models, methods or sectors within a single analysis or analytical model. There are a large number of IAMs that are potentially relevant for adaptation (see Dickinson, 2007) and approximately 30 global IAMs which focus on economics (Stanton et al, 2009). However, only a few of these include adaptation and most of the cited studies on global adaptation come from the PAGE model (Hope, 2006) and the DICE/RICE/AD-RICE family of models (Nordhaus, 2008). These global models combine the scientific and economic aspects of climate change within a single, iterative analytical framework, linking economy, emissions, climate, and economic costs together with feedbacks. In order to facilitate analysis of economic costs, simplified climate projections and simplified impact relationships which link changes in climate to

economic damage at a very highly-aggregated level are used. The models have mitigation modules that allow the analysis of the costs and benefit of climate policy and even optimal policy.

Some models also have adaptation modules or functions. The PAGE model can assess the economic costs of climate change with or without adaptation. Adaptation is represented by parameterized functions, disaggregated by type of effect and region, which reduces the severity of economic costs up to a certain level of temperature change. Using this model, it is also possible to compare the benefits of adaptation with the costs (as a net present value), although it cannot optimize adaptation and mitigation. Within the AD-RICE model, it is possible to separate the damage function into adaptation costs and residual damages. While adaptation and mitigation are not modelled as substitutes, the model can use a preferred combination of mitigation and adaptation in response to climate impacts.

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