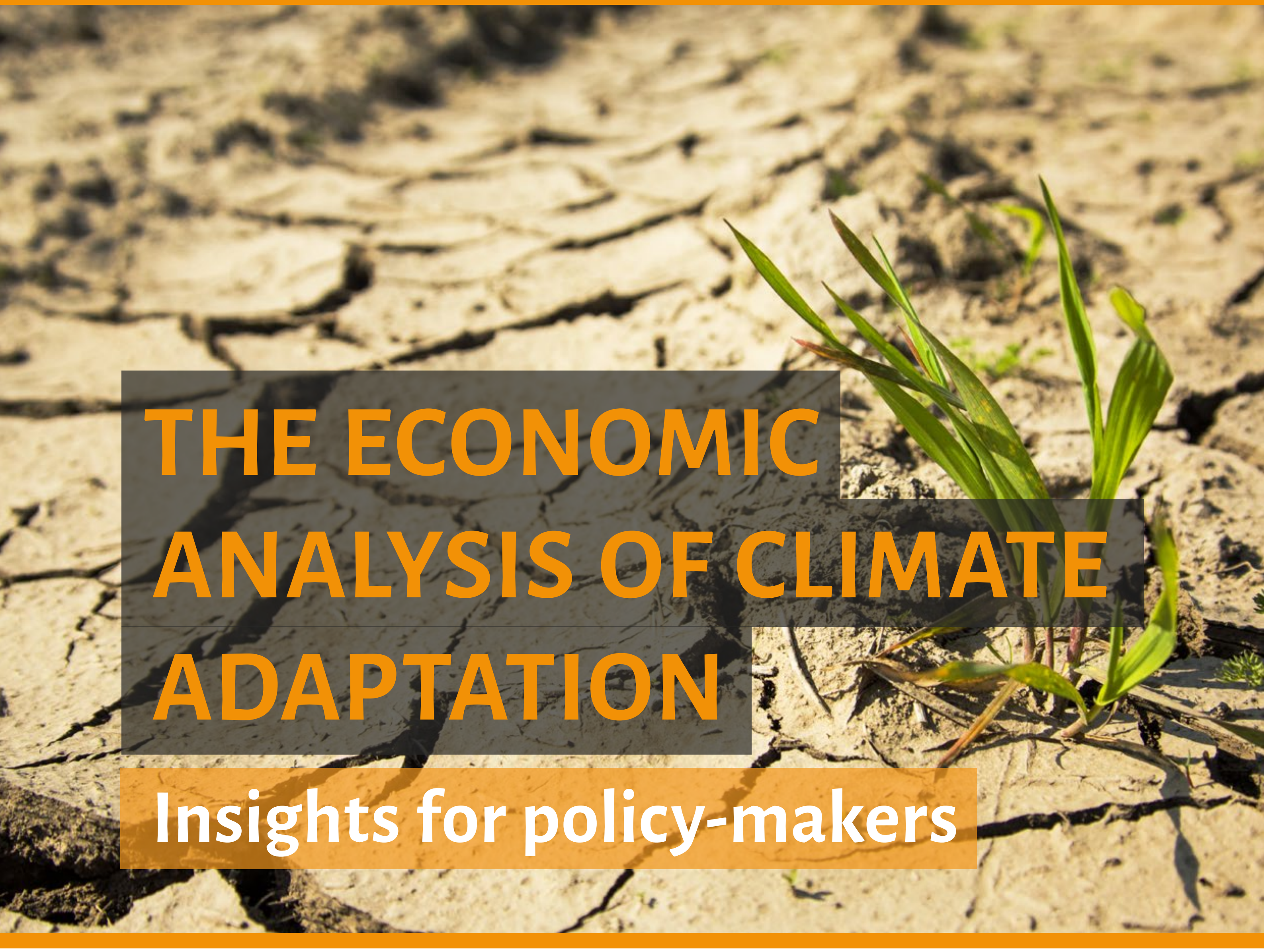
ECONADAPT / THE ECONOMICS OF ADAPTATION



THE ECONOMIC ANALYSIS OF CLIMATE ADAPTATION

Insights for policy-makers

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Citation

Rouillard, J., Tröltzsch, J., Tarpey, J., Lago, M., Watkiss, P., Hunt, A. Bosello, F., Ermolieva, T., Goodess, C., Mechler, R., Parrado, R., Sainz de Murieta, E., Scussolini, P. (2016). The economic analysis of climate adaptation: Insights for policy-makers. ECONADAPT deliverable 10.3

To find out more about the ECONADAPT project, please visit the web-site: **www.econadapt.eu**

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The ECONADAPT project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No. 603906.

WHAT WILL YOU FIND IN THIS DOCUMENT?

HOW CAN THIS DOCUMENT HELP YOU?

With climate change impacts increasing and becoming widespread, decision makers face the need to take informed decisions on the long term costs and benefits of investing in different infrastructure projects or policy programmes. The use of **economic analysis can provide valuable information on the value, efficiency and feasibility** of adaptation projects and strategies.

This guide has been developed as part of the **ECONADAPT project**, funded by the European Commission under the Seventh Framework Programme. The objectives of the project are to build the knowledge base on the economics of adaptation to climate change and to convert this into practical information for decision makers, in order to help support adaptation planning.

This guide aims to:

- Inform **the application of economic assessment tools to adaptation**. In particular, it provides information on methodologies, data and evidence for practitioners with a more technical background.
- Target **interested policy makers and eonomists**, some of whom may use or develop the methods further, others who may simply gather information on how to interpret results or methodological approaches. Furthermore, it can be of interest to a wider group of experts, stakeholders, and students carrying out case studies.
- Provide **linkages to the more detailed information** available online through the **ECONADAPT toolbox** and **ECONADAPT library**.

What was the FP7 ECONADAPT (2013–2016) project about?

The aim of the ECONADAPT project was to **provide user-orientated methodologies and evidence relating to economic appraisal criteria** to inform the choice of climate change adaptation actions using analysis that incorporates cross-scale governance under conditions of uncertainty. A critical theme was to support the application of adaptation economics in the period following the publication of the **EU's 2013 Adaptation Strategy**, focusing on key decision areas that need enhanced economic information, and on the key users of such information. The project has received funding from the EU's Seventh Framework Programme for research and technological development under grant agreement No. 603906.

HOW TO NAVIGATE THIS DOCUMENT?

This guidance document is organised in a manner that corresponds with the approach that might be taken by policy-makers in the context of adaptation decision-making.

- The concept of **economic appraisal of adaptation** is first introduced to provide background for the subsequent more detailed methodologies.
- **A general framework for the economic appraisal of adaptation** is presented. This highlights key steps in the analytical process for prioritising adaptation options, and can guide decision-making in different decision contexts
- The type of analysis and the methods used will largely depend on individual adaptation situations. **Five groups of adaptation "challenges"** are presented: Project Appraisal, Policy Impact Assessment, Disaster Risk Management, Macro-economic Assessments and International Development. A structured approach to the economic analysis is then described in detail for each challenge, accompanied by practical examples.
- **Further project information** is provided at the end of the document which may be useful.

What you will not find in this document!

This document aims to present guidance on the application of economic appraisal in the context of climate change adaptation. However:

- It does not offer a **one-size-fits-all approach** to economic appraisal of climate change adaptation options. An important conclusion to be drawn from this guidance is that each adaptation situation is unique, and so must be treated as such.
- It does not provide **compulsory steps** to be followed when undertaking economic appraisal of adaptation options. Again, adaptation situations must be treated independently in order for any economic appraisal to be valid.
- It does **not repeat the basics** of climate change adaptation or explain the fundamental of economic appraisal. It is expected that the target audience will have a basic understanding of these issues.
- Nor does it go into **great detail** on each economic method. Many involve complex modelling and calculations. The role of this document is thus not to describe the actual implementation of these economic tools, rather to shed light on when they can be useful while offering a basic overview of each method's application.

HOW CAN ECONOMICS SUPPORT DECISION MAKING IN CLIMATE CHANGE ADAPTATION?

Why should I use economics?

Adaptation is increasingly recognized as an important part of any policy, since unavoidable climate change will affect every part of our society. The progressive adoption of adaptation strategies and plans has been accompanied by greater consideration of the costs and benefits of alternative courses of action. Economic analysis for adaptation however is not only a question of costs or financial return of climate proofing projects.

There is wide recognition that economic analysis currently used in adaptation can provide valuable information for decision-makers and stakeholders, for example by:

- Bringing clarity on trade-offs associated with different development paths in the medium to long term, and providing an indication of **the net value of different options under different possible futures**;
- Highlighting in a more transparent way **the value of future benefits**, including the importance that current generations place on the future. This can ultimately enhance **the consideration of sustainability principles** in decision-making;
- Strengthening the capacity of society to envision and plan strategically **in face of high uncertainty** and supporting the identification of robust solutions capable of high performance against a large number of futures, thereby **enhancing the resilience of society against future risks**;
- Presenting a **structured approach** to design, implement and evaluate projects, measures and policy programmes, and enabling the comparison of trade-offs between wait-and-see strategies and immediate action. This can ultimately support the application of the precautionary principle and **enhance the capacity of society to adapt** to non-linear dynamics in the climate and natural system.

What does it involve?

The economic assessment of adaptation measures is different from a normal economic appraisal, in that **the focus of analysis is on managing uncertainties and risks**. It must take into account different time-scales, complex systemic relationships and dynamics, multiple sources of uncertainties, etc…

Furthermore, mainstreaming adaptation involves **embedding adaptation decisions within multiple sectors and decision contexts**, which vary in relation to the nature of the intervention, its spatial and temporal scales and its institutional context.

Why should you worry about uncertainties?

Uncertainty is a state of having limited knowledge where it is impossible to exactly describe existing state or future outcome. There are various sources of uncertainties in adaptation: lack of information, too much information, or conflicting information, measurement errors, linguistic ambiguity, subjectivity of opinions.

Three types of uncertainties are typically considered:
- Epistemic uncertainty: lack of information or knowledge for characterizing phenomena;
- Normative uncertainty: the absence of prior agreement on framing of problems and ways to scientifically investigate them;
- Translational uncertainty: incomplete or conflicting scientific findings.

It is important to take into account that an overabundance of information or contradicting information also can lead to uncertainty; thus, gathering more data and information to reduce epistemic uncertainties may not always be successful in reducing uncertainty.

A number of principles structure the economic analysis of adaptation:
- Investments are seen **as dynamic processes** which should respond to new climatic and socio-economic conditions. There is thus a strong focus on iterative risk management and learning.
- There is a focus on **strategic scoping, phasing** and **prioritisation** of adaptation, considering responses adapted to current climate variability and future climate change over longer periods of time.
- There is a **much greater attention on early steps** to adequately characterise current policy objectives, wider non-climatic drivers, baselines and interventions, as well as the context for decisions.
- Practical adaptations are seen as **portfolios of measures**, taken in front of uncertainties about climate changes, which allow future society to deal with unforeseen events in a robust and flexible way. Investments may involve a more broad set of response types than an optimisation approach would allow.

A policy-led framework to adaptation economics

The ECONADAPT project has supported the development of a "policy led framework", characterised by the following:
- There has been a **move towards a policy-orientated approach** framed around adaptation, coupled with a greater emphasis on integrating (mainstreaming) adaptation into current policy and development.
- There has been a shift to look at **the phasing and timing of adaptation**, with an increasing recognition of uncertainty and the use of iterative risk management approaches.

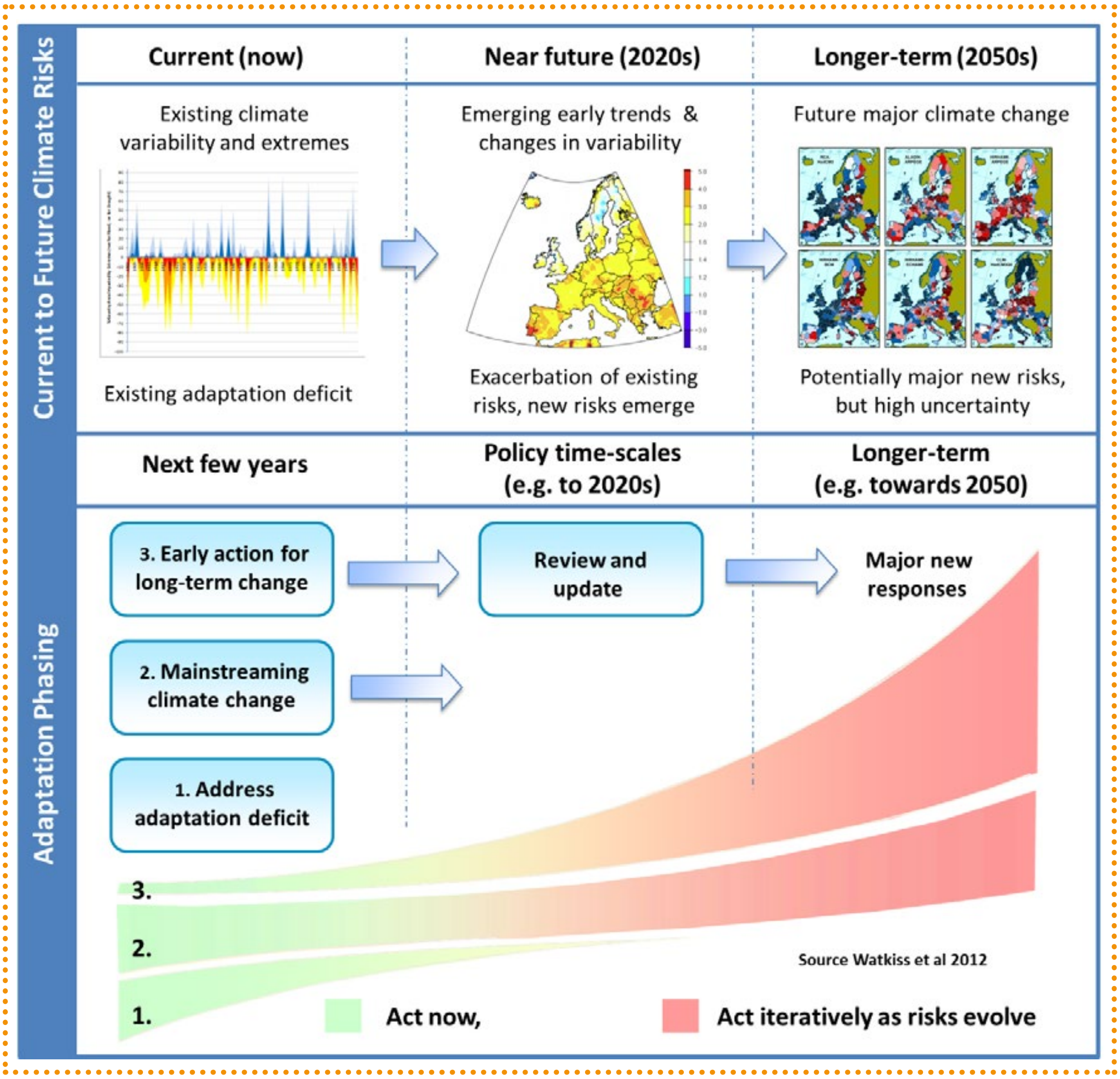
It starts with current climate variability and then assesses future climate change, considering uncertainty. It then maps out how adaptation decisions perform against these risks, and recommends categorising actions into three types of early policy decisions and associated interventions, i.e. actions that could be undertaken in the next decade for addressing the impacts of short, medium and long-term climate change, under conditions of uncertainty.

These are:

- **Immediate actions that address the current risks** of weather and climate extremes (the adaptation deficit) and also build resilience to future climate change. This includes early capacity-building and the introduction of low- and no-regret actions, which provide immediate economic benefits as well as future benefits under a changing climate.
- The integration of adaptation into immediate decisions or activities **with long life-times**, such as infrastructure or planning (climate smart development). This involves different options compared to the immediate actions addressing current risks (described above) because of future climate change uncertainty. It involves a greater focus on climate risk screening and the identification of flexible or robust options that perform well under uncertainty.
- **Early monitoring, research and learning** to start planning for the future impacts of climate change. This includes a focus on adaptive management, the value of information and future option values and learning so that appropriate decisions can be brought forward or delayed as the evidence and knowledge emerges. The three categories can be considered together in an integrated adaptation strategy, often termed a portfolio or adaptation pathway.

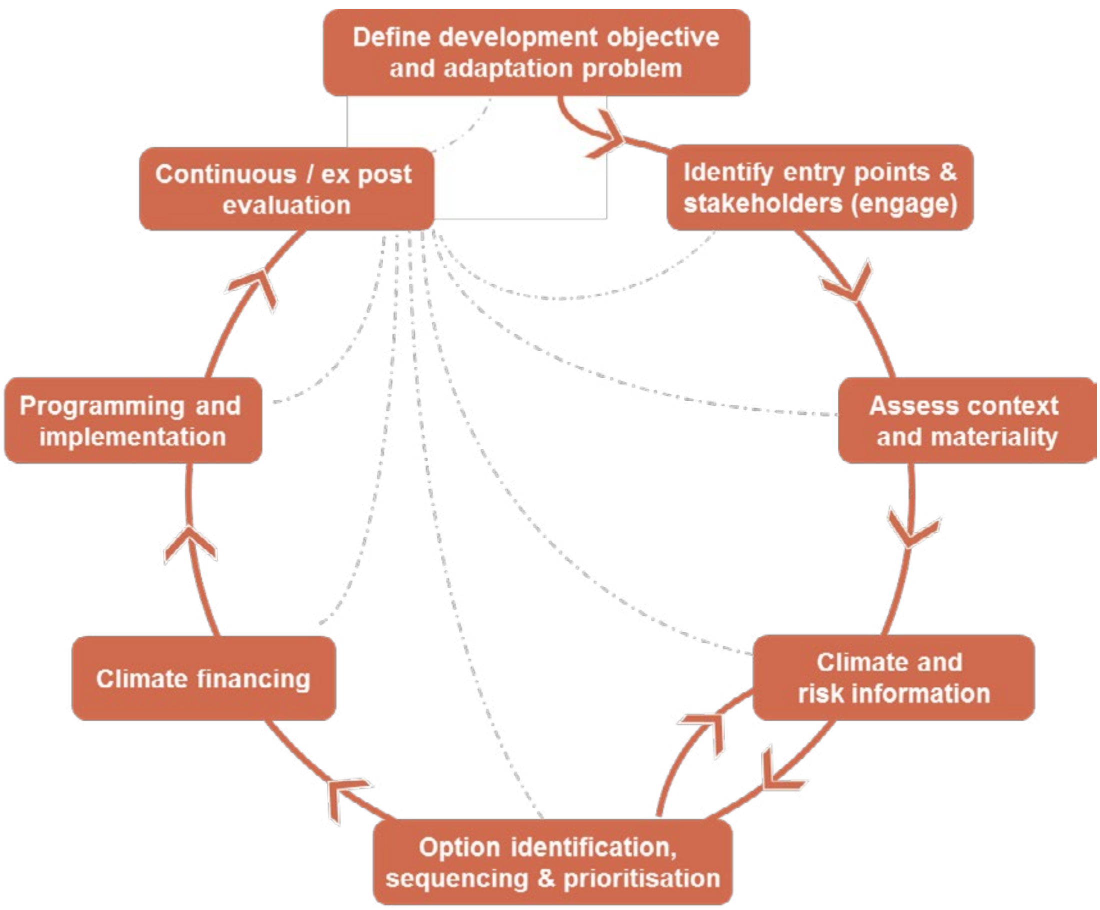
More information on the policy-led framework canbe found **here.**

An illustration of the framework is shown in the figure on the next page. The framework starts with climate change (top), which is split into a number of linked risks, each related to different policy problems and time-scales. Starting with current climate variability and extremes (top left), i.e. the adaptation deficit. Over time, climate change will affect these existing impacts, and lead to major new risks (top right), though often with high uncertainty. In response, an adaptive management framework has been recommended for adaptation (bottom).


Current to Future Climate Risks
Current (now)
Near future (2020s)
Longer-term (2050s)
Existing climate variability and extremes
Emerging early trends & changes in variability
Future major climate change
Existing adaptation deficit
Exacerbation of existing risks, new risks emerge
Potentially major new risks, but high uncertainty
Adaptation Phasing
Next few years
Policy time-scales (e.g. to 2020s)
Longer-term (e.g. towards 2050)
3. Early action for long-term change
Review and update
Major new responses
2. Mainstreaming climate change
1. Address adaptation deficit
3.
2.
1.
Source Watkiss et al 2012
Act now,
Act iteratively as risks evolve

WHAT ARE THE MAIN STEPS INVOLVED IN ECONOMIC ANALYSIS OF CLIMATE CHANGE ADAPTATION?

In the ECONADAPT project, a framework was developed for the economic analysis of climate adaptation in different adaptation decision making contexts. The application of the framework can help frame the overall consideration and early prioritisation of adaptation and aligns with a typical policy or appraisal cycle. It has particular relevance: 1) for short listing options and 2) for prioritising the shortlisted options. It aligns to a more practical and implementation focused assessment, focused on supporting early adaptation decisions, including within mainstreaming. The framework can be applied to help in the identification, timing and sequencing of adaptation and the short-listing of options. This can help identify focus areas for a sector plan or strategy or identifying a list of options for individual projects.



These steps are presented in more detail below.

Defining the adaptation problem

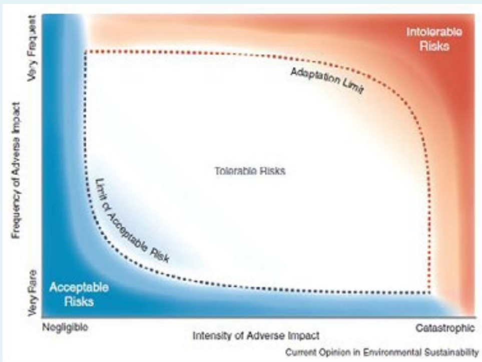
The policy-led approach recommends starting the assessment by framing the overall aims and objectives towards adaptation. This orientates the analysis to provide information to inform early decisions for policy makers. Critically, this is usually focused around the question of 'what do I need to do in the next five years?', noting this may include immediate actions but also early interventions to start adapting to future climate change. This framing is particularly important in aligning to the adaptation planning process and the prioritisation of early actions for early climate finance.

Considering uncertainties in decision-making

Adequate consideration of uncertainties - and their interaction - is necessary when designing an adaptation project. However, managing all uncertainties is a challenging task. While reducing epistemic uncertainty by acquiring knowledge or reducing normative uncertainties through participatory processes is possible, translational uncertainty cannot be reduced.

A risk framework can represent a good strategy to deal with uncertainties. Risk can also be defined as the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems, economic, social and cultural assets, services, and infrastructure.

Three broad risk categories can be used to guide decision-making: acceptable risks, tolerable risks, and intolerable risks (which exceed a socially negotiated norm). The figure maps these categories of risk on a two dimensional space. One can see that the type of risk depends on the degree of the potential impact and also its probability (frequency). The low probability catastrophic events can be of the same high degree of risk as very probable events with a moderate impact. The boundaries have a fuzzy structure due to the qualitative definition of acceptable, tolerable, and intolerable risks (e.g. different opinions of stakeholders). The shading around the limits indicates those actors' views of what is acceptable, tolerable or intolerable risk may vary. Adaptation may be seen as action aimed at maintaining the position of a given valued objective (such as a technical norm of flood protection) within a tolerable area relative.



Assessing and managing risks involves a number of steps: describing and modelling the systems to be managed; identifying hazards related to the system functioning; selecting the events that may initiate accident(s); quantitatively analysing the accident(s) (including exposure and vulnerabilities); evaluating risk and carrying out the decision making (or deliberative) process. Several economic methods are available to quantitatively or qualitatively analyse the economic risk of alternative investment options (see below).

It is important to highlight that in order to reduce uncertainties from different subjective opinions, a clear way of communication and the use of a well-founded vocabulary can help avoid linguistic ambiguity. Transparency generally helps; however, particular care should be given to the way information on scientific methods, statistics and the like are communicated, including ranges and so on. Communication on uncertainty should be different for different types of audiences.

Source: the figure was taken from Renn, O., Klinke, A., 2013. A Framework of Adaptive Risk Governance for Urban Planning. Sustainability 5, 2036–2059. doi:10.3390/su5052036

Identify entry points and stakeholders

There is an increasing emphasis on integrating (mainstreaming) adaptation into current policy and development, rather than implementing measures as a stand-alone activity. This requires the integration of adaptation into existing policies and processes, taking account of broader policy objectives and wider costs and benefits, not only for climate change risks. Importantly, this aligns the process of adaptation to development, which is a key issue in the developing country context. A component of this mainstreaming process is to find relevant entry points, that is, to identify opportunities in the national, sector or local planning process where adaptation can best be integrated.

It is necessary to engage with stakeholders at different stages in the project, in bilateral and multilateral meetings, and to ensure good communication and exchange of information.

Dealing with uncertainties through social learning

One of the ways to cope with multiple perspectives and interpretations of governments, organizations, private enterprises and individuals lies in social learning. We can consider two types of uncertainties which are connected with social learning: informational uncertainty (due to the lack of knowledge) and normative uncertainty, which is linked to perception of acceptable risk. Planning processes can take a dynamic learning approach to climate modelling based on the availability of more robust information; estimates are regularly updated with advances in knowledge and understanding of the risks posed to society by any given climate disaster. In order to address the issue of uncertainty over time in climate policy paths, the dynamic learning approach can be employed by creating decision points along policy paths to incorporate improved information and models.

Selecting time horizons

Two notions matter particularly when deciding whether to focus on short- or on long-term future in the assessment.

- Short term: On the one hand, focusing on the shorter term often seems more appealing to meet the horizon of interest of many stakeholders (e.g., investors, local and national governments). But on the other hand for many impacts, like sea level rise, short time horizons entail small differences between climate change scenarios, hampering the comparison of impacts and therefore of adaptation between high- and low-emission scenarios.
- Long term: While reasoning in terms of the end of the century (or beyond) may seem to make little sense to many stakeholders, in the long term drastic differences in impacts between scenarios become evident and can be quantified. Also, this ultimately forms the basis for studies of primary importance in the climate change discourse, such as the comparison of the costs of adaptation versus the investments needed to mitigate emissions.

Assessing the context and materiality

Gathering a preliminary level of knowledge in a context analysis is essential to correctly aim the following steps of the appraisal. This includes:

- Characterising the physical context, synthesising knowledge on the environmental features, the climate, and the hazard;
- Characterising the socio-economic context in order to define the boundaries of the adaptation target, identifying which people and activities are relevant;
- Characterising the policy, institutional and stakeholder context, by preparing e.g. an extensive list of the people, companies and institutions involved, and of their normative and executive responsibilities.

Climate and risk information

The next step is to develop the climate information and risk information. In line with the iterative approach, this should start with current climate variability and then look towards future climate change projections, with a strong emphasis on capturing uncertainty.

This analysis of risks should also be undertaken within the context of the adaptation decision, i.e. who and what decision it aims to inform on. In the case of a specific infrastructure project, for example, the focus may be on investigating the economic costs and benefits of enhancing resilience in the design. In a more complex policy or programme mainstreaming setting, it will include a broader focus on the risks to various activities, noting the life-times of different areas and decisions.

Sourcing and using climate information for adaptation economics

Climate information should be credible, legitimate, salient and timely. There is a tendency for the physical climate science community to focus on the first two criteria, whereas the last two are particularly important for stakeholders and policy makers focused on adaptation. Climate experts working with the adaptation community need to be flexible particularly in response to ad hoc requests and bespoke applications. At the same time, sourcing and using climate information is not something that adaptation economic experts should undertake alone, but in partnership with climate experts. Building relationships, trust and understanding between these different communities is essential.

More information on the use of climate information in adaptation economics can be found ***here***.

Hazard assessment

More specifically on hazard assessment, it is essential that a range of possible future outcomes is selected, both in terms of the physical-climatic world and of the socio-economic world.

Future climatic developments that have been adopted by the latest IPCC report in 2013 are the so-called Representative Concentration Pathways (RCPs), which correspond to a range of four different narratives that bring about different intensities and timing of greenhouse gas emissions. For each of these emission scenarios, General Circulation Models (GCMs) are employed to calculate the evolution of climate variables, such as temperature, humidity and precipitation, for the rest of the century and beyond. Future socio-economy is accounted for by the so-called Shared Socioeconomic Pathways (SSPs).

Studies on regional to local scale are generally based either on statistical downscaling of GCM results, or on Regional Climate Models (RCMs). The latter incorporate boundary and forcing conditions from GCMs to which they are interfaced ("embedded"), and are run at higher resolution, which enables more accurate the representation of specific climate mechanisms, such as those due to irregular local topography. When the expertise available to the practitioners allows, it is worth applying RCM or statistical downscaling.

Regarding time horizons, the practitioner should consider that climate change is a gradual process. Generally, impacts will be proportional to the time horizon selected. But while for the most moderate climate change scenario the situation is expected to stabilize after a few decades, for the highest one, impacts will increase for a longer time. To sample the evolution of climate change-driven processes, the approach taken often involves selecting at least two time horizon of focus: the short term (e.g. 2030 and 2050) and the long term (e.g. 2070 to 2100).

Impact assessment

An efficient way to deal with the quantification of climate change impacts is to express them as changes in the risk faced. Risk assessment provides important information for decision-making, including on the hazard faced, as well as the exposure and vulnerability of the population.

Selecting climate and socio-economic scenarios

Even though Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) are decoupled, and many combinations between them are possible, this step is important to make sure that the chosen combination of climate/emission and socio-economic scenarios is coherent. The following combinations are recommended, which in a way cover the extremes of the future spectrum of possibilities:

- RCP2.6 and SSP1: Successful sustainable technologies are implemented, strongly reducing emissions and leading to the mildest climate change scenario. Further, diffused development enables even capacity for adaptation.
- RCP8.5 and SSP3: No implementation of policies to address climate change results in high use of fossil fuels to meet growing energy demand, and intense climate change unfolds. Further, development equality is low, and capacity for adaptation is locally highly limited.

While likely impacts can be assessed based exclusively on historic datasets, it is very beneficial, to the ends of the adaptation appraisal, to have access to a model that is able to simulate future impacts. A model enables altering one or more of the risk components (hazard, exposure, vulnerability) to incorporate and to understand the effect (i.e., the risk reduction) of adaptation.

Obtaining reliable data on the climate change-induced hazard is the most essential aspect of any assessment. A characterization of the hazard intensity on a map allows for the spatial analysis of the impacts. Accounting for the people and assets that are located in the reach of the hazard is the second most important phase of the impact analysis.

Information about the vulnerability links the exposed people and assets to the hazard they may experience, and enables quantifing the damage suffered. Most often, vulnerability is represented in the so-called ”stage-damage” (or ”vulnerability”) functions, which report the proportion of damage for a given amount of hazard.

Option identification, sequencing and prioritisation

Each adaptation measure has features that make it more or less suitable to the given context.

The modeling framework for the impact assessment can be used to calculate impacts of climate-driven hazards both with and without the selected adaptation measure(s). Contrasting future outcomes under the two assumptions will then allow to evaluate the effectiveness of the measures. Still, oftentimes it may be unclear how the existing assessment model(s) can take into account some impacts, e.g. from soft adaptation measures such as early-warning systems or some types of impacts, e.g. increasing the copying capacity of residents. It is important to account for what the modeling framework is able to consider, and what it cannot.

Adaptation measures are effective under some circumstances and, many measures lose part or all of their effectiveness past certain system threshholds. For example, a dam that is meant to protect the city downstream from river flooding will stop serving its purpose once precipitation and discharge in the basin, and thus water levels at the dam, will pass some critical threshold, also called adaptation ”tipping point”. The moment when the tipping point is reached typically depends on the hazard, e.g. a heavy precipitation event or a hurricane leading to flooding, or a climate change scenario, and can be determined by modeling the system under different scenarios in multiple future time horizons. Because of large uncertainties related to occurance of catastrophes and also to future climate scenarios and to modeling limitations, the timing of tipping points is generally difficult to pinpoint.

Reviews on the costs and benefits of adaptation in different sectors is available. More information can be found **here**.

To avoid reaching a tipping point, the decision-maker is faced with a set of feasible adaptation options: e.g., raising the dam further, and/or altering the course of the river downstream, and/or changing land use practicies (e.g. deforestation) upstream. If no other option but the current can be adopted anymore, the current option is often called a ”lock-in” option. The decsion-maker needs to be very aware that decisions may lead to possible lock-in situations, when the choices of future generations are strongly limited.

The economic assessment involves quantifying the value of the proposed adaptation measures. A number of methods are available, be it through a cost-benefit, cost-effectiveness or multi-criteria framework or using methods that derive robust adaptation strategies under uncertainties and risks, in particular, of catastrophic nature.

The following two tables summarise the main groups of economic tools and their potential use, and compares their strength and weaknesses. There are no hard-or-fast rules on which tool to use in which application, though, certain techniques do align to various elements of the policy led framework. There is no “one-size-fits-all” approach to economic appraisal; each method presents a unique set of strengths and challenges. It is important to carefully select the most appropriate approach for each individual adaptation decision making situation.

Main groups of methods in adaptation economics and their potential use

	APPROACH	SUMMARY	POTENTIAL USE
Traditional economic decision support	Cost-Benefit Analysis	Values all costs and benefits to society of all options, and estimates the net benefits/costs in monetary options	To identify low- and no-regret options in the near future. As a decision support tool within iterative climate risk management
	Cost-effectiveness analysis	Compares costs against effectiveness (monetary/non-monetary) to rank, then cost-curves for targets/resources	As above, but for market and non-market sectors where benefits are not monetised
	Multi-criteria analysis	Allows consideration of quantitative data together for ranking alternative options	As above, but for scoping options. Can complement other tools and capture qualitative aspects
Uncertainty framing	Iterative risk management	Uses iterative framework of monitoring, research, evaluation and learning to improve future strategies	For appraisal over medium-longer term. Also applicable as a framework at policy level
Economic decision making under uncertainty	Real-option analysis	Allows economic analysis of future option value and economic benefit of waiting / information / flexibility	Economic analysis of major capital investment decisions over the medium term. Analysis of flexibility within major projects
	Robust decision-making	Identifies strategies which are optimal (robust) against a large number of plausible scenarios	Identifying combination of strategic (long-term scenario-independent) and operational (short-term scenario-dependent) decisions
	Portfolio analysis	Economic analysis of optimal portfolio of options by trade-offs between return (net present value) and uncertainty (variance)	Project based analysis of future combinations. Designing portfolio mixes as part of iterative pathways

Main strengths and limitations of economic tools to support adaptation decision-making

METHOD	STRENGTHS	CHALLENGES	DEALING WITH UNCERTAINTY
Cost-benefit analysis	Most useful when climate risk probabilities are known and sensitivity is small. Also where clear market values can be used	Valuation of non-market sectors / non-technical options. Uncertainty limited to probabilistic risks / sensitivity testing	Does not explicitly deal with uncertainty, but can be combined with sensitivity testing and probabilistic modelling
Cost-effectiveness analysis	As above, but for non-monetary sectors and where pre-defined objectives must be achieved	Single headline metric difficult to identify and less suitable for complex or cross-sectoral risks. Low consideration of uncertainty	Does not explicitly deal with uncertainty, but can be combined with sensitivity testing and probabilistic modelling
Multi-criteria analysis	When there is a mix of quantitative and qualitative data	Relies on expert judgement or stakeholders, and is subjective, including analysis of uncertainty	Can integrate uncertainty as an assessment criterion, however usually relies on subjective expert judgement or stakeholder opinion
Iterative risk management	Useful where long-term and uncertain challenges, especially when clear risk thresholds	Challenging when multiple risks acting together and thresholds are not always easy to identify	Deals explicitly with uncertainty by promoting iterative analysis, monitoring, evaluation and learning
Real-option analysis	Large irreversible decisions, where information is available on climate risk probabilities	Requires economic valuation (see CBA), probabilities and clear decision points	Deals explicitly with uncertainty by analysing the performance of adaptation for different potential futures
Robust decision-making	When uncertainty and risk are large. Can use a mix of quantitative and qualitative information	Requires high computational analysis and large number of runs	Explicitly incorporates uncertainties and risks, in particular, systemic dependent risks, to derive robust solutions
Portfolio analysis	When number of complementary adaptation actions and good information	Requires economic data and probabilities. Issues of interdependence	Deals explicitly with uncertainty by examining the complementarity of adaptation options for dealing with future climates

Regarding their application to different adaptation contexts, it is worth highlighting:

- For analysis that is focused on current climate variability (the adaptation deficit), existing decision support tools can be used, including Cost-Benefit Analysis (CBA) and Cost-Effectiveness Analysis (CEA);
- As adaptation interventions are often in areas that are difficult for valuation, and usually involve a lack of quantitative information, Multi-Criteria Analysis (MCA) is often used;
- For long-term applications in conditions of a low current adaptation deficit, Iterative Risk Management (IRM) may be more applicable.
- When investments are nearer term (especially high upfront capital irreversible investments), there is potential for learning as new climate risk information available becomes available, and where there is an existing adaptation deficit, Real Options Analysis (ROA) is a potentially useful tool;
- For the analysis of adaptation in the face of uncertainty, when risk of maladaptation is high, Robust Decision Making (RDM) can be employed. RDM has broad application for current and future time periods and focuses on robustness rather than optimality as a decision criterion;
- For the analysis under high uncertainty of combinations of adaptation projects which are potentially complementary, Portfolio Analysis (PA) can be a useful approach.

A light touch approach to the application of economic evaluation tools

While the tools are presented individually, it should be noted that they are not mutually exclusive. Many of these methods are resource intensive and technically complex, and this is likely to constrain their formal application to large investment decisions or major risks. Given this, a critical question is whether their concepts can be used in 'light-touch' approaches that capture their conceptual aspects, while maintaining a degree of economic rigour. This would allow a wider application in qualitative or semi-quantitative analysis. This could include the broad use of decision tree structures from Real Option Analysis, the concepts of robust decisions from Robust Decision Making, the shift towards portfolios of options from PA, and the focus on evaluation and learning from Iterative Risk Management for long-term strategies.

Financing, programming and implementation

In many assessments, the production of a prioritised adaptation plan marks the end of the analysis. However, within a policy centred approach, there are additional activities that need to be considered as part of the assessment. Critically this includes the financing of the plans towards implementation: unless a source of finance is identified, a plan will sit 'on the shelf', reducing the relevance and impact that the detailed analysis has sought to inform.

Indeed, it is more useful to consider the source of potential finance to implement a plan from the start – rather than waiting to the end of the assessment to consider this. This is important because the requirements of funders differ – and should thus be considered from the very start of the project in the design of information and analysis framework. This relates to the broad framework (the justification of the project, or the framing in terms of activities, outputs, outcomes, safeguards and M&E, but also in terms of the economic and financial information required (benefit to cost ratio, financial (project Internal rate of return) or general value for money criteria). The types of implementation and the implementing agents – and the mix of public and private adaptation – will also influence the modality of funding, such as whether it is grant based or involves public-private partnerships (concessionary loans, innovation grants, etc.).

There are also some additional factors when moving to implementation. Adaptation costs are higher when working with practical adaptation, because of the additional capacity building costs, as well as the additional opportunity, transaction or policy costs associated with implementation (noting such costs are usually omitted in 'unit cost' estimates). These need to be included in the overall design and economic appraisal of adaptation.

One further issue is that thecapacity building and soft options are more challenging to appraise in economic appraisal. Many of these options can be quantified using value of information measures, for both early direct responses, as well as for informing future orientated decisions. There are also approaches that exist for assessing socio-institutional and organisational options, including the use of alternative approaches such as switching values.

Continuous / ex-post evaluation

The policy-led framework encompasses a reflexive-participatory framework based on iterative risk management: it encourages the continuous incorporation into decision-making of new knowledge on the complex dynamics of social–ecological systems and their interactions with a changing climate as it becomes available. There are number of dimensions to take into account:

- Procedures for planned evaluations and revisions including scope and periodicity
- Responsibilities for the monitoring and evaluation process, ensuring a partnership and participative approach
- Procedures for anticipated decision chains

In the following chapters different examples for the application of the general framework will be described.

Private involvement in adaptation

Stakeholders that will substantially benefit from the adaptation (e.g., farmers, industries, consumers) may be considered to share the public investment burden. Policy frameworks for fostering private adaptation are very contextual and can draw on a large range of policy instruments. Their development needs to be grounded in a sequential and adaptive process.

More information into private involment in adaptation can be found ***here****.*

APPRAISING PROJECTS

When is it useful?

Large capital investments have long life times, and they are thus vulnerable to future climate risks. There are also risks of lock-in situations in adopting large, inflexible assets. At the same time, major new structures often take many years to plan, finance and build; thus it may not be possible to adopt a preventive or precautionary strategy and wait for better knowledge and reduced uncertainties.

Economic analysis methods can help consider adaptation dimensions in the appraisal of projects, especially if including large infrastructure investments. They can help integrate the value of future knowledge and flexible design in projects. They can bring transparency in the weighing of current and future preferences and trade-offs. Furthermore, they can help assess the incremental costs of additional investment expenditure against their effectiveness in reducing the risks of future (uncertain) climate change in the longer-term.

An application to inland and coastal flood risk management

The following presents an illustration of the application of the policy-led framework to inland flood protection for the city of Prague (Czech Republic) and to coastal and river flood protection in Bilbao (Spain). The application of the policy-led framework focuses on the use of climate information with risk data to prioritise adaptation options and the treatment of uncertainties.

More information can be found on the Bilbao case study **here** and on the Prague case study **here**.

Defining the adaptation problem

The Czech study carried out an ex-post appraisal of adaptation of flood risk protection built from 1999 to 2014, for which the corresponding investments and social benefits were included in a cost-benefit analysis. The Spanish study carried out an appraisal of an infrastructural measure that is currently planned, which consists in the conversion of an urban peninsula into an island, so as to reduce flood risk from the combination of river and coastal flooding.

Assessing the context and materiality

The step consisted in synthesising knowledge on the geo-morphological and hydrographic features, the climate, and the hazard proneness of the cases' area. The boundaries of the cases were defined, identifying which people and activities are exposed to climate-related risk.

The Czech case study focused on Prague, located in the Lower Vltava river basin district, one of two river basin districts in the Vltava river basin that are both managed by the Povodí Vltavy, state enterprise. Prague is the dominant economic unit in the river basin, and the floodplain area encompasses residential areas as well as several important industrial areas, recreational zones such as urban parks and also agricultural areas in the south of Prague.

The Spanish case study focused on a district of Bilbao situated in a flood prone area of the estuary. The area had been shaped by the requirements of the manufacturing industry accompanied by a fast growing population in the mid 20th century.

Climate and risk information

In the Prague case, different combinations of compatible climate and socio-economic scenarios were selected. Climate data were included from a wide range of climate models, and thus adequately sampled the inter-model uncertainty. For the Bilbao case, results of only one climate model were used, after ensuring that the dataset was representative of the multiple models' ensemble mean.

However, in the Prague case, conditions were simulated at present and at the end of the century. Simulating multiple future time slices greatly improves the appraisal of future benefits of adaptation, but requires more computational power. In Bilbao, the study makes use of climate forcing data from the downscaling of a suite of state-of-the-art Regional Climate Models. New definitions of flood hazard probabilities were created under the new IPCC emission scenarios, RCPs 4.5 and 8.5.

For both cases flood maps for floods of multiple return periods were produced, which allowed addressing floods as stochastic events. For the Prague case, simplified relationships and data interpolation were used to obtain flood extents from maximum precipitation. Exposure datasets were intersected with flood maps, using vulnerability curves. Country-specific vulnerability curves (i.e., depth-damage curves) were applied.

In the Bilbao case, floods of different magnitude were treated as discrete possibilities, thus likely underestimating the expected annual damage resulting from their joint probabilities. Exposure datasets were obtained from land use maps, which were retrieved with very high spatial detail. The following factors were considered: population, economic activity, and areas of environmental interest potentially affected. Impacts also included intangible and non-monetary metrics, such as health and disruption of traffic.

Option identification, sequencing and prioritisation

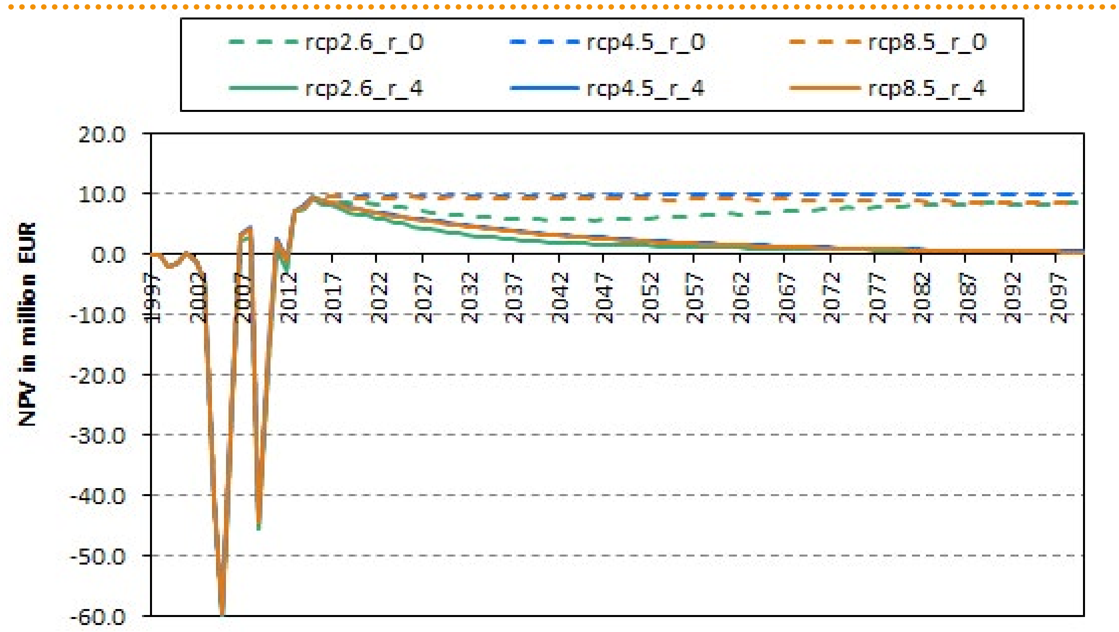
In the Prague case, adaptation measures to increased inland flood risk consisted of line measures (e.g. fixed anti-flood earth dikes, reinforced concrete walls, mobile barriers) and barriers in the wastewater system (e.g. backflow preventers). In the Bilbao case study, the main adaptation measure to coastal flooding was the opening of the Deusto channel, turning the area under examination from a peninsula to an island. An additional measure to be implemented in Zorrotzaurre is the elevation of the urban area developed along the Deusto channel.

Within ECONADAPT a tool has been set-up that enables the screening of possible adaptation options in flood and water management, and filtering them according to their characteristics. More information can be found **here**.

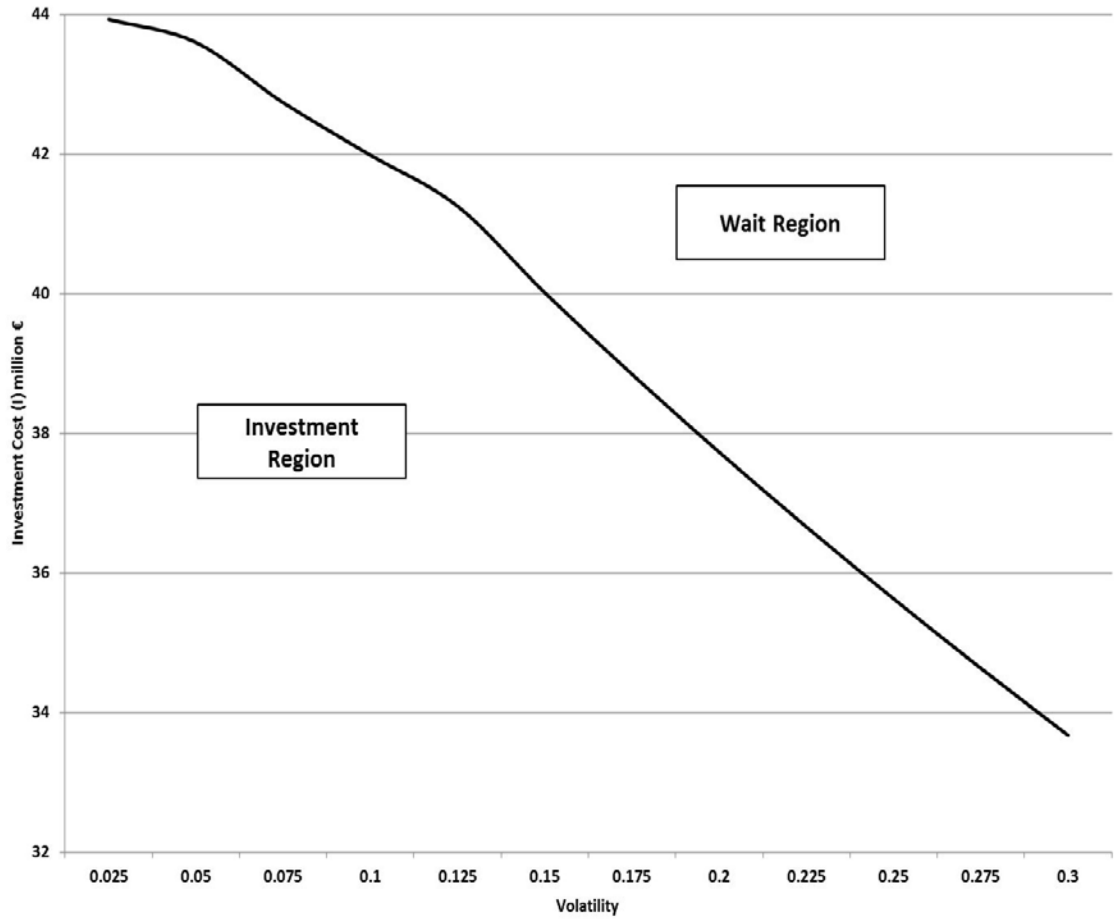
Two methodologies were applied in the economic appraisal:

- For the Prague case study, cost-benefit analysis was used, implemented with an extensive sensitivity analysis: on climate scenarios and model-uncertainty, economic growth, discount rates, infrastructure cost variables and depth-damage functions;
- For the Bilbao case study, three approaches were combined: stochastic modelling, estimation of two risk measures (Value-at-Risk and Expected Shortfall) and real-option analysis. The Value-at-Risk (VaR) is a standard measurement and well recognised by international financial regulatory bodies. The VaR of damage resulting from river flooding in the case study expressed the losses that could occur with a given confidence level of 95%, for a time interval of 85 years. Expected Shortfall, ES, represented the average damage of the 5% worst cases. ES is, therefore, a better measure of risk for low probability but high damage events.

The graph below displays the annual Expected Net Present Value (ENPV) of flood protection measures in Prague according to different climate conditions (represented by RCP scenarios) and discount rates. The dashed lines represent a discount rate of 0%, while the solid lines are discounted at 4%. The average value of ENPV for all RCP scenarios is € 626 million, if we assume 0% discount rate. The differentiation between RCPs will have a moderate impact on ENPV, the RCP2.6 scenario will decrease the value by 30%, RCP4.5 will increase ENPV by 6% and RCP8.5 decreases by 4%. The investments are thus efficient across scenarios of changing future climate. However, when considering 4% discount rate, then the effect of RCPs on ENPV is larger, the change is -107%, 14% and -7% for RCP2.6, RCP4.5 and RCP8.5, respectively. Using a discount rate above 4% meant that the project was not longer efficient.



In Bilbao, results showed a range of 266–330 M€ for VaR (95%) and 371–445 M€ for Expected shortfall (ES) (95%) in the baseline. The opening of the canal is expected to reduce not only the expected damage but also the level of risk, that is, the damages that would occur in the worst 5% of the cases. Average expected damages would be reduced by 41 to 58 M€, while ES decreases with the opening of the canal by 174–205 M€ during the period under assessment. The final step was to evaluate the economic impact of different investment timing using real-option analysis. The figure shows the results that determine the boundary value of investment cost between the "investment region" and the "wait region" for a limited time period. The graph shows that the greater the volatility, and therefore in uncertainty, reduces the investment boundary. In other words, greater volatility makes potential investors more demanding and they invest only when the cost is lower.



Key lessons

The sensitivity analysis in the Prague case study showed that the critical factor in the CBA assessment is the selection of a discount rate. Discount rates in the range up to 3% still enable that the adaptation option generates positive Net Present Value. However, if discount rate is set at 4% and above, the project is no longer efficient.

In Bilbao, the use of several economic measures of uncertainties in infrastructure investments (i.e. expected damages through stochastic modelling, value at risk and expected shortfall and real-option analysis) provided different types of information to decision-making. The main advantage of the methodologies presented is the capacity to consider and integrate multiple sources of uncertainties in the assessment, to inform not only decision on whether or not to invest, but also on the optimal timing for investment.

APPRAISING POLICIES AND PROGRAMMES

When is it useful?

Adaptation is increasingly recognised as an important part of any policy, as unavoidable climate change will affect every part of our society. Mainstreaming adaptation in sectoral policies or investment programmes is especially relevant as they involve the flow of substantial funds and will affect the livelihood of many people. Integrating the ability of policies to enhance adaptive capacity, as well as contributing to prior development objectives, is therefore essential.

Furthermore, cross-sectoral, rather than narrow sectoral analysis, needs to be a part of an impact assessment that can take into account the cross-sectoral multiple dependencies and objectives. Economic analysis can help examine these linkages.

An application to European agricultural policy

More information on this case study can be found **here**.

The following presents an application of the policy-led framework to the appraisal of EU agricultural policies, in particular the Common Agricultural Policy (CAP). The application of the policy-led framework focused on context analysis and the integration of climate data into an economic analysis based on robust decision-making.

Defining the adaptation problem

The case study aimed at assessing which adaptation options lead to synergies between the direct CAP payments for sustainable resource management, climate change mitigation through bio-energy use as well as private and public investment in ecosystem management for adaptation. In particular, it examined how uncertainties may affect decisions for the timing and magnitude of public investment in ecosystem management for adaptation as related to direct CAP payments.

Policy appraisals often concentrate on single measures and single objectives, insufficiently addressing the fact that each single policy can fulfil several objectives, and different policies can enhance or impede each other's objectives. Therefore the case study employed an appraisal methodology which considers several policies at the same time and derives an optimal mix of different policies to reach an anticipated objective.

Assessing the adaptation context

A review of the EU CAP reform was performed to assess the current policy context. Based on a literature study and stakeholder consultation, it scoped out the problems and needs that decision-makers faced with when developing adaptation policies in the context of the CAP reform in order the make the European agricultural sectors more climate resilient.

Adaptation context analysis of the CAP: some key results

- Although the current CAP already has several mechanisms to enhance adaptation and to pay more attention to sustainability and climate resilience, further strengthening of these mechanisms, focusing specifically on proper uncertainties and risks representation and management, should be considered and informed by more substantial monitoring systems.
- The set of options for mainstreaming climate adaption in the CAP ranges from simple provision of information on climate change and adaptation options in the context of the CAP policies, at one extreme, to a fundamental revision of the CAP mechanisms, at the other extreme. This leads to much larger shares of the CAP payments that are directly related to environmental targets and investments in adaptation.
- Although the rural development and CAP policies aim at fostering a climate resilient agricultural sector in Europe, currently there still is a high risk that despite the large amount of CAP subsidies, or even as a result of these, the agricultural sector is developing in a direction that makes it more vulnerable to weather extremes that may occur under climate change.
- A variety of alternative mechanisms are identified in the CAP that can be used to stimulate and facilitate adaptation including insurance, capacity building, networks, and partnerships. However, currently, it is not clear how the proposed measures will be implemented in practice and whether the speed and intensity of the actions are sufficient to provide the required resilience in the agricultural sector.
- In the context of water quality management, the CAP support may currently lead to developments in manure management, nitrogen leakage, and eutrophication that aggravate existing problems. For this reason, it is important to harmonize the CAP system further with policy areas such as biodiversity conservation, landscape, and water and air quality.
- Although private actors, farmers in the agricultural sector clearly have responsibility for adaptation to climate change, many farmers have imperfect information on climate change impacts and the adaptation options that are available and suitable. This implies that it is important to consider whether the financial means incorporated in current CAP arrangements can be used to provide stronger incentives to farmers to adapt to climate change and therefore to make the agricultural sectors in Europe more climate resilient.

Climate and risk information

A priority area in this case study was to further develop the representation of the yield functions impacted by climate change which are relevant to the developed modeling exercise. To this end, the literature on the impacts of climate change on agricultural yields was reviewed, in particular those that have been modelled using crop models and used them as an input into economic models.

There was a variety of modeling set-ups adopted in the studies reviewed, the differences including: basic setups (time horizon, spatial resolution, regional setup, sectoral resolution for general equilibrium models); different reported variables, different definitions of these variables (e.g. prices), different baselines; choice of socio-economic scenarios; derivation of biophysical crop yield changes; inclusion of global trade relations and inter-regionally consistent climate change effects on crop yields; and adaptation assumptions.

The papers in the assessment found that while aggregate effects are relatively small, this masks large regional differences, in particular, more positive effects in Northern Europe and negative effects in Southern Europe are found. Furthermore, effects in the agricultural sector are large compared to other sectors for Northern and Southern Europe. However, the inclusion of international trade effects – as well as explicitly excluding or including adaptation – is decisive for results and can potentially reverse signs regarding output changes.

Option identification, sequencing and prioritisation

Clearly, a sophisticated integrated multi-regional cross-sectoral modelling framework is more likely to be able to undertake such an analysis. This case study explored the potential for the Global Biosphere Management Model (GLOBIOM) - a stochastic Integrated Assessment Model (IAM) – to do this.

GLOBIOM includes climatic and systemic risks of different kinds and security (safety) criteria that enable buffering of various shortfalls, e.g. production and consumption, to meet Food-Energy-Water-Environment Security requirements at regional and global levels, which is important for planning agricultural sustainable development policies. The criteria also included targets and norms on the emission of greenhouse gases, water, and fertilizer utilization norms.

The stochastic GLOBIOM was applied to compare synergies and trade-offs between Pillar II structural policy measures (costly, often irreversible, that can imply high sunk costs and lock-in situations, e.g. investments in irrigation systems, food/feed storage capacities) and non-structural Pillar I measures (measures that can be reversed or adjusted for on short notice, such as payments per hectare) in the CAP. The approach minimizes total costs of the decisions providing policy makers with flexibility for revising the measures in light of newly acquired knowledge about uncertainties.

Strong synergies and trade-offs between Pillar I and Pillar II, non-structural and structural measures, were found. In some regions, the introduction of rather moderate grain storages can not only increase adaptive capacity towards climatic shocks, but also decrease water demand, save investments into irrigation expansion, stabilize profits and thereby decrease the demand for income support. Agricultural policies have to account for the risk exposure of the location and the potentials of the location to adapt. Implementation of agricultural reforms in one region can affect other regions. Thus, introduction of CAP measures, in particular, changing structure of CAP subsidies from coupled to direct payments, can lead to subsidizing free riders, decrease incentives for investments in long-term structural adaptation, cause a decrease of "self-sufficiency", an increase of import dependence, changes in trade balance and market structure, an increase in market risks, a decrease in food security, and socio-economic instabilities.

The stochastic GLOBIOM provides insights regarding robust distribution of subsidies based on location-specific risk-exposure, profitability and security indicators. Under a scenario of robust subsidies combined with storage facilities, the demand for irrigated area can be decreased by about 6% compared to the case without storages.

Financing, programming and implementation

Results indicate the need to pay particular attention to the differences and synergies between the measures of the two CAP pillars. While independent deterministic evaluation of measures can result in ineffective distribution of CAP funds, the coherent analysis of dependencies and trade-offs leads to more effective adaptation. It has been shown that different payment schemes lead to different outcomes in terms of increasing demand and cropping area for some regions and crops, whereas they lead to a decrease for other regions and crops. Moreover, effects differ when analyzing direct payments alone or together with other policy measures such as storage capacities. The clearest example here is the demand for irrigated land. The demand for irrigated land reduces when direct payments and storage facilities are provided. Hence, different policy measures may act as substitutes in different regions.

Moreover, explicit treatment of uncertainties and risks for robust adaptation strategies saves considerable maladaptation and sunk costs compared with investments into adaptation projects appraised using scenario-by-scenario deterministic analysis of alternative climatic scenarios, in this case yield shocks. For example, decisions evaluated with respect to a single shock scenario, e.g. average yield scenario, can substantially underestimate land demand as well as production technologies able to hedge production risks in extreme scenarios. By taking into account the variability of yields, the stochastic GLOBIOM identifies the portfolio of land uses and technologies required to hedge the risks and leave the society better-off regardless of what shock scenario occurs.

Key lessons for the EC Policy Impact Assessment Guidelines

- The EC Policy Impact Assessment Guidelines (PIA) for preparing policy proposals, (European Commission, 2009), suggest that risk assessment is based on only one baseline scenario. However, with a longer term perspective that adaptation requires, problems can occur when a different scenario than projected materializes. We therefore suggest that the entire appraisal and specifically the risk assessment should be carried out based on at least three scenarios, perhaps using the IPCC Shared Socioeconomic Pathways (SSPs).

- In section 9 of the PIA guidance document, three ways in which the different options can be appraised are described. These are cost-benefit analysis, cost-effectiveness analysis, and multi-criteria analysis. None of these include a rigorous assessment of policies under uncertainty and risk. We, therefore, suggest combining risk assessment with these three appraisal tools by, for example, integrating into this text descriptions of other appraisal tools, such as Real-Options Analysis (ROA), Portfolio Analysis (PA) and Robust Decision Making (RDM) that are already being used in the project appraisal of adaptation options. The stochastic IAM we use in the agricultural policy context incorporates a number of the principles incorporated in these tools and could also be promoted in this regard.

- Given the very detailed and comprehensive list in tables 1-3 of the PIA guidance, on economic, social and environmental impacts, all relevant sectors of society appear to be covered. But as conventional tools may fall short of being able to incorporate the effect of a policy on different sectors, it may again be worthwhile to refer to the possibility of using, e.g. stochastic IAMs to integrate a multi-sector assessment where competing objectives need to be made explicit. We therefore suggest that developing and using such models may be helpful for the appraisal of other complex policies in the face of climate change.

APPRAISING IN THE INTERNATIONAL DEVELOPMENT CONTEXT

When is it useful?

One of the largest areas of adaptation investment in the next few years will be associated with European international development assistance (from the European Union and Member States) to developing countries, in line with international climate agreements. Recent analysis of existing European climate funds and current flows reports that these adaptation finance flows will be considerable.

Better consideration of adaptation in international development assistance involves improving a number of adopted practices in existing economic appraisals. Adaptation appraisal would involve greater clarity regarding the benefits of dealing with existing adaptation deficits as opposed to securing the effectiveness of future adaptation. It also would improve the consideration of future benefits as current used discount rates in developing countries are much higher than in developed countries.

An application to coffee production and tea plantation in Rwanda

More information on this case study can be found **here**.

In Rwanda, the case study undertook an economic and financial analysis to investigate the justification for adaptation. The case study applied a policy-orientated iterative climate risk management (ICRM) approach, with an economic and financial analysis to assess options. The application focused on the option identification and financing steps of the policy-led framework. It first identified the current and future climate risks and the types of early policy decisions, and from this, identified two areas of adaptation to consider in the overall plan.

Defining the adaptation problem

The first area considered was to identify possible low-regret options that could help address the current impacts of weather and extreme events. These were built around options that improve current productivity and/or quality for tea and coffee and, enhancing coffee production. The second area of analysis considered early decisions with a long life-time, focusing on the Rwanda national tea expansion plans. This is an example of climate smart land-use planning, in order to address the question of where (i.e. which areas) to expand new tea production.

Option identification, sequencing and prioritisation

The study identified relevant areas across the three types of early policy decisions for addressing short, medium and long-term climate change under uncertainty:

Application of economic rules for decision-making under uncertainty

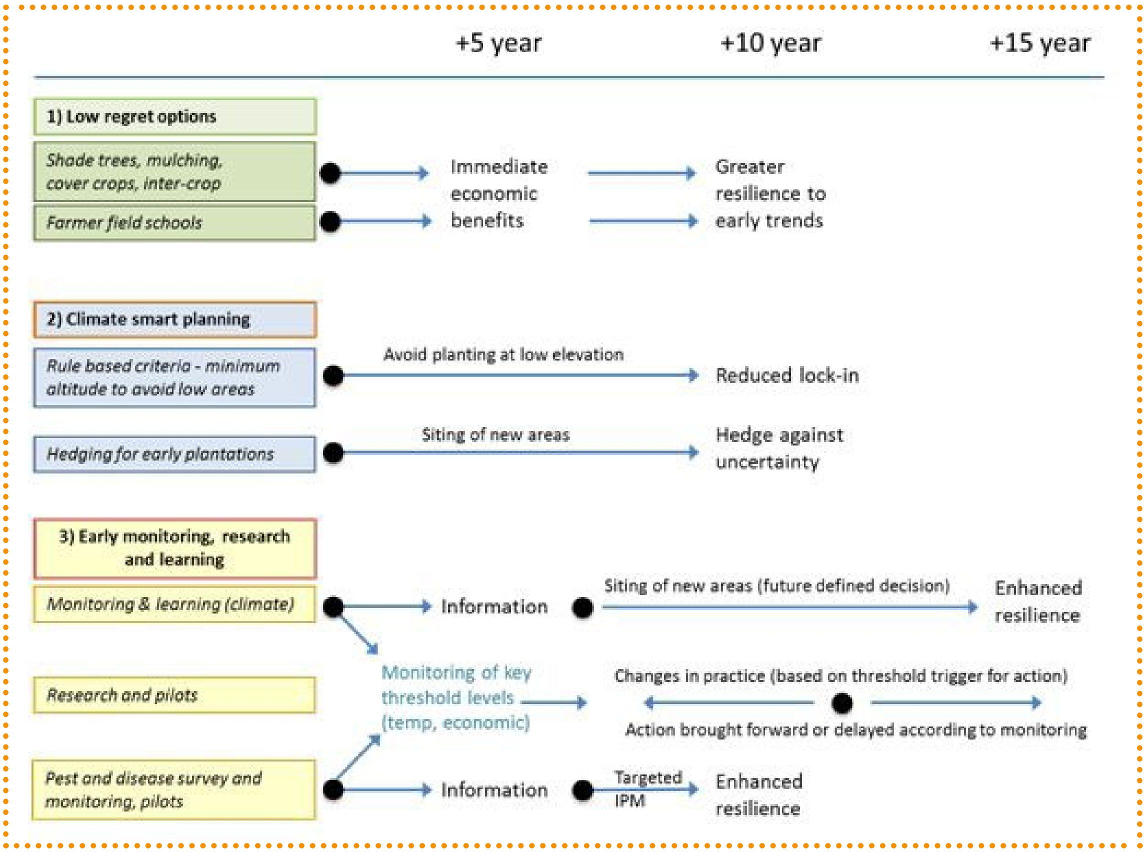
The case study adopted a number of decision-making under uncertainty concepts.

- First, it adopted a rule based criteria to determine elevation thresholds for tea production under current and future climate e.g. to identify areas likely to be unsuitable given the lowest level of future climate change. This minimises the risk of lock-in. The threshold set was a minimum level of 1800 metres (above mean sea level) for new tea areas, noting this rules out some areas that have been potentially selected as being suitable for new tea expansion. The rule was based on an economic analysis.
- Second, the study started to analyse the potential for a portfolio based approach to hedge against future risks. This involved a balanced portfolio of planting across different elevation zones – for each expansion area. This minimises the risks of planting in a narrow elevation zone that subsequently turns out to be poorly suited to the future climate, and thus helps maximise the return on investment. It also helps hedge against the dynamic nature of the shift in climate over time, as the optimal suitability shifts with gradual warming.
- Finally, the analysis considered longer-term adaptive management options. It considered the potential benefits of investing in monitoring and surveillance to provide information to improve future decisions. This recognises that such information has an economic benefit as it allows different (informed) actions in the future, which in turn generate higher benefits or lower costs. This is often referred to as the value of information. The study considered two such examples, looking at how the costs of producing enhanced information compares to the subsequent benefits.

- Early low regret options to address current variability and build future resilience, focusing on capacity building and climate smart agriculture;
- Including flexible and robust actions into near-term decisions with a long life-time, primarily around land-use plans and agricultural expansion; and
- Early actions and learning, as part of an iterative approach, to start preparing for future major climate change, centred on major future risks.

The case study showed that the application of a policy-orientated ICRM framework was extremely useful in developing the timing and phasing of adaptation, and translating this through to practical interventions that could form the basis for the adaptation strategy. It showed that a portfolio of interventions is needed, to address the different (temporal) risks and different types of decisions, with a combination of methodological approaches. The portfolio is summarised below.

The study found high economic benefits from investing in early low-regret options that address current weather risks, especially climate-smart options whose benefits increase with climate change. These options had high benefit to cost ratios and high internal rates of return, and are an immediate priority for early adaptation.



In relation to future orientated risks, the study found economic benefits from some options – but importantly not all. A robust finding was that planting new production areas at very low altitudes today (e.g. towards the lower end of current production ranges) would not make economic sense. The analysis also showed that planting at higher altitudes, which will become better suited in the future, involves a more complex trade-off, and the choice of strategy is important. Early indicative analysis suggests a portfolio approach, which looks to hedge against uncertainty, would be a more robust strategy.

However, a further finding is that given the long planting periods, there is time to learn, and investing in early monitoring and risk information to help to improve future siting decisions. This highlights a key finding of the study, i.e. with the application of an adaptive management framework and investments in early monitoring, research and learning.

Financing, programming and implementation

The case study found that there is a greater need for capacity building, institutional strengthening and soft options (non-technical) in this developing country context, to enable efficient and effective adaptation. This led to a greater focus on building complementary portfolios of options, even to address specific risks. As an example, the case study identified the need for capacity building for farm level interventions (e.g. farmer field schools) and institutional strengthening and support (e.g. international technical assistance support for adaptation to government ministries), alongside climate smart farm-level options. Many of these additional activities are associated with implementation, and importantly they are often omitted in many technical or academic studies.

Climate smart agriculture options need to factor in the opportunity costs from labour and land, and there is a need to factor in the additional costs of capacity building (e.g. farm advising service) to ensure the uptake and effectiveness of practice. Similarly, an option focused on ecosystem based adaptation will need to factor in the necessary institutional and governance arrangements and costs (e.g. enforcement or community based involvement) to ensure the option is effectively maintained.

Key lessons

The research highlighted that, while CBA is likely be appropriate for early low regret options, other approaches that have more sophisticated treatments of uncertainty are needed for longer-term decisions.

In the case study , data and information was a limiting factor in the analysis, i.e. there was very sparse climate risk information (downscaled) for the projects/programmes, and there were significant additional resources needed to collect and build the baseline information for the analysis.

A further finding was the need to undertake both an economic and financial appraisal, in order to provide the necessary information for subsequent climate finance applications (which required both). The case study showed that there was a strong economic case for low-regret adaptation.

TOWARDS CLIMATE RISK MANAGEMENT: TACKLING DISASTER RISK MANAGEMENT AS PART OF ADAPTATION

When is it useful?

There is a long history of managing climate-related and geophysical-driven extremes - such as heatwaves, droughts, and heavy precipitation - via disaster risk management (DRM). There is much overlap between current practice of DRM and climate change adaptation activities. Both pursue a similar goal, namely the reduction of negative impacts of climate change and disasters, respectively, on the natural environment, human society and economies by anticipating risks and uncertainties and addressing vulnerabilities.

Current DRM practice can be seen as an early adaptation measure within an iterative climate risk management approach. It can help address the existing adaptation deficit and iteratively integrate new scientific knowledge on climate change (e.g. emerging early trends and changes in variability that exacerbate existing risks or create new risks), acknowledging the uncertainties associated with climate change and paving the way for mainstreaming climate change in disaster risk management.

An application to Austria and the EU

This case study focuses on Austria, a country that has been subject to recurrent flooding, and which was hit by large-scale flooding in 2013, which led to massive losses and substantial stress to public finance. As one of the first comprehensive national assessments of climate change, the Austrian Panel on Climate Change showed that warming in Austria is stronger than the global average, leading to increasingly severe risk and the need to upgrade adaptation efforts.

More information on this case study can be found **here**.

Defining the adaptation problem

In 2012, Austria developed its national adaptation strategy, which was co-generated with a large set of stakeholders and identifies many options, which are now being prioritized in terms of their costs, benefits and potential to reduce impacts and risk. “Protection from natural hazards” and “DRM” are two of 14 activity categories that are covered in the climate adaptation strategy. Over the last decade there has already been a paradigm shift in the choice of policy instruments to address disasters towards a more pro-active - or planned adaptation - approach, putting a stronger emphasis on ex-ante DRM.

Comprehensive climate risk management (CRM) requires joint efforts by the private and the public sector. The focus here is on the crucial role of the public sector in the provision of DRM as early action on climate change. The public sector has to step in to guarantee the local provision of DRM by planning ahead for extreme event risk. Taking this long term view is not an easy proposition for the public sector, as disaster risk constitutes a contingent liability, i.e. costs that accrue only in case of an event. However, not considering these contingent liabilities ex-ante in the public budgeting process may eventually lead to severe fiscal stress once an extreme event occurs. Progress in public sector risk planning has been achieved based on tools available to systematically assess and manage risks in the fiscal balance sheet. Austria, with its disaster fund, already has an instrument in place to take some of the implicit climate risks out of their balance sheets and make these contingent climate related liabilities more explicit.

Identify entry points and stakeholders

The key instrument for financing public disaster risk management in Austria is the Austrian disaster fund (in German "Katastrophenfonds"). While the Federal Ministry of Finance administers the resources of the disaster fund, two other federal ministries – the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) and the Federal Ministry for Transport, Innovation and Technology (BMVIT) – as well as the nine Austrian federal provinces are responsible for the implementation of measures regarding the protection from natural hazards. Originally truly accumulating in nature, the accumulation of reserves has been capped with the issuance of the current disaster fund law in 1996 at a level of EUR 29 million until 2012 and EUR 30 million since 2013. Surpluses from the disaster fund were redistributed to the general budget as the build-up of the reserve was capped.

Severe floods in 2002, 2005 and 2013 – with cost estimates for the 2002 and 2013 floods amounting to more than EUR 3 billion and EUR 0.9 billion respectively – led to situations where the fund's usual resources (including the reserve) were not sufficient to cope with the damages of these catastrophic events.

Assessing the context and materiality

Critical elements of the assessment involve: (i) understanding historical risks and impacts, (ii) understanding current adaptation practice dealing with extreme events and natural hazards in Austria, (iii) public budget analyses, and (iv) climate risk-based fiscal and economic modelling. These multiple methods enable a comprehensive discussion of the current CRM practice, potential future climate risk and the impact on a county's fiscal position, which all can eventually be integrated to identifying robust adaptation pathways for Austria.

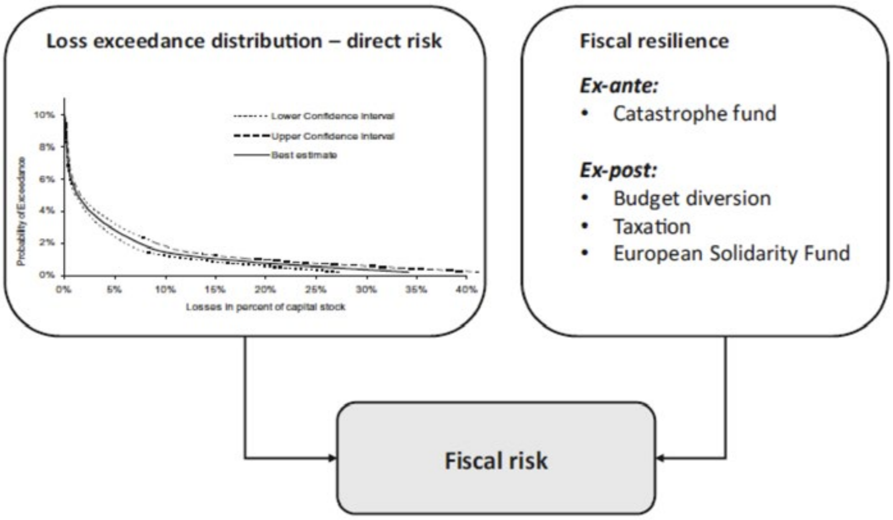
Climate and risk information

Modelling future fiscal stress from climate-related events involves linking climate risk (such as flooding) modelling and climate scenario analysis building on the IIASA CATSIM models.

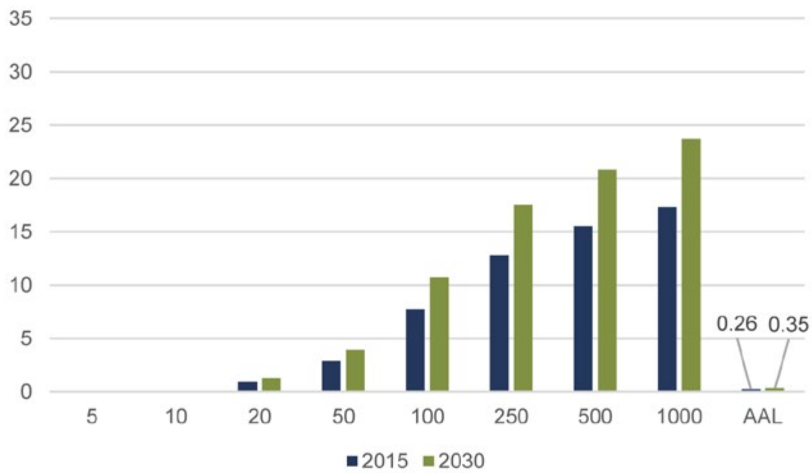
CATSIM employs probabilistic modelling of disaster risk to understand the current and future stress imposed on the fiscal position. CATSIM follows the common practice in catastrophe models and evaluates monetary catastrophe loss as a function of hazard, exposure, and vulnerability modules. Losses are summarized with the help of risk metrics or loss distributions, which inform about the probability that losses do not exceed a given level. This task is complex and usually data as well as resource intensive. In Austria, for example, several flood hazard models on local scales exist, however, currently only two flood risk modelling approaches provide country-level flood loss distributions.

In this case study, projected GDP and demographic composition in Shared Socioeconomic Pathway (SSP) 2 was used as an illustrative example for medium-levels of climate warming. In a next step, the flood risk is linked up with an estimate of fiscal resilience to gauge fiscal risk.

The figure shows how fiscal risk was modelled as a function of losses (direct risk) and fiscal resilience based on the CATSIM framework. By integrating potential future economic losses due to climate risks with the public resources available for absorbing these risks, the relevant layer of risk at which a specific country might experience fiscal stress in the future, and concrete options to remedy this situation, can be identified.



The figure below shows probabilistic projections of flood losses (with flood protection measures) for different return periods in Austria calculated with a copula approach (in billion 2012 EUR). The probabilistic modelling results gave not only information about the changes in average losses but also about changes of the tails, i.e. extreme risk. While average losses are expected to increase from 260 million EUR in 2015 to 350 million in 2030, policy makers should also pay attention to the full loss distribution, particularly the tails of the distribution.



When talking about catastrophic events it is the low probability, high impact events that should matter most in decision making, as in case of occurrence such events could impose severe stress on federal budgets and can overburden risk instruments, such as the Austrian disaster fund, exactly at the moment when they are needed the most.

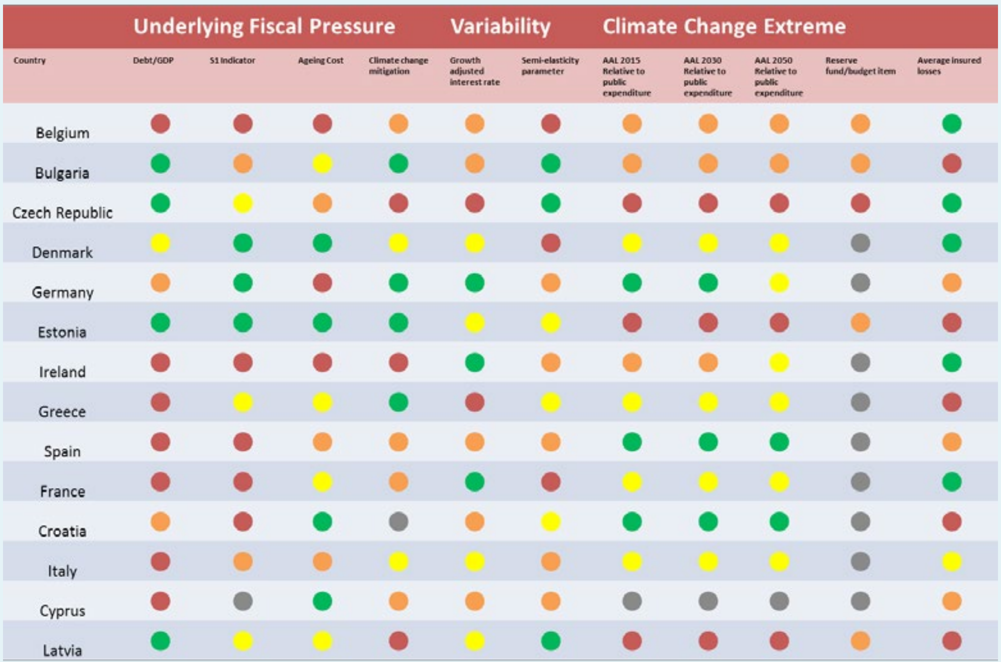
In addition to disaster risk, there are many pressures on the fiscal position. To concurrently assess those, a scorecard approach is useful, which was applied and extended to the case of Austria and risks in the EU more broadly. A policy scorecard is a common approach used in EU wide assessments in a variety of policy domains, including, more recently, its development for use in climate change adaptation.

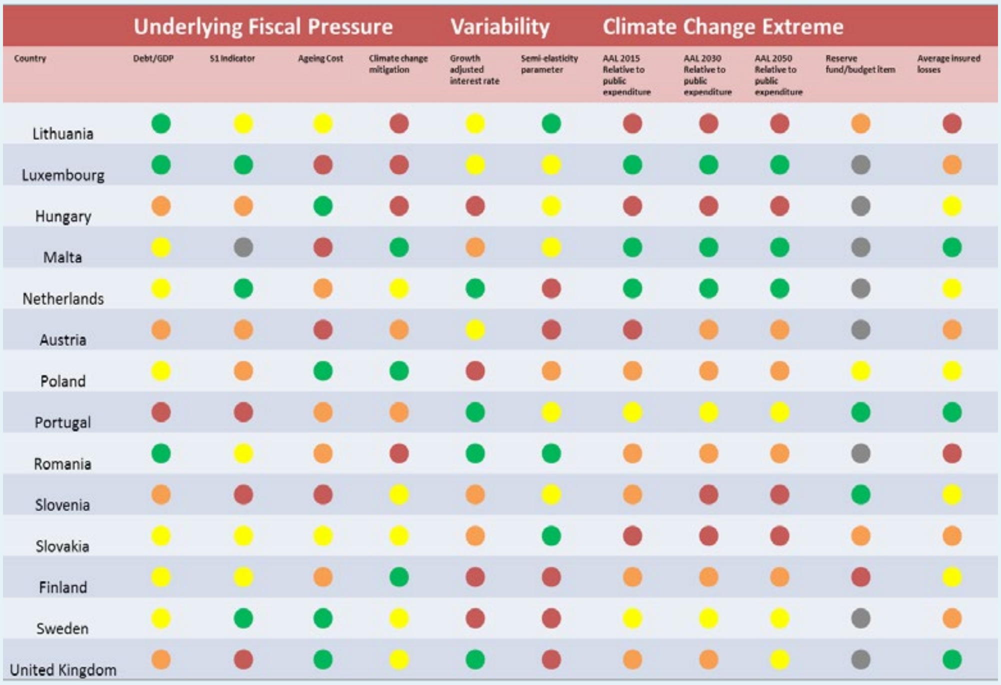
Using policy scorecards to assess pressures on the fiscal position

The scorecard is developed to show data from the following three domains: 1) Underlying fiscal pressure, 2) Macroeconomic & fiscal variability, 3) Climate change extreme risk (DRM Fiscal Capacity).

- For underlying fiscal pressure, the scorecard shows four variables: current debt-to-GDP, the primary balance needed to stabilize debt at 60% in year 2030 (also known as the S1 indicator for the Fiscal Sustainability Reporting of the European Commission), the projected increase in fiscal burden due to demography-related costs (ageing, health, longer-term care, education), and projected changes in the fiscal burden as a result of climate change mitigation. This set of indicators illustrate the current fiscal health and consolidation requirements of each EU member country, along with the additional longer-term challenges posed by both climate and socioeconomic changes under the SSP 2 scenario.
- For macroeconomic and fiscal variability, the scorecard shows the historical variability of three variables: growth adjusted interest rate, exchange rate and semi-budget elasticity parameters (describing how budgetary expense and revenue responded to a percentage change in the output gap). This set of indicators show how future debt burden may deviate from baseline projections (assuming past variability is indicative of the future variability of these variables). These variables are also used in the stochastic-debt assessment, described in the next section.
- For climate change extreme risk, the scorecard shows five variables: annual average loss (AAL) calculated for 2015, AAL projected for 2050 (relative to the size of projected government expenditure), current availability of reserve funds and budgetary allocation, historical observations of average insured losses, and availability of other budgetary mechanisms. This set of indicators show both direct risk posed by current and future risk of extreme weather events, together with the availability of fiscal and economic resources to cope with these kinds of risks. To gather information on governments' ability to cope financially with current extreme weather events, this study sent out email surveys to relevant ministries (e.g. ministries of finance and disaster management agencies) in each EU member state.

Results of applying the scorecard approach to EU 28 are shown below.



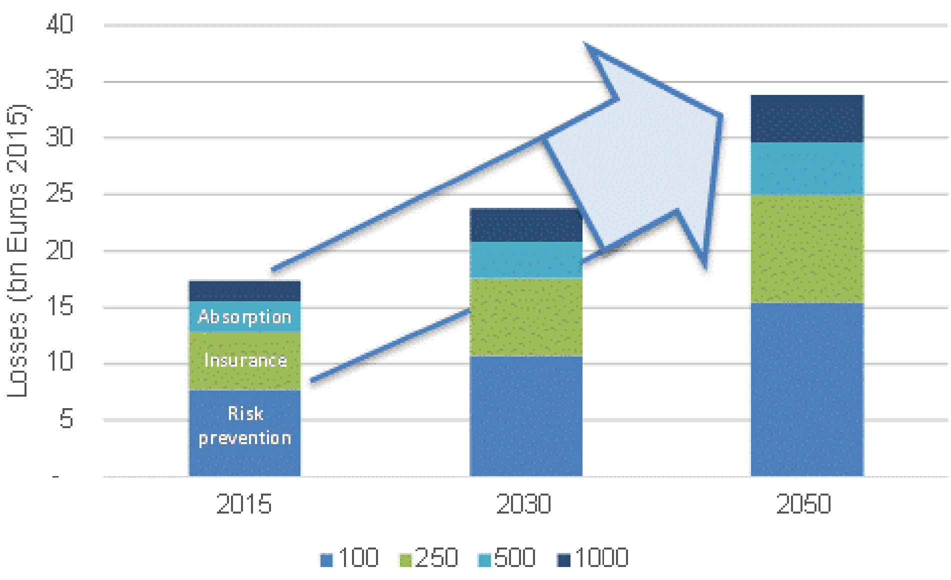


For more information see: Mochizuki, J., Mechler, R., Hochrainer-Stigler, S., Schinko, T. (2016). Pan-European Assessment of Fiscal Consequence of Climate Extremes. Deliverable 5.2. ECONADAPT

Option identification, sequencing and prioritisation

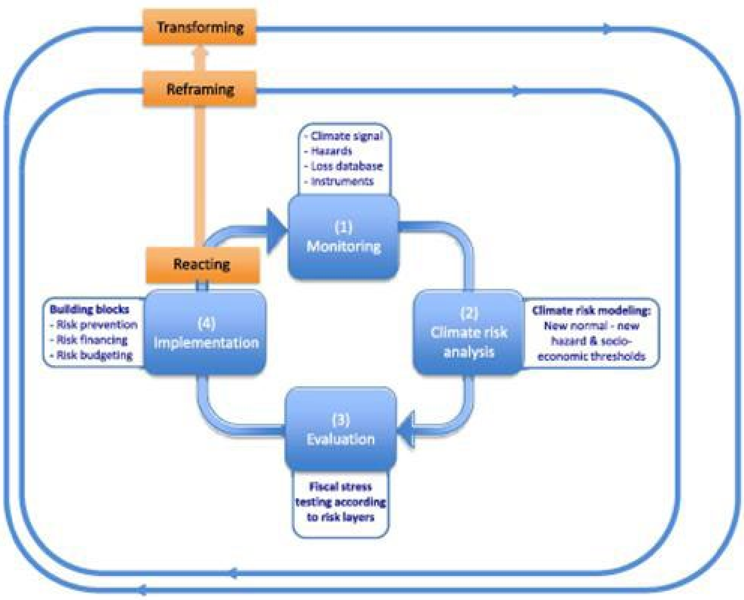
A mix of policy measures, carefully selected under a risk layering lens, is needed to fully implement the CRM conceptualization generally and in Austria: risk reduction measures for low layers of risk, potentially financed by a reformed disaster fund, risk financing, e.g. via insurance, for medium layers of risk, and national and internationally coordinated disaster relief in combination with alternative risk transfer mechanisms for high risk layers. Proactively engaging with all three layers of risk and fostering explicit budgeting for contingent disaster risk liabilities is needed to reduce climate stress on public budgets and to ensure fiscal stability in the future.

Instead of relying on a single risk management measure, a more comprehensive and integrative approach to climate risk management was employed. As there are different kinds of climate related risks, some occurring frequently with only minor impacts while others rather infrequently but devastating, it is recommendable that countries employ a varied portfolio of instruments, each carefully chosen to be applicable for a certain layer of climate related risk and iteratively adjusted over time with evidence. The figure presents a risk layering approach to deal with probabilistic projections of flood losses for different return periods in Austria. For low layers of climate risk – characterized by high probability of occurrence but comparably low impacts –, risk reduction is often the most effective and cost efficient way forward. Ex-ante preventive measures, such as constructing flood barriers, could be financed, e.g. through a disaster fund as in Austria.



Financing, programming and implementation

The figure presents a generic operational climate risk management framework closely aligned to the policy-led framework. At its core, this framework consists of four steps and is embedded in a comprehensive participatory process, which at every stage requires thorough stakeholder involvement (e.g., DRM practitioners, the research community, affected communities, and representatives of ministries of finance, ministries of the interior and environmental ministries). Step (1) of the approach includes monitoring existing instruments, new scientific knowledge on climate change (e.g., emerging early trends and changes in variability that exacerbate existing risks or create new risks), natural hazard data (e.g., hydrological data), loss databases, and the climate signal. This is the basis for step (2): a model-based analysis of climate risks acknowledging the uncertainties associated with climate change in order to identify the new normal, which is characterized by new hazard-based and socioeconomic thresholds. This is followed by step (3): testing and evaluating the new normal according to different layers of climate risk, and potentially by an update of the measures already in place or the implementation of new instruments framed around the building blocks risk prevention, risk financing, and risk budgeting: step (4).



Key lessons

The approach and findings organised around a climate risk management framework described here are of relevance beyond the case of Austria. Many countries and communities are feeling the impact of changes in extreme events and are looking for robust strategies to reduce and manage the risks in a changing climate. Regions are developing improved approaches for absorbing the increasing burdens, such as in the EU through reforming the European Solidarity Fund or setting up regional risk pools for buffering against the financial risks from extremes, such as in the Caribbean or Africa. Finally, the international community is committed to jointly tackle disaster risk based on the principle of moral responsibility via the Sendai mandate as well as through the Warsaw Loss & Damage mechanism, which is based on recognized liabilities. Fundamental to all these approaches is a broad-based and actionable perspective on climate risk management, which will see further attention over the years to come.

MACROECONOMIC APPRAISAL

When is it useful?

One focus of adaptation economics to date has been bottom-up in nature, working at the sector level. Another focus is on macro-economic consequences and implications for public finances in Europe.

To analyse investment in adaptation and how it could affect growth, competitiveness and employment, advanced analysis of the macro-economics of adaptation is necessary. This constitutes the key approach leading to an efficient use of resources at macro-level, effective concentration of efforts and design of successful policies to tackle a long-term challenge such as climate change.

One major way to explore these effects is through the use of Computable General Equilibrium (CGE) models which have been regularlyused to investigate the economic implications of climate change. CGE models can capture and describe market adjustments induced by a localised shock onto the global context and the feedback of macroeconomic dynamics on each single market.

An application to the study of planned adaptation

A macroeconomic assessment of adaptation must take into account both short-term and long-term effects as well as considering potential synergies and trade-offs with mitigation policies. One key research area for the macroeconomic assessment of climate policies is the trade-off between mitigation and adaptation. In brief, mitigation aims to reduce climate change damages by slowing greenhouse gas emissions, while adaptation aims at reducing climate change damages by reducing the impacts on human and natural systems.

Applications of macroeconomic appraisal can be found for planned adaptation in agriculture **here** and in sea-level rise **here**.

As part of ECONADAPT, a methodological approach was developed to extend CGE implications associated to two specific adaptation measures: i) coastal zone protection against sea-level rise, and ii) use of irrigation services to reduce the adverse effects of climate change in agriculture. After conducting the analysis of the economic effects of coastal protection and irrigation in separated studies, ECONADAPT has thus conducted a global analysis on the economic implications resulting from the combination of a mitigation policy simulating the pledges countries submitted to the UNFCCC as Intended Nationally Determined Contributions (INDCs) during the last COP 21 in Paris, with adaptation consisting in optimal protection against sea-level rise (SLR). Both of them are implemented by 2030.

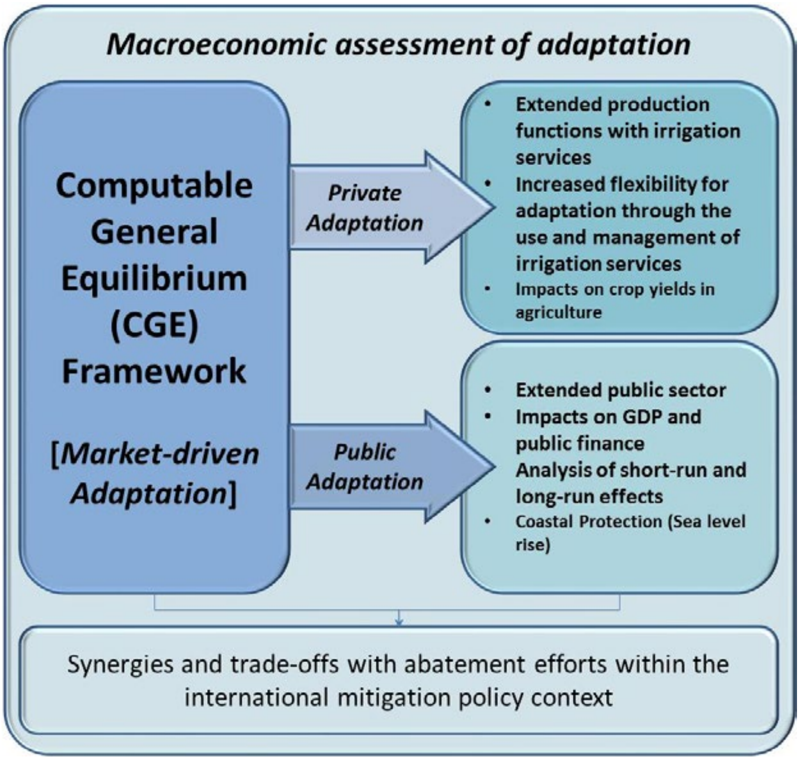
Methodological approach

Generally speaking, the CGE methodology is particularly suited to address the effects of market-driven adaptation, i.e. agents' reactions triggered by changes in relative prices. However, modelling planned adaptation measures is much more challenging. In addition to the lack of data and the specificity of the different types of adaptation, there are also methodological complexities to adequately capture the multiplicity of channels through which adaptation expenditure operates and produces effect.

Against this background, ECONADAPT proposed different methodological approaches to conduct CGE macroeconomic assessments of adaptation going beyond the usual autonomous market-driven type (see Figure 1). The first, addressed planned adaptation in the form of public spending for coastal protection. The ECONADAPT project extended a known CGE model with a more detailed description of the public sector allowing to account not only for the final effects of coastal protection on GDP, but also for its impacts on public finance.

The second relates to the possibility of private agents to adapt by changing the demand of specific services able to decrease adverse impacts of climate change. For this particular case, the ECONADAPT project focused on the use of irrigation services as a strategy to reduce yield losses. For this purpose the production function of the agricultural sector in the CGE model mentioned before, has been extended to account for irrigation services.

The figure shows a synthesis of the macroeconomic assessment methodology.



Insights into the macro-economics of adaptation

The ECONADAPT project assessed the effects on GDP and public budgets of interacting adaptation, mitigation, and international support for climate change policies from developed to developing countries. This was done considering adaptation against sea-level rise financed with "adaptation bonds" jointly with the international mitigation efforts deriving from the INDCs submitted to the 2015 COP 21 in Paris for 2030. In addition, the analysis examined the effects of a Climate Fund based on the pledge by developed countries to provide between $ 30 and $100 billion per year by 2020 to developing regions for mitigation and adaptation activities.

Adaptation and mitigation implemented jointly could entail slightly lower GDP costs than the sum of mitigation and adaptation GDP costs when implemented in isolation. This positive interaction effect is explained by the revenues that mitigation actions implemented with taxes or auctioned permits raise. These revenues accrue to the public budget; decrease the need by the public sector to emit bonds and thus borrow money from the private sector to finance coastal protection expenditures; decrease thus the crowding out of public current expenditure on private investment; and eventually decrease the penalization on the capital accumulation process.

The introduction of the Climate Fund is clearly beneficial for the recipients i.e. developing countries. All of them see a decrease of both GDP losses and deficits. What is interesting to note is that developed countries, even though experiencing a deficit increase, as part of their financial resources are channelled out, may experience lower GDP losses as well. This result depends upon two factors:

- The first and more straightforward is that developed countries can benefit from the lower contraction of economic activity in developing countries.
- When receiving the funding, economic activity in developing countries increases (slightly), emissions are higher (slightly) and the carbon tax needed to achieve the respective INDCs is higher (slightly). This favours the relative competitiveness of developed countries goods and services in international markets.

Key lessons

There are two key messages from the analysis conducted. The first message regards the fact that public adaptation expenditure crowds out private activity. The second key message is related to the way adaptation is financed. Indeed, the distortionary crowding out effect of adaptation and the consequent penalization of growth is lower when adaptation expenditures are financed through taxes rather than through public debt.

While taxes have a regressive effect on private consumption, public debt crowds out private investment. The latter effect is more noxious for economic growth and capital accumulation. In this sense, coupling adaptation with mitigation efforts based on a carbon tax can be an appropriate strategy.

Developed countries can benefit from supporting developing countries in their climate change policies. The lower contraction of developing countries' economic activity can benefit developed countries either directly through lower demand contraction internationally, but also through lower/higher relative competitive losses/gains following the implementation of mitigation objectives.

LOOKING FOR MORE INFORMATION?

Insights into the economics of adaptation

The following methodological information is available at **econadapt-toolbox.eu/insights**.

Framing of adaptation economics

- Framing adaptation economics in decision-making: a policy-led framework
- Sourcing and using climate information for economic assessments of adaptation
- Energy: Cost & benefits of adaptation
- Health: Cost & benefits of adaptation
- Agriculture: Cost & benefits of adaptation
- Infrastructure: cost & benefits of adaptation
- Coastal zones: cost & benefits of adaptation
- Water and flood management: cost & benefits of adaptation
- Biodiversity and ecosystem services: cost & benefits of adaptation

Micro-economic foundations

- Framework for the evaluation of system-wide adaptation
- Analysing trade-offs between development and adaptation
- Evaluating adaptation options through the elicitation of preferences
- Dealing with changing preferences over time
- Treatment of future learning: Real-Option Analysis
- Treatment of future learning: Acceptable Risks Analysis

Scaling, aggregation and transfer

- Private adaptation of adaptation goods: potential and policy instruments
- Integrating distributional objectives in the cost-benefit analysis of adaptation options
- The Use of Non-Monetary Metrics to Assess Adaptation Actions: Multi-Criteria Analysis
- The Use of Non-Monetary Metrics to Assess Adaptation Actions: Cost-Effectiveness Analysis
- Transferring values between locations in climate change adaptation
- Applying alternative discounting rules: the Equivalency Principle

Treatment of uncertainty and risks

Uncertainties and causes of uncertainties in climate change adaptation

Uncertainties and risk analysis in climate change adaptation

Integrated uncertainties and risk management for robust decision making

Methods for expressing risk and ambiguity in economic analysis

Assessing systemic risks in adaptation

Economic project appraisal

Appraisal of adaptation to river flood at the Vltava river, Prague

Appraisal of adaptation to river and coastal flood in Bilbao

Disaster risk management

Assessing flood risk management: The Netherlands

Assessing flood risk management: Czech Republic

Assessing flood risk management: Austria

Assessing flood risk management: United Kingdom

Fiscal consequences of extreme weather risks in Europe

International development support

Prioritisation of adaptation in the development context: Rwanda

Prioritisation of adaptation in the development context: Zanzibar

Policy Impact Assessment

Adaptive management of rural land use systems: the Common Agricultural Policy

Risk attitudes and preferences for adaptation in agriculture

Stochastic modelling for robust decision-making: the Common Agricultural Policy

Macro-economic effects of adaptation

The role of autonomous adaptation in global assessments at global level

Economy-wide implications of planned adaptation: the case of sea level rise

Economy-wide implications of planned adaptation: the case of agriculture

ECONADAPT / THE ECONOMICS OF ADAPTATION

THE ECONOMIC ANALYSIS OF CLIMATE ADAPTATION – INSIGHTS FOR POLICY-MAKERS

ECONADAPT Toolbox:
econadapt-toolbox.eu

Sources for data on costs and benefits of adaptation
econadapt-toolbox.eu/data-sources

Library of publications related to adaptation economics
econadapt-library.eu

Further policy briefs and Deliverables of the project
econadapt.eu

The FP7 ECONADAPT project was led by the University of Bath and undertaken by the following consortium of European research organisations: