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A review of the economics of adaptation and climate-resilient development

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A Review of the Economics of Adaptation and Climate-Resilient Development*

Paul Watkiss

EXECUTIVE SUMMARY

This working paper aims to inform the development community about the current state-of-knowledge and emerging thinking on the economics of adaptation and the application to development. The paper is based on a detailed review that has considered five key themes. The key findings are summarised below.

The review has first considered the methods and frameworks for assessing adaptation. This finds that the framing of adaptation has changed in recent years - consistent with a more practical and early implementation-based focus. This has major implications for the economic analysis of adaptation. A number of key shifts have been identified. First, there has been a move towards a policy-orientated approach, in which the primary objective of the analysis is framed around adaptation ('adaptation assessment'). This involves major differences in scope and approach to the previous literature, which uses a science-first, 'impact assessment' driven method. Second, there is a greater emphasis on integrating (mainstreaming) adaptation into current policy and development, rather than implementing as a stand-alone activity. Third, there has been a shift to differentiate the phasing and timing of adaptation, with an increasing recognition of uncertainty. This has led to a framework that starts with current climate variability and then considers future climate change, considering early low-regret options and longer-term adaptation interventions respectively, along with the use of decision making under uncertainty and iterative adaptive management.

The second area of review has explored the types of adaptation interventions that are being recommended at national, sector and local level, and their potential analysis in economic appraisal. This also finds a change in recent years, which follows from the methodological shifts above. There is now a greater emphasis on capacity building, non-technical adaptation and early low-regret options. Alongside this, there is more awareness of the process of adaptation and the need to address the socio-institutional issues and barriers (market failures, governance failures, policy failures and behavioural barriers). Importantly, these lead to some challenges for the appraisal of climate resilient development, notably for analysing the costs and benefits of capacity building, technical assistance and institutional strengthening. It also requires a set of different appraisal methods to cover the different elements associated with the phasing and timing of adaptation. This includes the analysis of early low-regret options (e.g. conventional cost-benefit analysis), capacity building (non-technical options and the value of information) and future options under uncertainty (risk of lock-in versus flexibility and robustness, the value of information and option values, the benefits of risk diversification and portfolio strategies).

The third area has synthesized recent estimates of the costs and benefits of adaptation. While previous studies have reported a low evidence base in this area, the review has found two recent evidence lines (for developing countries) which have significantly increased the available knowledge. First, there have been a large number of global and regional initiatives on the economics of climate change/costs of adaptation at the national level. Second, there has been a greater focus on early adaptation responses, which often involve the application of existing options to new contexts, and for which there is existing economic information. Taken together, there is now a reasonably large literature of relevance for the costs and benefits of adaptation, with over 500 relevant papers and studies identified, though these are primarily in the grey literature. A synthesis of this evidence base has identified some key findings. First, while the information base has expanded significantly, it is concentrated in some sectors (notably coasts, agriculture and water): important gaps remain in areas such as ecosystems. Second, in line with the findings above, the methods for identifying options and assessing costs and benefits have changed, as have the options considered, especially in the most recent studies. Third, more recent implementation and policy orientated studies indicate adaptation costs will be higher than previously indicated, due to the need to consider multiple risks, uncertainty, and the additional opportunity and transaction costs associated with implementation, with the latter especially important in the developing country context.

The fourth area has investigated methodological issues with the economic appraisal of adaptation. Previous studies have identified a number of the key challenges in this area and this review has analysed the current state-of-the-art and implementation practice. This includes a review of objectives, baselines, discounting, equity, transferability and additionality. While the academic theory in many of these areas has advanced, the finding is that this has not yet transferred into common (appraisal) practice: this is due to time, resource and capacity constraints, but also because in many areas, there remains no agreed consensus on best practice. Moreover, the increasing use of mainstreaming in adaptation (indirectly) addresses many of these challenges, because it leads to a greater use of existing development and sector practice, and the methods, approaches and assumptions already in place for appraisal.

The final area of the review has focused down on one particular methodological challenge: the incorporation of uncertainty in appraisal. This is an area that has also developed significantly in recent years. As the most common techniques used in economic appraisal have limitations in coping with this challenge, a suite of new decision support tools have emerged that advance decision-making under uncertainty. This includes real option analysis, robust decision making, portfolio analysis, rule based criteria and iterative risk management. The review has assessed these approaches and analysed the existing literature for adaptation case studies, identifying around 30 examples, of which around one third are in developing countries. It has also reviewed these methods, concluding that none of them provides a single 'best' method for all adaptation. They all have strengths and weaknesses, and their suitability varies with the type of application. However, all of the new methods – at least when applied formally - are complex to use and require high resources. Whilst they have potential application for major development investments, the capacity and resources required are a barrier to their application in more routine project appraisal. As a result, a key priority is to develop more pragmatic (light-touch) versions of these methods, which can capture their core concepts while maintaining a degree of economic rigour.

Finally, a number of the key issues during the review have been identified for a more detailed analysis and the identification of good practice examples, for analysis in the next phase of the project. These include: the mainstreaming of adaptation into development planning; the appraisal of building (adaptive) capacity and distributional effects; the phasing and prioritisation of adaptation; and light-touch decision-making under uncertainty. The findings will be written up as a second working paper.

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Introduction

This working paper aims to inform the development community about the current state-of-knowledge and emerging thinking on the economics of adaptation and the application to development. The paper is based on a detailed review that has considered five key themes.

- The methods and framing for the analysis of adaptation.
- The types of adaptation applications and relevant economic support.
- Updated estimates of the costs and benefits of adaptation.
- Methodological aspects of adaptation appraisal.
- Analysis of uncertainty in adaptation appraisal.

The review was undertaken with financial support from Canada's International Development Research Centre (IDRC) through the project on the 'Economics of Adaptation and Climate-Resilient Development'[1]. It has also drawn on research work being undertaken as part of the ECONADAPT project on the economics of adaptation[2], funded by the 7th Framework Programme of the European Commission.

[1] The project is being led by the Grantham Research Institute, London School of Economics. The aims of the project are to help inform the development community about the current state-of-knowledge, and emerging thinking on the economics of adaptation and its application to development, with a focus on methodology, data, gaps and challenges, research capacity, and policy implications. The project has been split into three phases: i) an initial review phase to provide a synthesis and review of existing information on the economics of adaptation, including a state-of-the-art report (the focus of this paper); ii) an evaluation phase to assess a number of concrete adaptation projects to deepen methodological lessons for both adaptation researchers and practitioners; and iii) a research phase, which focuses at the macro-level, to undertake targeted research that can help the adaptation and development communities better understand the economic implications of specific adaptation and development choices. The views expressed in this report are entirely those of the authors and do not necessarily reflect the views of IDRC. It is highlighted that a number of the sections of this review have been included in a report published by the OECD: 'Climate Change Risks and Adaptation: Linking Policy and Economics' (OECD, 2015) to further enhance dissemination of the findings.

[2] The ECONADAPT project is funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 603906. The views expressed in this publication are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission. The European Community is not liable for any use made of this information.

I: The Framing of Adaptation (Economics)

Key findings:

- *The framing of adaptation has changed significantly in recent years, consistent with a more practical and early implementation-based focus. In turn, this is changing the economic analysis of adaptation. Three key shifts have been identified:*
- *There is a move towards more policy-orientated studies, in which the objectives are framed around adaptation ('adaptation assessment'), with an aim to inform early interventions. This involves major differences to science-first, 'impact assessment' studies.*
- *There is a greater emphasis on integrating (mainstreaming) adaptation into current policy and development, rather than as a stand-alone activity.*
- *There has been a move to consider the phasing and timing of adaptation, due to an increasing recognition of uncertainty. This has translated into the separation of current climate variability and future climate change, and respectively current, short and longer-term adaptation interventions, accompanied by the use of iterative climate risk management and decision making under uncertainty.*

This section summarises the first area of review, which has considered the overall framework for adaptation. The section starts by outlining earlier practice and synthesizes the literature on the problems with such approaches. It then reports on the key changes that have emerged in the literature over recent years in response to these challenges.

Earlier Studies

Most of the earlier literature on adaptation, especially on the economics of adaptation, used scenario-based impact assessment (I-A) (see Carter et al., 2007: UNFCCC, 2009). Such studies adopt a logical, scientific and sequential approach, starting with future socio-economic scenarios and climate model projections, then assessing future impacts and costs from climate change (so called '*impact assessment*'). The analysis of adaptation is then considered as the final step in this chain, with the potential consideration of adaptation costs and benefits, and even an analysis of the optimal response. Such an approach has been termed a science-first approach (Ranger et al, 2010: Wilby, 2012).

However, the review has found that there is a considerable literature (e.g. Füssel and Klein, 2006; UNFCCC, 2009; Ranger et al; 2010; Watkiss and Hunt, 2011) that identifies problems with this classic impact-assessment approach, especially for informing policy makers. This is because:

- The studies have insufficient consideration of immediate and short term time-scales of relevance for early adaptation,
- They do not consider wider (non-climatic) drivers and existing policy - including baseline policies and programmes of relevance to current and future climate risks;
- They focus on a narrow set of technical (engineering) adaptation responses, excluding the diversity of adaptation options;
- They ignore the factors determining the adaptation process itself, including socio-institutional policy context, actors and governance.

The conclusion from this literature is that impact-assessment driven studies – on their own - do not provide the necessary information for practical- and policy orientated adaptation, i.e. for early implementation. This is particularly a problem for adaptation mainstreaming (see below), especially in developing countries, where the focus is on the short-term, the wider non-climatic drivers usually dominate, and the policy context is critical for successful implementation.

There is also one additional and highly critical challenge for adaptation - uncertainty - which is poorly covered in existing impact-assessment studies. A considerable literature identifies this as the most important methodological challenge for adaptation (e.g. Hallegatte, 2009; Wilby and Dessai, 2010).

This climate uncertainty arises in a number of forms. First, at the current time it is not clear what future emission pathway the world is on, i.e. whether this is towards a future 2°C or a 4°C world. This makes a major difference to the level of adaptation needed. Second, even if the future emission pathway were known, there is very large additional uncertainty that arises from different climate models. The range of projected change from alternative models is as large as the scenario uncertainty, and for some climate parameters such as precipitation, the use of different models can even alter the sign of the change (i.e. whether climate change will lead to increase or decrease in rainfall, see Christensen et al, 2011).

Impact-assessment studies do not take account of this uncertainty, because they are highly stylized and focus on adaptation as a response to a defined future projection. They analyse the idealised response to an individual future climate change simulation, even if they subsequently repeat this calculation for a number of alternative simulations (one-at-a time). This predict-and-optimise approach therefore presents information on how adaptation responses might change across a range of future projections, but it does not inform the policy maker on what to do now, given this future uncertainty exists (and is often very large). As highlighted by Watkiss et al. (2014), the use of mean values (or probability weighted expected values) does not address this uncertainty, and will optimise to the centre, even when the direction of change varies across simulations: it therefore has the potential to misallocate resources by over-investing in risks that do not emerge, or implementing measures that are insufficient to cope with more extreme outcomes.

As a result of these various challenges, the framing of adaptation has moved away from the impact assessment methods – at least as the only approach for informing adaptation. The review has identified three key shifts, summarised in turn below.

Policy Orientated Approaches

Following from the discussion above, there is an observable shift in the literature on adaptation (see ECONADAPT, 2015). Policy-orientated studies now put more focus on adaptation as the objective, rather than considering it at the end of a classic science-first, impact-assessment study.

This shift, where the overall objective is considered from the perspective of informing adaptation – has been termed a 'policy-first' approach (Ranger et al., 2010). Critically, this requires a greater understanding of current drivers, non-climate policy and existing adaptation.

Alongside this there has been recognition that climate adaptation does not involve one single response (i.e. a technical solution to future climate risk). Instead there has been a greater focus on identifying types of adaptation. These adaptation responses (or problem types) are often presented as a set of building blocks or a spectrum of options (McGray, et al, 2007; Klein and Persson, 2008). These break-down adaptation activities into early activities associated with addressing current vulnerability and building adaptive capacity, then longer-term elements associated with mainstreaming climate risks, and preparing for and tackling longer-term challenges. These approaches have also been translated into practical frameworks for identifying and analysis adaptation (e.g. see Hinkel and Bisaro, 2014).

More recent updates of these frameworks have combined these various aspects, and work with decision-led assessment, aligning the types of activities and decisions to adaptation pathways or iterative frameworks (e.g. Watkiss and Hunt, 2011: Downing et al, 2012). In such cases, the interventions over time can be combined to give an overall portfolio of actions, sometimes termed an 'adaptation pathway', which aligns to an adaptive management framework that encourages evaluation and learning. Importantly, from an economic perspective, each activity (or building block) is a different problem type, requiring different types of information, and varying methods of economic appraisal (Li, Mullan and Helgeson, 2014).

Mainstreaming

A second important shift, particularly at national level (in both developed and developing countries) is towards mainstreaming adaptation. Indeed, the recent National Adaptation Plan (NAPs) guidance recommends the mainstream of adaptation (LDC expert group, 2012).

While there is still no formal definition of mainstreaming (in the IPCC), the term is broadly used interchangeably with 'integration'. Mainstreaming is therefore the integration of adaptation into existing policies and decision-making, rather than through the implementation of standalone adaptation policies, plans or measures.

The focus on mainstreaming is synergistic with the policy-first approach outlined above, in that it considers existing policy and objectives, non-climate drivers, multiple objectives and ancillary costs and benefits. It also has to understand the context for an intervention and the current decision-making process.

An important component of the mainstreaming process is to find relevant entry points (OECD, 2009: UNDP, 2011), that is, to identify opportunities in the national, sector or project planning process where climate considerations can best be integrated. Critically, these will differ with each specific adaptation problem. This makes it is essential to understand and integrate adaptation within the existing socio-institutional landscape, especially as adaptation will be one of many policy objectives, and not necessarily the dominant one.

One implication of mainstreaming is that it implies a much greater degree of resource and analysis, when compared to a science-first impact assessment (although the information from impact studies provide a valuable input into the mainstreaming process). This can be seen in examples that have applied mainstreaming concepts to national adaptation implementation (e.g. see HMG (2013) in the UK and OECD (2014) for Ethiopia and Columbia). Mainstreaming also requires a good understanding of the individual organisations, networks and processes for making relevant decisions, recognising these will differ with sector and application. It also requires more information and inputs to allow an economic appraisal that aligns with standard policy practice and the reality of multiple drivers and objectives, e.g. in relation to the policy background and context, existing objectives, and other cost and benefit categories.

Given the importance of mainstreaming for resilient development, this subject has been selected as an area for more detailed review and case study identification in the evaluation phase of the study.

Phasing and Timing of Adaptation

A key characteristic of adaptation relates to the profile of costs and benefits over time (DFID, 2014). In many cases, the most important impacts of climate change are likely to arise in the future, say 2040 and beyond. Within economic analysis, the benefits of adapting to these changes accumulate over long time horizons, while the costs may be incurred before. Using the public discount rates conventionally used in OECD countries, typically being between 3% and 6%, future adaptation benefits from climate change in the medium term and beyond are small in current terms and thus rarely justify early intervention. For developing counties, where social discount rates / social opportunity cost of capital are 10% or higher (OECD, 2015), this issue is even more severe: indeed, benefits that accrue in 20 years are very low when expressed in present value terms. Compounding this, the high uncertainty often makes it unclear if these future benefits will actually be realised

As a result of these factors, there has been a shift to consider the timing and phasing of adaptation, taking account of future uncertainty. This has been captured in the literature through frameworks or principles for early and long-term adaptation. Examples include Ranger et al., (2010); Watkiss and Hunt (2011); Fankhauser et al. (2013). This change was reported in the IPCC 5th Assessment Report, where the term ‘iterative climate risk management’ was used (IPCC, 2014).

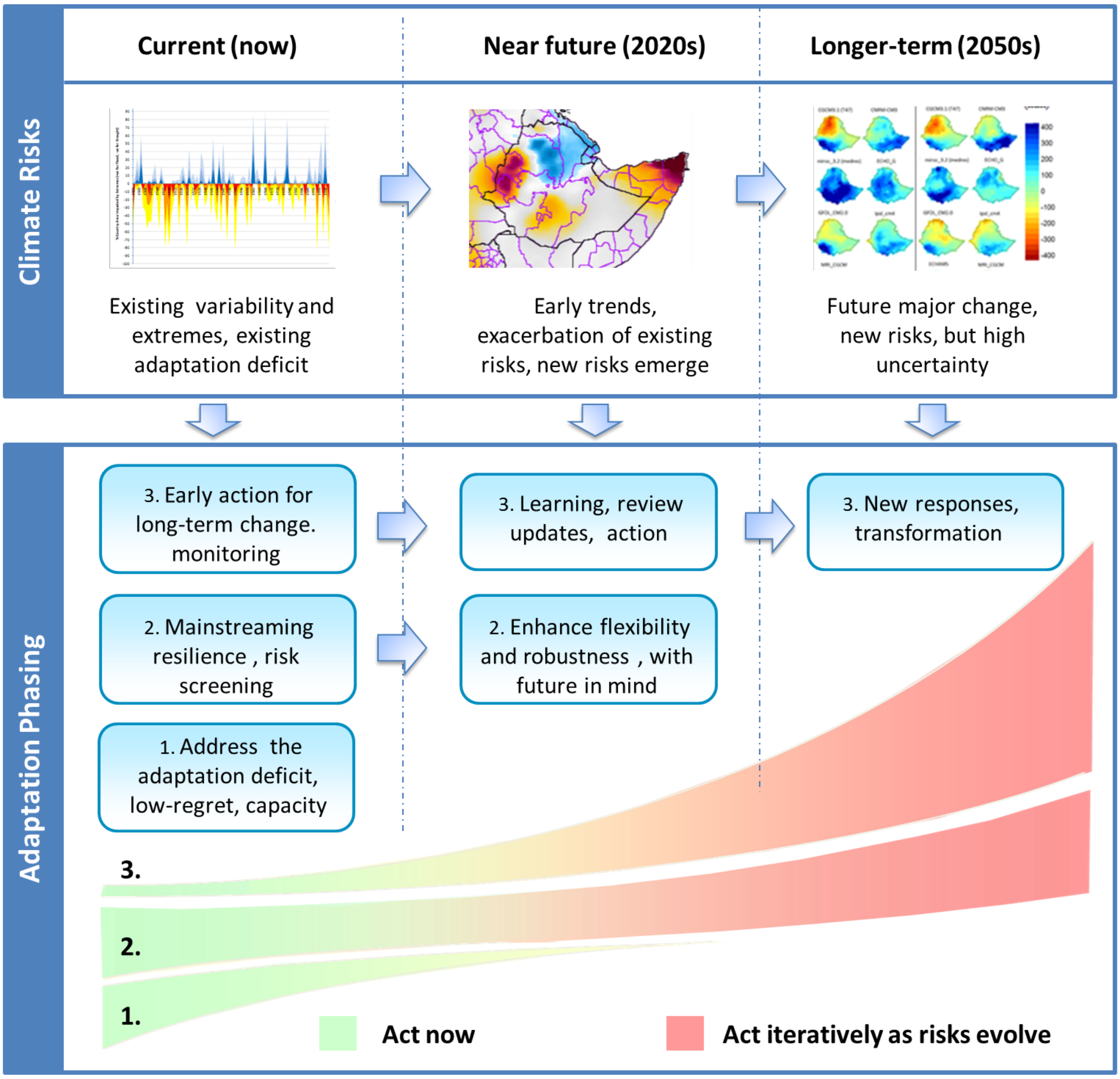
In general terms, these frameworks follow the concepts of adaptive management and encourage a focus on immediate low-regret actions, combined with an evaluation and learning process to improve future strategies and decisions. An example of such a framework is summarised below (Watkiss, 2014). This frames climate change risks by starting with current climate variability (the adaptation deficit) and then looks to future climate change, including uncertainty. The focus is on policy relevant decisions, i.e. those which are needed and justified (in economic terms) in the next decade for climate resilient development, both now and in the future. Three broad types of adaptation decisions are identified for early adaptation within the framework, each with different needs in terms of economic analysis and decision-support.

First, immediate actions that address the current adaptation deficit and also build resilience for the future. This involves early capacity-building and the introduction of low- and no-regret actions (e.g. UKCIP, 2006; IPCC, 2012), as these provide immediate economic benefits: such actions are usually grounded in current (development) policy and can often use existing decision support tools.

Second, the integration of adaptation into immediate decisions or activities with long life-times, such as infrastructure or planning (e.g. Ranger et al, 2014). This requires different tools and methods to the low-regret actions above, because of future climate change uncertainty (DFID, 2014). It involves a greater focus on climate risk screening, identification of the risks of lock-in, and for appraisal, a shift away from standard appraisal to methods that consider flexibility or robustness.

Finally, there is often an immediate need to start planning for the future impacts of climate change, noting the high uncertainty. This may be due to the long life-times of decisions, or the potential magnitude of future risks. Such problems can be addressed using adaptive management (Tompkins and Adger, 2005: Reeder and Ranger, 2011), the value of information and future options/ learning.

The three categories can be considered together in an integrated adaptation strategy or an adaptation pathway (Downing, 2012).



Source: Watkiss, 2014.

This new framing leads to very different methods and adaptation interventions, with a greater emphasis on early adaptation actions, the introduction of different types of interventions, and the use of different economic support: these are discussed in the next chapter.

II: Types of Adaptation Interventions

Key findings:

- *The second area of the review has focused on the types of adaptation interventions that are being recommended at national, sector and local level, and their potential analysis in economic appraisal.*
- *Consistent with the methodological changes and new frameworks identified in Chapter I, the review also finds a shift in the types of adaptation options that are being recommended for early implementation.*
- *There is now more emphasis on early options that address current climate variability in the short-term (and build resilience for the future), with low-regret options, including capacity building and non-technical adaptation. There is also a focus on early options to address future risks in the long-term, taking account of uncertainty, either for early decisions which have a long life time (e.g. infrastructure) or for future long-term risks, where early action is warranted.*
- *This new focus has implications for the types of economic appraisal needed, to allow analysis of the costs and benefits of capacity building, and for addressing the phasing and timing of adaptation using decision making under uncertainty.*
- *Alongside this, there is more awareness of the process of adaptation and the need to address socio-institutional issues and barriers (market failures, governance failures, policy failures and behavioural barriers).*

The second area of review has focused on the types of adaptation interventions that are being recommended at national, sector and local level, and their potential analysis in economic appraisal.

Types of Adaptation Interventions

The shift towards policy-first adaptation and early mainstreaming that was set out in the previous chapter also affects the types of adaptation interventions of relevance for climate resilient development. This is of particular relevance for the early implementation of adaptation in developing countries, especially in the context of national adaptation planning.

More recent studies – especially those that are policy and climate finance orientated - have a greater emphasis on early adaptation interventions. They seek to address the current risks of climate variability, to provide early benefits and build future resilience, and focus on low-regret options, including capacity building and non-technical responses (soft, green and behavioural measures).

This shift was confirmed by reviewing a number of more recent national climate change strategies and action plans to examine the key adaptation options being recommended, e.g. in Bangladesh (MoEF, 2009), Rwanda (RoR, 2011), Tanzania (URT, 2012) and Zanzibar (RGS, 2014).

Critically, the options prioritised in these action plans differ significantly from the options typically considered in the earlier impact-assessment literature, as the latter focus mostly on technical options (e.g. dikes for flood protection, irrigation for agriculture). Instead, the action plans priorities early research, monitoring, awareness raising and capacity building, and they include much more specific early low-regret interventions, e.g. for immediate interventions that are targeted to vulnerable regions. This includes a focus on disaster risk reduction, sustainable agriculture, etc. However, many of these early options overlap with existing development activities (for an example, see Ethiopia, FRDE, 2014 and OECD, 2014).

Complementing this, at least in the academic literature, there is an increasing use of new approaches that inform future orientated decisions, to analyse the risks of lock-in, the value of information and future option values, as well as the benefits of flexibility and robustness, risk diversification and portfolio strategies (for a recent review, see Watkiss et al, 2014). These can also identify 'low-regret' options, as they consider the economic justification for intervention, but critically they are not focused on delivering immediate benefits. Similarly, many of these early actions to address longer-term challenges involve early non-technical actions, such as research and monitoring, as part of iterative adaptive management pathways. The inclusion of such actions leads to a widening of what can be termed 'low regret' adaptation, see box.

Low Regret Options

Numerous studies recommend that no- and low-regret actions are a good starting point for early adaptation, as they offer benefits now and lay the foundation for future resilience (UKCIP, 2006; Watkiss and Hunt, 2011,:Ranger and Garbett-Shiels, 2012; IPCC SREX, 2012).

No-regret adaptation is defined (in the IPCC glossary) as adaptation policies, plans or options that "*generate net social and/or economic benefits irrespective of whether or not anthropogenic climate change occurs*". This includes options that address the current adaptation deficit (e.g. disaster risk management), options that are more efficient and generate cost savings (e.g. improving irrigation efficiency) or options that address existing problems (e.g. reducing post-harvest losses), though many of these are similar to development options.

There is, however, no agreed definition of low-regret options, and a review of various studies (DFID, 2014) identifies the following: i) options that are no-regret in nature, but have opportunity, transaction or policy costs; ii) options that are have benefits (or co-benefits) that are difficult to monetise; iii) low cost measures that can provide high benefits if future climate change emerges; iv) options that are robust or flexible, and thus help with future uncertainty.

In DFID (2014) - and this review - a pragmatic definition of low-regret options is used - that focuses on promising 'early' adaptation options that have low-regret characteristics. This includes options that are effective in addressing the current adaptation deficit, but also future-orientated, low-cost options that build resilience, flexibility or robustness, as well as capacity building and the benefits of the value of information.

Critically, this shift in the types of adaptation options has implications for the methods used for economic appraisal. This is explored in the next section.

Categorising Adaptation Options for Economic Appraisal

The review has identified generic types of adaptation actions, using the frameworks outlined in the previous chapter (Ranger et al., 2010; Watkiss and Hunt, 2011; Fankhauser et al. (2013): Ranger, 2013: DFID (2014)) as well as the LDC national adaptation plans reviewed (see above). The information has then been used to categorise adaptation interventions into a set of activities that make sense in the short-term from an economic perspective, i.e. to address:

- Immediate risks (current climate variability and extremes, i.e. the adaptation deficit),
- Immediate decisions which have a long life time (e.g. infrastructure, planning) and
- Future long-term risks, where some early action is warranted.

For those options that address the immediate risks, i.e. the current (economic) adaptation deficit[3], an important differentiation is made between options that have a strong overlap with current development (*good development*), which may be more appropriate for implementation through existing country programmes, and options that directly address climate variability (*addressing climate variability*). Both these are associated with concrete early actions (e.g. technical implementation, major investment, scale-up and roll out). These options can often be assessed with traditional economic appraisal tools. They typically have high benefit to cost ratios and deliver immediate economic benefits, as well as helping build resilience. For example, Mechler (2012) reports high BCRs (4:1) for DRR measures in developing countries and DFID (2014) reviews a large number of early options and identifies positive BCRs.

Alongside this, there is also a separate early category of *capacity building*, reflecting the need for non-technical options to help deliver adaptation. These activities are likely to be associated with institutional strengthening and awareness-raising, but also information provision that will support early actions, e.g. seasonal forecasting for agriculture, improved forecasting for early warning for disaster risks reduction (DFID, 2014). Often these measures are highly synergistic to the low-regret options above, creating the enabling environment or increasing the effectiveness of delivery. They can therefore be introduced as complementary packages of options, e.g. as portfolios rather than single technical solutions (see Di Falco and Veronesi, 2012 for an example in agriculture). However, these non-technical options have very different characteristics to the more outcome based options (above) and have benefits that are more difficult to assess quantitatively. It is possible, however, to assess them using the value of information and there is a reasonable literature of such an approach with respect to climate services (Clements, 2013) including in the climate change context (Macauley, 2010).

Given the importance of these capacity building options for climate resilient development, the economic appraisal of capacity building (including technical assistance and institutional strengthening) has been selected as a topic for more detailed analysis in the evaluation phase of the study.

For the second set of options, i.e. those that focus on immediate decisions with a long-life time, a differentiation is made between resilience building (building resilience into infrastructure or planning) using *low-cost options / climate risk screening / reducing lock-in/ including robustness and flexibility* and non-technical options, such as *information and capacity*, that enable or enhance these activities (e.g. see Fankhauser et al, 2013: Ranger, 2013).

This group of interventions focus on early decisions that will be influenced by climate change in the future. This may be associated with climate sensitive infrastructure (e.g. hydro-plants or critical infrastructure) that could be affected by changing trends (e.g. river flows) or extremes (e.g. floods) from future climate change. It also includes the analysis of early decisions to minimise the risk of lock-in for the future, e.g. using urban or land-use planning decisions to avoid areas at possible increased future risk (Ranger et al, 2014). Much of this centres on using climate risk screening, to avoid or minimise future risks at the outset (e.g. AfdB, 2011), due to the general assumption that it is more expensive (and sometime impossible) to retrofit later. It also can include changes in design, whether this is by simple over-design (low cost) or upgrading of design standards (Wilby and Keegan, 2012), a consideration of future robustness (against many futures, rather than optimised to one future) (Dessai

[3] The IPCCC (2014) defines this as the gap between the current state of a system and a state that minimizes adverse impacts from existing climate conditions and variability. In this study, we use a different definition, which recognises that it is not economically efficient to reduce the adaptation gap to zero (indeed, even highly developed countries have an adaptation deficit). The critical criterion therefore is that the existing adaptation gap is sub-optimal, i.e. that the benefits of reducing risks outweigh the costs.

and Hulme, 2007: Lempert and Groves, 2010), or building infrastructure with the potential to be upgraded easily in the future (flexibility) (Hallegatte, 2009). However, there is an important trade-off between early action – and the associated early costs – versus future longer-term benefits, due to the importance of discounting (DFID, 2014). In the developing country context, this is a particularly issue, due to high discount rates (or the rates of return on investment) and it means that the choice of these future orientated options has to be made carefully, to avoid misallocation of resources, whether this be due to the high costs of additional up-front capital investment, or the early opportunity costs from actions that prevent short-term economic benefits (e.g. land planning constraints).

Finally, there is a separate set of longer-term (future-orientated) interventions associated with early decisions for addressing future climate challenges. This is where early action may be needed for long-term risks (Ranger and Reeder, 2011; Watkiss and Hunt, 2011), either because a decision time-scale takes a long-time (e.g. decades) and thus some early steps are warranted to start planning for the future now, or because there are major (even irreversible) long-term risks –with high uncertainty – and early information can help inform future decisions and can help keep future options open. This includes the application of iterative adaptive management, and usually focuses on early research and monitoring (the value of information) to inform future decisions: this it also aligns with real option analysis (see Chapter V).

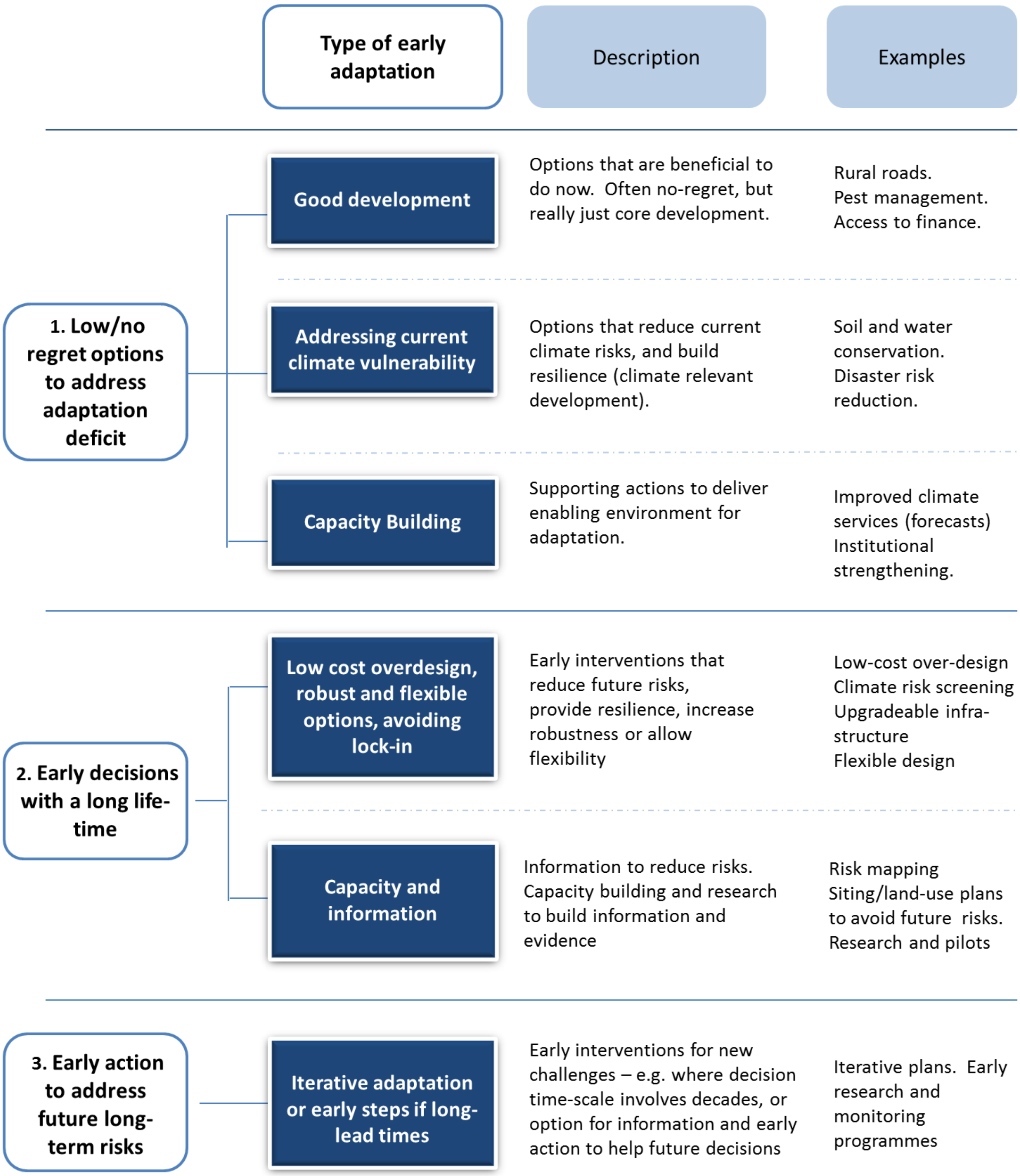
An illustration of these different categories of adaptation is shown below.

What is critical to note is that these different categories of adaptation involve different economic concepts, and require analysis of varying types of benefits (over differing time-scales). They also require different information inputs and different economic appraisal techniques. As an example, the analysis of capacity building will require different approaches to a hard flood protection. Similarly, there are additional concepts involved in assessing future resilience when compared to early low-regret options, because of consideration of uncertainty. A summary of some of the key differences and the categories of benefits are shown below.

Examples of the Differences in timing and types of benefits, and analysis methods

Intervention	Timing of Benefits	Type of Benefits	Analysis
Good development	Now (and also adaptive capacity for the future)	Increased productivity/efficiency	Classic benefit to cost ratio
Addressing current variability	Now (and also resilience for the future)	Reduced damage costs	As above, but with information on climate risks
Initial capacity building	Now (and also adaptive capacity/resilience for the future)	Value of information	Qualitative. MCA or value of information assessment
Resilience for the future	Some now, but mostly future	Reduced damage costs	Risk screening, real options, robust decision making, etc.
Capacity for the future	Some now, but mostly future	Value of information	Qualitative or value of information assessment
Iterative adaptation and early steps	Future	Value of information	Iterative pathways, real options analysis.

Source: Updated from DFID, 2014.



Adapted from DFID 2014: Fankhauser et al. (2013): Ranger, 2013:

Barriers to Adaptation

Alongside the shift on different types of options, outline in the figure above, there is now more awareness of the process of adaptation and the need to address the socio-institutional issues and barriers to adaptation (Cimato and Mullan, 2010: Moser and Ekstrom, 2010; HMG, 2013: Klein et al., 2014). These barriers make it harder to plan and implement adaptation actions, or lead to missed opportunities or higher costs. These include market failures, policy failures, governance failures and behavioural barriers.

There is a literature that explores these barriers or constraints to adaptation, which recognises there is a disconnect between an idealised model of adaptation planning and the reality of how it plays out in practice. These lessons include the need to identify key barriers to effective adaptation (including market, policy, behavioural and governance failures), to build organisational adaptive capacity, and to introduce enabling actions that are likely to lead to more effective adaptation. The literature review has summarised recent information.

Market failures can occur due to lack of information, the presence of externalities and public goods, information asymmetry and misaligned incentives. Economic theory applied to adaptation (e.g. Fankhauser, Smith and Tol, 1999; Cimato and Mullan, 2010), as well as empirical observations (Osberghaus et al., 2010a; Wing and Fisher-Vanden, 2013) indicate that such actions will not receive appropriate levels of private investment. For example, Lee and Thornsbury (2010) point out that under different market structures (monopoly, oligopoly or perfect competition), the ability of investors to reap the benefits of adaptation will vary, and therefore also their incentives to invest in it.

Policy failures occur when conflicting policy objectives co-exist (which is often) and there are not appropriate mechanisms for addressing these trade-offs (Frontier Economics, 2013). For example, urban development objectives may not take into account the vulnerability of assets and human systems to climatic stresses. Also, when policies result in market distortions (e.g. price or income subsidies), people will under- or over-adapt depending on how their adaptation choices will translate into income changes (Fankhauser, Smith and Tol, 1999).

Governance failures refer to ineffective institutional decision-making processes, e.g. when the current structure of institutions and regulatory policies is poorly aligned to account for adaptation objectives (Craig, 2010; Stuart-Hill and Schulze, 2011; Eisenack and Stecker; 2012; Huntjens et al., 2012; Herrfahrdt-Pähle, 2013). Adaptation typically requires multiple actors and institutions with different objectives, jurisdictional authority and levels of power and resources. The complexities of governance networks can often constrain adaptation (see Klein et al., 2014). Overlapping mandates of government tends to create conflicts and slow adaptive responses. Further, lengthy bureaucratic processes and lack of transparency are an impediment to fiscal planning and access to finance, particularly relevant for developing countries (Setz et al., 2008). Poor - or lack of - leadership (Moser and Ekstrom, 2010), lack of a clear mandate, and the short-term political cycle can also represent barriers to effective decision-making for adaptation (Lehmann et al., 2012). Corruption within institutions also undermines adaptation efforts (Lesnikowski et al., 2013; Schilling et al., 2012). It is highlighted that many of these challenges are particularly important in the least developed country context.

Behavioural barriers are concerned with the observed inability of individuals to take apparently rational decisions (i.e. to maximize their net benefits or utilities) and their cognitive limitation in attempting to achieve their goals. This limitation manifests itself as inertia, procrastination, and the use of time-inconsistent discounting (see Cimato and Mullan, 2010). Social values and beliefs can also support or hamper adaptation (Jones and Boyd, 2011; Stafford-Smith et al., 2011; Adger et al., 2012) as they frame how societies develop rules and institutions to govern risk, and to manage social change and the allocation of scarce resources (Ostrom, 2005).

Individuals, institutions and the natural environment will clearly adapt within the boundaries of their adaptive capacity (see Oberlack and Neumarker, 2011; Kuch and Gigli, 2007; Osberghaus et al., 2010b), and physical and biological constraints. Gender, age, education, access to infrastructure and finance, and access to markets and technology are all elements that determine the adaptive capacity of social systems. Natural systems' ability to adapt will be possible within certain climatic thresholds, and can be hampered by other non-climatic stresses (Klein et al., 2014; Cimato and Mullan, 2010), and the presence of physical barriers (e.g. the lack of corridors for species migration).

Finally, it is noted that many of these barriers relate to early adaptation, or what is sometimes termed 'incremental adaptation' (i.e. which maintains the essence and integrity of a system or process at a given scale).

There are likely to be a further set of barriers and challenges in moving beyond such actions, towards transformational adaptation (IPCC, 2014), i.e. adaptation which changes the fundamental attributes of the system. This is identified as an important research gap.

III: Cost and Benefit Estimates of Adaptation

Key findings:

- *The knowledge base on the costs and benefits of adaptation has evolved significantly in recent years. There are now many more studies at national, regional and local scale, with coverage in both developed and developing countries.*

- *In terms of the coverage by sector and risk, estimates of the costs and benefits of adaptation have moved beyond the previous focus on coastal zones and now extend to water management, floods, agriculture and the built environment. However, major gaps remain for ecosystems and business/services/industry.*

- *In line with the findings in previous chapters, the methods for identifying options and assessing costs and benefits have changed, and as a result, so has the focus of recent studies and the types of interventions (towards early options).*

- *More recent implementation-based and policy-orientated studies indicate higher costs of adaptation than the earlier literature. This is because these later studies address existing policy objectives and standards, they consider multiple risks and recognise and plan for uncertainty, and they include the additional opportunity and transaction costs associated with policy implementation.*

The analysis of the costs and benefits of adaptation has an important role in justifying the case for action, and for prioritising available resources to deliver greatest social, environmental and economic benefits. This information is relevant at the global level, as an input to the discussion on international financing needs. It is also relevant for national adaptation plans, to allow efficient, effective and equitable strategies, and for local and project level adaptation, as a key input to appraisal. This area of the review has synthesized the recent estimates of the costs and benefits of adaptation. This summarises the recent evidence base as collated by the ECONADAPT study (2015).

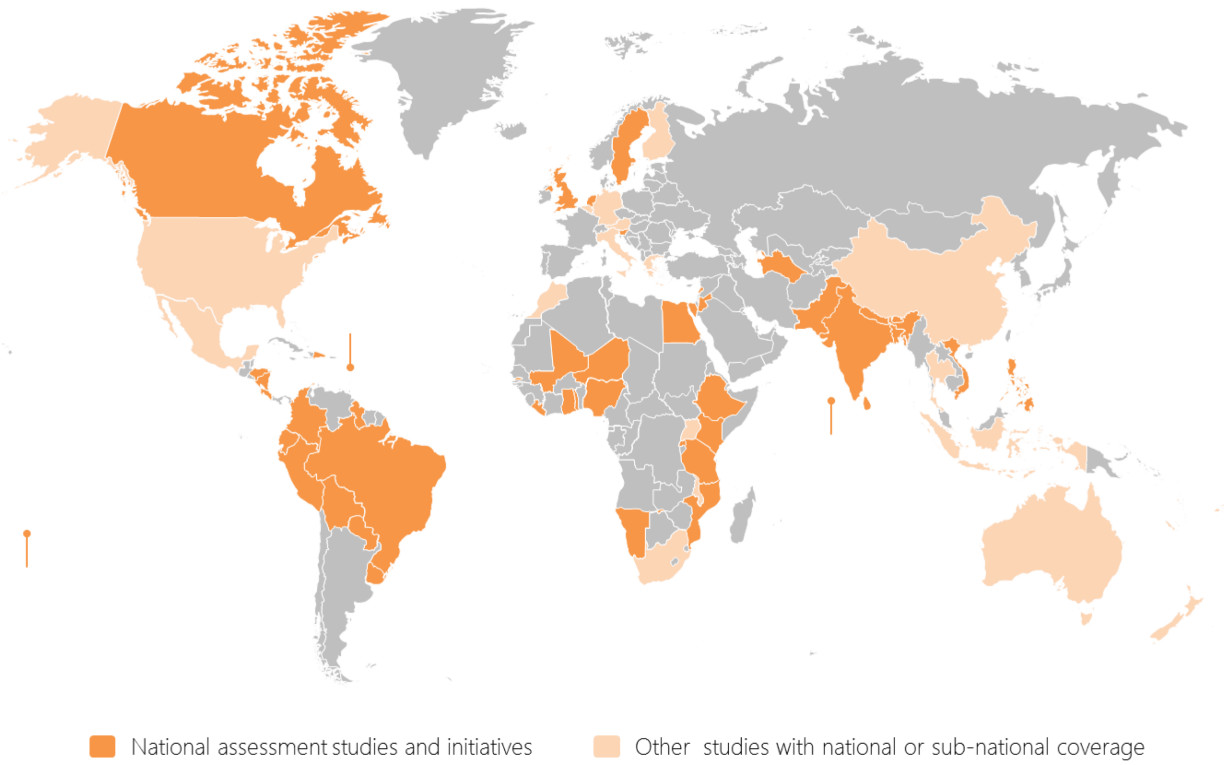
Evidence Base on Adaptation Cost and Benefits Estimates

Over the past few years, there have been several reviews of the costs and benefits of adaptation (Adger et al, 2007; OECD, 2008; UNFCCC, 2009; Agrawala et al., 2011a: Chambwera et al, 2014). These report a low evidence base. However, in recent years, two new evidence lines have emerged which have significantly increased the available knowledge, especially for developing countries.

First, there have been a large number of national level initiatives: varying from one or two key sectors through to economy wide assessments. These are shown in the figure below.

Second, there are more studies that focus on early adaptation, considering the application of existing options to new contexts or locations. As these focus on existing interventions, there is often ex ante or ex post economic information available on costs, as well as effectiveness and potential benefits.

These two factors have led to a much larger number of studies – and evidence– on the costs and benefits of adaptation. These have been collated as part of the ECONADAPT study (ECONADAPT, 2015) with around 500 studies identified. A synthesis of this review is presented here.



Coverage of national studies on the costs (and benefits) of adaptation

Source: ECONADAPT (2015).

National studies and aggregated estimates in developing countries

A series of global initiatives have taken place over the last five years, which have focused on generating adaptation cost estimates at the national scale in developing countries. This includes:

- The EACC country studies (in Bangladesh, Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Vietnam), which used impact-assessment, but also provided more detailed (bottom-up) assessment and considered economy wide effects (World Bank, 2010).

- The United Nations Development Programme (UNDP) Investment and Financial Flows initiative (UNDP, 2011), which estimated the costs of adaptation through to 2030 in 15 countries (Bangladesh, Colombia, Costa Rica, Dominican Republic, Ecuador, The Gambia, Honduras, Liberia, Namibia, Niger, Paraguay, Peru, Togo, Turkmenistan, and Uruguay) for 1 or 2 key sectors.

- The UNFCCC National Economic, Environment and Development Study (NEEDS), which assessed the short- and long-term costs of adaptation and financing needs in Egypt, Ghana, Jordan, Lebanon, Maldives, Mali, Nigeria and Pakistan (UNFCCC, 2010).

It is stressed that these three sets of studies use different methodological approaches. The EACC study used a scenario-based impact-assessment framework. However, it did consider alternative climate futures. The UNDP study centred on investment and financial flows, which look at the additional adaptation investment needed on top of baseline development: while a large number of countries were covered, in each case it was generally limited to analysis of 1 – 2 sectors. Finally, the UNFCCC NEEDS project assessed the short- and long-term costs of adaptation financing needs using a variety of approaches.

Additionally, a large a number of other regional and country level studies have been undertaken. These include studies in Bangladesh (ADB, 2014). Brazil (Margulis et al., 2010), Bhutan (ADB, 2014), Caribbean (CCRIF, 2010: ECLAC, 2011a), Central America, China, Ethiopia (FDRE, 2015), Guyana (ECLAC, 2011b), Kenya (SEI, 2009), India (Markandya and Mishra, 2010: ADB, 2014), Indonesia (ADB, 2009), Maldives (ADB, 2014); Nepal (IDS, 2014: ADB, 2014), Philippines (ADB, 2009), Peru (PAC, 2013), Rwanda (SEI, 2009b), Samoa (ECA, 2009), South Africa (AIACC, 2006; Cartwright et al., 2013), Sri Lanka (ADB, 2014), Tanzania (GCAP, 2010: GoT, 2014), Thailand (ADB, 2009), Uganda (CDKN, forthcoming) and Vietnam (ADB, 2009). References are provided in ECONADAPT (2015). The majority of these use impact-assessment methodologies to derive economic costs and then consider adaptation, though there are some exceptions.

The wide range of methods and assumptions makes aggregation of these studies – and cross comparison to global estimates – very challenging. Nevertheless, an initial analysis (UNDEP, 2014) concluded that these country studies indicate much higher adaptation costs for developing countries than reported in the global studies, i.e. higher than the $70 to 100 billion/year for all developing countries in the period 2010- 2050 reported in the EACC study (World Bank, 2010), particularly after 2030. As examples, the adaptation costs in the national UNDP IFF studies indicate costs that are almost an order of magnitude higher than the global impact assessments for the same sectors. Even within the EACC study itself, the costs of adaptation for countries are 20% higher when estimated in national studies than for the same countries in the global assessments, and more than this when higher warming scenarios are considered.

There are some reasons to explain these differences. The coverage of the global studies are partial (see Parry et al, 2009) and only consider a sub-set of impacts and risks. National studies generally include a greater coverage and this leads to higher estimates (though they may omit low cost market-based adaptation, such as from international trade). National studies usually also consider a wider range of climate projections: as an example the EACC (2010) study is based on funding adaptation for 2°C of climate change, but higher levels of warming lead to much higher adaptation costs, even in the medium-term (UNEP, 2014). Further, there is often more consideration of decision making under uncertainty in national studies, and this increases costs, as it requires different responses when compared to a predict-then-optimise framework. Finally, more practically focused studies indicate a number of cost categories are being ignored in many global estimates, notably around opportunity, transaction and policy costs, particularly in the least developed countries due to governance and capacity challenges.

Sector and Risk Estimates

Previous reviews have assessed the coverage of adaptation costs and benefits by sector. Such studies have shown (OECD, 2008; Chambwera et al, 2014) relatively high coverage for the coastal sector and for agriculture (for benefits), as well as some studies of energy and infrastructure costs.

The updated coverage of sector and risk based has been reviewed as part of the ECONADAPT project. The findings are summarised in the Table below.

The results clearly show that there is a greatly expanded coverage of costs and benefits - estimates now extend to water management, floods, agriculture and the built environment (including health and energy related adaptation to heat). However, major gaps still remain for ecosystems and business/services/industry. Nonetheless, some caution is needed in interpreting these findings: even in the sectors where there is high coverage, the full range of climate risks and adaptation options, is partial, especially in the developing country context.

The studies also use a diverse set of methods, socio economic assumptions, cost metrics and benefit categories, as well as discount rates. This makes inter-comparison difficult.

Coverage of estimates of the costs and benefits of adaptation

Risk / Sector	Coverage	Cost	Benefits
Coastal zones and coastal storms	Comprehensive coverage (flooding and erosion) at global, national and local level in impact assessment studies. Good evidence base on early low regret options and iterative adaptive management including policy studies and decision making under uncertainty (ROA)	✓✓✓	✓✓✓
Floods including infrastructure	Growing number of adaptation cost and benefit estimates (impact assessment studies) in a number of countries and local areas, particularly on river flooding. Evidence base emerging on low regret options and non-technical options. Some applications of decision making under uncertainty.	✓✓	✓✓
Water sector management including cross-sectoral water demand	A recent focus on supply-demand studies at the national level, but a range of global, river basin or local studies available. Focus on supply, engineering measures; less attention to demand, soft, and ecosystem-based measures. Some examples of decision making under uncertainty, particularly robust decision making, with policy relevant studies.	✓✓	✓
Other infrastructure	Several studies on road and rail infrastructure. Examples of wind storm and permafrost.	✓	✓
Agriculture (multi-functionality)	High coverage of the benefits of farm level adaptation (crop models), and some benefits and costs from impact assessment studies at global and national level. Evidence base emerging on potential low regret adaptation, including climate smart agriculture options (soil and water management)	✓✓	✓✓
Over-heating (built environment, energy and health)	Good cost information on heat-alert schemes and some cost-benefit studies for future climate change. Increasing coverage of autonomous costs* associated with cooling from impact assessment studies (global and national). Growing evidence base on low-regret options for built environment (e.g. passive cooling).	✓✓	✓
Other health risks	Increasing studies of preventative costs for future disease burden (e.g. water, food and vector borne disease), but coverage remains partial.	✓	✓
Biodiversity / ecosystem services	Low evidence base, with a limited number of studies on restoration costs and costs for management of protected areas for terrestrial ecosystems.	✓	
Business, services and industry	Very few quantitative studies available, except for tourism, some focusing on winter tourism and some on autonomous adaptation from changing summer tourism flows*.	✓	

* can be considered an impact or as autonomous adaptation. (i.e. unplanned)
Key:
✓✓✓ Comprehensive coverage at different geographical scales and analysis of uncertainty
✓✓ Medium coverage, with a selection of national or sectoral case studies.
✓ Low coverage with a small number of selected case studies or sectoral studies.
The absence of a check indicates extremely limited or no coverage.
Source: ECONADAPT (2015).

Finally, the number of more policy orientated and iterative studies remains low. The review therefore cautions against the simple reporting of the costs of adaptation and further analysis of transferability is a key research priority.

Discussion

An analysis of the evidence above reveals a number of key insights.

First, most of the estimates are from grey literature – only 25% are academic peer reviewed articles (ECONADAPT, 2015). This is partly due to the recent emergence of national studies, as well as the recent increase in studies (and the time delay to publication), but it does also raise some issues.

Second, following the earlier chapters, there are also now two distinct sets of literature. The first group of studies use impact-assessment and focus on technical adaptation. These dominate the future orientated literature is (i.e. on future climate change). However, these studies are stylised, they focus on technical adaptation and they do not consider decision-making under uncertainty. The second group of studies align to the new iterative framing and focus either on early low regret-options (to address current climate variability and build resilience) or decision making under uncertainty for the longer-term (see later chapter). These studies often are more policy-orientated, and are focused on delivering information for early practical adaptation planning.

It is very difficult to directly compare the two sets of literature, because they use different framing, methods and assumptions. However, a synthesis of the overall literature does reveal some interesting insights

First, a lesson from policy-orientated studies is that adaptation costs are often higher when working with the current policy environment, multiple risks and wider non-climatic drivers. This may be because of existing standards of acceptable risks are higher (i.e. above the economic optimum) or because of the need to balance many competing factors in appraisal. These studies also reveal the higher time and resources are needed to understand the background policy context for more practical adaptation.

Second, in terms of medium to longer-term adaptation, there are large differences between the classic impact-assessment (I-A) studies and the new focus on decision making under uncertainty. Implicitly, studies that consider uncertainty involve higher adaptation costs when compared to I-A studies that predict-and-optimise alone, as they involve some additional actions or prioritise robustness over optimisation. However, studies that consider uncertainty often show that such interventions are preferable (i.e. have higher net present values) when compared to a situation where uncertainty is excluded.

Third, there is a wider literature emerging on the costs and benefits of early low-regret options. This targets current climate variability and early resilience over the next decade or so, thus the timing differs to I-A studies. These are an early priority for developing countries and include low regret measures such as disaster risk reduction, sustainable (climate smart) agriculture, etc. A review of this literature has found that many low-regret options exist which have high benefit to cost ratios (DFID, 2014: ECONADAPT, 2015). Many of these options have potentially lower costs or offer wider co-benefits when compared to engineering based options (as identified by Agrawala et al. (2011), though as highlighted above, assessments of capacity building and non-technical options are more challenging, and thus less well captured in the literature.

Further, the more policy-orientated and practical studies reveal important opportunity and transaction costs associated with implementation, which will lead to much higher out-turns in practice (i.e. ex post). This replicates the lessons from the mitigation domain, where it was found that negative cost options (no-regret) were rarely as easy or as cheap to implement as predicted in the technical cost-curve analysis (for an example, see Ecofys, 2009). Nearly all adaptation options – even low or no-regret interventions- have important opportunity, transaction or policy costs (DFID, 2014), which are not included in impact-assessment derived estimates. Examples include the opportunity costs of climate smart agriculture (McCarthy et al., 2011), the land acquisition / opportunity costs of set-back zones or planning controls (Cartwright et al., 2013), the enforcement costs for ecosystem based options (Watkiss et al., 2014) and even the resource costs associated with heat alert systems (Hunt et al. 2010). This is likely to mean that the costs of adaptation are likely to be higher than presented in the current global or national estimates, as the latter primarily only count the immediate technical or engineering costs. Further exploration of this issue is a priority.

In the context of this work, it is highlighted that many of the issues above are particularly important for adaptation in developing countries. There is therefore an issue of the transferability of (ex ante) estimates of costs and benefits to developing countries, especially given the assumptions of high effectiveness and low costs, and there are major implementation challenges – which will involve higher costs - due to the existing capacity, development and governance challenges, which are likely to involve additional technical assistance and programming activities.

IV: Methodological Aspects of the Economics of Adaptation

Key findings:

- *There are a number of methodological challenges with the economic assessment of adaptation. This includes issues around adaptation objectives, baselines, discounting, equity, transferability and additionality. The review has reviewed the current state-of-the-art and implementation practice in these areas.*

- *While the academic theory in many of these areas has advanced, a key finding is that this has not yet transferred into common (appraisal) practice: this is due to time, resource and capacity constraints, but also because in many areas, there remains no agreed consensus.*

- *The increasing use of mainstreaming in adaptation (indirectly) is, however, removing many of these challenges, because it leads to a greater use of existing development and sector practice, and thus the use of methods, approaches and assumptions already in place for appraisal.*

Challenges with the Economics of Adaptation

Previous studies (EEA, 2997: OECD, 2008; UNFCCC, 2009; Chambwera et al, 2014) have identified a number of key challenges with the economics of adaptation. These include assumptions regarding the choice of discount rate and distributional issues. They also include issues of baselines, analysis of non-technical options, issues of scale and aggregation, and transferability of benefits and costs. These challenges potentially apply at both the policy and programme levels, as well as the project-level. The review has surveyed the literature on these challenges, to identify the current state-of-the-art and the approaches used in implementation. The findings are summarised below. It is highlighted that the additional challenge of uncertainty is considered in more depth in chapter V.

The objectives, baseline and additionality for adaptation

In a standard economic appraisal, two of the early steps relate to i) setting the study objectives, and ii) producing a baseline (a 'do-nothing' counter-factual) to allow comparison against other options. These two issues have been identified as problematic for adaptation in previous studies (Parry et al, 2009: UNFCCC 2009), and have been re-considered as part of this review.

In any analysis of adaptation, whether at strategic or project level, the framing and objectives used have a major influence on the costs and benefits of adaptation (Parry et al, 2009). Studies with a strong economic perspective will aim to maximise economic efficiency / social welfare, or estimate the optimal balance of adaptation costs, benefits and residual impacts. These studies are likely to lead to different outcomes - and costs and benefits - when compared to studies that use pre-defined objectives, such the acceptable levels of risk[4].

Most of the earlier adaptation literature surveyed (ECONADAPT, 2015), adopts one of these two approaches. However, it is also possible to use a different framing, based around a stronger equity or ethical perspective, which is relevant when considering the role of international climate finance and

[4] An objective often used in the disaster risk literature, e.g. where the objectives might be to provide a 1 in 100 year level of protection against storm-surges or floods, and maintain this under future climate change: for an example in the adaptation context, see Rojas et al, 2013.

adaptation in developing countries. An example of is the World Bank EACC study (World Bank, 2010), which set an objective such that countries would fully adapt up to the level at which they enjoyed the same level of welfare in the (future) world as they would have without climate change.

Clearly the choice of objective influences the amount of adaptation, and in turn, the costs of adaptation. Lower costs arise when a stronger economic perspective is adopted, because a higher level of residual damage is allowed, and adaptation avoids the high cost options towards the upper end of the adaptation marginal cost curve (where costs are likely to rise dis-proportionately). It is therefore extremely important to identify the framing and specific objectives that have been set when considering existing adaptation costs, especially when looking to transfer or aggregate estimates.

The wider problem, however, is that different actors will have a different view on the most appropriate adaptation objectives, especially when this relates to the broad principles of international finance for adaptation in developing countries (i.e. on whether one is providing the finance, or receiving the finance and bearing the residual impacts). However, in practice, this is unlikely to be so much of an issue for two reasons.

First, it is clear that different objectives already exist across different policy areas and sectors, and different objectives even exist for the same sectors in different countries. As an example (Watkiss and Hunt, 2011), the UK uses cost-benefit analysis for flood investment while other European countries (such as the Netherlands) have used pre-defined levels of acceptable risks. This leads to different levels of current protection investment and a different balance of costs, benefits and residual damage. Similarly, even with the UK, a different approach is used to look at the investment in the health sector (cost-effectiveness) compared to the road transport sector (cost-benefit analysis). Similar issues arise in the developing country context, and between different actors (e.g. the World Bank versus a country government). Critically, as there is no standardisation of objectives in existing policy, why should this be any different for adaptation?

Second, and related to this, as adaptation becomes mainstreamed, the objectives will be increasingly aligned to the underlying sectoral and policy context, i.e. it is more likely that adaptation appraisal will use the existing methods and objectives, rather than seeking to introduce 'new' approaches and standards because of climate change. This is likely to be particularly the case in developing countries, because of the priority for early low-regret adaptation, and the strong overlap between early adaptation and development.

These same factors are also likely to apply to the issue of baselines. In theory, the baseline assumptions, and the future time-scales under investigation, lead to large variations in estimates. There are issues of what to include in terms of future socio-economic drivers and the effects on future exposure, vulnerability and adaptive capacity, noting these effects can be positive as well as negative. As an example, there are large differences in adaptation costs for future health adaptation in developing countries between studies that consider future development (e.g. EACC, 2010) and those that don't (e.g. Ebi, 2008), because of difference in baseline impacts and thus adaptation needs.

There is also the additional issue of the existing adaptation deficit (the gap between the current state of a system and a state that minimises adverse impacts from existing climate variability), as adaptation to future climate change will be less effective if these have not first been addressed (Burton, 2004). Studies that exclude the gap (such as the DIVA model estimates for coasts, Brown et al, 2011) will have lower adaptation costs, because they assume high levels of existing protection and thus smaller marginal costs.

However, as studies become more policy-orientated and move to mainstreaming, and especially as they focus more on short-term adaptation (the priority in developing countries), there will be more alignment with existing practice and baseline projections (e.g. in the five year plans and longer-term development planning vision), taking account of existing conditions, and aligning to future development pathways.

Nonetheless, some challenges remain. There is a potential issue in relation to the additionality of finance[5]. For future orientated studies, the mapping of adaptation and development baselines (and synergies and trade-offs) is rarely explicit in either appraisal guidance or in practical decision-making. The best-known attempt at this mapping was undertaken by Hellmuth and Callaway, (2006) who developed a matrix that systematically identified the alternative combinations of development and adaptation options, differentiating between development options adjusted for climate risk, and adaptation options adjusted for development. In practice, these frameworks are complex to apply, and require large amount of quantitative information: a review of the literature has found very few examples where such an approach has been included.

Some recent studies have started to consider these issues in more pragmatic terms. The climate resilient strategy for Ethiopia (FRDE, 2014: OECD, 2014) is a good example. This identified that 63% of the existing agricultural budget was already funding resilience-oriented activities, and of the adaptation options identified in the strategy, 38 of the 41 priority options were already included in various plans or programmes. The key issue for additionality was therefore to undertake a detailed policy review and to identify existing policies and programmes, to identify the adaptation gaps.

Discounting

Any appraisal of strategies that delivers benefits in the future has to identify the appropriate discount rate to use, reflecting the standard practice of discounting costs and benefits in future periods to enable comparison to costs and benefits today. In the mitigation domain, the issue of discount rates has been a major source of contention, notably following the Stern review (2006), which adjusted rates to account for inter-generational wealth transfers given the very long time-periods involved.

In the adaptation domain, the choice of discount rate can have a major influence of the justification for interventions with early costs and future benefits, as a higher discount rate reduces the importance of longer term benefits when expressed in current prices. This is exacerbated by the fact that impacts in the distant future are much more uncertain.

A review of the current literature (from the ECONADAPT, 2015 inventory) reveals a wide range of discount rates have been used in the existing adaptation studies in developing countries, i.e. existing practice is varied. Many studies use the standard rates in use in the country or used by development partners/IFIs (e.g. the 10 – 12% rates used by DFID and the World Bank), although some studies use lower rates (e.g. many of the countries in the UNDP investment and financial flow analysis used a 5% discount rate, and some studies effectively a 0% rate)

Nevertheless, the issue of discounting for adaptation is not quite as critical as for mitigation for two reasons. First, the move towards the phasing and sequencing of adaptation set out in Chapter I means that the policy focus of adaptation is now much shorter than for mitigation. The priority is for low-regret adaptation to address current climate variability over the next decade or so, thus benefits are likely to accrue immediately (i.e. costs and benefits will fall within the same time period). Even when looking at longer-term adaptation interventions, the timeframe will generally be limited to the next few decades, rather than the end of the century, as with mitigation.

[5] This term is generally used with respect to international climate negotiation text for developed countries to provide, "new and additional" climate change financing to developing countries. The term 'new' generally refers to the fact that the funds should represent an increase over past and existing climate-related funds.

Second, in many cases (and especially when mainstreaming), there will already be a discount rate in use that is appropriate for the underlying decision context, e.g. aligning with the development country government, development partners or IFI appraisal process. It will usually be appropriate to use these discount rates, i.e. standard public sector discount rates.

Nonetheless, in developed countries, where discount rates are high (e.g. typically 10 – 12%, as measured by the standard Ramsey formula or a similar value if the marginal social opportunity cost of capital is used), this can be problem even for short-term climate resilient development (although this may be somewhat mitigated by adjusting future values, e.g. to apply an uplift to reflect rising per capita incomes and willingness to pay). Similarly, market rates (and the rate of return on investment) will deter longer-term adaptation investment decisions made by private sector actors, and in developing countries, these rates will inhibit adaptation.

Therefore, while the use of typical discount rates will reflect current preferences, and allow the effective allocation of resources, it will reduce the attractiveness of more sustainable options, which usually takes several years to fully develop, e.g. for sustainable agriculture or green ecosystem based options (Berger and Chambwera, 2010). It will also reduce the attractiveness of any early action to address longer-term major impacts, even when this is considered using decision making under uncertainty (i.e. for robustness, flexibility, the value of information and future option value), unless early benefits (or co-benefits) can also be realised.

To address this, investments in adaptation that have long life-times, (for example, over 30 years in the OECD, and probably much less than this in developing countries), may be more appropriately discounted at declining rates (though for consistency, other, non-adaptation, public sector investments should be subject to the same discounting profile). Such rates are already recommended for use in some OECD countries[6] (HMT, 2007), but the review has found no examples of their application in developing countries. A key issue – and one that warrants some further research – is what might be the appropriate declining discount scheme for developing countries for adaptation, noting that to have a material impact on future benefits, the scheme would need to start declining much more rapidly than the UK scheme, because of the much higher initial discount rate in developing countries.

Finally, it is also apparent that climate change has the potential to lead to impacts that are not marginal, and in line with the mitigation literature, this might justify a different set of discount rates, such as the intra-generational rates in use in the UK (HMG, 2008).

Equity and distributional effects

A further issue that has been raised in previous reviews is around the distributional patterns of climate change, which disproportionately impact on poor and vulnerable groups (IPCC, 2014). In economic terms, this is important, because a dollar impact to a poor person is not the same as a dollar impact to a rich person (due to the diminishing marginal utility of additional consumption) and similarly an extra dollar spent on adaptation will give more benefit to a person who is poorer (Watkiss, 2011).

In the mitigation domain, this is critical when aggregating impacts up over space and time, and is major source of disagreement and contention as it involves ethical and moral assumptions (see

[6] Where the appraisal of a proposal depends materially upon the discounting of effects in the very long term, the received view is that a lower discount rate for the longer term (beyond 30 years) should be used: the main rationale for declining long-term discount rates results from uncertainty about the future, as this uncertainty can be shown to cause declining discount rates over time (HMT, 2007).

Anthoff et al, 2007: Anthoff et al, 2009). While these are important for adaptation for global assessments, these aggregation issues are much less important for national to local scale adaptation.

However, at this level another problem emerges. In the context of adaptation, cost-benefit analyses does not capture inequality and impacts on the most vulnerable, as it focuses on more valuable assets and groups (e.g. Cartwright et al., 2013). There is also a question of how costs and benefits can be balanced where one community or stakeholder benefits and another suffers, or the extent the costs of adaptation should be borne by the beneficiaries and to what extent they should be shared across a larger population group (Fankhauser and Soure, 2012) - though in the developing country context, where international climate finance is involved, this is less of an issue.

It is possible to take these distributional issues into account in economic appraisal by using equity (distributional) weights or looking at the distributional effects of policies or projects. However, within the literature review, no adaptation studies were found that had applied equity weights, and while there was some literature that discussed possible distributional consequences, this was only qualitative. More broadly, this reflects the practice in development economics, especially for more practical orientated appraisal, where the use of distributional weights is rare.

What is clear, however, is that it may be advantageous to consider (and even use) these distributional weights or distributional analysis more frequently than is currently the case, especially when looking to target climate finance to the most vulnerable. Given this is important for adaptation in resilient development, this subject has been identified as an area for more detailed analysis in the evaluation phase.

Scale and transferability

At a practical level, the implementation of adaptation is often at a local scale (e.g. flood prevention in a city) but rises up to national and international scales in relation to the overall policy context (e.g. regulations relating to water allocation (Agrawala and Fankhauser, 2008). Any higher scale decisions should derive information from the bottom up perspective, and conversely, lower scale decisions should take account of parameters that are set at the regional and national level. However, in most cases there will not be local estimates of the costs of impacts or adaptation, and there are issues with the transferability of aggregated estimates down to the local scale. This leads to a question over the transferability of adaptation costs and benefits over scale and between contexts and regions.

Unlike mitigation costs, adaptation costs and benefits tend to be heavily influenced by local geographic, environmental and economic factors, i.e. they are risk, site and location specific. This can be seen from the results of the literature review. As an example, there are often large differences in the applicability of climate smart agriculture options such as soil and water conservation, because of different climate risks. IFPRI (2009) found major differences between high-rainfall and dryland areas, in terms of the most appropriate measures. Similarly, the costs of adaptation can vary significantly, even for unit costs: McCarthy et al (2011) found very large variations in the costs of the same climate smart options in different countries. Likewise, economic benefits, such as those associated with increased water availability and improvement in agricultural yields will be site specific (dependent on crop choice, soil fertility and market prices), and vary with time. To illustrate, Branca et al (2012) found very large differences in the benefits between studies and contexts for climate smart agriculture, due to differences in baseline conditions and yield improvements.

What is interesting is that these factors even seem to affect the attractiveness (benefit to cost ratios) of many low-regret options (DFID, 2014). As an example, while building codes are often cited as a potential low-regret option to address future challenges (IPCC, 2012), the literature reveals a more complex picture. In the US, very high building codes can be justified because of the high value of property (ECA, 2009), however, in a study of the Caribbean (CCRIF, 2010) and in St Lucia (Hochrainer--Stigler et al. 2010) they were found to have modest to low benefit to cost ratios, with the lower values due to a combination of the risk profile and the existing cost and life-time of the asset. Similarly findings have emerged for ecosystem based adaptation (World Bank, 2011), with lower attractiveness in higher income countries due to the large differences in land and labour costs.

All of this means that caution is needed when transferring adaptation costs. This is the case even if these are unit costs or benefits, but especially when transferring overall study results or conclusions, as different studies use different methods, objectives, time-scales, climate scenarios, and assumptions, and estimates of the costs (and benefits) of adaptation are conditional on these.

The compilation of adaptation costs and benefits, and practical guidance on their transfer (reflecting the issues above) is therefore a priority. This is an issue that is being taken forward within the ECONADPT project, and this is highlighted as a source of potential future guidance on this subject.

Discussion

This section of the review has revisited a number of the methodological issues with adaptation. While the academic theory in many of these areas has advanced in recent years, a key finding is that this has not yet transferred into common (appraisal) practice: this is due to time, resource and capacity constraints which is a barrier. The larger scale and the increased number of actors now involved in adaptation also means that the appraisal processes has become more challenging, with differing views on how to best address these issues.

However, the lack of consensus is perhaps not very surprising and does not present a particularly new challenge: in many cases there are differences in practice for existing economic appraisal in developing countries, and there is no agreement or consensus on the approach (e.g. whether on discount rates or equity weights). Furthermore, the increasing use of mainstreaming in adaptation (indirectly) is reducing the influence of many of these problems, because mainstreaming leads to a greater use of existing development and sector practice, and thus the use of methods, approaches and assumptions already in place for appraisal.

Finally, what is clear is that the assumptions used to address these issues can have a large impact on results. A consequence of this is that the results of any studies – and the estimates of the costs and benefits of adaptation they produce - have the potential to be misleading if viewed in isolation. It is important for any study to be transparent about the assumptions used and implications of these on potential decisions.

V: Analysis of Uncertainty in Appraisal

Key findings:

- *One of the key challenges for adaptation appraisal is the high uncertainty involved. The most common techniques used in economic appraisal have limitations in coping with this, and a suite of new decision support tools have emerged that advance decision-making under uncertainty.*

- *These approaches include real option analysis, robust decision making, portfolio analysis, rule based criteria and iterative risk management. The review has considered these methods and identified around 30 case studies, of which around one third are in developing countries.*

- *However, all of the new methods – at least when applied formally - are complex to use and require high capacity and resources. Whilst they have potential application for major development investment, the capacity and resource needs are a barrier to their application in more routine project appraisal.*

- *A key priority is thus to develop more pragmatic (light-touch) versions of these methods, which can capture their core concepts while maintaining a degree of economic rigour.*

The final area of the review has focused down on one particular methodological challenge: the incorporation of uncertainty in appraisal. This is an area that has also developed significantly in recent years, with an increasing focus on the incorporation and treatment in decision-support tools and methods.

Decision Making Under Uncertainty

In the OECD, standard public policy and project appraisal usually involves a systematic decision-making process: understanding the problem and setting objectives; identification of options; appraisal of options (and implementation approach); planning and implementation; and finally monitoring and evaluation. This is often formalised through guidance on (regulatory) impact assessment or economic appraisal and evaluation, for both policy and project decisions.

In developing countries, there is more variation in the degree of systematic decision making and guidance, though the general concepts apply, and in many cases, these processes are introduced when overseas development assistance or finance is involved, as they are undertaken by the development partners or international finance institutions as part of project justification, due diligence and safeguards.

In the adaptation context, the earlier application of impact-assessment was not undertaken within this broader policy appraisal framework. However, in recent years, there has been a shift to align adaptation to the policy implementation cycle and towards mainstreaming, which makes it important to apply this classic policy cycle. Examples of this are the UN PROVIA initiative (PROVIA, 2014: Hinkel and Bisaro, 2014) and the National Adaptation Planning Guidance (LDC expert group, 2012).

In terms of the usual policy or project cycle, there are two points where decision support tools are particularly important;
i) for shortlisting options and
ii) for prioritising the shortlisted options.

The process of identifying a short-list of options (e.g. scoping or feasibility) includes, for instance, identifying focus areas for a national plan or strategy, options for mainstreaming climate change into a development sector plan or identifying a broad list of options for an individual policy or project. The aim of these processes is to filter options down to a manageable short-list of priorities, which can then be appraised. There are standard methods for shortlisting options, which include scoping economic analysis, simple attribute analysis and ranking, or stakeholder consultation and expert elicitation. These are common to most policy, programme or project cycles.

In the climate adaptation context, more recent scoping assessments have started to use iterative climate risk management to help with the phasing and timing of adaptation, as this can actually help the filtering process during the initial screening phase (e.g. see FRDE, 2014). This can allow analysis of which types of options to implement first, as well as which options may be needed early on to help with future climate change. As an illustration, this might identify early enhanced disaster risk management, which address the current adaptation deficit and helps to build future resilience, and also highlight opportunities for including "resilience" into infrastructure development or planning processes, where there are long life-times, and advancing research and monitoring to help future longer-term decisions.

The subsequent prioritisation of shortlisted options, i.e. appraisal, is often assisted with the use of decision support methods and tools, such as cost-benefit analysis. The formal application of such approaches is widespread in the OECD, as part of regulatory impact assessment (e.g. HMT, 2007), but less common in developing countries, where practice is more varied. As noted above, these support methods are commonly used by development partners and IFIs, and they are therefore likely to be used for adaptation in developing countries where international climate finance is involved.

There are a number of distinctive factors that are important for decision-making for prioritising adaptation options in appraisal, which does make it particularly challenging (DFID, 2014). Importantly, there are no simple common metrics to compare and prioritise different adaptation interventions and these cannot easily be standardised given the highly site- and context-specific nature of adaptation. This contrasts with mitigation, which targets a common burden (greenhouse gas emissions) and can prioritise options in terms of the cost of abating a tonne of CO_2 equivalent, using cost-effectiveness analysis and simple cost-curves.

The analysis of adaptation options therefore involves additional steps to assess impacts and to assess potential benefits (when compared to mitigation). Furthermore, many of these impacts are in non-market sectors (e.g. health, ecosystems) and many adaptation options are non-technical in nature. While there are several techniques for incorporating non-market benefits in cost-benefit analysis, this can be a resource intensive process, and this further complicates the quantification and valuation of different options.

More uniquely, adaptation has to also consider the dynamic and changing nature of climate change over time, including the inter-dependencies in climate risks, and in particular, the issue of future climatic (and socio-economic) uncertainty (Hallegatte, 2009).

As highlighted in Chapter I, this has become central to the appraisal of adaptation in the more recent literature, as it affects both the selection of adaptation options and the decision-framework for prioritisation.

Due to the challenge of uncertainty, the most common techniques used in policy appraisal (e.g. cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis) have limitations in coping with adaptation. This point was re-enforced by the latest IPCC report, and the chapter on the 'Economics of Adaptation', which reported that "*economic thinking on adaptation has evolved from a focus on cost* *benefit analysis and identification of 'best economic' adaptations to the development of multi-metric evaluations*" (Chambwera et al., 2014) and that "*economic analysis is moving away from a unique emphasis on efficiency, market solutions, and benefit-cost analysis of adaptation to include consideration of non-monetary and non-market measures; risks; inequities; behavioural biases; barriers and limits and consideration of ancillary benefits and costs*"

Therefore, along with a growing evidence-base and examples on the use of traditional decision support approaches for adaptation (cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis) there are also new approaches that are being applied that allow for consideration of uncertainty. These are discussed in the next section.

Methods for Decision Making Under Uncertainty

While there are a potentially large number of possible approaches for considering uncertainty, the review has found that the adaptation literature has concentrated on five key methods.

These include real option analysis, robust decision making, portfolio analysis, iterative risk management and rule based methods. A detailed review of these options, and their application for use in adaptation decision making, was presented in Watkiss et al. 2014. This review has summarised this information, and updated the review, particularly for the application in developing countries for climate resilient development

A summary of the approaches is shown in the figure below. The different methods are categorised into three areas: traditional decision support tools for appraisal, uncertainty framing, and economic decision-making under uncertainty. The latter two categories build on the principles in the first but are distinct because they introduce a dynamic component (e.g. for iterative risk management and real options analysis) or they use a different/additional criterion (robust decision making or portfolio analysis), or do not rely on probabilistic data (rule-based methods).

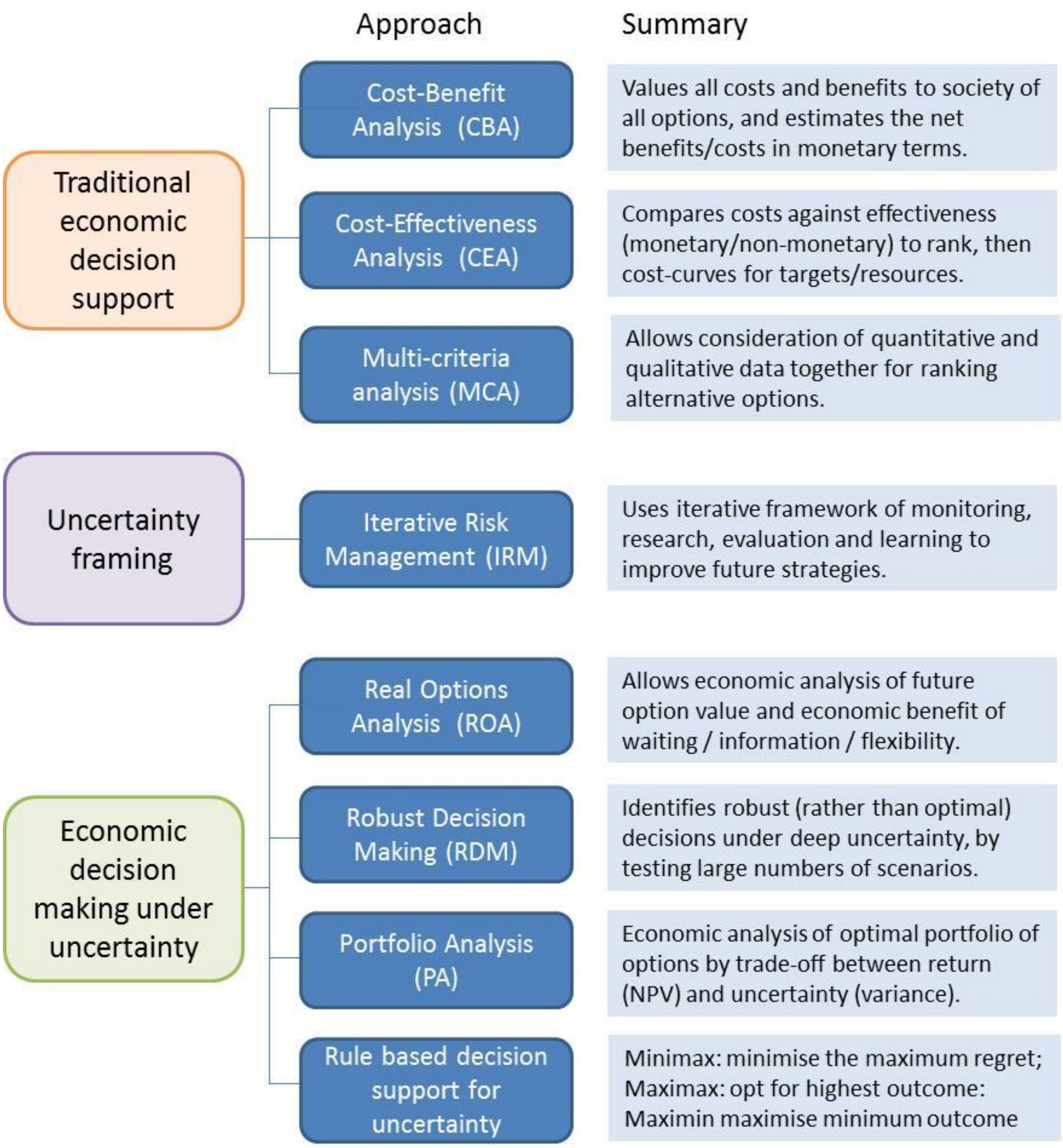
While the traditional methods at the top of the page are often suitable for early low-regret options, the use of uncertainty framing or decision making under uncertainty are needed to tackle longer-term climate change (DFID, 2014). Indeed, these new approaches align to the iterative framework and concepts presented in Chapter I.

In this review, we have updated the literature on applications and case studies (reported in Watkiss et al, 2014), adding additional information from the ECONADAPT project inventory of studies (ECONADAPT, 2015). While increasing, a key finding is that the number of economic applications of these tools (to adaptation) remains low, in both absolute terms and relative to the use of conventional tools such as cost-benefit analysis and cost-effectiveness analysis.

The literature review had identified around 30 case study applications, though this number is increasing. In general, the applications of the new decision orientated approaches are concentrated in a few sectors, notably coastal and water management, as these lend themselves to the techniques. For coastal zones, this is due to relative simplicity of sea-level rise, which is a slow-onset change for which the direction of change is certain (i.e. an increase). This makes the generation of probability distributions possible[7]. Coastal protection also often involves large, up-front capital investment and

[7] In practice, climate uncertainties are rarely characterised in such terms, and even when probabilistic-like projections exist, e.g. Murphy et al, 2008, these provide a probability distribution for individual emission scenarios, rather than a composite probability distribution for all scenario futures and all models together (although this is less of an issue in very early time periods, before emission scenarios diverge). This is a critical

this has led to applications of real options analysis. For water management, the future climate uncertainty is often higher, and as a result, there has been more application of robust decision making (to address deep uncertainty).



Decision support tools for adaptation economic appraisal

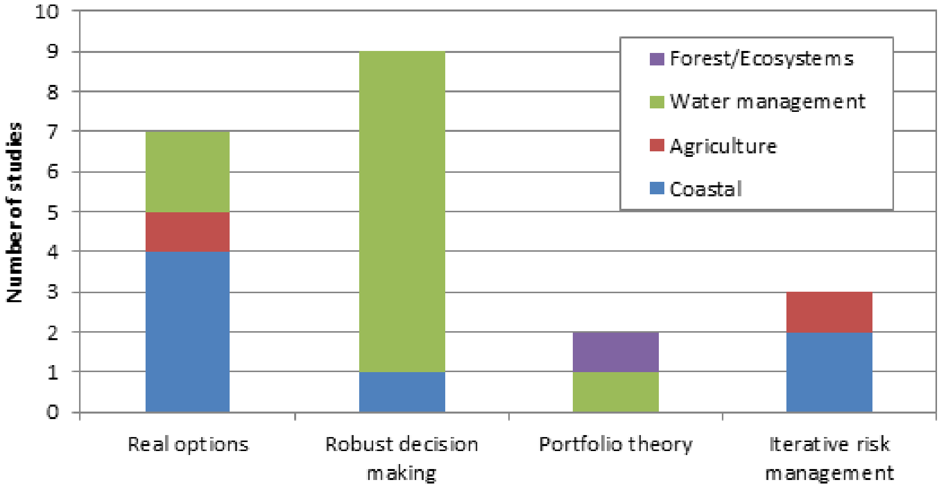
Source: Updated from Watkiss, P. et al. (2014.

These applications are predominantly stand-alone assessments, rather than mainstreaming assessments. Most of them are academic studies, focused on technical adaptation, rather than application for direct project or policy appraisal. They are also predominantly focused on the project scale, with only one or two examples at the national scale in policy appraisal. Most of the applications

issue, especially for techniques that require probability/expected value (ROA and PA). This tends to favour RDM and IRM tools when climate change uncertainty is large.

identified (around two-thirds) are in OECD/Annex 1/developed countries; however, there are still applications in developing or non-Annex I countries[8]: a list is presented below.

Recent economic application of new decision support tools for adaptation



Source Updated from ECONADAPT (2015).

Applications of Tools for Adaptation in Developing / Non-Annex 1 Countries

Tool	Applications
Real Options Analysis (ROA)	Jeuland and Whittington (2013) applied ROA for a water resource / investment planning case study in Ethiopia along the Blue Nile to investigate flexibility in design and operating decisions for a series of large dams. Linquiti and Vonortas (2012) analysed investments in coastal protection using real options with case studies in Dhaka and Dar-es-Salaam, and report this leads to better use of resources. Scandizzo (2011) applied ROA to assess the value of hard infrastructure, restoration of mangroves and coastal zone management options in Mexico, concluding ROA highlights the value of gradual and modular options. Dobes (2010) applied real options in the Mekong Delta, Vietnam, with a comparison of net present values of two housing alternatives. The World Bank (2009) applied ROA to agricultural irrigation in Mexico (World Bank, 2009).
Robust Decision Making (RDM)	Lempert et al., (2013) applied RDM to look at robust flood risk management in Ho Chi Minh City (Nhieu Loc-Thi Nghe canal catchment area) in Vietnam: the analysis found that infrastructure may not be sufficiently robust and suggests that adaptation and retreat measures, particularly when used adaptively, can play an important role in reducing risks. Dyszynski, and Takama (2010) applied RDM to investigate drought index based micro-insurance in Ethiopia. There are also a number of studies on hydro-power developments in Africa that are using the conceptual framework behind RDM (e.g. ECRAI: World Bank, 2015).
Portfolio Analysis (PO)	No applications found
Iterative Risk	There is an application of iterative risk management at the national scale in Ethiopia for the

[8] There are different definitions and categories by which countries can be grouped and the list of countries differs with each. There are therefore differences in the countries in the OECD and the UNFCCC Annex I, as well as for other definitions of what constitutes developed or developing countries. In this analysis, we combine the various definitions to cover the widest possible grouping.

Assessment (IRM)	agriculture sector, in the of the CRGE (Climate Resilient Green Economy) Strategy for Agriculture (FRDE, 2014, see OECD, 2014).

Source: This study, based on ECONADAPT inventory.

Discussion of Decision Making Under Uncertainty Methods

The review has also considered the applicability of these methods, updating the previous analysis by Watkiss et al. (2014). This reveals that there are no hard or fast rules on when to use which tool and that none of them provides a single 'best' method for all adaptation appraisal. They all have strengths and weaknesses. However, certain tools lend themselves more to specific contexts, sectors or problems. These issues are summarised in the table below

Decision-Support Tool	Strengths	Challenges	Applicability	Potential use
Cost-Benefit Analysis (CBA)	Well-known and widely applied.	Valuation of non-market sectors / non-technical options. Uncertainty limited to probabilistic risks / sensitivity testing.	Most useful when climate risk probabilities are known and sensitivity is small.	To identify low- and no-regret options. As a decision support tool within iterative climate risk management
Cost-Effectiveness Analysis (CEA)	Analysis of benefits in non-monetary terms.	Single headline metric difficult to identify and less suitable for complex or cross-sectoral risks. Low consideration of uncertainty	As above, but for non-monetary sectors (e.g. ecosystems) and where social objective (e.g. acceptable risks of flooding).	As above, but for market and non-market sectors where benefits are not monetised.
Multi-Criteria Analysis (MCA)	Analysis of costs and benefits in non-monetary terms.	Relies on expert judgement or stakeholders, and is subjective, including analysis of uncertainty.	When there is a mix of quantitative and qualitative data. Can include uncertainty performance as a criteria	As above, as well as for scoping options. Can complement other tools and capture qualitative aspects.
Iterative Risk Assessment (IRA)	Iterative analysis, monitoring, evaluation and learning.	Challenging when multiple risks acting together and thresholds are not always easy to identify.	Useful where long-term and uncertain challenges, especially when clear risk thresholds.	For appraisal over medium-longer term. Also applicable as a framework at policy level.
Real Options Analysis (ROA)	Value of flexibility, information.	Requires economic valuation (see CBA), probabilities and clear decision points.	Large irreversible decisions, where information is available on climate risk probabilities.	Economic analysis of major capital investment decisions. Analysis of flexibility within major projects.
Robust Decision Making (RDM)	Robustness rather than optimisation.	High computational analysis (formal) and large number of runs.	When uncertainty is large. Can use a mix of quantitative and qualitative information.	Identifying low- and no-regret options and robust decisions for investments with long life-times.
Portfolio Analysis (PA)	Analysis of portfolios rather than individual options	Requires economic data and probabilities. Issues of inter-dependence.	When number of complementary adaptation actions and good information.	Project based analysis of future combinations. Designing portfolio mixes as part of iterative pathways.

Source: Adapted from Watkiss, P. et al. (2014).

Existing decision support tools, including cost-benefit analysis, can be used for studies that are focused on current climate variability, though adaptation interventions are often in areas that are difficult to value and may involve a lack of quantitative information. In such cases, cost-effectiveness, multi-attribute analysis (or multi-criteria analysis) may be more practical, notwithstanding the limitations of these approaches.

For the analysis of short-term decisions with long life-times / longer-term challenges, the use of new decision support tools is warranted. Robust decision making has broad application for current and future time periods. When investments are nearer term (especially with high up-front capital investments), and where there is an existing adaptation deficit, real options analysis is a potentially useful tool. For long-term applications in conditions of low current adaptation deficit, iterative risk assessment may be more applicable. Importantly, while the tools are presented individually, they are not mutually exclusive.

Whilst these tools have primarily been developed in the context of project-level appraisal, in principle they can be used to inform the development of policy initiatives at the national and sectoral scale. Iterative risk frameworks and robust decision making have most potential for programme and sector analysis though they are more proven at the project level. However, at this national level, they serve principally as an organising framework, often with semi-quantitative versions due to data availability, though they can provide a good guide to the economic sense of the initiatives.

At the project level, where data is available, all the tools can be applied more quantitatively. However, tool selection will be influenced by data availability and the level of uncertainty. Several approaches, such as real options and portfolio theory, require subjective probabilistic inputs (at a minimum) and preferably use objective probabilistic inputs. This is a challenge for climate projections, particularly in the developing country context where observed data and future projections are often missing or highly aggregated.

It is worth noting that the differences between the tools are not limited to data and capacity constraints but may have a material impact on the order of prioritisation of adaptation. Klijn, Mens and Asselman (2014) demonstrate that applying robust decision making results in a different order from cost-benefit analysis, and cost-benefit analysis produces a different order from cost-effectiveness analysis.

Finally, an analysis of all these new methods – at least when applied formally – is that they are resource-intensive and technically complex. Indeed, this constrains their formal application to large investment decisions or major risks. Therefore, they are more likely to be applied to large priority projects for adaptation or specific adaptation projects, rather than contribute to adaptation mainstreaming. They also have limited potential for widespread application to many applications, e.g. as might be needed when implementing a national adaptation plan. These issues are likely to limit future application, especially in developing countries.

A critical question is therefore whether the concepts in these uncertainty approaches can be used in "light-touch" approaches that capture their conceptual aspects, while maintaining a degree of economic rigour, both at policy and project level. This would allow a wider application in qualitative or semi-quantitative analysis. This could include the broad use of decision tree structures from real options analysis, the concepts of robustness testing from robust decision making, the shift towards portfolios of options from portfolio analysis, and the focus on evaluation and learning from iterative risk assessment for long-term strategies. There has been some progress advancing these types of light-touch applications (Hallegatte et al., 2012; Ranger et al., 2013). However, more research needs to be undertaken to better understand how and where the trade-offs between quantitative analysis and pragmatic application can be made. Given this finding, the potential for light-touch applications has been selected as a topic for more detailed analysis in the evaluation phase of the study.

Next steps

As part of this review work a number of areas have been identified for a more detailed analysis and the identification of good practice examples. The topics include:

- The mainstreaming of adaptation into development planning,
- The appraisal of building (adaptive) capacity and distributional effects,
- The phasing and prioritisation of adaptation, and
- Light-touch decision-making under uncertainty.

The findings will be written up as a second working paper, linked to the evaluation phase of the project.

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