ECONADAPT

The Economics of Adaptation

Funded by the European Union

Distributional objectives and non-monetary metrics

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Deliverable number	D2.3
Work Package Number	WP2
Submission date	06/05/2016
Type of Activity	RTD
Nature	R = Report
Dissemination level	Public

Document information

Title:	Distributional objectives and non-monetary metrics.
Authors:	Rouillard, J., Tröltzsch, J., Lago, M., Markandya, A., Sainz de Murieta, E., Galarraga, I. Paper on private adaptation: Rouillard, J.JJ., Tröltzsch J., Lago, M. Paper on distributional objectives: Markandya, A., Sainz de Murieta, E., Galarraga, I. Paper on non-monetary metrics: Lukat, E., Rouillard, J., Lago, M., Troeltzsch, J.
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Work Package Number	WP2
Deliverable number	D2.3
Filename:	ECONADAPT_D2.3.doc
Document history:	-
Type of Activity	RTD
Nature	R = Report
Dissemination / distribution level	CO = Confidential, only for members of the consortium (including the Commission Services)

Citation:	Overall citation: Rouillard, J., Tröltzsch, J., Lago, M., Markandya, A., Sainz de Murieta, E., Galarraga, I. (2016). Distributional objectives and non-monetary metrics. FP7 Econadapt project, Deliverable 2.3. Citation per paper Rouillard, J.JJ., Tröltzsch J., Lago, M. (2016). Private provision of public adaptation goods. In Rouillard, J., Tröltzsch, J., Lago, M., Markandya, A., Sainz de Murieta, E., Galarraga, I., *Distributional objectives and non-monetary metrics*. FP7 Econadapt project, Deliverable 2.3. Markandya, A., Sainz de Murieta, E., Galarraga, I. (2016). Transfer of distributional weights parameters. In Rouillard, J., Tröltzsch, J., Lago, M., Markandya, A., Sainz de Murieta, E., Galarraga, I., *Distributional objectives and non-monetary metrics*. FP7 Econadapt project, Deliverable 2.3. Lukat, E., Rouillard, J., Lago, M., Troeltzsch, J. (2016). Use of non-monetary metrics/weights in adaptation decision-making. In Rouillard, J., Tröltzsch, J., Lago, M., Markandya, A., Sainz de Murieta, E., Galarraga, I., *Distributional objectives and non-monetary metrics*. FP7 Econadapt project, Deliverable 2.3.
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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.

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Executive Summary

This report was produced for Work Package 2 of the FP7 ECONADAPT project which carries out research in the economics of adaptation to man-made climate change. WP2 of the project on *the micro-economics of adaptation* reviews and develops methods to better provide empirical data for undertaking the economic assessment of adaptation, focussing on a number of data parameters that are currently poorly characterised for the adaptation context. To a large extent, the development of parameters appropriate to the economic assessment of climate change has been led by research undertaken in the greenhouse gas (GHG) mitigation context.

This report presents a number of methodological developments useful for the economic assessment of climate change adaptation, namely on the consideration of distributional issues (focusing on the role of private provision of adaptation in relation to public provision, and on equity weights) and the use of non-monetary metrics. This report in particular examines in more detail the appropriateness of transferring practices from the mitigation and other assessment contexts to the adaptation context. It is divided into three papers, each of which stand as individual guidance on matters related to: i) the potential of private provision of adaptation goods, ii) the transfer of distributional weights parameters in adaptation, and iii) the use of non-monetary metrics in adaptation.

The first paper presents methods to examine the extent to which the private provision of adaptation goods can be further incentivised, focusing in particular on those adaptation goods with public benefits. This paper takes stock of the recent scholarship, consolidates definitions of key terms, and moves towards a policy-oriented, cross-sectoral and European discussion of private adaptation. It first provides an analysis of adaptation measures that provide adaptation benefits, exploring the differences between adaptation goods that deliver mostly private benefits and those that deliver public benefits (called also public adaptation goods). It then discusses the circumstances under which private provision is made possible, focusing on drivers for private actors to implement adaptation measures. The paper argues that private actors have few incentives to provide public adaptation goods where those goods do not result in clear private benefits. Consequently, the paper examines how a range of policy instruments can deliver incentives for private adaptation, in particular for the delivery of public benefits. Each policy instrument is discussed with regards to their performance against policy-relevant criteria (e.g. effectiveness, efficiency, distributional impacts). The paper then provides a short discussion on the applicability of policy instruments, in terms of creating policy mixes, sequencing implementation, and ensuring a learning-by-doing (adaptive) approach. The paper concludes on some key evaluative questions to help policy-makers assess the scope of private adaptation for delivering public adaptation goods with public benefits in multiple contexts.

The second paper specifically presents methods to consider transfer of distributional weights parameters. The report surveys the recent literature and outlines some limitations and possible solutions on the use of cost-benefit analysis (CBA) in adaptation decision-making, specifically focusing on why and how employment effects, distributional concerns and risk aversion should be taken into account in CBA. These elements are, for a number of reasons, typically ignored in traditional CBA. Specific chapters of this report include 1) a brief introduction to cost-benefit analysis, the limitations of this assessment approach to account for employment effects, equity

and risk aversion and thus to assess the costs and benefits of adaptation options, and possible solutions, 2) a case study showing how these elements can be included in CBA and how accounting for employment, equity and risk aversion can affect investment decisions, and 3) a number of conclusions highlighting the need for further research and evaluation on the consideration of those parameters (i.e. employment, equity and risk aversion) in adaptation CBA.

The third paper presents methods to consider non-monetary metrics in adaptation decision-making. The report surveys the recent literature and outlines some key lessons learned and limitations on the use of non-monetary metrics in adaptation decision-making, specifically focusing on reviewing the application of Cost-Effectiveness Analysis (CEA) and Multi-Criteria Analysis (MCA). After cost-benefit analysis, these two methods are the most established and common approaches for taking into account dimensions that are complex or controversial to monetise in economic assessments. Specific chapters of this report cover each method and presents 1) an outline of key characteristics of non-monetary metrics and how they are developed in CEA and MCA, 2) a list of previously used non-monetary indicators, criteria and metrics for assessing adaptation options, and 3) an overview of their usefulness and limitations for informing adaptation decision-making. The adaptation literature on non-monetary metrics remains overall very limited, and it appears that most studies rely heavily on existing metrics developed in CEAs and MCAs to evaluate options/choices in other policy fields. The report concludes by highlighting the need for further research and evaluation on the practical applications of non-monetary metrics in adaptation.

Overall, guidance presented in this deliverable can be used in a variety of contexts where decision-makers and economists are interested in investigating the potential of private adaptation or the implications of distributed costs and benefits in the target population, or when limitations arise from the use of cost-benefit analysis and non-monetary metrics must be used to assess the relevance of specific adaptation options. Guidance presented in this deliverable was used to inform other ECONADAPT WPs, in particular WP6 which develops and tests economic assessments for informing project-level adaptation. Further conclusions on the application and implications are thus available in those WPs.

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1 Introduction

The ECONADAPT project

The ECONADAPT FP7 project carries out research in the context of Europe's adaptation to man-made climate change. The economics at the base of decision-making about adaptation actions are examined, and particular attention is paid to the inherent aspects of uncertainty and multiplicity of scales in the climate change predicament.

The project's aims are to provide decision-makers and stakeholders, at the various scales applicable in the European context, with economic methodologies, evidence and appraisal criteria to guide and coordinate adaptation action. The climate change areas on which the project focuses range from the short-term effects of extreme weather events, to the long-term costs of climate-related risk, and from the macroeconomic consequences of impacts, to the assistance to developing countries in their response to expected climate developments.

The facilitate the project's scopes, ECONADAPT is organized in three methodological Work Packages (WP) (WPs 2 to 4), that are meant to inform and provide operational input to five WPs (WPs 5 to 9) that are centred on policy case studies. Besides these, other work packages focus on the project-supporting aspects of the framing of the policy-focussed economic analysis (WP1), stakeholder engagement (WP11), the final set-up of a toolbox for economic assessment of adaptation (WP10), dissemination (WP11) and project management and integration (WP12).

Work Package 2

WP2 on *the micro-economics of adaptation* develops methods to better provide empirical data for undertaking the economic assessment of adaptation, focussing on a number of data parameters that are currently poorly characterised for the adaptation context. The methods developed will be designed to maximise their transferability across geographical scales and levels of assessment. Empirical data that results from the testing of these methods will then be applied in the economic assessments to be undertaken in WPs 5-9. Overall it has four main objectives:

- To elaborate methods to identify the opportunity costs of adaptation in relation to development and GHG mitigation objectives.
- To examine public acceptability and preferences for policy options and individual adaptation actions.
- To develop and test methods to quantify key parameters required for the economic assessment of adaptation give uncertainties in future climate and socio-economics.
- To develop and test methods to incorporate distributional objectives and non-monetary metrics in the economic assessment of adaptation.

Aim of this report

To a large extent, the development of parameters appropriate to the economic assessment of climate change has been led by research undertaken in the GHG mitigation context. Foremost amongst these has been discussion around discounting, the role of equity weights, aggregation, and the role of monetary metrics compared with nonmonetary metrics. Appropriateness of transferring practices to the adaptation context from the mitigation and other assessment contexts has not been investigated in detail, noting that there are many context specific differences. A further aspect of distributional analysis is the relative burden of adaptation cost between public and private sectors. The current stress on public finances in Europe implies a need to ration adaptation resources. Potential for private agents to supply public adaptation given appropriate institutional arrangements for policy instrument implementation. Finally, there has been limited attention to the role of non-monetary metrics in economic assessment of adaptation with respect to their importance as a means of communicating the effectiveness of alternative adaptation actions and as an input to established decision rules such as Cost-Effectiveness Analysis (CEA) and Multi-Criteria Analysis (MCA).

In this context, and as part of WP2, task 2c aims to provide insights on methods regarding distribution objectives and non-monetary metrics, including:

- Sub-task 1: Evaluating the potential for private provision of public adaptation goods

Description of sub-task 1
On the basis of a critical review of both the grey and academic literature, this sub-task will identify the institutional and policy design features that best enable private agents to supply public adaptation. It will include an analysis of adaptation measures and their contribution to delivering public adaptation goods. Furthermore, it will be analysed which of these adaptation measures could be or have to be implemented by private actors. The main part of the sub-task concentrates on analyses of policy instruments and institutional design to deliver incentives for private adaptation. Therefore, different successful examples will be reviewed and evaluated against criteria like efficiency, windfall gain, transferability. The findings of this review will be differentiated by geographical and sectoral contexts within Europe.

- Sub-task 2: Transfer of distributional weight parameters

Description of sub-task 2
Transfer of distributional weight parameters. This sub-task will evaluate the appropriateness of transferring distributional weights – both temporal and spatial - currently used in other contexts (e.g. GHG mitigation, biodiversity conservation, etc.) to the EU and MS adaptation policy context. The evaluation will consider the potential importance of factors such as the absolute levels of factors such as the absolute level of income as well as distributional effects.

- Sub-task 3: Use of Non-monetary metrics/weights

Description of sub-task 3
This sub-task will develop and test rules for adopting non-monetary weights in multiple sectors for use in cost-effectiveness and multi-criteria analysis of adaptation. In order to derive such rules we will review the use of existing non-monetary metrics in both (cross-) sectoral development and adaptation assessment to date. In conjunction with stakeholders, (identified in WP1), the review will identify the primary reasons for current use of non-monetary metrics – whether as a result of established convention, effective communication, inappropriateness of monetary metrics, etc. – in order to determine their value in measuring the effects of adaptation. This review will be comparative and will evaluate the usefulness of monetary metrics in the specific contexts considered. On the basis of the review, guidance will be developed as to the appropriate use of existing metrics, and new indicators proposed where identified as adding value to adaptation assessment.

This deliverable presents the result stemming from these three sub-tasks, and is divided into three main chapters accordingly. Chapter 2 examines the extent to which the private provision of adaptation goods can be further incentivised, focusing in particular on those adaptation goods with public benefits. Chapter 3 examines the transfer distributional weight parameters. Chapter 4 examines the use of non-monetary metrics in adaptation decision-making.

2 Private provision and public adaptation goods

This chapter takes stock of the recent scholarship, consolidates definitions of key terms, and moves towards a policy-oriented, cross-sectoral and European discussion of private adaptation. It first provides an analysis of adaptation measures that provide adaptation benefits, exploring the differences between adaptation goods that deliver mostly private benefits and those that deliver public benefits (called also public adaptation goods). It then discusses the circumstances under which private provision is made possible, focusing on drivers for private actors to implement adaptation measures.

The chapter argues that private actors have few incentives to provide public adaptation goods where those goods do not result in clear private benefits. Consequently, the chapter examines how a range of policy instruments can deliver incentives for private adaptation, in particular for the delivery of public benefits. Each policy instrument is discussed with regards to their performance against policy-relevant criteria (e.g. effectiveness, efficiency, distributional impacts). The chapter then provides a short discussion on the applicability of policy instruments, in terms of creating policy mixes, sequencing implementation, and ensuring a learning-by-doing (adaptive) approach. The chapter concludes on some key evaluative questions to help policy-makers assess the scope of private adaptation for delivering public adaptation goods with public benefits in multiple contexts.

Benefits of private adaptation

Climate change adaptation -the adjustment in natural or human systems in response to actual or expected weather and climatic risks- has become an urgent policy question with climate change impacts increasingly being felt, the lack of early strong efforts to mitigate global emissions of greenhouse gases, and stronger evidence of the extreme impacts of forecasted changes. To date, much focus in the academic literature and in policy has emphasised the role of the public sector (e.g. central government, environmental agencies, local councils) in delivering adaptation action (Mendelsohn, 2006; Osberghaus et al., 2010). Public provision of adaptation has been advocated primarily because adaptation goods are difficult to value (e.g. long timescales involved, uncertainties, non-monetary benefits) and, therefore, private markets have long failed to be pro-actively created (Mendelsohn, 2006). Public provision has also been promoted when equity and fairness and security of supply are of primary political importance such as for some cases of sanitation services (Osberghaus et al., 2010), or where large-scale adaptation projects and initiatives would entail high transaction costs and large capital resources.

Nevertheless, effective adaptation will necessarily be based on the involvement of a large range of actors, not the least private ones. Private actors are understood here as economic agents (e.g. individuals, non-governmental organisations and businesses) grouped into sectors. Table 1 presents a list drawn from frequently used sector typology in the environmental management literature. To limit the scope of analysis, households (e.g. families or individuals members of the family) are not considered.

In liberal economies, private actors strongly influence decision-making in many economic sectors, such as agricultural land use management, forestry, the construction of infrastructure and buildings, or drinking water and wastewater plants. Private actors can contribute to climate change adaptation in several ways. It can act as a driver for innovation and technological development, as well as the diffusion of adaptation technologies and practices, for example through appropriate investment policies and the provision of consulting services. This may be helpful at a time when state intervention is increasingly being limited. The private sector can in that regard mobilise additional financial resources and technical capacity, and help engage civil society and community efforts.

Table 1. Examples of private actors in different sectors

Sectors	Main actors	Example of private adaptation measures (taken from UNFCCC, 2015)
Agriculture & forestry	Landowners, land managers, manufacturers, distributors	Ensuring reliable supply of coffee with (e.g. Starbucks International project in Mexico Chiapas)
Built environment	Architects, building industry	Improving thermal balance of houses and buildings (e.g. The 100K Home by Mario Cucinella Architects)
Energy	Network operators, energy producers and distributors, households	Building distributed and mixed energy supplies for remote communities (e.g. Ankur Scientific Technologies Pvt. Ltd. In India)
Finance	Banks, insurances, accountants	Developing holistic loan and insurance solutions (e.g. HARITA project by Swiss Re for combination of community projects, insurance, micro-credit and savings)
Health	Various	Reducing risk of disease migration and epidemics through preventive action and improved treatment (e.g. Malaria programme by BHP Billiton in Mozambique)
Industry	Manufacturers, distributors	Develop alternative products, or improve the efficiency of resource use for securing supply in the future (e.g. more resilient fibre to replace cotton programme by Naturally Advanced Technology)
Transport	Infrastructure operators, rail/plane/boat operators, logistic companies	Modifying construction and maintenance practices to increase resilience of railways (e.g. International Union of Railways Adaptation of Railways to Climate Change project)
Water sector	Wastewater and drinking water companies	Guaranteeing security of supplies (e.g. Anglian Water 5 year water resource management plan)

A more resilient private sector could also protect society from large-scale economic costs. For example, the timely delivery of food or other traded goods (e.g. water, energy, clothes) is an important dimension in a business operation in order to avoid loss of economic opportunities (e.g.

temporary closure of facilities). Investment from the private sector in securing production and supply, taking into account climate extremes and long term climate change risks, would prevent local disruption of economic activity, global risks in economic systems, and large adaptation costs in the future.

Delivering adaptation goods through private adaptation

Adaptation measures include a wide variety of products, technologies, activities, and ecosystem services. In economic terms, adaptation goods[1] can be defined as "*commodities and services that minimise the harmful impact on human and ecological systems of future weather and climatic risks*". Public goods[2] in particular are non-rival (one's use of the good does not reduce another individual) and non-excludable (one cannot be restricted from its use). Many adaptation goods have characteristics of public goods in that they can be enjoyed by multiple actors. In many cases however, adaptation measures and their resulting goods are very localised and can be targeted, leading some to refer to adaptation goods as club goods (i.e. exclusion is possible but use is enjoyed jointly without affecting the use of another) or as "local" public goods (Osberghaus et al., 2010). A typical example is the provision of flood risk protection, which can be freely enjoyed by everyone *as long as they live in the area being protected*. In this context, private and public adaptation goods may be associated with their degree of private and public benefits delivery (Tompkins and Eakin, 2012, see Figure 1). Public adaptation goods deliver public benefits defined here as positive impacts on societal actors *other than to those providing the adaptation good*, as opposed to private benefits, which are associated with positive impacts to *those providing the adaptation good*.

The design, location or extent of an adaptation measure can affect its delivery of public benefits. For example, the uptake of household water saving technologies may reduce one's water bill, at least in the short term[3], (i.e. private benefit) but will only have a noticeable public benefit against water scarcity (i.e. aggregated reduction in water demand) when enough households have adopted those technologies. In other situations, private adaptation may result in negative externalities, i.e. public bads. For example, flood embankments protecting private farmland in the upland may increase the risk of urban areas being flooded downstream. Avoiding those negative externalities can be seen as a public benefit: an alternative measure to building a flood embankment may be to promote less intensive farming practices upstream to protect urban areas downstream. Such adaptation measure may then not be optimal for the individual farmers, but beneficial for the public.

It is important to note that it may be difficult to distinguish private and public benefits. For example, an electricity network operator financially gains from reducing the risk of damages due to extreme weather events on the infrastructure, and the resultant interruption of service. However, the

[1] The definition of "goods" used here includes what Begg et al. (1987) call goods (i.e. "physical commodities", p 2) and services (i.e. activities which can be consumed or enjoyed only at the instant they are produced, p 2) These may be commercial or non-commercial.

[2] See Begg et al. (1987) for a general discussion of public goods, and Sandberg (2007) for public goods in the context of environmental management.

[3] In theory, if water tariffs are based on volumetric pricing, installing water efficient devices can result in lower bills. However, in practice, large reduction in water demand in an existing water network may reduce the income of the water company. To maintain cost-recovery, tariffs may be raised, resulting in a net increase in individual water bill in the longer-term.

benefit not only accrues to the operator, but also to the consumers and the wider society, in that disruptive blackout can be avoided (knock-on effect on the economy and societal welfare). Because companies may not sufficiently insure their consumers against such interruption of supply, greater public involvement may be required, for example in the form of stronger regulations (Osberghaus et al., 2010).

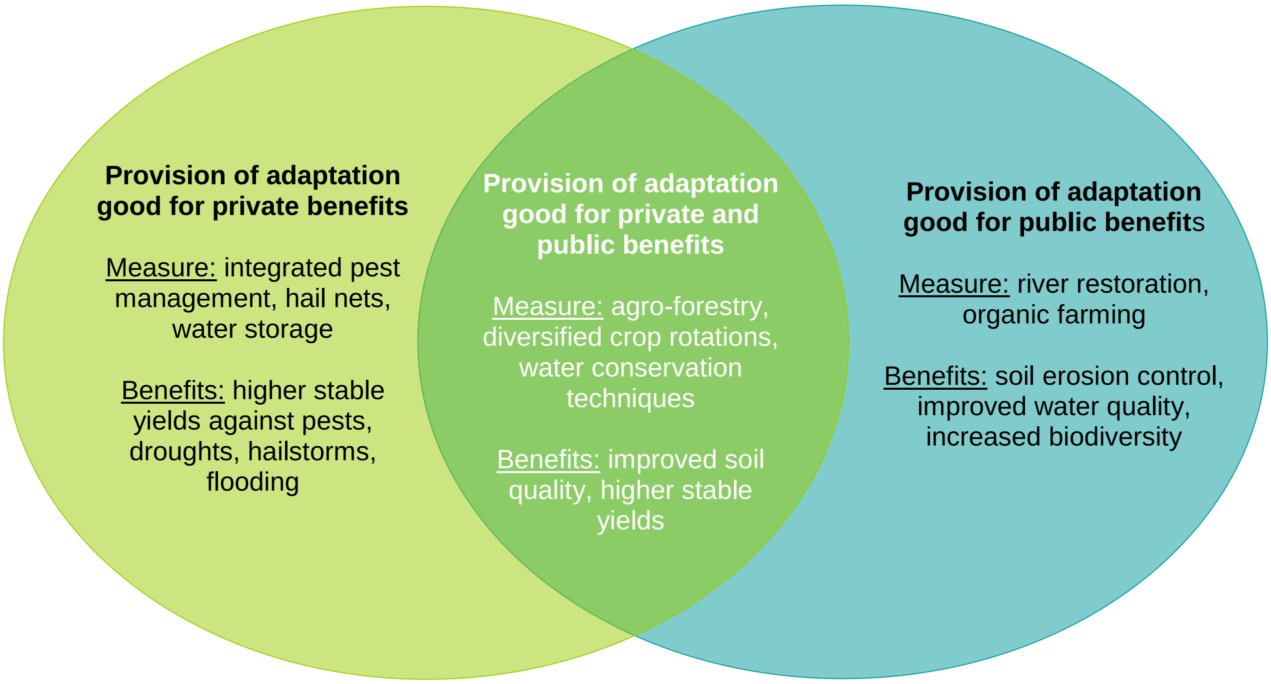

Figure 1. Provision of adaptation goods: from private to public benefits. The example of agriculture

Table 2 includes examples of adaptation measures potentially resulting in public benefits in key sectors. As explained above, public benefits are interpreted in the broad sense, in that benefits that may appear at first mostly private (e.g. re-locating private assets beyond areas at risk) can ultimately have some public benefits (e.g. increased energy security, reduced risk of service supply, reduced costs for the whole economy). The challenge is to identify when (cumulative) private benefit results in a public benefit. Table 3 presents specific examples of public and private benefits of taking actions to secure the delivery of key traded goods in modern society. Agricultural and wood products for example are in most countries private goods traded through private markets. Selecting crops that can cope with e.g. higher average temperatures and higher water scarcity can reduce the risk of crop failure and income loss for the farmer (i.e. private benefit). The associated public benefit is greater food security, especially when crop selection is applied to whole regions so as to reduce the risk of large-scale crop failure.

Table 2. Examples of private adaptation measures delivering adaptation goods with public benefit (in brackets: relevant public benefit).

Sectors	Temperature changes	Storms	Water scarcity and droughts	Flooding	Sea level rise
Agriculture & forestry	Adequate crop selection (food security)	Use of tree shelters and hedgerows (soil erosion control)	Water efficient technologies (water demand reduction)	Reduced impact logging (run-off infiltration)	Natural habitat restoration (wave energy buffer)
Built environment	Cooling systems (reduced risk to human health)	High resistance material for buildings (reduced risk to life)	Greywater reuse (water demand reduction)	Sustainable urban drainage systems (run-off retention)	Raised building foundations (large-scale damage reduction)
Energy	Reservoir release (environmental protection)	De-centralised production (energy security)	Higher dams for hydropower (energy security)	Higher dams for hydropower reservoirs (water retention)	Re-locating power plants beyond areas at risk (energy security)
Health	Cooling systems in hospitals (reduced risk to human health)	High resistance material for buildings (reduced risk to life)	Water efficient technologies (water demand reduction)	Re-locating of assets beyond areas at risk (reduced risk of disruption of service)	Re-locating of assets beyond areas at risk (reduced risk of disruption of service)
Industry	Alternative cooling systems (reduced risk of industrial blackout)	High resistance material for buildings (reduced economic disruption)	Water efficient technologies (water demand reduction)	Re-locating of assets beyond areas at risk (reduced economic disruption)	Re-locating of assets beyond areas at risk (reduced economic disruption)
Transport	Heat-resistant infrastructure (reduced risk of travel disruption)	Maintenance of network (reduced risk of travel disruption)	-	Shifting alignments beyond areas at risk (reduced risk of travel disruption)	Shifting alignments beyond areas at risk (reduced risk of large-scale travel disruption)
Water sector	Water treatment (reduced risk to human health)	-	Leakage control (water demand reduction)	Water retention basins (run-off retention)	Re-locating wastewater plans beyond areas at risk (improved water quality)

It is important to note that the public and private nature of traded goods in Table 3 mainly refers here to their typical legal status in liberalised, advanced economies. A high level of public subsidisation or regulatory control is often seen as equivalent to public ownership (whether the good is, in legal terms, in private or public hands).

Table 3. Public and private nature of traded goods in typical liberalised, advanced economies, related adaptation goods, and their public and private benefits. Adapted from Kenedy and Corfee-Morlot, 2012)

Traded goods	Agricultural and wood products	Water	Electricity	Transport
Public/private nature	Private goods	Seen as mixed public/private good	Mostly private good although essential service	Private good in many respects
Main business models for trading good	Private provision dominating worldwide	Public provision although private concession also frequent	Broad range of models from public provision to regulated monopoly and privatised or partially privatised elements	Public provision although concessions frequent
Example adaptation action	Adequate crop selection	Water efficient technologies	De-centralised production	Shifting alignments beyond areas at risk
Private benefit	Reduced risk of crop failure and income loss	Reduced risk of water shortage	Reduced electricity bills	Reduced maintenance/recovery costs
Public benefit	Food security	Water demand reduction	Energy security	Reduced risk of travel disruption

Overall, three types of adaptation good provisioning can be differentiated with different degrees of private and public benefits. First, *provisioning for private benefits* results in clear individual gain. It may be important in these cases to look at negative externalities. Second, *provisioning for public benefits* results in gains for other actors than those delivering the adaptation good. *Provisioning with private and public benefits* results in gains for those providing the adaptation good and broader society.

Incentives for private provision of adaptation goods, and the role of governments

In standard economics, social actors are assumed to maximise personal welfare. In adaptation, private actors may therefore only deliver adaptation goods where the private benefits of taking action are clear and significant. Table 4 presents such opportunities for the private sector. A number of threats arise from climate change, from human risks, to production, logistical, demand and financial risks. Purely self-interested individuals may take pro-active adaptation action against such risks when the benefits incurred to them outweigh the costs. Broadly speaking, private actors may be interested to protect private assets and maintain value against climate risks. A farmer, for example. would build a dyke to protect a shed or a valuable crop, while businesses would buy private insurance or prepare for alternative supply chains (e.g. transport of goods) against extreme weather events. Alternatively, private actors may have an interest in increasing profitability, strengthening competitive advantage, seizing new business opportunities, and expanding market share. Private actors may for example look for cost savings (e.g. more efficient use of natural resources), or may develop and sell new adaptation goods and services. Good risk management and reputational gains may also matter as it may increase attractiveness for investors and qualified labour.

Table 4. Opportunities for adaptation in the private sector: some examples. Adapted from SCCIP (2010)

Type of risk	Description	Opportunities	Benefits
Production risks	Changes in type, quality and quantity of primary products (e.g. crop varieties); increased regulatory requirements on use of natural resources (e.g. water use)	Development of alternative supply sources (e.g. development of new crop variety); increased resource use efficiency (e.g. water saving technologies)	Reducing risk of supply scarcity, responding to future regulatory changes, and securing competitive advantage
Logistical risks	Disruptions and damages to operations, transportation, infrastructure, and products (e.g. damages to rail network)	Redundancy and flexibility in supply chains and business operations (e.g. alternative trade routes)	Reducing losses during extreme events, enhancing trust in company, and attracting investment
Demand risks	Change in consumer behaviour and regulatory requirements for more products increasing climate resilience	Developing products increasing climate resilience (e.g. improved insulation material)	Securing competitive advantage and reducing losses
Financial risks	Climate vulnerable investments, customer default, loss of value	Diversification of portfolio and activities (e.g. alternative income sources, investment in climate proofed projects)	Reducing vulnerability to future environmental and financial shocks
Human risks	Human health and safety	Good risk management	Enhancing reputation and attracting investment

Two types of adaptation processes have been identified in the literature: autonomous and pro-active. Autonomous adaptation refers to responses to experienced climate and its effects, without planning explicitly or consciously focused on addressing climate change (IPCC, 2014). In contrast, planned adaptation refers to the pro-active activities occurring in response to forecasts and projections of future impacts. Mendelsohn (2006) argues that ”planned” private provisioning of adaptation goods will mainly occur in sectors where financial performance is dependent on an adequate and timely response to climate change and whose goods are traded (and therefore have an established monetary value), such as agriculture, forestry, energy and insurance.

Tompkins and Eakin (2012) in contrast differentiate deliberate from accidental provision, and consider a wider range of behavioural factors than sole economic ones. Private actors may provide public adaptation goods for maximising profits or non-monetary benefits (such as risk reduction and enhancing reputation), but also for altruistic reasons where private actors may value providing help to other people for the pleasure of giving. Altruistic behaviours, although rare, occurs, for example when individuals often adopt behaviours that are strongly driven by moral codes (e.g. sustainability, egalitarian goals). Businesses and industries may be engaged in philanthropic activities in order to strengthen their reputation, or their green and ethical portfolio. For example, the Rockefeller Foundation Resilient Cities Challenge provides technical support and resources to 100 cities improve their urban resilience. For Tompkins and Eakin (2012), accidental supply may arise from self-interest (where supply of the public good is closely associated with a private benefit) or from co-benefits (positive externalities).

Recent surveys show that the private sector still has limited awareness of, and interest in, climate change adaptation (Agrawala et al., 2011b), and the adaptation literature abounds with evidence of the barriers posed by knowledge gaps and uncertainties of future climate change impacts (Füssel, 2007; Osberghaus et al., 2010; Mees et al., 2012). The private sector may not believe that climate change related events can disrupt their operations, implying that adaptation is unnecessary or premature. Lack of accuracy and precision, especially regarding local and regional impacts, and the possibility of unpredictable changes, does not prevent against the risk of mal-adaptation and financial losses –limiting the cost-effectiveness of any adaptation action today. In addition, financial barriers exist, such as the immediate costs of building capacity and the natural discounting of future benefits (Biagini and Miller, 2013). The private provision of adaptation goods with public benefits faces the particular issue that the private sector is not yet economically rewarded for taking adaptation action in current market conditions.

Given the barriers facing private provisioning presented above, public interventions have been proposed to incentivise the private provision of adaptation goods (Mendelsohn, 2006; Osberghaus et al., 2010; Tompkins and Eakin, 2012; Mees et al., 2013). Public involvement in fostering private provision of adaptation goods has therefore been supported, especially when these adaptation goods have strong public benefits (Tompkins and Eakin, 2012). Figure 2 presents one way to schematise the conditions for different degrees of public involvement:

- Private provision should occur when market failure is minimal: private actors have good awareness of climate; there is a clear private benefit in taking action; and benefits materialise in the short term.
- In contrast, public provision should occur market failures are significant: private actors are not well aware of the benefits of adaptation; there is no clear benefit in taking action; benefits occur in the long term; when transaction costs are high (e.g. coordination costs for ensuring adaptation by large number of individual actors); and when benefits accrue to the individual but impose costs to the community. Public provision may also be warranted when the benefits for groups of social actors are high while the costs are disproportionate on individual actors.

In this context, public involvement in supporting private adaptation should be dependent on considering (i) how it helps maximise welfare of individuals and groups disproportionately impacted by climate change impacts and adaptation, or (ii) how it helps maximise public benefits.

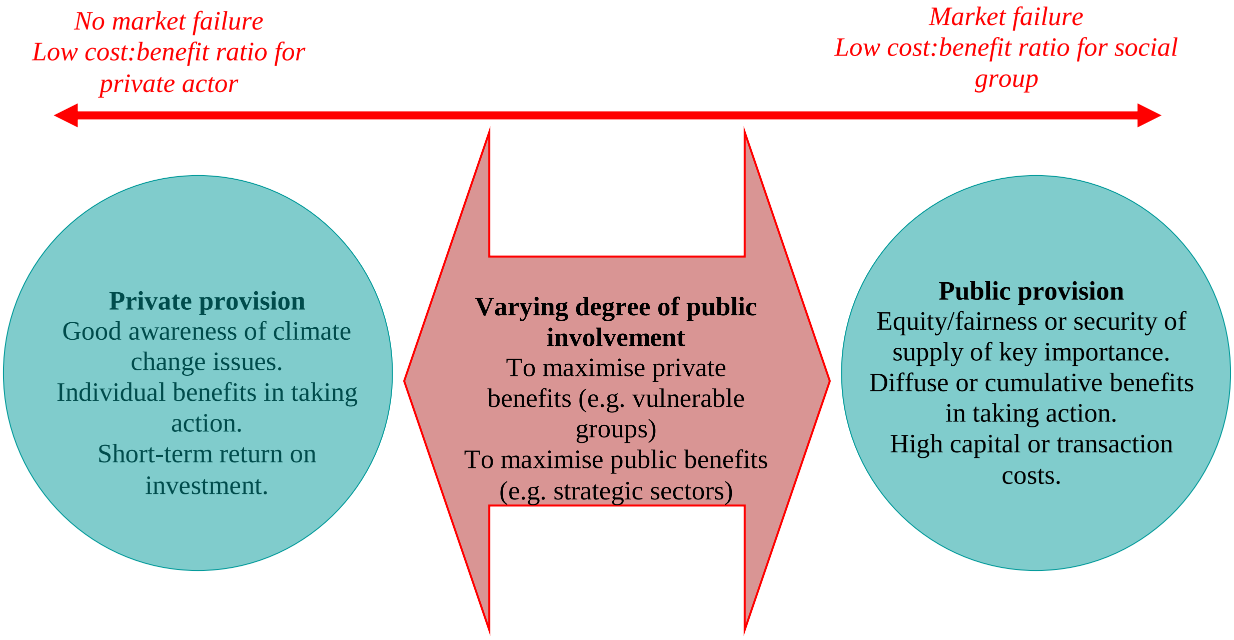

Figure 2. Some key contextual factors for public or private provision of adaptation goods

It is important to note that the level of public involvement depends on broader political and social dimensions. For example, different political ideologies and worldviews may support or challenge public intervention for supporting private action. Public provision may be acceptable where fair and equitable distribution of costs and benefits between social actors and groups is of key importance, and actors believe that the state has a role in re-distributing these costs and benefits. There are also challenges with incentivising greater private adaptation, such as the moral hazard with shifting public responsibilities in adaptation to private entities, as some authors argue this may be an argument for governments for inaction (Biagini and Miller, 2013). Other issues include the acceptable forms and levels of public involvement, and issues of effectiveness, efficiency and equity with public interventions. These are examined in the next section

Private provision and policy instrumentation

Nine policy instruments were selected to present a range of possible public interventions to promote private provision of public adaptation goods based on listing by the OECD (2008) and Bräuninger et al. (2011). Table 5 presents the nine policy instruments investigated and map them against the types of incentives that private actors may have in providing public adaptation goods (as discussed in the previous chapter). Private provision here includes both deliberate supply (i.e. direct provision of public adaptation goods) and accidental supply (i.e. indirect provision via co-benefits of adopting practices or technologies that primarily enhancing private resilience). The table is further discussed in the following sections.

Table 5. Matching instruments with intended type of private provision of public adaptation goods

Instrument	Encouraging private provision of public adaptation goods: Through financial reward	Through interest in non-monetary benefits	Through altruism	Through coercion
Awareness-raising		X	X	
Regulation				X
Public-private partnerships	X	X		
Subsidies	X	X		
Tariff, charge and tax	X			X
Trading	X	X		
Payment for Ecosystem services	X	X		
Insurance		X		

In addition, the potential performance of policy instruments is assessed against three criteria: effectiveness, efficiency, and distributional impacts. The assessment of the performance of policy instruments is difficult to do in a generic way, and depends very much on the specific purpose and context in which an instrument is used; however some broad observations can be made (Gunningham and Sinclair, 1998), based on the following:

- The effectiveness of a policy instrument can be assessed against its capacity to promote changes in behaviour, practices and technologies amongst private actors that result in public benefits.
- Its efficiency is dependent on the extent to which effort is used for implementing the policy instrument and achieving the desired impact (i.e. transaction costs).
- Its distributional impact is related to the share of the costs between public and private actors, and between sectors and social groups.

Awareness-raising

Awareness-raising is the least coercive policy instrument, and aim to foster adaptation by informing and encouraging private actors in understanding, assessing and managing climate change risks. In adaptation, awareness-raising can contribute by bridging the information gap described in the previous section by providing detailed information on the consequences of not adapting to anticipated effects, and the benefits of taking pro-active action.

Awareness-raising programmes are applicable to most sectors, although, in climate change adaptation, they are currently well developed for agriculture. An example of global significance is for example the CGIAR Research Program on Climate Change, Agriculture and Food Security[4] which aims to enhance knowledge and raise awareness on climate change impacts and resilience building in agriculture, for example through its research activities on ”climate information services and climate-informed safety nets”. Because awareness-raising programmes rely on voluntary uptake, one of their main advantages is their low transaction costs and distributional impact. Information is produced and disseminated, but no enforcement mechanism is required. The main disadvantage however is that the provisioning of adaptation goods with public benefits can only be promoted effectively via this instrument if private benefits are also obtained. For policy-makers therefore, the challenge when designing awareness-raising programmes is to select adaptation actions that clearly benefit private actors, but that ultimately result in public benefits (i.e. co-benefits).

Awareness-raising programmes can nevertheless target non-economic motivations in private actor decision-making, such as psychological and sociological drivers. Peer-pressure in particular can have a big influence on people’s motivations and decision-making. For example, there is evidence that farmers may adopt land management operations that are collectively valued, i.e. the “good farmer”. Promoting new common values such as resilient businesses to climate change could result, in the long term, to voluntary uptake of resilience practices. Altruistic drivers are rarer, although individuals can adopt behaviours that are strongly driven by moral codes (e.g. sustainability, egalitarian goals). Businesses and industries may be engaged in philanthropic activities in order to strengthen their green and ethical portfolio. The most effective instruments may be those raising awareness of the non-financial benefits and ethical dimensions of taking adaptation action to climate change impacts. Messages may emphasise best practice, the moral imperative of taking action, and expected gains in social and community status.

Regulations

To the contrary of awareness-raising programmes, regulations are the most coercive policy instruments. They put legal requirements on societal actors to take specific adaptation action without financial support or compensation. Regulations are often seen as constraints for the private sector, and are therefore often associated with high transaction costs (e.g. cost for negotiating the regulation, enforcement costs). However, by setting common performance requirements, regulations can open new business opportunities, and reduce financial risks for companies investing in adaptation technologies. Regulations may be particularly justified when a private action has strong negative externalities on societies’ adaptation level. Regulations are therefore highly relevant for promoting private provisioning of public adaptation goods. For example, regulations have been suggested to promote green roof installation and prevent the excessive impermeabilisation of land surface in towns in view of climate change impacts on extreme rainfall (Mees et al., 2012).

Regulations may be used to ensure specific performance standards in some private markets or to ensure private investments are climate proofed. For example, building codes are being used in London to improve the energy balance of new buildings (e.g. increase resilience against heatwaves). Planning regulations are being used in Singapore to set minimum levels for reclaimed land (CDP, 2014). However, the particular use of regulations need high levels of justification and legitimacy, which may be difficult to achieve given the large uncertainties pertaining to climate

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[4] See http://ccafs.cgiar.org/

change adaptation. Regulations acting against private interest can face significant non-compliance issues, and can entail high transaction costs for the monitoring and enforcement procedures needed during implementation.

Public-private partnerships (PPPs)

PPPs include a class of contractual instruments between public and private actors that enhance the ability of the public sector to provide public services thanks to the involvement of the private sector. The provision of public adaptation good therefore arise from a close partnership between the public and private sectors. PPPs have for example been used for flood protection projects and coastal defences where public financial resources were limited in the short-term (e.g. pay for the capital costs), but projects had strong public benefits in the long-term. Private involvement led to the raising of additional resources in the short-term.

Many forms of PPPs exist (Fankhauser et al., 2008). In the most "privatised" form, the private sector has control over all assets, including investment, maintenance, and operations decisions, although some specific, strategic decisions remain subject to regulatory oversight. This is usually used for large-scale capital investments for which the private sector can shave off financial risks with long-term contracts (e.g. decades). Alternatively, concessions in the form of long-term contracts are often used. In those cases, the private sector has full responsibility for the operation of the asset, usually recouping investment costs with service provision revenues (i.e. tariff collections). Under management and lease agreements, the private sector takes control on operations for shorter time, but also bears less financial risks, and initial capital investment is assured by the public. Private revenues are conditioned to pre-agreed performance targets.

PPPs have rarely been used for climate change adaptation, and therefore frameworks and approaches remain untested in this context (Fankhauser and Soare, 2013). PPP is especially attractive to public authorities in times of budgetary constraints, and offer significant opportunities for the provisioning of public adaptation goods. PPPs can help lever private sector investment into delivering resilient infrastructures, and enhance the performance of infrastructure management or service provision under changing climatic conditions (Kennedy and Corfee-Morlot, 2012). For the private sector, PPPs could be an opportunity to secure long-term business opportunities in adaptation while minimising financial risks. In particular, PPPs can reduce borrowing costs (e.g. interest rates on loans and guarantees) for investors into adaptation businesses or activities (Bräuninger et al., 2011).

Subsidies

Subsidies are payments from public bodies to private actors with the objective of incentivising specific technological or behavioural change. Subsidies allow the capture of positive externalities, such as the delivery of public adaptation goods. They are most justified when adopting specific practices by private actors can result in the delivery of public adaptation goods, but these are not rewarded by the market (e.g. financial gain) or society (e.g. reputational gain). Subsidies may also be used to prevent specific private practices that result in losing adaptation goods (i.e. negative externalities). One such example is the agri-environment scheme of the European Rural Development Programme where some measures encourage businesses to adop less intensive farming practices. Reducing negative externalities may enhance the provision of public adaptation (e.g. more resilient ecosystems). However, paying individuals and businesses to avoid negative externalities may not be justified in all situations (i.e. moral hazard).

Subsidies can take the form of e.g. payments from a public body to private parties (as regular payments or one-off such as grants), tax reductions, etc. Grants have been used in Australia to help farmers manage climate change impacts through soft adaptation measures (Bräuninger et al., 2011). Payments rely on the voluntary participation of private actors, who need to be interested in adopting the targeted behaviour, practice or technology. Inertia in uptake is possible and subsidies may not be very effective or efficient in fostering large-scale uptake in the short-term. Tax reductions are easier to administer, but they have the disadvantage of being less transparent and may not equitably impact all actors (Bräuninger et al., 2011). Tax reductions have not yet been used in adaptation, but could be applied to support research and development, or to support use of resilient materials in the building sector.

Tariffs, charges, and taxes

Tariffs -a price paid by users to a service provider for a given quantity of service (Delacamara et al., 2014) - can be used to increase the relative price of non-resilient technologies and practices against resilient ones, thereby creating an incentive to private actors to adopt resilient technology or practice. Block tariffs for example have been used on water bills to incentivise lower water use, and feed-in tariffs have been used to increase the revenues of micro-generation by private actors.

Charges are compulsory payments to a competent body for engaging in an activity to be avoided (e.g. mal-adaptation). Taxes are also compulsory payments, but applied by a fiscal authority onto private actors for encouraging uptake of specific practices or technologies. In adaptation, charges and taxes can increase the short term costs of taking non-resilient behaviours. A land use tax on sealed soil area could provide an incentive for avoiding further sealing (which would exacerbate flood risk downstream) (Bräuninger et al., 2011). In addition, charges and taxes can create demand, and therefore business opportunities, for adaptation products or services. Although charges and taxes can receive social opposition, they have a wide applicability and can foster large-scale adaptation.

The effect of using tariffs, charges and taxes on the provision of public adaptation goods can be either direct or indirect. These instruments can for example directly encourage practices or the use of technologies that result in public adaptation benefit (e.g. tax on land sealing). Private provision can also occur through the co-benefits associated with the private adoption of more resilient practices and technologies. For example, the adoption of water saving technology leads to lower individual water use, increase water availability, and reduce overall pressure on water resources and related ecosystems.

Trading

Trading involves the exchange of rights or entitlements to consume, abstract, and discharge a good with the aim of maximise overall welfare (Delacamara et al., 2014). In adaptation, markets can help to ensure efficient use of consumed natural resources within and across sectors under growing resource scarcity with climate change, yielding substantial adaptation public benefits by strengthening the resilience of groups of actors. Some have proposed trading of adaptation goods themselves, although the viability of such market remains untested. Bräuninger et al. (2011) for example suggest establishing markets for trading net value of property or human health (using the World Health Organisation Disability-adjusted life years saved) protected.

Project offsets could be used to minimise negative externalities (i.e. maintain the provision of public adaptation goods). Efficiencies of environmental markets are limited by high transaction costs due to the costs of setting up the right institutional framework to allocate property rights, measure and monitor traded goods, and enforce market rules (Delacamara et al., 2014). Trading ensures lower value uses are rewarded for allocating good to higher value uses. However, over time trading can reinforce social disparities (Delacamara et al., 2014), and considerable social opposition has been observed if the good is perceived as a non-commercial good (e.g. water).

Payments for ecosystem services (PES)

In contrast to trading, PES is a particular form of market that focuses on paying private actors for the wider public benefits of adopting (usually) land use practices that maximise ecosystem services. It is based on negotiated voluntary arrangements between two private parties. Because maximising ecosystem services can play an important role in adaptation, PES can have several applications in the private provisioning of public adaptation goods. PESs can strengthen the long term revenues of private actors by economically incentivising its production. They can thus create new opportunities and reduce financial risks of individual businesses. While PES are likely to be more socially acceptable (because private providers are rewarded for their provision of public goods), they put an additional burden on beneficiaries, may entail high transaction costs, and can receive criticism by interest groups on value grounds (i.e. commodification of nature).

Insurances

Insurances are economic instruments that are put in place before a disaster, and share and pool risks in order to create entitlement to compensation after a disaster (Bräuninger et al., 2011). Different types of insurances are relevant for adaptation, such as the indemnity-based insurances, index-based insurances, weather derivatives, and catastrophe bonds (Fankhauser et al., 2008). They involve the payment of a premium in order to be protected in the event of a loss, and draw on private actors' aversion to risk and willingness to pay for income stabilisation (Delacamara et al., 2014).

Insurances have long been used to manage the impacts of extreme weather events, and increasingly for adaptation. They may help communicate to private actors new risks associated with climate change, either as a condition for coverage (e.g., by dictating storm-resistant construction) or through differential premiums reflecting the higher probability of damages in some locations or activities. The main focus of insurances is to help the insured body cope with private losses due to exceptional events, and, as such, they mainly result in private benefits. However the use of insurance can help spread large-scale risks, thereby increasing the resilience not only of individual actors but regions, countries or sectors. Insurances can also be used to incentive the re-distribution of risks between social actors. For example, public insurance schemes are been proposed to farmers who voluntary inundate their land to reduce flood risk downstream.

Indemnity based insurances offer a compensation against actual loss, while index-based ones moves away by indexing the payout against some pre-agreed criteria or levels. Index-based insurances may be more effective than indemnity-based ones at acting as incentives to take adequate loss-reduction action, because the gap between insured and actual losses may grow as climate risks increase. Weather derivatives and catastrophe bonds are used by the financial sector to spread risks, and may therefore gain more prominence as the potential for more frequent, low, or one-off large losses increase with climate change (Fankhauser et al., 2008).

A major challenge with insurance schemes is that they need accurate and reliable information to estimate loss profiles, and set the adequate pricing of premiums. With climate change, historical data cannot be used, and the ability to forecast future risks remains limited. It is likely that uncertainties with future impacts of climate change will result in increased premiums, although this does not reflect the real additional risks of climate change. Factoring climate change into insurance schemes may therefore decrease their overall efficiency. In addition, higher climate variability and extreme events will increase the cost of insurance, which will be passed on to customers through higher premiums. Social groups with already the lowest purchasing powers will be most affected (Osberghaus et al., 2010). Insurances can also be an incentive not to take appropriate action (i.e. the "moral hazard" issue), and face similar problems as other economic instruments, such as inertia in uptake, reliance on social and cultural factors, and lack of information and financial capacity in particular by most vulnerable communities (i.e. exposed and poor).

Private provision and implementation

The use of specific policy instruments and the involvement of public authorities will vary according to the targeted private actors and the degree to which it supports public benefits. One may think of a "ladder" of increased public involvement as more public benefits are expected at the expense of private benefits (Figure 3). For example, public involvement may be minimal (e.g. awareness-raising, small grants for capital investment) if there is the potential for high levels of private benefits in taking adaptation action, for instance when new business opportunities arise by developing/selling adaptation products, or when adaptation leads to avoiding business disruptions against extreme events. Additional incentives for uptake through governmental intervention will be necessary where adaptation measures mostly deliver public benefits and no or few private benefits, or act against private interests. Such "incentives" may represent financial support (e.g. payments for profit losses) to regulatory action that constrain individuals from doing things that serve their own interests but have adverse effects on others (e.g. land-use regulations).

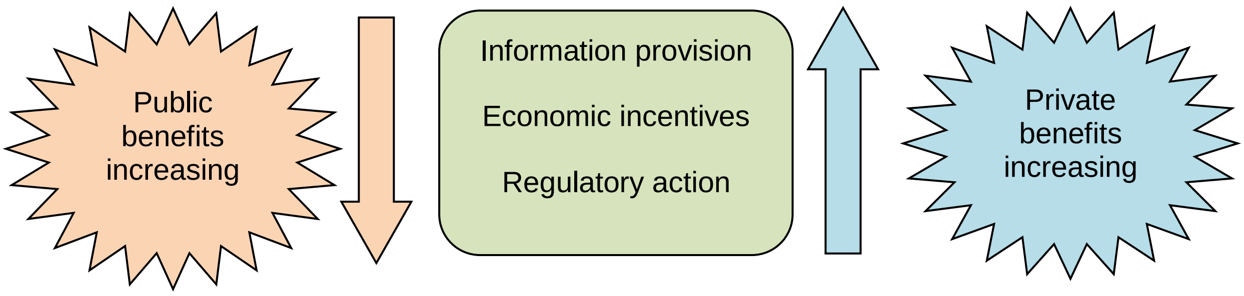

Figure 3. Ladder of public involvement

Following the ladder, public involvement may focus on emphasising the private economic benefits of taking adaptation action through awareness-raising programs, to using a range of economic instruments helping to overcome initial capital investment costs, payments for adaptation services provided, and regulatory action to prevent economic activities with negative externalities.

Incentives for taking action may follow, increasing in strength, e.g. from small loans and tax breaks to the creation of insurance and markets. Regulatory action when strong evidence is built and impacts are felt.

Creating “mixes”, i.e. combination of policy instruments, is usually recommended in many circumstances in order to exploit relative strength, build synergies, and reduce conflicts (Gunningham and Sinclair, 1998; Howlett, 2009). For example, to secure the environmental effectiveness of a trading scheme, a cap might need to be introduced to ensure traded rights do not exceed relevant pollution loads or water use (Delacamara et al., 2014). Given the lack of established policy instruments for adaptation, no experience of intentionally designed adaptation policy mixes could be found[5]. In theory, no ideal mix exists. Instead, policy mixes should be sensitive to the particular contexts in which they are crafted (Gunningham and Sinclair, 1998). For example, relevant factors include: individual perception, social norms and expectations, or political acceptability, as well as institutional factors such as (resource) rights and the legal framework (Delacamara et al., 2014). Economic instruments may benefit when combined with regulatory instruments or the provision of information, in particular where direct monitoring is limited or difficult to achieve, or where governmental action need to be highly targeted spatially. In general however, the overlap of instruments should be avoided unless their complementarity is well identified, and they mutually reinforce each other. This is why it is very important to re-evaluate the impacts of a policy mix every time a change occurs in any of its components (Delacamara et al., 2014).

Given the difficulty of anticipating changes in the long-term, many authors advocate a progressive learning-by-doing or adaptive management approach to avoid “mal-adaptation”. An adaptive approach may first focus on short term impacts (less uncertain) and then on long-term impacts as knowledge increases and the strength of climatic changes becomes stronger and more established.

Building adaptive capacity has become a popular concept to better prepare society to future impacts, and could represent a coherent framework for steering private provisioning of adaptation goods. Adaptive capacity is in particular favoured with an adequate supply of resources, technologies, knowledge and skills that enable social actors to respond to evolving circumstances, and an effective system that enable to test new knowledge, and learn from those experiments. Thus, with its role in supplying adaptation products and services, the private sector not only contributes to strengthening development and adaptation objectives but also to increasing adaptative capacity.

To increase adaptive capacity, the environmental governance literature widely advocates collective processes where knowledge is co-produced and decisions are made on a consensual basis or through balanced compromise. By favouring deliberative forms of decision-making, interest, belief and value conflicts become more transparent, encouraging social actors to reconsider their position in light of others’ perspective. Fostering greater private provisioning of adaptation goods may thus not only be based on setting up regulatory or economic instruments, but also on establishing appropriate participatory processes that emphasise open and transparent

[5] In the previous example, an adaptation measure could be the introduction of the cap, so as to increase resilience by encouraging lower and more efficient resource use, and essentially retaining the benefits of the original mix. Climate impact projections could be taken into account when setting the levels or rules governing the cap.

sharing of information, equal treatment of interests, willingness and commitment to (re)consider each other's beliefs and views (Mostert et al., 2007).

In practice this means that governments may need to engage closely with the private sector in order to increase acceptance of policy instruments and their effectiveness aiming at fostering the private provision of adaptation goods. Typical steps when designing new policy instruments should include (Delacamara et al., 2014):

- Very early engagement, involving private actors in decisions about both the strategic directions of research and development activities and policy development;
- Transparent and accountable decision-making (e.g. detailed and publicly available records of meetings and agreements for future reference), and maintaining close exchange throughout the policy process;
- Building the capacity of administrative staff of the responsible authorities;
- Continuous informing, involving and exchanging with the private sector.

Conclusions

The paper has investigated the potential for the private provision of adaptation goods with public benefits through a review of the grey and academic literature. It has discussed the characteristics of relevant adaptation options, their potential delivery by private and public actors (including a sectoral differentiation), and their contribution to delivering adaptation goods with public and private benefits. It was shown that, while private adaptation measures do not necessarily result in public benefits, many can be considered as contributing to different degrees to societal resilience and development. Key factors also include the scale of the measure and its cumulative impact. The review then assessed the conditions in which private adaptation is performing best against public delivery of adaptation action. It showed that private adaptation is best when private actors have a good awareness of climate change issues, strong individual benefits exist in taking adaptation action, and a short-term return on investment exists. Public intervention may be necessary, and justified, for securing the provision of adaptation public benefits. The review then explored how different types of public policy instruments can support private adaptation, and their performance against key evaluative criteria, including effectiveness, efficiency, and distributional impact. The paper shows that policy mixes may help overcome the comparative disadvantage of different policy instruments, but that such an approach needs to be grounded in a sequential and adaptive process of design and implementation.

A number of key questions can be derived from the analysis above in order to guide the assessment of the potential for private adaptation delivering public benefits. This is presented in Figure 4.

The first step is to characterise the climate related risks faced, the adaptation actions required, and their public and private benefits. Table 2 can be used as an example of how to identify the public and private benefit of taken adaptation action.

The second step is to assess what private actors can do to deliver adaptation actions, and to what extent private provision is preferable to public provision. Table 3 presents examples of private adaptation action with public benefits that can be taken by different sectors, while Figure 2 provides some key contextual factors for identifying the relevance of private and public provision.

It is important to consider barriers on private adaptation delivering public benefits (e.g. information/awareness gaps and uncertainties, discounting of future benefits, path dependency, lack of financial resources and reward), as well as drivers for taking action (e.g. see Table 4 presenting types of opportunities for private actors).

The third step is to screen how different public policy instruments can foster private adaptation for public benefits. The relevance of policy instruments will differ depending on the intended effect and how they influence private actor decision-making (see Table 5).

The fourth step is to examine how instruments may perform against key factors and how their combinations can help overcome relative limitations. Sequencing policy instrument use over time can also be a pragmatic way to progressively build capacity for private adaptation (see Figure 3). Specific design in the particular context in which policy instruments are implemented will require a structured multi-actor exchange and collective learning.

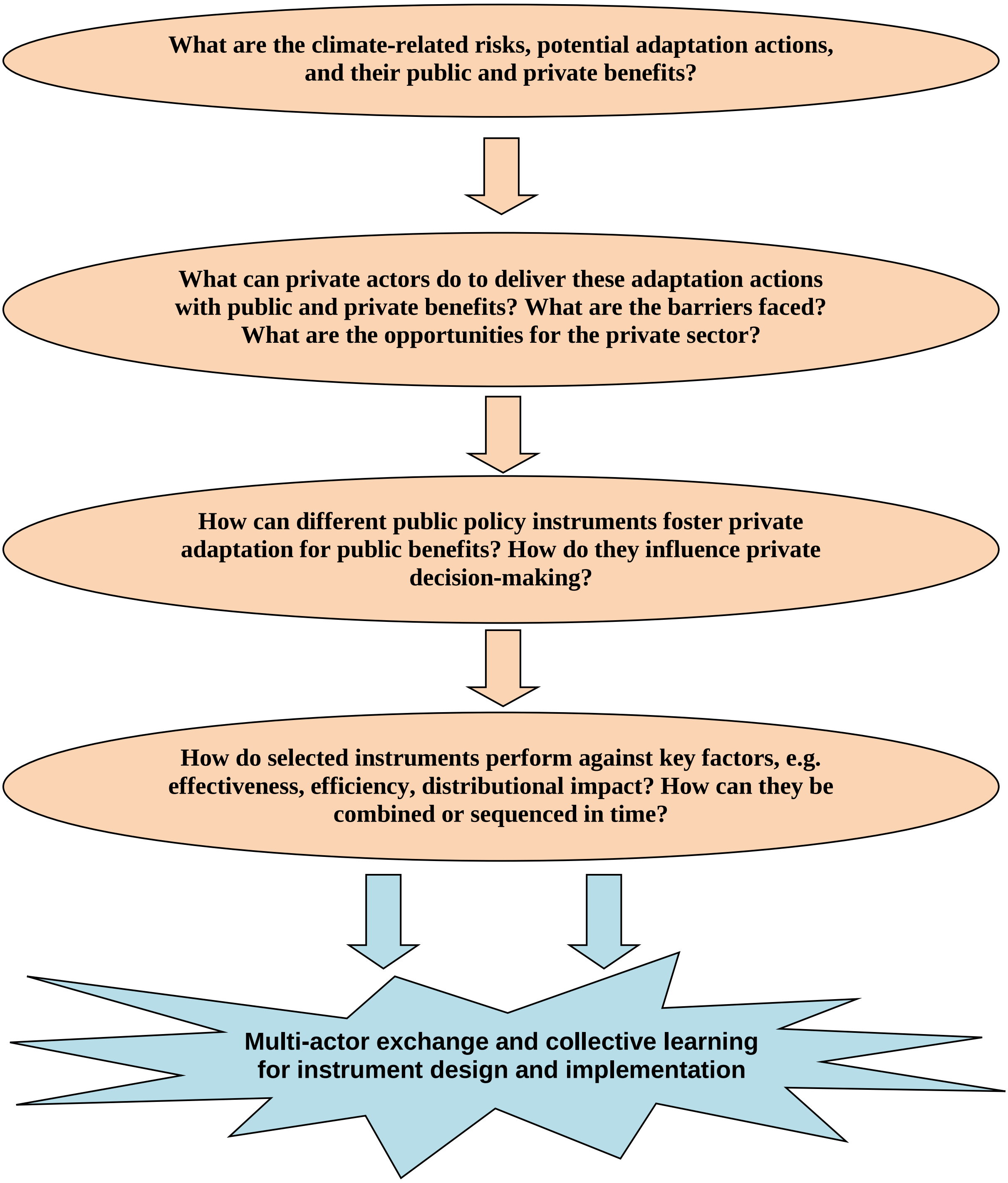

Figure 4. Key assessment questions for exploring the potential of private adaptation to deliver public benefits

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3 Transfer of distributional weight parameters

This chapter outlines some limitations on the use of Cost-Benefit Analysis (CBA) in adaptation decision making. This method is one of the most commonly used methodological approaches to assess the costs and benefits of adaptation options. The document provides criteria and empirical values for overcoming CBA limitations on its use in adaptation decision making. It focuses in particular on distributional benefits from employment (to take account of effects on employment), distributional weights (to take account of equity concerns) and risk aversion. These issues are usually not taken into account in traditional CBA. The information presented in this paper is based on reviewed publications from the literature. Most of the publications represent academic literature including scientific articles, proceedings and books. Grey literature including international organisations such as UN agencies is also used.

This chapter is divided into two main sections. First, a short introduction on the strength and limitations of CBA as applied to assess adaptation projects is presented. This section includes the outcomes of the literature review on how to overcome these limitations, including a synthesis of empirical evidence existing in the literature and their usefulness. It follows a case study that shows how theory can be implemented in practice. The paper concludes on some key messages and recommendations.

Cost-Benefit Analysis of Adaptation Options

Current and projected climate change will impact on a variety of systems and sectors that are essentials for human wellbeing. Numerous countries, regions and municipalities are adopting measures to adapt to climate change. Adaptation options need to be based on robust assessment approaches that enable decision makers to efficiently allocate scarce resources. Assessing the costs and benefits of adaptation options is an important part of this process, as it helps to identify the most appropriate interventions for reducing vulnerability, enhancing adaptive capacity and building resilience. Cost-Benefit Analysis (CBA) is a commonly used approach to assess the costs and benefits of adaptation options.

CBA is often used to assess adaptation options when efficiency is the only decision making criteria. A CBA involves calculating and comparing all discounted costs and benefits of an investment project, expressed in monetary terms. The comparison of discounted costs and benefits, and the subsequent calculation of the Net Present Value (NPV), the Benefit Cost Ratio (BCR) and/or the Internal Rate of Return (IRR), can help to inform decision makers about the likely efficiency of an adaptation project. A positive NPV (benefits exceed costs) means that a project is considered desirable. The IRR calculates the interest rate internally which represents the return of the given project. A project is rated desirable if this IRR surpasses the average return of public capital determined beforehand. Thus, CBA provides a basis for prioritising possible adaptation measures.

The strength of CBA is that it compares costs and benefits using a single metric, provided that we are able to measure all benefits in monetary terms. Although it is not the focus of this paper, we must acknowledge that the latter can be challenging as most of the times there are costs and benefits with non-market value (e.g. environmental goods and services, and social or cultural values) which are difficult to estimate. Along with strengths, CBA has some limitations. CBA tends to ignore employment effects. Another limitation of CBA is that it puts particular emphasises on efficiency, thus failing to account for equity considerations related to the distribution of benefits and cost across affected stakeholders. Risk aversion is also typically ignored in CBA (Noah K. 2014).

The following sub-sections present in more detail the reasons why employment effects, equity and risk aversion tend not to be considered in traditional CBA. These sections also clarify that the reasons for not considering these elements in the analysis are **not valid**, and give some guidance on how they can be incorporated into CBA. Section 3 describes, using a case study, how employment, equity and risk aversion can be taken into account.

Taking account of effects on employment

Adaptation investments may affect employment by directly creating jobs, facilitating job creation, or augmenting labour supply. The social profitability of an investment project is greater when labour is correctly evaluated and incorporated into the analysis. This can be done translating observed market wages into shadow wages by conversion factors (i.e. coefficients computed as the ratio between the shadow and market wage).

Ignoring this correction may lead to an underestimation of the social benefits of public investment, especially in labour markets with high unemployment where employment changes may have significant net efficiency benefits which should be included in CBA (Bartik, T. J. 2012). Nonetheless, traditional CBA has usually ignored effects of public investment on employment. Masur, J.S. et al. (2011) argue that cost-benefit analysis does not take into account jobs because the economists who developed cost-benefit analysis made classical assumptions that labour markets “clear” (i.e. no involuntary unemployment and no other distortions exist). On this view, the efficiency benefit in the labour market of additional employment is nil. With involuntary unemployment, when a policy increases employment of an individual or group, this change has large benefits.

The literature analysing how to measure and to include jobs in CBA is extensive and with a long history (e.g. Lewis 1954; Dasgupta and Pearce 1972; Sen and Marglin 1972; Little and Mirrlees 1974; Roberts 1982; Marchand et al. 1984; Boadway and Bruce 1984; Brent 1984; Dreze and Stern 1987; Cowell and Gardiner 1999; Yitzhaki 2003; Johansson-Stenman 2005; Creedy 2006; Fleurbaey, Luchini, Muller, and Schokkaert 2013). Most researchers share the intuition that the efficiency benefits of increased employment are higher when involuntary unemployment is high, but the approaches used vary and the employment benefits estimates differ. Estimates of employment benefits of the policy’s direct earnings effects range from 0% to some multiples of 100% (Bartik, T. J. 2012).

The empirical literature also shows a wide range of conversion factors (Bo et al., 2009). Jacoby (1993) found estimates of the conversion factor between 0.37 and 0.58 in Peru. In India, Skoufias (1994) found a conversion factor of 0.83 for males and 0.63 for female workers. Adbulai and Regmi’s (2000) analysis estimate a conversion factor of 0.414 in Nepal. Lal (1979) estimated shadow prices for Jamaica and found a conversion factor of 0.73. Londero (2003) found conversion factors ranging from 0.41 (administrative labour with high benefits) to 1.0 (foreign employees) in Colombia. Picazo-Tadeo and Reig-Martinez (2005) estimate a conversion factor of around 0.68 in the Spanish agricultural sector. Honohan (1998) found that the cost-benefit methodology used in Ireland for the evaluation of industrial projects was consistent with conversion factors of at most 80%. The mean of conversion factors over time in Belgium is of 0.72 (De Borger, 1993). Using sectoral employment and data from the Australian Bureau of Statistics, Saleh (2004) found that conversion factors differ across sectors and range between 0.94 for Intermediate Clerical, Sales and Service Workers and 1.01 for Elementary Clerical, Sales and Service in that country. Bo et al. (2009) found values between 0.38 -for many regions in Spain, Portugal, France, central Italy, UK and Ireland, northern Germany, Baltic and Scandinavian countries- and 0.46 -for regions of southern Spain, southern Italy, northern France, northern Greece, east Germany, Hungary and Poland. A discount of around 0.10 is found in many regions, including capitals such as Paris, London, Wien, Amsterdam, Stockholm.

In spite of the vast theoretical and empirical contributions and the requirements of project evaluation by international organizations (e.g. European Commission, Asian Development Bank, World Bank) and national governments (e.g. Australia, Belgium, Canada or Ireland), actual estimation and practical applications of shadow wage rates have been limited.

Considering distribution of benefits

Standard or traditional CBA emphasizes the growth or efficiency objective, often to the detriment of the equity objective. It is thus notoriously insensitive to distributional concerns. CBA quantifies well-being impacts by summing monetary equivalents: the amounts that individuals are willing to pay for policies they prefer, or to accept in return for policies they do not prefer. CBA will favour a policy with a positive sum of monetary equivalents, even if some are made worse off by the policy. Nor is CBA sensitive to the distribution of these valuations across the population. For example, if a policy produces net benefits for higher income individuals and net costs for lower-income individuals, CBA will choose the policy as long as the (positive) sum of monetary equivalents of the higher-income group is larger in magnitude than the (negative) sum of monetary equivalents of the lower-income individuals.

This bias towards the growth objective has been usually justified on the grounds that this would ensure that the available resources yielded the maximum increment in total national income, and that governments can use fiscal devices to redistribute project-generated income in any desired direction (Squire, L. et al., 1975). But the capacity of governments to redistribute income is sometimes limited, especially in developing countries which sometimes lack the necessary administrative and organisational structures. Arguably, distributional considerations should be incorporated into CBA (Adler, M.D., 2013). In other words, the effect on the incomes of different groups in society (that is, the distribution effect) must be looked at as well as the effect of the project on the allocation of resources (that is, the efficiency effect). This can be done via so-called "distributional weights", where monetary equivalents (e.g. benefits) would be adjusted by weighting factors reflecting incomes of people receiving benefits or bearing the costs of a project (with lower-income individuals tending to get larger weights). Therefore, it is possible to account for the benefits to different groups by applying a distributional weight according to their relative income level.

Let us assume the following social welfare function (Atkinson, 1970) for estimating the income distributional weights attributable to incomes of individuals belonging to different income groups in a region or country:

where:

$$W = \sum_{i=1}^{N} \frac{AY_i^{1-\varepsilon}}{1-\varepsilon}$$

W: social welfare function

Y_i: income of individual i

ε : elasticity of social marginal utility of income or inequality aversion parameter

A: constant

The social marginal utility of income is defined as:

$$\frac{\partial W}{\partial Y_i} = AY_i^{-\varepsilon}$$

Taking per capita national or regional income, $\bar{Y}$, as numeraire, we can set the marginal welfare at that level of income as one:

$$\frac{\partial W}{\partial Y_i} = A\bar{Y}_i^{-\varepsilon} = 1$$

And

$$\frac{\partial W}{\partial Y_i} = SMU_i = \left[\frac{\bar{Y}}{Y_i}\right]^{\varepsilon}$$

Where SMU is the social marginal utility of income going to group 'i' relative to the income going to a person with the average per capita income. The values of SMUi are in fact the weights to be attached to the costs and benefits to group 'i' relative to average costs and benefits. We need estimates of Y and ε in order to estimate the income distribution weights using equation 3.

This method of dealing with distributional considerations goes back to the 1960s, when Weisbrod (1968) argued that distributional considerations are relevant to political decision-makers. This issue was included in benefit cost manuals such as Squire and van der Tak (1975), but it fell out of favour in the 1990s and later when concerns with income distribution declined. It was also criticised on the grounds that we do not know the value of ε. However, Stern (1977) argued that we can derive such a value from government social policies and suggested a figure close to 1.0. Lambert's (2003) paper contains a comprehensive review of studies deriving ε values from observed policies, reporting estimates in the range of 1.40-1.94. Gouveia and Strauss (1994) and Young (1990) found ε values between 1.52 and 1.94 for the US. In addition, Young informed ε values of 1.63 and 1.40 for West Germany and Italy respectively. Subjective inequality comparisons are typically made by assuming a range of fixed illustrative values for the inequality aversion parameter. Atkinson (1970) compares subjective inequality in 12 countries using ε values of 1.0, 1.5 and 2.0. Moore (1996) used values of 0.5, 1.0 and 2.0.

In very broad terms, this evidence suggests that an extra Euro to someone earning 1000 Euro is worth twice as much as to someone receiving 2000 Euros a month (UK Treasury 2003). Empirical evidence shows that there is increasing utility to benefits with decreasing income. Yet, distributional concerns are not always included in CBA (Mechler R., 2005).

Accounting for risk aversion

It is generally assumed that individuals are risk averse and concerned about their expected utility. Individuals are willing to pay for insurance which limits their loss in case an unfavourable event takes place, e.g. their home are flooded. In other words, individuals usually do not only consider the expected return but also the distribution of the return. Being exposed to a risk, constitutes a cost to risk averse individuals, and they are willing to pay (WTP) in order to reduce or eliminate the risk.

Nevertheless, risk aversion is typically ignored in CBA. As Noah K. (2014) explains, there are two potential explanations for this. First, there is an extensive public economics literature on conditions whereby governments should behave in accordance with **risk neutrality** (i.e. zero risk aversion) with respect to risky public investments with uncertain costs and benefits (e.g. adaptation projects). This reasoning goes back to the 1970s, when Arrow and Lind (1970) showed that when populations are relative large the risk premiums for small public investments with uncertain effects converge to zero because they can essentially be “spread out” among members of society. If the population is sufficiently large, both individual risk premiums and the sum of all risk premiums converge to zero. In the situations in which this result holds, the effects of risk aversion can safely be ignored. However, this rationale for ignoring risk aversion when evaluating risky public investments does not provide any basis for ignoring risk aversion in the presence of pre-existing environmental uncertainty, when risk cannot be “spread out” across the population. The arguments for risk neutrality are valid for projects that have uncertain costs and benefits, not for projects that reduce uncertainty that exists in the absence of environmental policy (“baseline” or “business-as-usual” uncertainty). Policies that reduce pre-existing environmental uncertainty will provide risk-reducing benefits to all affected risk-averse individuals, and in no sense is the risk “spread out” across affected stakeholders. Policy evaluations should therefore account for risk aversion in situations when pre-existing uncertainty is significant.

Second, there are theoretical difficulties to attempt to quantify risk aversion and there is thus no well-accepted level of societal risk aversion. Computational and theoretical difficulties of estimating risk premiums exist, but are not a valid justification.

Assuming that individuals are risk averse, the expected losses avoided (i.e. benefits) estimated under the standard cost-benefit analysis underestimate the willingness of households to pay to avoid the costs because they do not include the WTP for the reduced risk. The latter can be valued by calculating the expected utility from a scenario in which the household maximizes expected utility.

Case study: Costs of climate change-induced flooding in Bilbao

Previous studies

A previous study commissioned by the Basque Government (2007) estimated the costs of the impacts of flooding of the Ría de Bilbao in the city of Bilbao. The main results for the baseline case and the reference case (by 2080) are summarised in Table 1 and Table 2, respectively.

Under the base case (Table 1), total damages for each event range from €5.53 to 6.84 million for 1-10 year return period, €241.34 to €294.43 million for 1-100 year return period, and €444.30 to €538.24 million for 1-500 year return period.

Table 1. Estimated total damage by flood event in the baseline (2005 prices).

Base case	APF = 1/10		APF = 1/100		APF = 1/500	
	Low	High	Low	High	Low	High
	€ mn/event	€ mn/event	€ mn/event	€ mn/event	€ mn/event	€ mn/event
Direct property damages						
Residential property	4.67	5.72	164.83	197.59	235.15	176.45
Non-residential property	-	-	24.67	25.95	101-03	106.26
Cultural heritage	-	-	0.20	2.01	1.02	10.13
Other effects						
Temporary accommodation	0.04	0.04	1.07	1.07	1.68	1.68
Additional power	0.26	0.26	7.56	7.56	8.68	8.68
Health – anxiety	0.02	0.02	0.61	0.61	0.67	0.67
Health -injury and fatalities	0.03	0.16	13.22	26.89	46.38	80.14
Emergency services	0.50	0.61	20.28	23.78	35.97	40.39
NRP – forgone profit	-	-	8.30	8.30	12.19	12.19
Rail disruption	-	-	0.21	0.21	0.86	0.86
Road disruption	NQ	NQ	NQ	NQ	NQ	NQ
Secondary effects	0.01	0.01	0.38	0.45	0.67	0.79
Total	**5.53**	**6.84**	**241.34**	**294.43**	**444.30**	**538.24**

Note: NQ = not quantified. APF = annual probability of flooding. NRP = non-residential property

Source: Basque Government (2007)

Using the information in Table 1 the authors constructed loss-probability curves for flooding of the Ría de Bilbao. These curves depict a continuous relationship between flood severity (characterised by AFP) and levels of damage, over the range AFP = 1.0 to APF = zero. Integrating the area under these curves yields a measure of the expected (average) annual damages from flooding of the Ría de Bilbao. Expected (average) annual damages, under the Base Case scenario, range from €225.11 (low estimate) to €275.60 million (high estimate); in 2005 prices.

Under the reference case (Table 2), total damages in 2080 range from €5.60 to 6.93 million for 1-10 year return period, €248.15 to €303.28 million for 1-100 year return period, and €455.29 to €553.63 million for 1-500 year return period.

Table 2. Estimated total damage by flood event in 2080 (2005 prices).

Reference case	APF = 1/10		APF = 1/100		APF = 1/500	
	Low	High	Low	High	Low	High
	€ mn/event	€ mn/event	€ mn/event	€ mn/event	€ mn/event	€ mn/event
Direct property damages						
Residential property	4.73	5.80	164.87	203.53	241.95	284.44
Non-residential property	-	-	24.67	25.95	101.03	106.26
Cultural heritage	-	-	0.24	2.35	1.20	11.86
Other effects						
Temporary accommodation	0.04	0.04	1.11	1.11	1.72	1.72
Additional power	0.26	0.26	7.75	7.75	8.89	8.89
Health – anxiety	0.02	0.02	0.62	0.62	0.69	0.69
Health -injury and fatalities	0.03	0.17	14.13	28.52	49.21	84.46
Emergency services	0.51	0.62	20.82	24.42	36.70	41.25
NRP – forgone profit	-	-	8.30	8.30	12.19	12.19
Rail disruption	-	-	0.25	0.25	1.00	1.00
Road disruption	NQ	NQ	NQ	NQ	NQ	NQ
Secondary effects	0.01	0.01	0.39	0.46	0.69	0.81
Total	**5.60**	**6.93**	**248.15**	**303.28**	**455.29**	**553.63**

Note: NQ = not quantified. APF = annual probability of flooding. NRP = non-residential property

Source: Basque Government (2007)

Using the information in Table 2 the authors went on to construct loss-probability curves for flooding of the Ría de Bilbao for the Reference Case scenario (inclusive of socio-economic change). Integrating the area under these curves, they estimate the expected (average) annual damages, under the Reference Case scenario, to range (in 2005 prices) from €229.25 to €281.27 million.

Finally, the loss-probability curves for the Ría de Bilbao under a climate change scenario were constructed. The authors estimated that the expected (average) annual damages during the 2080s, under the Climate Case scenario, would range from (2005 prices) €358.46 to €439.77 million. The additional flood risk that results from climate change thus ranges from €129.21 to €158.5 million. In other words, climate change increases flood costs by 56.4%.

More recently, Osés, Eraso et al. (2012) estimated the costs of flooding in the city of Bilbao following the implementation of an investment project – opening of the Canal of Deusto – to be carried out in order to protect several areas of Bilbao against flooding. The authors considered:

- An opening-width of the canal of 50 metres (the final opening is 70 m width).
- The height of the water layer goes from 1,07 m in the baseline to 0,70 m with the opening.
- In average, the height reduction is assumed to be 0.885 m, as $\frac{1{,}07+0{,}7}{2} = 0{,}885$ m.
- This height reduction is considered to be equal in every section, as it “quantifies” the additional draining achieved with the opening of the canal.
- The water velocity is assumed to be the same as in the baseline.

The results obtained (see Table 3) show that the reduction in damage is very significant compared to the base case. Floods with 10 years return period no longer cause damage so that estimated damages are reduced by €5.53 million – 100% - (from 5.52 million euros to 0 million euros) in the most conservative estimate. In the case of 100- year return period floods, estimated damages are reduced by €162.72 million - 67.42 % - (from 241.34 million euros to 78.62 million euros) in the most conservative estimate. In the case of 500-year return period floods, estimated damages are reduced by €136.40 million - 30.70% - (from 444.30 to 100.30 euros) in the most conservative estimate. In percentage, the damage reduction decreases as the return period increases.

Table 3. Estimated total damage by flood event after the opening of the canal

Channel 50 m						
	Low	**High**	**Low**	**High**	**Low**	**High**
	€ mn/event	**€ mn/event**	**€ mn/event**	**€ mn/event**	**€ mn/event**	**€ mn/event**
Direct property damages						
Residential property	-	-	61.36	73.49	192.05	228.34
Non-residential property	-	-	-	-	41.81	43.98
Cultural heritage	-	-	0.20	2.01	1.02	10.13
Other effects						
Temporary accommodation	-	-	0.40	0.40	1.35	1.35
Additional power	-	-	2.77	2.77	8.13	8.13
Health – anxiety	-	-	0.22	0.22	0.65	0.65
Health – injury and fatalities	-	-	6.76	13.18	28.24	50.32
Emergency services	-	-	6.57	7.86	25.02	28.91
NRP – forgone profit	-	-	-	-	8.30	8.30
Rail disruption	-	-	0.21	0.21	0.86	0.86
Road disruption	NQ	NQ	NQ	NQ	NQ	NQ
Secondary effects	-	-	0.12	0.15	0.47	0.56
Total	**-**	**-**	**78.62**	**100.30**	**307.91**	**381.53**

Note: NQ = not quantified. APF = annual probability of flooding. NRP = non-residential property

Source: Osés Eraso et al., 2012

Using the information in Table 3, the authors constructed loss-probability curves for flooding of the Ría de Bilbao with the opening of the Canal. Integrating the area under these curves, they estimated the expected (average) annual damages to range from (2005 prices) €11.03 to €14.16 million. The expected (average) annual damage decreases by 95%. The benefits, valued as expected losses avoided, are estimated to range from (2005 prices) €214.08 to €261.44 million.

New flood-risk scenarios under climate change

Within the European project ECONADAPT, we have defined new flood risk scenarios for the Bilbao area under RCP 4.5 and 8.5 in 2100. Additionally, to the impacts of climate change, these scenarios show the situation with and without the opening of the canal. Figure 1 shows the flood risk map for the 10 year return period floods. Very little difference is identified in terms of extension of the flood.

When we analyse the changes in flood-risk areas under the 100-year return period under RCP4.5 we observe that there is one main area in which the risk is reduced (Figure 2), which is Deusto. Another small area at risk exists in the Arenal. The new urban development in Zorrotzaurre would not get affected due to the planned increase in the urbanisation level. Nevertheless, we will consider that all the affected areas are beneficiaries when considering flood depth. Results for RCP8.5 are very similar.

Figure 1. The 10-year return period flood risk map. In dark blue the areas affected without the opening of the canal, while the light blue area represents the potentially flooded areas once the canal has been built.

Figure 2. The 100-year return period flood risk map. In dark blue the areas affected without the opening of the canal, while the light blue area represents the potentially flooded areas once the canal has been built.

Finally, Figure 3 shows the flood risk maps for the 500-year return period floods. The beneficiaries in terms of extension again concentrate in Deusto, but again the main improvement from the Deusto canal seems to be related to flood depth rather than extension. Results are very similar for RCP 8.5.

Figure 3. The 500-year return period flood risk map. In dark blue the areas affected without the opening of the canal, while the light blue area represents the potentially flooded areas once the canal has been built.

Table 5 shows the number of people in each neighbourhood affected by flooding before and after the opening of the canal for the 10-year return period flood under RCP 4.5. From this information we can draw three main conclusions: (1) All affected assets benefit from a decrease in flood height; (2) There are few beneficiaries when considering only flood extension; (3) Zorrotzaurre is a main beneficiary, but mostly due to the increase in the urbanisation level rather than the opening of the Canal itself.

Damages in Bilbao for floods with 100 years return period after the opening of the Canal under a climate change scenario are estimated to range from €241.69 to €289.96 million (2005 prices). The benefits of the adaptation measure, valued as expected losses avoided, are estimated to range from (2005 prices) €116.77 million (low estimate; from €358.46 million under a climate change scenario in the absence of adaptation measure to €241.69 million under a climate change scenario after the opening of the canal) to €149.81 million (high estimate; from 439.77 million under a climate change scenario in the absence of adaptation measure to €289.96 million under a climate change scenario after the opening of the canal). Damages are estimated to decrease by over 65%.

The benefits of the adaptation measure in 2005 prices have been converted into equivalent 2015 prices by using inflation factors. This gives a benefit, in 2015 prices, ranging from €142.52 million to €182.84 million. This figures are then used in our CBA.

Cost-benefit calculations

Table 6 shows the cost-benefit analysis done for the Canal of Deusto considering different elements in the analysis, as explained in section 2: (i) standard CBA; (ii) accounting for benefits on employment creation; (iii) including distributional weights for benefits; and (iv) taking account of risk aversion.

Table 5. Beneficiaries of opening of the canal by neighbourhood considering flood extension

Neighbourhood	Number of affected people		Beneficiaries T10 – RCP 4.5
	T10 - RCP 4.5	T10 - RCP 4.5 with CANAL	
ABANDO	0	0	0
BOLUETA	0	0	0
CASCO VIEJO	0	0	0
CASTAÑOS	0	0	0
IBARREKOLANDA	0	0	0
INDAUTXU	1	1	0
LA PEÑA	0	0	0
LA RIBERA	230	3	227
OLABEAGA	109	109	0
SAN FRANCISCO	34	34	0
SAN IGNACIO	68	68	0
SAN PEDRO DE DEUSTU	0	0	0
ZORROTZA	7	7	0
Grand Total	**449**	**222**	**227**

Table 6. Calculation of NPV and IRR considering different elements (in 2015 prices)

	Net Present Value	Internal Rate of Return
Standard CBA (simplest case)	-1.98	4.2%
Distributional Benefits from Employment	0.33	5.2%
Distributional Weights	0.03	5.0%
Risk Aversion	0.88	5.4%

The standard CBA is the "simplest" case. It uses market data on costs. In the simplest case, estimated benefits do not include benefits on employment, weights for benefits or risk aversion. The benefits on employment case adds effects on employment to the standard case. The weights for benefits case takes into account both benefits on employment and distributive concerns, but still considers risk neutrality when estimating the benefits of the adaptation measure. Risk aversion is taken into account in the last case, which adds this issue to previous calculations.

Standard analysis

The benefits of flood control were estimated at €142 million in 2080, which are worth €28 million in 2020 (obtained by multiplying the future 2080 benefits by a factor of 19.5%, which accounts for the 2020-2080 growth).

In the standard analysis of costs and benefits of flood control, the benefits are valued as expected losses avoided. Thus in the Bilbao flood control, the losses from a 1:100 year-flood are estimated at 0.28 million euros in 2020, rising to 1.42 million euros in 2080 - these estimates are the losses from a 1:100 year-flood in that year, times the probability of such a flood (i.e. 0.01). In the first four years of the project (2016-2019), there would be investment costs of €3.025 million per year[6]. There would not be protection against flooding and thus no benefits before the structure was finished. In year 5 (i.e. 2020), it is assumed that there would be no extra costs but expected benefits of €0.28 million. The increase from €0.28 million in 2020 to €1.42 million in year 2080 is due to assumed increases by 5% annually from 2020-2030, 3% from 2031-2050, and 2% from 2051 to 2080. Discounting expected benefits over time and subtracting investment costs of the opening of the Canal, estimated to be 12.1 million euros, would thus lead to a NPV of €-1.98 million over the whole lifetime of the project. The IRR is calculated at 4.2%, below the average return of public capital used in this analysis. This analysis is based on a discount rate of 5 percent, which is a typical value used for evaluating development projects (see Mechler, 2004), and an expected life of the structure of 61 years.

A negative NPV indicates that the costs of the project exceed the projected benefits, so that the project results in a net loss and should not be made. An IRR below the discount rate used means that the project should to be developed. Therefore, under this scenario – standard CBA - the investment project is not efficient and should not be carried out. This analysis is however incomplete, as it does not consider some other relevant elements that may change the results of the analysis.

Distributional benefits from employment

The opening of the Canal may affect employment by directly creating jobs, facilitating job creation, or augmenting labour supply. We can go one step further in our CBA and make it more sophisticated by considering effects on employment.

We have included such employment by splitting the investment costs between capital costs (60% of total costs) and labour costs (40% of total costs), and adjusting the latter for unemployment using a 0.46 conversion factor as proposed in Bo et al. (2009)[7] which reduces labour costs (i.e. labour costs adjusted for unemployment < labour costs). Under this conditions our CBA leads to a NPV of 0.33 million euros, while the IRR is calculated at 5.2%. Thus, in this scenario, the investment project turned efficient (i.e. given the available data and assumptions used, the project would be efficient in terms of avoidance of damages due to flooding and inundation in Bilbao) due to the net efficiency gains linked to employment changes.

Once the benefits on employment are included in the analysis, **the opening of the Canal turns efficient**. The critical point here is that failing to account for employment creation leads to an underestimation of the net benefits of the project.

Distributional benefits from employment and distributional weights

Empirical evidence shows that there is increasing utility to benefits with decreasing income. In very broad terms, this evidence suggests that an extra Euro to someone earning 1000 Euro is worth

[6] Investment costs of the opening of the Canal are estimated to be 12.1 million euros (2015 prices). Source: Zorrotzaurre.com

[7] Bo CD, Florio M & Fiorio CV. (2009) suggested conversion factors between 38 and 46%

twice as much as to someone receiving 2000 Euros a year (UK Treasury 2003). We can go one step further in our CBA including distributional income concerns.

Assume we have a population with an average income of €20,000 per annum. Considering the weights to be attached to individuals at different income levels showed in the table below, a cost of €1 to a person with income of €5000 is given a value of €4 if ε is set at 1 and €16 if ε is set at 2. And so on for other income levels.

Table. 7. Relationship between income level, weight and cost

	Weight	
Income	ε = 1	ε = 2
5,000	4	16
10,000	2	4
20,000	1	1
50,000	0.4	0.16
100,000	0.2	0.04

In our case study, considerations on the distribution of project benefits have been taken into account via "distributional weights", reflecting individuals' incomes (with lower-income individuals tending to get larger weights). We have estimated and used weights for project impacts takin into account income distribution among neighbourhoods. Weights have been calculated using the equation:

$$\mathcal{E}_i = \left(\frac{Y_i}{\overline{Y}}\right)^{-1}$$

Where, $\mathcal{E}_i$ is weight in neighbourhood "i", Y_i is income in neighbourhood "i" and $\overline{Y}$ is mean city income. The values of $\mathcal{E}_i$ are the weights attached to the benefits to group "i" relative to average benefits.

When we use weights for the different neighbourhoods based on their average income, the benefits from the project in 2080 are estimated at €1.37 million. The reduction in expected benefits reflects the fact that incomes of affected areas are higher than the average income of Bilbao. This is in line with empirical evidence, which shows that there is decreasing utility to benefits with increasing income.

If weighted benefits are €1.37 million and unweighted benefits are €1.42 million, we need to adjust benefits in years before 2080 by a factor of 0.964 (i.e. $\frac{1.37}{1.42}$) in order to include distributional concerns. Adjusting benefits by this factor reduces expected benefits (i.e. benefits adjusted for income < not adjusted benefits) compared to the benefits on employment case. Replacing these damages in the calculation thus leads to a slightly lower NPV equal to €0.03 million. The IRR is calculated at 5.0%.

Thus, in this scenario, the **investment project is still efficient but** becomes **less attractive**. The lesson here is that the value of a project depends not only on the benefits generated by the project and its effects on employment, but also on their distribution. This is in line with Adger et al. (2005), who argued that the success of adaptation measures depends not only on its effectiveness in meeting defined goals, but also on issues of equity.

Distributional benefits from employment, distributional weights and risk aversion

It is generally assumed that individuals are risk averse and concerned about their expected utility. Individuals are willing to pay for insurance which limits their loss in case an unfavourable event takes place, e.g. their home are flooded. In other words, individuals usually do not only consider the expected return, but also the distribution of the return. Being exposed to a risk constitutes a cost to risk individuals which are risk averse, and they are willing to pay (WTP) in order to reduce or eliminate the risk.

Nonetheless, standard cost-benefit analysis does not account for risk aversion. Assuming that individuals are risk averse, the expected losses avoided (i.e. benefits) estimated under the standard cost-benefit analysis of flood control underestimate the willingness of households to pay to avoid the event because they do not include the WTP for the reduced risk. We can value the latter by calculating the expected utility from a scenario in which the household maximizes expected utility. In 2020 the loss for a family in the event of a flood is around 0.28*1000000/21,422[8] = 13.07 euros. The average income for households affected is 19,647 euros a year in Bilbao. Hence the expected utility is given as:

$$EU = 0.99 \times U(19{,}647) = 0.01 \times (19{,}647 - 1{,}310)$$

The certainty equivalent for this combination is given by Y* where

$$U(Y^{*}) = EU$$

And the true loss, including loss due to risk, is given by:

$$Y^{*} - (19{,}647 \times 0.99 - 0.01 \times (19{,}647 - 1{,}310))$$

If we take a simple but commonly used utility function $\text{U}(\,y) = logY$, we get the following:

$EU = U(19{,}647) \times 0.99 + U(18{,}337) = 9.89 \times 0.99 + 9.82 \times 0.01 = 9.88$

And

$Y^{*} = e^{9.88} = 19{,}633.45$

The cost of the event is valued at 13.55 euros in 2020. This is greater than the expected damages, which are equal to 13.07 euros. In 2080 the difference is greater because damages are also greater, giving a damage of 78.35 euros, compared to an expected damage per household of 64.72 euros. Thus in order to account for risk aversion, **we need to adjust expected benefits** showing that the willingness of households to pay to avoid the event including the WTP of risk averse individual to reduce or avoid the risk is higher than the expected damage when risk aversion is not considered. For example, in 2020 we need to adjust the expected benefits by a factor of 1.04 (i.e. $\frac{13.55}{13.07}$) that will increase expected benefits compared to the case when risk aversion was not taken into account. The adjustment factor to risk in 2080 is 1.21. If we replace these damages in

[8] 21,422 is the total number of people affected by flooding before the opening of the canal for the 100-year return period flood under RCP 4.5

the calculation we get the figures in the fourth set of calculations, i.e., NPV equal €0.88 and IRR equal 5.4%.

Conclusions

CBA frequently does not account for the employment benefits of investment projects. Often it focuses only on efficiency, by comparing aggregate benefit figures with costs, and considers risk neutrality. Still, from the public policy discussions it is clear that distributional benefits from employment creation, distributional weights and risk aversion are often very important. In the case of distributional weights, a person who is richer (poorer) than another should be given lower (higher) weight relative to the poorer (richer). This can be done using distributional weights. The WTP for the reduced risk can be valued by calculating the expected utility from a scenario in which the household maximizes expected utility.

As it can be seen from our case study, the outcome of the CBA can be very different with and without weights for projects that particularly benefit either rich or poor people, with and without benefits from employment creation, and with and without considering risk aversion of individuals affected by projects. The results show that the NPV and the IRR vary over a range of values. All cases yield a positive NPV, except the simplest or traditional case, meaning that if the adaptation measure assessed would be put in place this year, the expected benefit over a period of 61 years would exceed its cost in all cases but the first one. This example illustrates the critical role that the elements considered plays in any adaptation measure cost-benefit analysis. The highest NPV is exhibited when we take risk aversion into account (NPV of 0.88).

The case underlines the importance of including all elements in the analysis for providing policy relevant information on the efficiency of adaptation options. In practice, simplicity of analysis is presumably one of the most important arguments in favour of the traditional cost-benefit analysis and against using weights or taking account of risk aversion. Providing guidance and values would help to policy evaluators to account for these elements in the estimates of the NPV of investment projects.

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4 Use of non-monetary metrics in adaptation assessments

This chapter takes stock of the recent scholarship, provides lists of indicators, criteria and metrics for assessing adaptation options in multiple policy areas, and outlines some key lessons learned and limitations on the use of non-monetary metrics in adaptation decision-making. It focuses in particular on non-monetary metrics developed through Cost-Effectiveness Analysis (CEA) and Multi-Criteria Analysis (MCA). These two methods are the most common methodological approaches for taking into account dimensions that are complex or controversial to monetise in economic assessments, and provide established approaches to develop non-monetary metrics.

The information presented in this chapter is based on reviewed publications from the Econadapt database and further literature obtained through searches in Google Scholar and Web of Science. In total 65 CEA studies and 40 MCA studies have been identified on adaptation. Most of the publications (78 %) represent grey literature including EU-funded project reports, reports of international and national (governmental) organisations such as OECD, UN agencies, and reports commissioned by national governments and the European Institutions. Academic literature includes (peer reviewed) scientific articles, dissertations, proceedings and books.

The chapter is divided into three main sections. First, a short introduction to the use of non-monetary metrics in adaptation assessment is presented. Second, the outcomes of the review on CEA is presented, with a focus on when to use CEA non-monetary indicators, a synthesis of metrics existing in the literature, and some lessons learned on their usefulness, their limitations and how to overcome them. The third section does a similar analysis for MCA non-monetary indicators. The chapter concludes with some key messages for further application.

Adaptation decision-making and non-monetary metrics

Adaptation to climate change is becoming a policy area in its own right. In Europe, the EU White Paper on adapting to climate change (released in 2010) followed by the EU Strategy on adaptation to climate change (released in 2013) have formalized adaptation action, and now provide a framework for Member State action. The EU Strategy promotes the development of National and Regional Climate Change Adaptation Strategies as well as further consideration and mainstreaming of climate change impacts and vulnerabilities into sectoral decision-making. A series of guidance documents were developed for decision-makers on how to develop adaptation strategies (e.g. EC, 2013a) and increase mainstreaming at policy (e.g. EC, 2013b) and project level (e.g. EC, 2011).

The evaluation of adaptation options can be performed via several types of assessments. In European law, it is commonly required to perform Strategic Environment Assessments (SEA) and Environmental Impact Assessments (EIA). SEAs aim to assess the potential environmental impacts of plans and programmes, while EIAs are used at the project level. SEAs and EIAs are based on a number of environmental dimensions against which policies and projects must be assessed. Complementing those, decision-makers can use a range of economic assessment tools which may better quantify in socio-economic terms the advantages and disadvantages of adaptation options (Watkiss, 2014).

The use of standardized or common metrics in economic assessments has been highlighted as a major area of development and research. There are several benefits in using such metrics. They can help evaluate, quantify and communicate the benefits of adaptation or climate-proofed policies and projects (see Rosenzweig and Tubiello, 2007 for agriculture). They can enable cross-sectoral comparison, and prioritise and allocate resources across a large range of options and activities.

The most commonly used type of economic assessment, Cost-Benefit Analysis (CBA), is based on the monetary valuation of all relevant (financial and economic) costs and benefits to government and society of all available options under scrutiny, so that the wider benefits and costs can be calculated and those measures that are found to deliver net benefits to society as a whole can be selected. CBA calculates an absolute measure, based on monetary metrics, resulting in the possibility to compare the worth of particular courses of action across policies and projects. CBAs are widely used in public policy and project appraisals, in particular in the UK where it is a requirement, following guidance by the UK Treasury Green Book, for certain types of projects such as flood protection (although it is not yet commonly used in adaptation). Nevertheless, CBA works best if parameters are clearly determined and using CBA in the context of climate change adaptation where uncertainties are high may require too many assumptions. CBA poorly addresses the complex issues of adaptation such as long time frame (adequate discount rates, inter-generational equity), high distributional nature of impacts, irreversible effects, or the existence of thresholds. Furthermore, monetary information can be difficult to obtain for several criteria relevant for decision-making, in particular for environmental (e.g. biodiversity loss) and social (e.g. health damage) impacts. A recent review highlights that there is yet little quantified information on costs and benefits of adaptation (OECD, 2015).

In this context, other types of methods can be used to better consider non-monetary metrics. These are Cost-Effectiveness Analysis (CEA) and Multi-Criteria Analysis (MCA), which belong to the category of decision making tools seeking to achieve some degree of rationalisation to inform policy decisions. CEA compares the financial costs of alternative options for achieving similar objectives in order to identify options that deliver a predefined target for lowest cost. As opposed to CBA, it quantifies benefits in physical terms rather than in monetary terms. MCA systematically assesses and scores options against a range of decision criteria, resulting in an overall ranking of options. As opposed to CBA and CEA, decision criteria can be expressed in quantitative or qualitative terms, and can be physical or monetary units. Each criterion is weighted to provide an overall ranking of options. CEA and MCA are widely applied in decision-making but their use has yet to be mainstreamed in the economic analysis of adaptation options. Investigating studies using these methods can provide a wealth of information on the use of non-monetary metrics relevant for adaptation policy.

The following two chapters present in more detail the reasons why and how non-monetary metrics are used in 1) CEA; and 2) MCA. The focus is on understanding when it is necessary to use non-monetary metrics in adaptation assessments, and what non-monetary metrics are most appropriate and useful for adaptation assessments.

Non-monetary metrics in Cost-Effectiveness Analysis

Non-monetary metrics in non-adaptation CEA

CEA is an optimisation method for finding the lowest-costs means to reach an objective (Tietenberg, 1992). CEA provides an assessment based on the identification of the least-financially-costly option for achieving a pre-defined policy target across a set of alternatives (unlike CBA which provides an assessment of the economic worthiness of an investment). CEA can be used to compare and rank alternative options by assessing options in terms of the financial cost per unit of benefit delivered. For example, it is widely used in the health sector in order to rank alternative treatment options. It has become the main appraisal technique used for climate change mitigation, as it allows a comparison and ranking of alternative options within and across sectors, using the metric of cost per tonne of GHG abated (€/tCO2). In water policy, the EU WFD mandates an ex-ante CEA to select from available measures the ones that deliver the established objectives in water quality management at minimum financial costs (Lago, 2009).

Under the EC WFD, that mandates the use of CEA for the selection of measures, the objective of the analysis is to achieve the desired environmental standards that define the objectives of the Directive at minimum costs. The prescription of the use of economic decision making tools, such as Cost Effectiveness Analysis (CEA) for the selection of measures in River Basin Management Planning is aimed at avoiding unnecessary financial costs of compliance. By predefining the standards to be achieved based on parameters to protect the biology of the water environment, the directive avoids the issue of economic efficiency and the estimation of costs and benefits of action for the selection of measures. These are only applicable when there is a case for exemptions and some sort of optimal judgement maybe required (Lago, 2009).

CEA consists of the following steps. First, alternative measures (or a combination of measures) to achieve a determined target must be identified. Second, their financial costs are calculated in monetary terms. Third, the output of each measure implemented towards the determined target is quantified. Finally, the cost-effectiveness ratio for each measure is calculated as the cost per unit output. Measures are ranked along this ratio. CEA thus focuses analysis on a single metric of performance, thus omitting a full analysis of any wider economic costs and benefits.

This may reduce the potential for cross-sectoral applications as different metrics need to be used for different targets.

The calculation of cost-effectiveness metrics involves careful attention to a number of dimensions (Balana et al., 2012):

- CEA only considers financial costs of abatement. Arguably wider economic costs are not considered in the analysis. In this respect, the "cost" components of a measure or activity in a project or a policy are limited to those only incurred by the investor (e.g. capital and maintenance costs) or the regulating authorities (e.g. cost of enforcement and monitoring), but the analysis omits a wide range of wider costs: including those incurred by society and targeted population. These may include further cost of compliance, social and environmental costs, etc. Ultimately, the choice in applying a CEA depends on the context in which it is to be used and the availability of reliable data.

- The “effectiveness” component can be measured in different ways too. It can refer to the effectiveness of measures in directly mitigating targeted pressures, or it can refer to the effectiveness in implementing measures. It can alternatively be assessed against the reduction of impacts of improvement in status. Furthermore, one measure may not be sufficient to reach a particular target.

Cost-effectiveness ratios are affected in different ways by climate change impacts. Climate change can modify the type of pressures (changing target/objective) or their scale (effectiveness dimension). The impact of extreme events may also change the effectiveness of particular measures or their costs, and future socio-economic changes can modify the costs of measures.

The use of specific metrics in adaptation is investigated below.

Non-monetary metrics in adaptation CEA

This section is divided into three parts. First, the scope of the identified adaptation CEA studies is examined. Second, the range of metrics used is presented. Third, the reasons for using non-monetary metrics through CEA, and limitations, are presented.

Scope of identified adaptation CEA studies

An examination of the policy areas covered by CEA studies included in the Econadapt literature database suggests a wide distribution (Figure 1). The most common policy areas are water management (11%), agriculture (15%), and coastal protection (12%) – although CEA studies can be found also on as many diverse areas as biodiversity, civil protection and disaster risk reduction and finance fields. Often, studies would cover multiple policy areas. The literature appears to have focused so far on empirical investigations (case-studies) and stand-alone methodological development. Systematic reviews are rare and focus on methodological developments in the application of CEA, instead of reviews of indicators used and their metrics. Remaining studies tend to be general (comparing CEA with other methods) or focus on guidance for the application of CEA. There is nearly an equal spread between high, middle and low income countries.

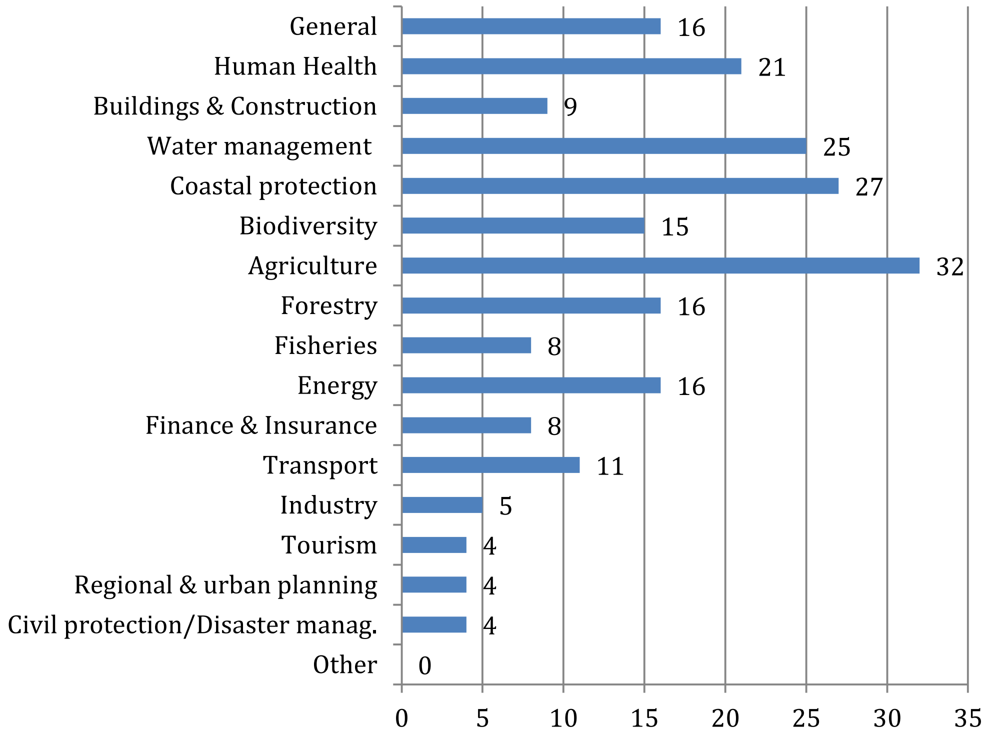

Figure 1: Policy areas regarded in the 65 publications. Multiple answers were possible.

Characteristics of non-monetary metrics

Given the limited application of CEA in adaptation, the following information builds first on key overviews (e.g. Watkiss et al., 2009; Werners et al., 2013) which usually drew on non-adaptation sector-specific applications of CEA to identify sector-specific indicators in adaptation. This is complemented with relevant publications identified through the ECONADAPT literature database and internet searches.

Flooding (including inland and coastal from sea-level rise)

Given the large number of studies considering flooding in the context of adaptation, indicators that assess the effectiveness of measures to combat flooding are manifold. In a review for the UK government to inform the process for the UK Climate Change Risk Assessment, Watkiss et al. (2009) identified a number of potential indicators for the area of flooding that are common to the hazard literature: number of people in the hazard zone, people at risk, number of people exposed to 100% probability of annual flooding (people to be moved), people at risk of land erosion, land area at risk or at loss (from flooding and erosion), wetland area at loss, capital value at risk (considering levels of risk) or at loss (100% probability), and adaptation costs. Other indicators mentioned focus on impacts of flooding: loss of life and damage to property, number of fatalities, human injury or illness, and social disruption. The authors note that land area at risk is largely favoured as a simple metric. Watkiss et al. (2011) further propose economic and human indicators for assessing measures for a large range of policy areas in Tanzania. With regards to flooding, proposed measures include a variety of grey, green and soft measures (e.g. land use planning, building standards for flood-wise construction and coastal defences) with indicators such as:

avoided damage costs expressed as cumulative area of land lost, land loss due to erosion and land loss due to submergence and with regards to the affected population, people actually flooded and forced migration.

The FP7 Mediation project (Werners et al., 2013) builds on the above work and differentiates between the following categories: exposure indicators, impact indicators, the cost per reduction in land area at risk or number of people at risk, economic indicators, expected annual damages, costs per ha comparing costs for the measure with the value of land protected, or it is suggested to use a pre-defined acceptable risks of flooding as threshold level.

The GIZ (2013a) suggests two indicators for project appraisals: saved wealth and saved health. They are defined as "the monetary value of public infrastructure, private property and income loss" or respectively as "the avoided number of years lost due to disease, disability and early death". The authors aim to express the total value of adaptation projects with these indicators and apply the suggested framework in a case study in Viet Nam in which a dyke replacement and the plantation of a mangrove protection belt in front of a dyke were evaluated. Broekx et al. (2012) also focus on avoidance of flooding in an economic approach. They suggested for the assessment of effectiveness of measures in the frame of the WFD avoided flood risk per year expressed in €/year for the measures dykes and flood plain restoration. The assessment aims to inform policy makers in the subsequent planning cycles of implementation of the policy.

To assess the possibilities for implementing natural flood retention measures, Frontier Economics et al. (2013) measure effectiveness in reducing run-off (i.e. increasing soil filtration, creation of cross-slope tree shelter-belts, changing agricultural field drainage), flood attenuation (i.e. floodplain reconnection, planting trees in flood plains, riparian planting), flood attenuation and reduction of discharges (i.e. storing water in rural areas). Indicators used included (in %): 1) reduction in run-off, 2) reduction in water height, 3) reduction in peak flow, 3) reduction in water velocity, 4) reduction in coarse sediment supply.

Health

Health is the only policy field in which one common set of indicators is applied: (costs per) Disability Adjusted Live Years (DALYs) and Value of a Statistical Life Year (VOLY) (Shadick et al., 2001; Ciscar et al., 2009). DALYs and VOLYs are widely used in non-adaptation decision-making, with thresholds used to indicate what losses are acceptable or not. Several other indicators are stated in the adaptation literature. Markandya and Chiabai (2009) and Frontier Economics et al. (2013) mention the cost per or number of deaths avoided and the cost per cases of sickness avoided. The effects of the adaptation action can also be assessed with regards to the avoidance of the occurrence of specific diseases, as e.g. respiratory or cardiovascular diseases, and the effects thereof on the health system (effect on admissions by use of air conditioning, see Ostro et al. 2010 and Hunt, 2008). Also the avoidance of death and number of years of life lost (Hunt, 2008) are potential metrics. A different approach is taken by the Mediation project (Werners et al., 2013) and Frontier Economics et al. (2013). They define health thresholds such as maximum occupational temperatures or comfort levels.

Agriculture

The field of adaptation in agriculture produces a broad range of indicators (although many of the studies focus on developing countries). A number of indicators focus on the stressors on agricultural production, such as heat/water stress, drought duration index (cumulative water stress over time), or irrigation requirements over availability. Other measures based on measuring the impact on agricultural production and broader socio-economic impacts: maturity rates, relative harvest index (RHI, that expresses the farmers' harvest relative to their historical baseline range (difference for farmer in between the actual harvest in the current year and that of a typical bad season in relation to the range between typical good and bad seasons), crop yield losses, crop suitability (no single unit), economic value at risk (net production value, agricultural GDP), land value at risk, and food demand over supply (nutrition index/number of people at risk of hunger) (Patt et al., 2005). Watkiss et al. (2009) mention that the mitigation potential of adaptation measures is important to consider as adaptation and mitigation should not react in a counterproductive way. In a wider sense of adaptation in agriculture, Broekx et al. (2012) measure effectiveness in the reduction in phosphorous load amongst other for the agriculture focussed measures buffer strips, cover crops, and reduced tillage.

All those indicators are partially very specific, as they only represent a share of the agricultural system and its linkages to other systems as for example water. The Mediation project (Werners et al., 2013) proposes a more all-encompassing indicator: the cost per change in value added from agriculture as a result of adaptation measures. This can be evaluated for selected groups of relevant social actors (e.g. producers, consumers). However, such all-encompassing indicators face the difficulty to take into account allocative and trade effects with significant scale effects (e.g. international trade).

Water management

The water management policy area relates here to the management of water quantity (scarcity and droughts) and water quality. In adaptation studies, most assessment relate to the management of water quantity. Indicators relate to the cost of providing water (per cubic meter) necessary to fill the provision gap (see e.g. Watkiss et al., 2009). Discrepancy of supply and demand is also represented in indicators presented by the Mediation project (Werners et al., 2013): thresholds for risk of supply disruption and acceptable environmental flows. Darch et al. (2011) take the angle of the water supplier and present deployable output as an indicator to assess effectiveness of measures with regards to aridity. The authors evaluate grey and soft measures with regards to manage water supply such as raw water transfer, desalination, and metering.

Despite the wide ranging expected impacts, the management of water quality under climate change has not been examined in many studies. Martin-Ortega et al. (2012) analysed the effectiveness of agricultural measures (green and soft measures e.g. establish cover crops, reduce stocking rates) and waste water treatment plants (P removal) as adaptation and mitigation measures that comply with the requirements of the WFD and Habitats Directive. They proposed indicators such as costs of phosphorous load reduction per hectare or per catchment. It is likely that a larger number of studies will be presented in the coming years as authorities will try to evaluate the costs of meeting, under climate change, WFD objectives (against not only chemical parameters but also ecological and hydromorphological ones) and other regulatory standards.

Buildings and Infrastructure

Despite the high number of studies referencing adaptation in building and infrastructure, not many indicators for assessing effectiveness of adaptation in that field could be identified. This is also due to the overlap of this field with adaptation actions in flooding, especially when regarding the flood damage to buildings or subsidence damage to building (Hunt 2008). Risk to buildings and infrastructure is usually defined in terms of acceptable risk (i.e. safety standard) and therefore can be highly specified to the local or national context. Hanson et al. (2011) measure in monetary terms as assets exposed. The mentioned adaptation options include green, grey and soft measures (early warning systems and evacuation, upgraded protection, building regulations. The respective impact indicator is stated in Hof et al. (2009): reduction of potential damages and associated costs. Watkiss et al. (2009) proposes an indicator for the expenditures for adaptation in the sector: increase in investment flows to climate proof infrastructure. The measures presented safety and regulatory standards.

Biodiversity

Biodiversity is usually not directly addressed in adaptation CEA. Three studies were identified that address indicators for adaptation with regards to biodiversity. Nauman et al. (2011) conducted a review on green infrastructure projects to summarise their extent, costs and benefits across Europe. They evaluated 127 studies. Although the study is not looking at adaptation per se, the reviewed studies mention adaptation to climate change as one of the main objectives to implement green infrastructure. They summarise the indicators in three categories:

1. Changes in the provision of green infrastructure (Area of habitat created/ maintained/ restored, length of corridors provided, area of floodplain restored, area of urban green space provided/ maintained, number of trees planted, number of green roofs provided);

2. Changes in the provision of ecosystem services (e.g. volume of carbon stored, level of reduction of flood risk, number of recreational users of green space or recreation days);

3. The economic and social impacts of green infrastructure projects (i.e. their impacts on employment, GDP and local communities).

The Mediation project (Werners et al., 2013) identified in their review critical targets (sustainable levels) and standards (overall objective) for assessing adaptation effectiveness in the field of biodiversity. As monetary option they mention possible cost per unit of ecosystem services. Another study that identifies an indicator for biodiversity mentions changes in species space (Hunt, 2008).

Outcomes: usefulness and limitations

A number of non-monetary metrics were described in the previous section, and are summarised here with indication of their usefulness in different contexts.

Table 1: Non-monetary metrics used for CEA in adaptation projects and policies

Policy area	Metrics used in CEA
Flooding (including inland and coastal from sea-level rise)	Level of reduction of flood risk or damages [%] Number of people living in the risk zone, multiplied by the probability of flooding per year [ ] Number of people at risk or affected by floods [ ] Reduction of maximum flood depth [cm] Extension of warning period [% or hours] Increase people's awareness [ ] Land loss [km^2] Additional expected economic damage or total residual damage costs [€/year]
Health	Disability Adjusted Life Years averted [DALY] Morbidity reduction range [%] Frequency of home visits by NGO outreach staff [%] Number of prevented deaths through heat waves [N/A] Reduction in diarrheal disease incidence [total numbers (cases averted)/year] Loss of life per decade [total numbers (cases averted)/year]
Agriculture	Percentage change in storage additions and withdrawals [%] Increased nutrient and water efficiency [ha and m^3/ha] Decreased soil erosion [m^3/year] Increase carbon sequestration in soil [t humus/ha/yr] Livestock Adaptation (e.g. Extension Services, Destocking, Choice of Breed, Game Switching, De-bushing) [t meat production/year] Crop Adaptation (training for irrigation farmers, increase of land under irrigation and mechanisation of rainfed subsistence land) [t/year]
Water management	Area of floodplain restored [ha] Avoided flood risk [] Assets exposed [%] Load reduction BOD, COD, N, P [kg load/ year]
Buildings and infrastructure	Effect on house price and the total value of property transactions [%] Green roof area per total roof area [%] Subsidence damage to buildings [N/A]
Biodiversity	Area of floodplain restored [ha] Area of habitat created/ maintained/ restored [ha] Area of urban green space provided/ maintained [ha] Area sustainably managed [ha] Ecosystems safeguarded [ha] Increase in protected areas [%] Number of species conserved [%] Effect on species population [%]
Energy	Change in energy demand and associated CO_2 emissions [%] Energy output through hydropower: No and 50% reduction in effective glacier runoff [GWh] Change in energy demand [GWh] Energy demand for cooling [GWh] Effect on energy saving [GWh/year]

In adaptation, CEA is usually recommended over a CBA when economic benefits are difficult to estimate or difficult to compare across scales and sites (Watkiss et al., 2009; Naumann et al., 2011; Frontier Economics et al., 2013). CEA is also useful when targets are set (e.g. regulatory standards) and authorities are mostly interested to identify the least cost path to achieve that single target (Brand-Sassen, 2004; Watkiss et al., 2009; Markandya and Chiabai, 2009; Werners et al., 2013). Cost-effectiveness criteria and metrics are more likely to be useful in health, water management, extreme weather and biodiversity policy areas, based on standards of acceptable risks or clearly defined targets (UNFCCC, 2009). As such CEA helps avoid the challenge of estimating controversial values such as the value of reduced health and morbidity. In addition, indicators are simple and transparent (Markandya and Chiabai, 2009). Outcomes are thus easier to communicate than e.g. CBA results.

Several limitations are associated with developing non-monetary metrics through CEA:

- CEA leads to a single non-monetary metric of effectiveness in relation to one and only one target which omits important risks and does not capture all costs and benefits (attributes) for option appraisal. This highlights the biggest limitation of the CEA method, which is the necessary condition that units of costs and effect should be of a comparable magnitude within the measures (Lago, 2009). This makes extremely difficult to compare baskets of measures as opposed to the costs and effect of single measures in isolation. In adaptation, it may be difficult to choose a single metric especially where several dimensions are important. Social impacts are probably the most sensible metric in sectors which are of greatest concern on people: agriculture, coastal resources, health. This is particularly true in the assessment of climate change impacts, but can be extended to adaptation.

- Adaptation is a response to a local or sectoral impact: any costs and benefits will thus be highly site or sector specific, as well as dependent on the type of impact considered. It will be difficult to use CEA to compare cost-effectiveness results across different scales (e.g. across sites, sectors, or impact-types, timeframes).

- CEA works best with options for which costs and effectiveness can be more easily evaluated. It is likely that it will be challenging to find relevant metrics for sectors where it has historically been difficult to use some. Also, it will likely work best with technical options, and less to capacity building and soft (green, policy, non-technical) measures.

- The time horizons for achieving targets (effectiveness) while incurring costs are different. The effectiveness of measures, especially for ecosystem-based ones, may only be visible after medium to long time periods whereas the costs occur directly with implementation. In addition, CEA is likely to be a dynamic metric as both cost and effectiveness will depend on contextual factors (climate change impacts, socio-economic situation). GIZ (2013a) suggest using different timespans with intermediate and final outcome (effectiveness) indicators.

In addition, CEA is essentially an optimization tool and is not, at its core, tailored to take into account uncertainties. Usually, no systematic assessment of uncertainty is carried out. Only a handful of the reviewed studies have included the degree of uncertainty that surrounds the effectiveness of measures. Uncertainties are often addressed by presenting lower, average and upper bound ranges of effectiveness, though very often there is no information about how these ranges were assessed. In situations of high uncertainty and imperfect knowledge, a specific cost-effectiveness ratio in time A may thus not be valid in time B, when contextual conditions have changed or when better knowledge reveals new relevant factors. Uncertainty may arise from the environmental system (effectiveness dimension), the economic system (cost dimension), and the political system (selected targets and objectives, acceptable measures) (Brower and Blois, 2008). Furthermore, predicting effectiveness and costs across a range of timescales will yield additional uncertainty. A range of methods are used to cope with uncertainty in the calculation of cost-effectiveness ratios: use of intervals of costs and effectiveness estimates (instead of point estimates), sensitivity and scenario analysis, and more complex ones such as stochastic programming and Bayesian belief networks (Balana et al., 2012).

Non-monetary metrics in Multi-Criteria Analysis

Non-monetary metrics in non-adaptation MCA

MCA establishes preferences between options by reference to an explicit set of objectives and for which is has established criteria to assess the extent to which the objectives are achieved. In contrast to CBA or CEA where measures are assessed against one single criterion, MCA can combine multiple quantitative and qualitative data using monetary and non-monetary units. Costs (and benefits) thus become only one potential criterion amongst many others. Using MCA, one can consider a wide set of criteria, even where quantification is challenging or limited.

MCA provides a structured approach to producing non-monetary information. First, alternative measures relevant to the overall target are selected. Second, a range of criteria or attributes relevant to the stakeholders are selected. Third, scores that measure the performance of an option against the criteria are assigned. Fourth, weights that measure the importance of different criteria to participating experts or stakeholders are assigned. Fourth, aggregated results are then calculated. As such, MCA does not result in multiple metrics for each indicator, but results scores (e.g. number of points) for each measure against each criteria and an overall score for each measure.

There exists different type of MCA approaches (e.g. MAUT; Outranking including PROMETHEE and ELECTRE; and AHP), which means that the metrics and the methods used to derive them also vary widely. They vary in the way values are assigned and combined, resulting in scores that have different meanings. Some are more capable of taking into account uncertainties or vagueness (of participants) while others are better able to deal with large number of dimensions and alternatives (Velasquez and Hester, 2013). The choice of method usually considers several factors including the complexity of the decision-making process, the needs of the stakeholders, and the level of available knowledge (Huang et al., 2011).

MCA provides a framework to consider multiple objectives and dimensions that stakeholders may want to take into account in decision-making, but for which existing standard evaluation methodology may not exist. It has been widely applied in environmental policies, but only rarely in adaptation.

Non-monetary metrics in adaptation MCA

This section is divided into three parts. First, the scope of the identified adaptation MCA studies is examined. Second, the range of metrics used is presented. Unlike the CEA chapter, this sub-section does not differentiate between sectors as the indicators and metrics considered are not necessarily sector-specific, but are more generic and can be applied to different types of measures. Third, the reasons for using non-monetary metrics through MCA, and limitations, are presented.

Scope and main objectives of studies

An examination of the policy areas covered by MCA studies included in the Econadapt literature database suggests a wide distribution (Figure 2). The most common policy areas are agriculture and water management. Often, studies would cover multiple policy areas. There are very examples of MCA applied to adaptation through empirical, case-study investigations. Most studies refer to the potential of MCA to inform adaptation, and provide general guidance (e.g. ADB, 2012). There are a higher number of studies set in high income countries (35%) as opposed to middle (35%) and low income (21%) countries.

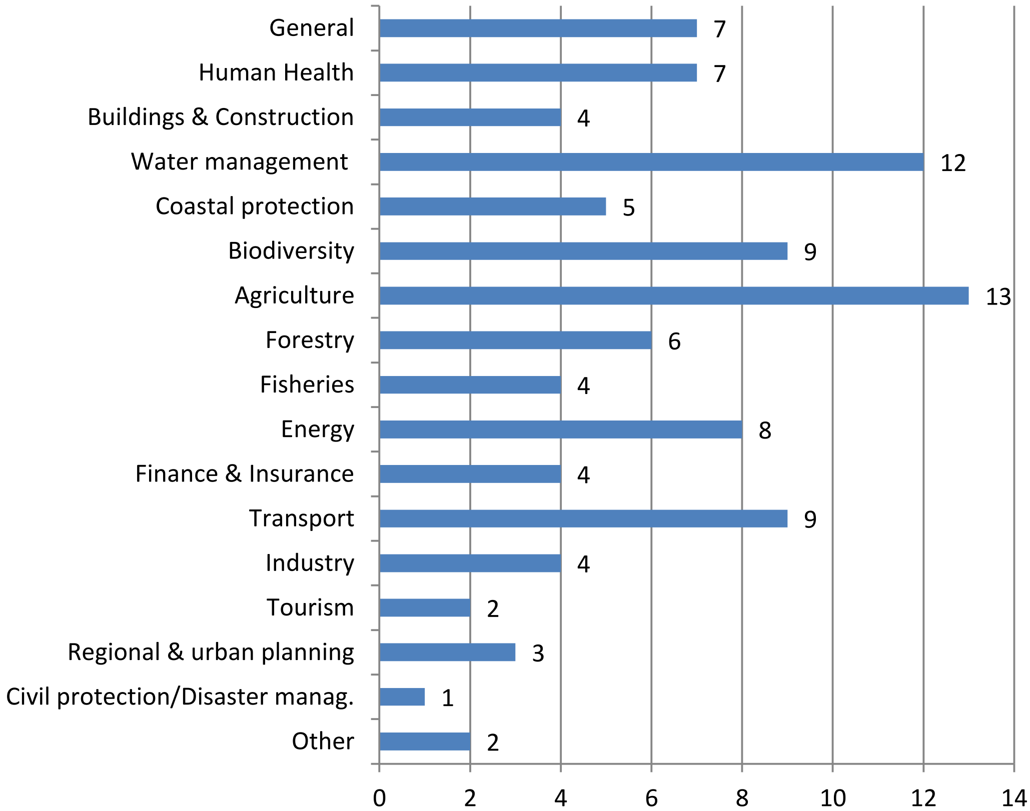

Figure 2: Policy areas regarded in the 40 publications. Multiple answers were possible.

Characteristics of non-monetary metrics

Criteria and indicators used assess adaptation options in the reviewed studies are varied and often follow a categorisation and framework of their own. However several specific criteria are also similar between studies. In an European context, Iglesias et al. (2007) present a number of criteria for assessing adaptation options that can help increase resilience of the agricultural sector. These include: technical feasibility, potential costs of implementation, cost-effectiveness, ancillary benefits, and cross-sectoral implications (e.g. water, tourism, energy). Adaptation measures assessed included technical (e.g. introduction of new cultivars), management (e.g. changes in cropping patterns, soil, landscape, water), or infrastructural (e.g. changes in drainage, irrigation systems, access, buildings).

In a comprehensive analysis for adaptation policy in the Netherlands, de Bruin et al. (2009) evaluate adaptation options for different policy fields with a more simplistic range of criteria: importance (whether the expected gross benefits that can be obtained), urgency for implementing the option, no-regret character, co-benefits across sectors and the effect on climate change mitigation. Options that were assessed comprise for the field of flooding green, grey and soft measures, e.g. more space for water: improving river capacity, widening the coastal defence area and evacuation plans. Starting from this framework, the Mediation project (Werners et al. 2013) adds a criterion covering the complexity of the option on technical, social and institutional level. The evaluated options include green, grey and soft measures such as retention of winter precipitation in forests, subsoil drainage of peatlands and adjusting crop rotation schemes and planting and harvesting dates.

Perrels et al. (2010) use MCA as an extension to a CBA in order to integrate stakeholder perspectives in the evaluation of options for flood risk management in Finland with a lower and a higher return period (50 and 250 years). The research team differentiated between use of resources (i.e. implementation costs and maintenance costs), impacts on the built environment (esthetic and planning concerns), and protection levels on households (damage to property), industry sectors (loss of production, other costs) and infrastructure (logistics, electricity production, water management).

Alvater et al. (2012) perform a climate proofing of EU policies. The impact assessment provides a set of relevant criteria for assessing adaptation across multiple sectors. These include effectiveness of adaptation (e.g. relevance, avoided damage), urgency (timescale, time-lag, lifetime), interactions, flexibility (no-regret, robust, flexible), efficiency (CBA, administration), and wider environmental and economic impacts.

More recently, the Bewater (2014) project selects the following criteria to assess adaptation options in river basin management: impact indicators (e.g. protection of surface water, preventing soil degradation, irrigating crops) and characteristics (e.g. timelag, implementation costs, effectiveness, potential to address climate change, feasibility, acceptability). A number of additional criteria are used following the MCA in order to support the combination of options across key challenges and future implementation: timeline of implementation, feasibility, robustness, flexibility, synergies and conflicts with policy objectives, acceptability, co-benefits, and cost-savings with joint implementation.

MCA is often used in the development of National Adaptation Plans (NAPs). The technical guidelines to support NAPs in Least Developed Countries (LDCs) proposes the following criteria: timing/urgency, cost, co-benefits, efficacy, flexibility or robustness, social and political acceptance, poverty reduction, strategic relevance for national development goals, and feasibility. Still in a developing context, Lee et al. (2014) develop a method for bottom-up integration of local stakeholder perception in climate change adaptation policy. Criteria were proposed, discussed and approved by local stakeholders in the three study sites where the research was deployed. They included two main types: impact criteria (e.g. economic benefits and costs of the option, spillover effects, distributional effects) and viability criteria (e.g. technical, compatibility with policy, public support and acceptance).

UNEP (2011) presents a multi-criteria method to assist local governments in the planning of climate change mitigation and adaptation actions for multiple sectors and applies it to three case studies (Mumbai, Yemen and South Africa –see Miller and Belten, 2014 for the Yemen case). Several indicators are developed and organised at three levels:

- 1st level: two criteria, including “inputs to” (or efforts required) and “outputs of” (or possible impacts) proposed policy options.
- 2nd level: seven criteria, two of which relate to the impact on the input side (public financing needs and implementation barriers) and five to impacts on the output side (climate-related, economic — including fiscal, other environmental, social, and political-institutional dimensions of development).
- 3rd level: 19 criteria, four of which on the input side (which include monetary and non-monetary costs that need to be met for effective policy action) and 15 on the output side (which relate to specific impacts on society, the economy and the environment).

Debels et al. (2008) explore disaster risk management options for Colombia, with particular focus on floods. A large range of adaptation specific criteria are used, such as robustness and flexibility and the level of resilience of options. The options are all soft measures including an improved radio communication network, enhanced stakeholder coordination and cooperation, capacity building and awareness-raising. The weights for the different criteria were assessed together with experts whereas the MCA was conducted with local municipalities.

A distinct set of studies use MCA onto a DPSIR (Drivers, Pressures, State, Impact, Response) framework. Ceccato et al. (2009) develop a wide range of variables with the DPSIR and identify with stakeholders in two case studies (upper Danube, Bramaputra) a set of nine criteria to evaluate four management approaches. Criteria cover the three main sustainability domain: environment (e.gg. basin morphology), society (population dynamics) and economy (agricultural production). In Yang et al. (2011), the MCA ranking is based only on hydrological and climate criteria (e.g. population density, slope of watershed, BOD load) that are then weighed by experts. Five adaptation options are evaluated for the suitability of adapting to climate change and urbanisation in central South Korea. Uncertainty is taken into account through the consideration of scenarios and a sensitivity analysis. Building on Yang et al. (2011) work, Chung et al. (2014) use a similar list of criteria but develop a fuzzy approach to better account for incomplete information and uncertainties.

The Water Evaluation And Planning (WEAP) tool -an integrated approach consistent of scenario analysis, modelling and MCA- also focuses on physical criteria. It was applied by Bhave et al. (2014) in a case study for the Kangsabati reservoir in Eastern India. Criteria used in MCA include: increased local water availability, runoff reduction, increasing soil moisture, proximity to agricultural land, increased awareness regarding water usage, cost, and profit. The process resulted in the prioritisation of three adaptation options: decentralization of water management, check dams, and increasing forest cover.

Outcomes: usefulness and limitations

A number of non-monetary indicators were described in the previous section, and are summarised in Table 2. Metrics used were typically qualitative (e.g. low/medium/high; good/medium/poor; short-term/medium-term/long-term; many/medium/few).

Table 2: Indicators used in MCA as stated in the reviewed studies.

Indicator	Definition
Standard indicators in MCA	
Importance/effectiveness	Expected capacity for achieving target, with the aim of maximising effectiveness
Costs/financing	Costs involved in design and implementation, with the aim of minimising public and private spending
Co-benefits	Benefits additional to those targeted or primarily sought for, with the aim of maximising co-benefits. This often refers to the protection of environmental resources and biodiversity, but can encompass other types of co-benefits such as on health, cultural heritage, etc.
Timelag	Time to achieve full effectiveness, with the aim of minimising it
Implementation ease	Suitability of existing regulatory and institutional framework to facilitate implementation
Policy integration (synergies/conflicts)	Institutional coherence between measures and existing policy targets and incentives, with the aim of maximising use of the existing framework and contributing to multiple policies
Feasibility	Availability of data, knowledge and technical capacity to design and implement measures
Acceptance	Level of social and political support and acceptability
Public participation	Level of engagement with non-expert actors and the broader society, and level of integration of local/traditional knowledge with scientific knowledge
Private investment	Capacity to trigger investments from the private sector
Improve economic performance	Capacity to foster competitiveness and increase economic output
Employment	Capacity to create jobs
Spillover effects	Distribution of positive and negative impacts to other economic sectors
Distributional impacts	Distribution of positive and negative impacts to different actor group, including specific attention to vulnerable groups. This may include attention to impacts on poverty levels and inequality.
Fiscal sustainability	Capacity to contribute to fiscal sustainability through impacts on government revenues and expenditures
Additional indicators used in adaptation	
No-regret	Non-climate benefits exceed costs of implementation so that benefits are secured under all potential futures
Urgency	Need of implementing options immediately or possibility to defer implementation at later point in time
Climate mitigation potential	Capacity to induce a reduction in greenhouse gas emissions
Extreme events	Capacity to deal with extreme climatic events such as heat waves, high wind speed, floods, and droughts
Robustness	Capacity to maintain effectiveness under different climatic and socio-economic development scenarios
Flexibility	Capacity of an option to be adjusted, complemented or reversed when it appears to be inappropriate at a future point in time (e.g. due to changing climatic or socio-economic conditions)
Level of autonomy	Capacity to self-govern the design and implementation of the option

The UNFCCC (2009) suggests that the use of non-monetary metrics through MCA in adaptation is most useful where a large range of dimensions need to be considered that cannot be easily represented through costs, benefits or effectiveness criteria. In particular, it is able to deliver a general ranking of options when multiple indicators with multiple different metrics are relevant to assess a set of measures (Debels, et al., 2008; de Bruin, et al., 2009; UNEP, 2011; LDC Expert Group, 2012; Werners et al., 2013).

MCA criteria are useful when data gaps exist as it is easy to use qualitative metrics. The method has advantages for the communication of results to decision makers and stakeholders as they can be based on simple measures that are already commonly used (Debels, et al., 2008). MCA metrics can easily be based on a participative process that allows expert and lay knowledge to be considered (UNEP, 2011; Werners et al., 2013; Bhave, et al., 2014; Lee, et al., 2014). However, this can also represent a weakness as the qualification or quantification of the criteria is highly depends on the quality of involvement of experts or stakeholders. Through MCA, participating actors are pressured to express preferences although they may lack knowledge, can miss important options or they may find it difficult to give consistent scores across alternatives. In addition, MCA outcomes are sensitive to the exertion of influence by powerful stakeholders. To develop reliable and useful values on non-monetary dimensions, stakeholder engagement needs to be well managed. The selection and involvement of stakeholders is crucial as well as attention to explain evaluation criteria and how different weighing affects outcomes (Lee et al., 2014). Simple indicators and scoring system are essential (GIZ, 2013b).

The metrics developed in MCAs are relative to each other and can only be used within the scope of the MCAs when comparing options. Together with the qualitative and subjective nature of the measurement, MCA is often not seen as a stand-alone methodology. As such, the assessment of non-monetary metrics within an MCA framework is often seem as a preliminary, scoping step in the selection of adaptation options (Debels et al., 2009; Lee et al., 2014; Miller and Belten, 2014). More detailed analysis, through e.g. CBAs, CEAs, or specific (qualitative or quantitative) assessments focusing on single indicators, may be necessary.

Several indicators in MCAs of adaptation cases can integrate uncertainties, for example criteria on no-regret, robustness, and flexibility (UNEP, 2011; Werners et al., 2013; Chung & Kim, 2014). This approach is however mainly qualitative and prone to subjectivity (Werners et al., 2013). UNEP (2011) suggests using sensitivity analysis (of most likely and worst case scenarios) in most cases, while most complex assessments through probabilistic approaches (considering the impact different levels of risks and impacts) may be used when sufficient data is available.

Conclusions

This overview paper has presented some of the non-monetary indicators and metrics currently used to assess adaptation options, and complemented early reviews with more recent developments. It provides tables listing potential indicators, as well as indications on why, when and how to use and develop non-monetary metrics in adaptation assessments.

The adaptation literature on non-monetary metrics remains overall very limited, and it appears that most studies rely heavily on metrics developed in CEAs and MCAs for non-adaptation issues. Further studies using and developing non-monetary metrics in adaptation are needed to complement the analysis presented in this paper.

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5 Conclusions

The deliverable presents a number of methodological developments useful for the economic assessment of climate change adaptation, namely on the consideration of distributional issues (focusing on the role of private provision of adaptation in relation to public provision, and on equity weights) and the use of non-monetary metrics. This deliverable has in particular examined in more detail the appropriateness of transferring practices from the mitigation and other assessment contexts to the adaptation context. Overall, guidance presented in this deliverable can be used in a variety of contexts where decision-makers and economics are interested to investigate the potential of private adaptation or the implications of distributed costs and benefits in the target population, or when limitations arise from the use of cost-benefit analysis and non-monetary metrics must be used to assess the relevance of specific adaptation options. Guidance presented in this deliverable was used to inform other ECONADAPT WPs, in particular WP6 which develops and tests economic assessments for informing project-level adaptation. Further conclusions on the application and implications are thus available in those WPs.