ECONADAPT

The Economics of Adaptation

Funded by the European Union

Disaster Risk Management as early adaptation.

Lessons learned, policy recommendations, and guidance.

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Deliverable number	5.3
Work Package Number	5
Submission date	November 18 2016
Type of Activity	RTD
Nature	R = Report
Dissemination level	Public

Document information

Title:	Disaster Risk Management as early adaptation. Lessons learned, policy recommendations, and guidance
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Date:	18 November 2016
Contact details	
Work Package Number	WP 5
Deliverable number	D5.3
Filename:	ECONADAPT D5.3.doc
Document history:	Final version
Type of Activity	RTD
Nature	R = Report, O = Other
Dissemination / distribution level	PU = Public
Citation:	
Copyright:	

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.

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

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Executive Summary

Disaster events at the European and global scales impose significant costs on the public and private sectors. These costs are bound to increase with projected shifts in intensity, duration, and frequency of climate-related extremes such as floods and droughts. As well, non-climatic drivers, such as exposed people and assets, and their vulnerability are important drivers behind rising costs from climate-related disaster events.

In light of these concerns, work package 5 of the ECONADAPT project presented a policy case study of climate risk management, providing comparative analysis of adaptation and disaster risk management for EU member countries. The analysis addressed both short- to longer-term changes in the frequency, severity and duration of extreme weather events resulting from climate change, but focussed strongly on riverine floods risk as the dominant climate-related risk in Europe and globally. The first task and deliverable of this work examined how European countries currently make decisions regarding the selection and design of risk management options at different scales. The second tasks focussed on the domain of public finance and fiscal planning, and how climate risk concerns could be considered iteratively in decision-making processes.

This final deliverable D5.3 synthesises lessons learned, policy recommendations, and provides some guidance. It is broken down into 3 challenges and related policy questions, which the research identified and tackled: (i) How to make the economic case at various governance scales? (ii) What is the experience of decision-making on investment into disaster risk management, particularly in light of climate change and uncertainties? (iii) What are useful tools and methods to support public sector risk management decisions in light of multiple stresses on public finance?

Assessing the economic case for adaptation to extreme events at different scales

We identify a strong case for sustained investment into disaster risk management (DRM) as early climate adaptation (CCA): an inventory of cost-benefit studies shows that the benefits over the lifetime of projects are substantially larger than the costs, which means that indeed DRM investments pay back. Also, almost three-quarters of the assessments of DRM investments collected in our database pay attention to climate-change aspects (sea level rise, rising riverine flood risk, changing precipitation patterns, etc.). What is more, we conclude that the narrow case for DRM investment (as part of early adaptation) can and is enhanced if further criteria relevant for the stakeholders are considered in decision-support, such as efficiency of options (how well is risk reduced), acceptability of investments, flexibility of implemented projects to accommodate climatic and socio-economic change and equity implications.

Decision-making on DRM as early adaptation

The evidence generated regarding the decision-making approaches on DRM shows some complexity at national, regional and local levels depending on the specific context and decision-making level. Some countries are actively factoring-in the effects of future climate change into flood risk management strategies.

Others focus strongly on addressing existing risks of extremes. Sophistication and implementation of methodological approaches varies largely - from simple updates of protection design standards based on one 'most-likely' scenario of future (climate) changes, to complex applications of pathways analysis and iterative risk management. Climate change concerns to build on DRM investments: tackle today's adaptation deficits caused largely by exposure and vulnerability dynamics. In terms of guidance, we would like to submit that the iterative risk management cycle, as proposed generally and tested for the case of Austria can be of general relevance. As we see it, an iterative CRM approach, co-developed with key national-level decision makers, constitutes a useful framework in terms of serving as a reflexive-participatory framework to address the existing adaptation deficit and the uncertainties associated with future climate change impacts and losses in policy and practice. Moreover, as new knowledge on the complex dynamics of social–ecological systems and their interactions with a changing climate becomes available, this CRM framework can inform the required iterative update of current learning and CRM practice within a learning loop framework.

Useful tools for considering multiple stresses and criteria in public and fiscal climate risk management

We find that the concept and method of risk layering integrated with a scenario-led participatory approach holds high appeal for many areas of disaster risk policy and management to work towards developing comprehensive risk management portfolios building on risk prevention, preparedness, risk financing and risk absorption. Also, applying the approach in a participatory environment can support negotiating roles and responsibilities for public and private sector players through formalised dialogue or informal role-play and other participatory exercises.

The climate risk scorecard and stochastic debt-assessment illustrate the importance of fiscal mainstreaming of climate risk in EU member countries. Focusing on increased flood risk in EU countries, economic risk of climate extreme events, relative to the size of economic and public finance resources available, is estimated to be high in a number of countries. At the same time, these countries also face the need for fiscal consolidation in the medium to longer-term, thus making proactive risk management especially important for these countries.

At the EU level, longer-term fiscal planning has thus far focused on incorporating the increased cost of ageing-related expenditure, whereas climate-related costs are only just beginning to be analysed. Unlike ageing cost estimates, which are projected using common underlying assumptions and shared widely with public and relevant institutions, climate related fiscal cost considerations still lacks such harmonized estimation methodology. As this report illustrates, shared socioeconomic pathways scenarios (SSPs) provide a useful framework for linking inter-related dimensions of demography, climate change and other socioeconomic trajectories, and this kind of approach will likely be effective in linking various fiscal policy concerns and designing appropriate fiscal risk managing policies under changing climate and socioeconomic trends. As EU member states strive for fiscal consolidation, sustainable growth and climate risk management in coming years, mainstreaming of climate risk into fiscal planning is becoming increasingly important.

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1 Introduction

Much of the concern about the impacts of climate change is related to projected shifts in intensity, duration, and frequency of climate-related extremes such as floods and droughts (EEA 2014). Science has shown climate change to alter the frequency, duration, and intensity of many natural hazards globally—heatwaves, droughts, and heavy precipitation (IPCC 2014)—as well as to modify heavy precipitation events on local to regional scales (APCC 2014). While the trends are clear, it remains a research challenge to identify how much of the risks associated with extreme events can be attributable to climate change. What is clear is that disaster events at the European and global scales impose significant costs on the public and private sectors.

There is a long history of managing climate-related and geophysically-driven extremes via disaster risk management (DRM). Recently, the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) (IPCC 2012) and the 5th Assessment Report (IPCC 2014), as well as other policy-relevant publications (e.g., UNISDR 2015), identified important synergies between disaster risk management (DRM) and climate change adaptation (CCA) with regard to risk drivers, policy instruments and actors. These reports made a call for further linking agendas for development practice and planning at the sub-national, national, and international levels (IPCC 2012; 2014; Saito 2013; UNISDR 2015). Even though the current state of scientific knowledge does not provide robust, quantifiable evidence that climate change is at the moment the unique, not even the most important direct driver of losses and damages linked to climate-related disasters, it can be argued linking DRM and CCA appears indispensable for managing the existing adaptation deficit.

Overall, climate-related extremes are associated with high and rising costs to public and private sectors, yet attention and investment choices compete with other priorities for public and private sectors. In light of these concerns and experience with managing risks, work package 5 of the ECONADAPT project provides a policy case study of climate risk management as early adaptation, providing comparative analysis of adaptation and disaster risk management for EU member countries. The work deals with both short- to longer-term changes in the frequency, severity and duration of extreme weather events resulting from climate change. Specifically, we focus on riverine floods risk as the dominant climate-related risk in Europe and globally.

The work has been broken down into two tasks and deliverables. Deliverable 5.1 (Kuik et al. 2016) examined how European countries currently make decisions regarding the selection and design of risk management options at different scales. The report proposed how climate change, and the uncertainty that goes with it, could be integrated into DRM strategies. Building on this analysis and findings, D5.2 (Mochizuki et al. 2016) focussed on the domain of public finance and fiscal planning, and how climate risk concerns could be 'mainstreamed' into public-sector decision-making processes. This deliverable assessed extreme event risks across an illustrative range of climate scenarios (with a short-term time horizon of 2030), examined the resulting fiscal repercussions and, identified options for better fiscal planning.

This final deliverable D5.3 builds on these analyses and findings in order to synthesise lessons learned and provide policy recommendations guidance. It is broken down to address 3 challenges linked to related research and policy questions, which are:

- How to make the economic case at various governance scales?
- What is the experience of decision-making on investment on DRM, particularly in light of climate change and uncertainties?
- What are useful tools and methods to support public sector risk management decisions in light of multiple stresses on public finance?

For each of the three challenges and questions, the discussion is organised as follows: (i) identification of policy and research questions; (ii) analysis and key findings, and (iii) lessons learnt, recommendations and guidance. We end with some general conclusions.

2 Assessing the economic case for adaptation to extreme events at different scales

2.1 Policy and research questions

The first research and policy question has been directed at understanding the economic case for sustained risk management investment at various governance scales.
Many European countries and local communities have developed Disaster Risk Management (DRM) and adaptation strategies that include strategies to cope with natural disaster risks. These strategies include options to prevent natural disasters from happening, to mitigate their impacts when they do happen, and to quickly recover in their aftermath. DRM options can operate at different scales: from international (e.g. coordinating foreign aid in the aftermath of a natural disaster) to local (e.g. strengthening local houses to withstand flooding).

The large variety of policy and project appraisal procedures and tools that exist can be classified into a number of groups. Rayner and Kuik (2010) distinguish: (1) assessment frameworks; (2) participatory tools; (3) scenario analysis tools; (4) multi-criteria analysis tools; (5) cost–benefit and cost-effectiveness analysis tools; (6) accounting tools, physical analysis tools and indicator sets, and (7) model tools (see Box 1).

In our assessment we focussed on cost-benefit analysis (CBA) as a popular and oft-advocated tool to choose between alternative DRM options. Ideally, CBA compares advantages (benefits) and disadvantages (costs) of options in a systematic and objective way, so that the option that provides the greatest net gain to society can be selected. The EU Floods Directive (2007/60/EC) requires that flood risk management plans "take into account relevant aspects such as costs and benefits, ..." (EU Flood Directive, 2007, Art. 3), and this has undoubtedly given an incentive to apply CBA in regions where it was not common before.

Beyond CBA, the work package research furthermore looked into participatory tools, scenario analysis, as well as modelling, which will be discussed further below.

2.2 Analysis and key findings

Analysis
While the application of CBA in the appraisal of DRM options is nothing new, there has not been comprehensive analysis for the EU. Existing inventories of DRM investments of this kind have largely focused on investments in developing countries or globally (Mechler et al., 2014; Mechler, 2016; Shreve and Kelman, 2014; Hawley et al. 2012).

Box 1: project appraisal procedures and tools

1) **Assessment frameworks** can be considered 'procedural tools', in the sense that they do not carry out a particular kind of analysis, but are procedures designed to connect to a decision-making process, and within which a range of different analytical tools can be applied (Finnveden et al. 2003). Examples include the EU's Impact Assessment system, Environmental Impact Assessment, Strategic Environmental Assessment and Integrated Sustainability Assessment.

2) **Participatory tools** can be used in decision-making processes with the aim of involving stakeholders in policy development. They can be defined as 'methods to structure group processes in which non-experts play an active role in order to articulate their knowledge, values and preferences' (van Asselt and Rijkens-Klomp 2002). There is a great variety of such methods and techniques, stemming from a broad range of disciplines, including focus groups, consensus conferences and repertory grid techniques. Stagl (2007) outlines how deliberative and participatory elements can be introduced into a range of traditionally less participatory tools, including multi-criteria analysis and forms of monetary valuation.

3) **Scenario analysis tools** include tools for defining and developing scenarios and interpreting the results. In essence, scenarios are constructed to assist in the understanding of possible future developments of complex systems (van der Heijden 2005). Tools assigned to this category include, for example, Delphi and cross-impact analysis (Helmer 1977), and scenario workshops (Andersen and Jaeger 1999).

4) **Multi-criteria analysis (MCA)** tools support comparison of different policy options on the basis of a set of criteria. Within this group at least three subgroups of MCA tools can be distinguished: (1) compensatory MCA tools, which allow compensation between different criteria, such as the multi-attribute value theory (Keeney and Raiffa 1976); (2) non-compensatory MCA tools, which do not, e.g. the dominance method (Jankowski 1995); and (3) partial compensatory MCA-tools, which allow for compensation between a limited number of criteria only (Brans and Vincke 1985). More recently, within this tool group evolutionary multiobjective optimising methods have gained momentum (Srinivas and Deb, 1994).

5) **Cost-benefit analysis (CBA)** monetises expected positive and negative impacts of a policy. The monetised results can be used to justify acceptance or rejection of a policy proposal by simply comparing costs with benefits (Pearce et al., 2006). The group **CBA tools** include techniques such as contingent valuation and hedonic pricing that are used to monetise certain impacts for which no market value exists. The **cost-effectiveness analysis (CEA)** tool is also included in this group because, like CBA, it is rooted in economics and plays a role in analysing policy options. However, unlike CBA, CEA cannot determine whether the benefits of different policies outweigh the costs (Pearce et al. 2006). CEA focuses on the cost-side of policy options, with the aim to find the most cost-effective option, i.e., the option that can deliver a pre-specified target at least costs.

6) **Accounting tools, physical analysis tools and indicator sets** are used for elucidating the physical side in an assessment, rather than the economic (Adriaanse et al. 1997). Three subgroups are distinguishable in this group: i) accounting tools, e.g. measures of economic welfare, which add the physical dimension to common economic accounts; ii) physical analysis tools, which can be used to calculate certain physical quantities such as an ecological footprint; iii) indicator sets which can be taken together to assess something specific within a broader assessment. Indicator sets can, for instance, be designed to measure poverty, hunger or economic competitiveness.

7) **Model tools**. Models are simplified representations of complex real-world phenomena that try to simulate real-world processes based on, or calibrated to, empirical information and with some relevance to actual policy decisions. Three categories of models can be distinguished: (1) socio-economic (e.g., general economy models); (2) bio-physical (e.g., climate models); and (3) integrated models (e.g., land-use models).

Source: Rayner and Kuik (2010)

In contrast, the present inventory is specifically focused on Europe, and therefore allows for studying the EU context in higher detail. In our search for evidence, we have made use of the aforementioned inventories and also of databases that are constructed in other Work Packages of the ECONADAPT project (WP1 and WP6). In addition, we have searched the existing grey and academic literature for additional studies. Due to linguistic limitations of the researchers, we have only collected studies in the English, Dutch, Spanish and German languages. o somehow restrict the scope of the research into the vast mole of material available, we have focussed on studies on risk management in the context of floods, although we also found some studies for other hazard types.

A database of DRM investments for floods in Europe was constructed, containing 110 observations on investments/projects from 32 studies and databases, covering 16 European countries. In addition, detailed case studies of DRM policies were carried out in Austria, Czech Republic, The Netherlands and the United Kingdom. The inventory developed is meant to help identifying commonalities and differences across contexts and identify which factors (variables) motivate different decision rules concerning DRM and adaptation investments. The inventory provides an overview of types of investments (flood control, flood damage mitigation, preparedness, and recovery), the size of these investments, decision tools applied to evaluate these investments ex-ante or ex-post (if available), and a number of other variables described below. In addition, Benefit-to-Cost ratios (BCR) and other performance indicators are presented, where available.

Findings

We first find that for the assessment of long-term investments in flood protection infrastructures, most countries employ some form of cost-benefit analysis (CBA). However, other decision-making tools such as CEA, multi-criteria decision-making analysis (MCA), and Real Options Analysis (ROA) are also used, sometimes as substitutes, but in most cases, as complements. The Netherlands provide an interesting example where CBA – together with other tools – is used at the highest level of decision-making on flood protection standards, and where much more participatory and multi-criteria approaches are employed for local-level decisions on the actual design of flood control infrastructures. The use of CBA and participatory decision-making is supported by the EU Floods Directive. In practice, CBA tends to focus primarily on tangible costs and benefits such as avoided direct damage to buildings and infrastructure. In order to include intangible damages in the equation (human casualties, health, environmental damages, etc.), decision-makers often take recourse to some sort of MCA. MCA approaches can range from very simple (setting protection standards on the most stringent of four criteria such as in The Netherlands) to rather advanced (such as MCA optimisation methods used in the United Kingdom). ROA is not a substitute for CBA, but rather an extension. It has not yet entered the standard toolbox of project appraisal, but it offers interesting possibilities for the appraisal of complex, long-term investments in flood protection. As yet, there is no single superior decision-making tool to fit all circumstances. We find that there is growing recognition across Europe, also promoted by the EU Floods Directive, that participatory approaches to decision-making should be employed, whenever this is feasible.

The second conclusion is that DRM offers good value for money. Across European countries and across a wide variety of DRM investments, we observed a mean and median benefit-to-cost ratio of 5.9 and 3.0, respectively. The mean BCR of the investments is 5.9 (N=84). This is very much in line with BCRs in the USA and global surveys of DRM investments, where average BCRs of 4.0 (MMC, 2005) and 3.7 (Mechler et al., 2014) are reported for DRM investments for all kind of hazards. So the return on DRM investments is high, even though intangible benefits are often not accounted for. These returns are high for investments in flood control, flood damage mitigation, as well as preparedness.

We recognize however, that it is possible that our sampling strategy, as those of the studies we cite, incurs in a systematic positive bias of the BCRs of investments, as it could be that successful investments and projects are more frequently reported upon in official documents, and therefore have a higher change of being represented in our database (publication bias).

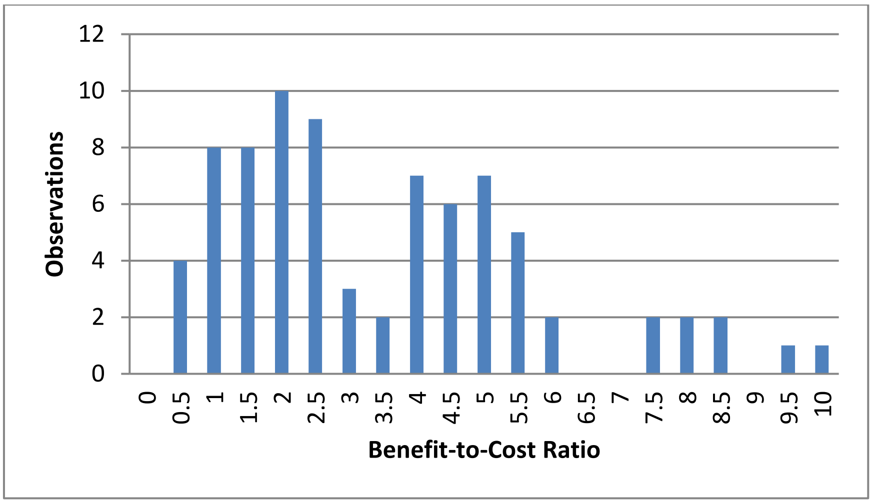

Figure 1 Frequency distribution of BCRs of DRM investments in Europe (the distribution is only shown for BCR's between 0 and 10, larger BCR's are not shown because they would negatively affect the readability of the graph).

2.3 Lessons learnt, recommendations and guidance

Overall, we uphold that making the economic case for DRM investment is relevant as countries are using project appraisal tools, such as CBA. Furthermore, a strong case can be made for DRM: our inventory shows that the benefits over the lifetime of projects are substantially larger than the costs, which means that indeed DRM investments pay back. In terms of specifically including climate change and impacts, the lesson that we draw from the results of the research is that DRM provides a good entry point to examine the state of affairs with decision making on adaptation to climate change. Almost three-quarters of the assessments of DRM investments that we collected in our database pay attention to climate-change aspects (sea level rise, rising riverine flood risk, changing precipitation patterns, etc.). This attention starts around 2004 and the majority of studies after 2004 (80%) take climate-change impacts into account in one way or another. The way that climate change is taken into account differs across and within countries, depending on the specific context and decision-making level.

What is more, we conclude that the narrow case for DRM investment (as part of early adaptation) can and is enhanced if further criteria relevant for the stakeholders are considered in decision-support, such as efficiency of options (how well is risk reduced), acceptability of investments, flexibility of implemented projects to accommodate climatic and socio-economic change and equity implications. Broadening the analysis leading into MCA decision support is helpful to involve a broader set of stakeholders, which are impacted and ideally benefitting from the prospects. Such a broader lens is fundamental to working towards more adaptive-iterative approaches, which are seeing emphasis in practice and theory as discussed further on.

3 Decision-making on DRM as early adaptation

While the general economic case for building on project appraisal tools can be made, in terms of broader decision-making frameworks, there is overall a shift towards iterative, bottom-up approaches to disaster risk management and climate adaptation that takes traditional appraisal procedures and tools forward which are used to assess the effectiveness and efficiency of DRM strategies and projects such as CBA (Mechler et al. 2008). Little insight and guidance exists with regard to such an approach, and the policy and research question addressed for has thus been: **What is the experience on decision-making on DRM, particularly in light of climate change and uncertainties?**

3.1 Analysis and key findings

Analysis

To understand how decisions are taken in the selection and design of DRM options in European countries at different governance scales, who is involved, and what (appraisal) tools are used to guide these decisions, we carried out an overview and case studies in four EU Member States: Austria, Czech Republic, The Netherlands and the United Kingdom. The selection of the case studies was partly motivated by the available expertise in the ECONADAPT consortium, and partly by the desire to represent different geo-physical regions, and differences in in risk cultures, governance and data availability. The case studies were carried out by national experts, mostly based on existing documentation. For the case study on the Czech Republic, knowledge from existing documentation was augmented by a number of face-to-face interviews with key decision-makers. The case studies started with general background information on flood risk and the flood risk management for the particular country, which lead into an examination of decision-making on DRM investments and projects on national, regional and local scales of governance as well as considering how climate change is taken into account in decision-making.

Findings

At the EU and MS level, climate risks are increasingly being evaluated in an adaptive and iterative manner: Different approaches towards this ‘new way of planning’ are being actively promoted and researched.

The sophistication of the approaches ranges from simple updates of protection design standards based on one ‘most-likely’ scenario of future (climate) changes, to complex applications of ‘Dynamic Adaptive Policy Pathways’ (The Netherlands), ‘Real Options Analysis’ (United Kingdom) and iterative climate risk management (Austria).

As an important case in point, the Delta Programme in the Netherlands advocates adaptive management (’adaptive delta management’) to address future uncertainties, including the impacts of climate change, in a ’transparent’ manner. Four principles are considered key to include in the project and policy appraisal (http://deltaproof.stowa.nl):

1. Linking short-term decisions with long-term tasking. This is needed to better anticipate future events so that future measures can be accomplished in a more cost-effective manner, and to avoid adaption measures that make future solutions impossible.
2. Incorporating flexibility in possible solutions. Maintaining flexibility is needed to enable response to climatic and social changes, and to use new knowledge as it becomes available.
3. Working with multiple strategies that can be applied alternately depending on developments. Methodologies to design alternative adaption pathways have been developed.
4. Linking different investment agendas, with other local authorities or private parties for the purpose of sharing costs, reducing impediments, or creating added value. This means that ambitions in other areas (e.g. agriculture, the natural environment, shipping and recreation) should be taken into account during planning. This too requires flexibility, as the option to link may require that the investments are adjusted, advanced or postponed.

These four points of departure are integrated in the proposed policy cycle of adaptive delta management (Figure 2).

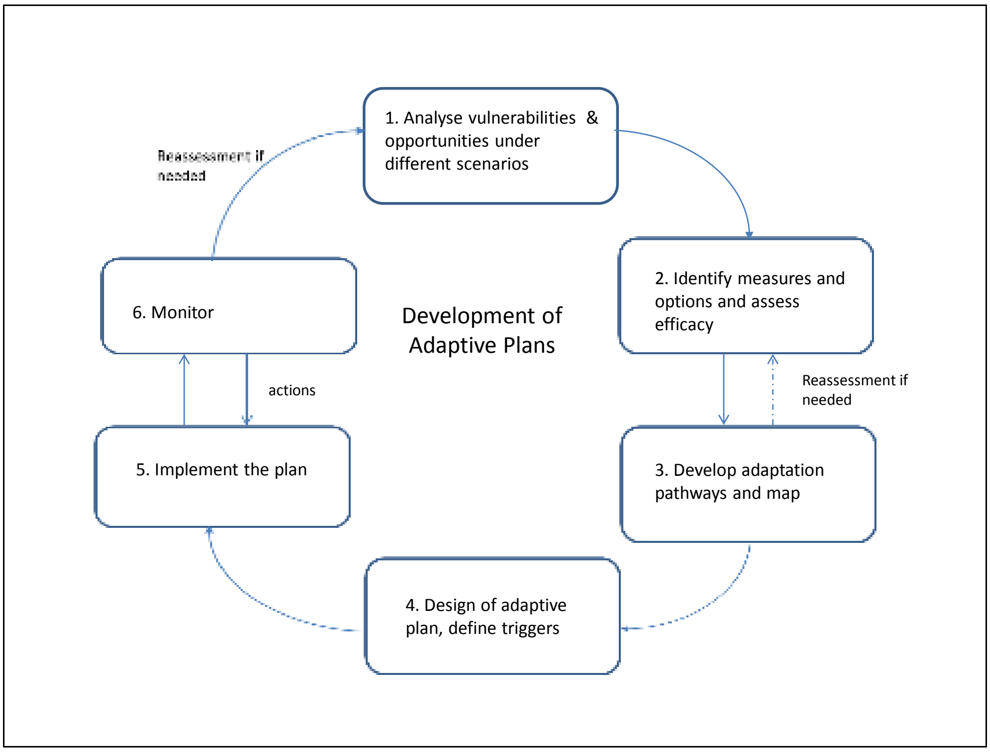

Figure 2: Policy cycle of adaptive delta management. Redrawn from Deltafact: Delta scenarios and adaptive Delta management (http://deltaproof.stowa.nl**).**

The Delta Programme in the Netherlands has also developed the notion of 'dynamic adaptation pathways', whereby measures are adopted to increase both the flexibility and robustness of existing risk management options (Haasnoot et al. (2013). Central to these adaptation pathways are adaption tipping points (or 'triggers') which are the conditions under which an action no longer meets its objectives. The timing of the adaptation point for a given action is scenario-dependent. After reaching a tipping point, additional actions are needed to keep meeting the objective. The adaptation pathways approach presents a sequence of possible actions after a tipping point in the form of adaptation trees (e.g. like a decision tree or a roadmap). Each possible route through the adaptation tree is an adaptation pathway. The graphical illustration of such an adaptation tree resembles a metro map (Figure 3).

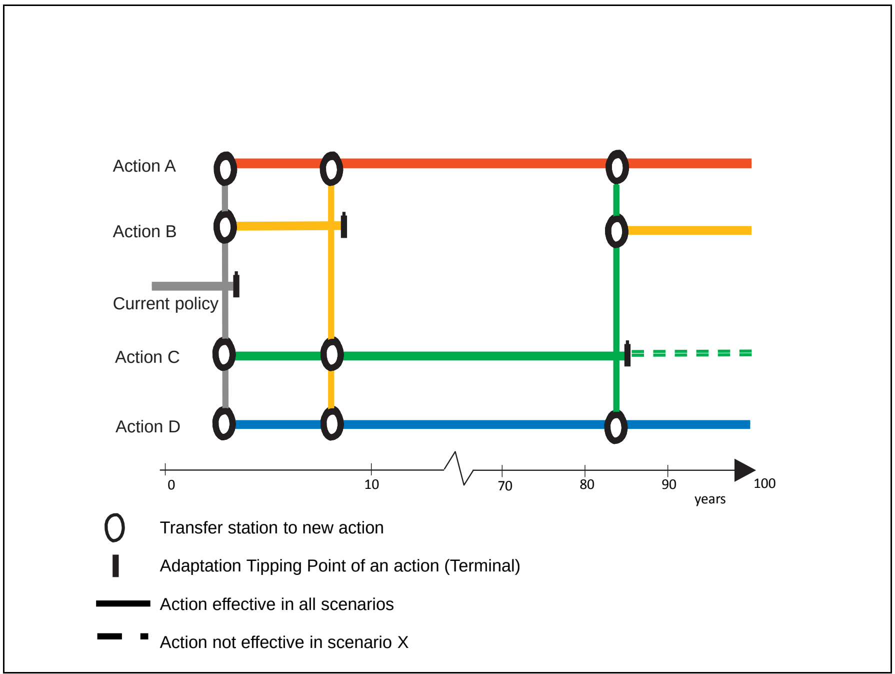

Figure 3: An adaptation pathways map. In the map, starting from the current situation, targets begin to be missed after four years. Following the grey lines of the current policy, four options and actions can be traced. (Haasnoot et al. 2013)

This approach is still under development and that there are many knowledge gaps to be filled. To this end the approach is currently being tested in a number of regional projects (e.g., the Delta programme Rijnmond/Drechtsteden, and the water boards Delfland and Aa en Maas).

The Thames Estuary 2100 project in the UK has adopted a similar approach, incorporating an iterative decision-making process. In this process, major milestones have been pre-determined up to 2050 in order to take account of new scientific information and learning, thereby enhancing the overall robustness of policy across multiple possible future developments (Watkiss and Hunt 2013). At the same time other countries, such as Austria and Czech Republic, are also addressing the risks of extremes by periodically updating the estimates of extreme event risk when new information on potential risks becomes available (see Schinko et al., 2016).

Furthermore, there have been conceptual contributions by analysts suggesting that CRM means comprehensively reducing, preparing for and financing risk, while tackling the underlying risk drivers, including climate-related and socio-economic factors (Mechler et al. 2014). Watkiss et al. (2014) see a key role for CRM in terms of serving as a blueprint for early action on climate change adaptation (CCA). This implies a significant overlap between current practice of disaster risk management (DRM) and CCA activities. Both pursue a similar goal, namely the reduction of negative impacts of climate change and disasters, respectively, on the natural environment, human society and economies by anticipating risks and uncertainties and addressing vulnerabilities (IPCC, 2012).

In Austria, work done under the ECONADAPT project (as well as the Austrian funded project PACINAS) with decision-advisors and stakeholders co-generated a generic Climate Risk Management (CRM) framework, applicable to other national and international decision-contexts. The Austrian case provided a good opportunity to develop and test such a framework. Exposed to various hazards, such as flooding, drought, and avalanches, Austria suffered losses of several billion Euro in riverine floodings in 2002, 2005, and 2013, leading to substantial stress on private and public financial reserves. At the same time, concern about climate change ranks high among Austrian stakeholders, and efforts involving the research, policy, and practice communities have been undertaken to understand the scope of future climate risk, as well as proper risk management and adaptation responses. As one of the first bodies to conduct a comprehensive national assessment of climate change, the Austrian Panel on Climate Change (APCC) showed in 2014 that warming in Austria has been more severe than the global average, that risks are bound to increase and that overall there is a need to upgrade adaptation efforts (APCC 2014). In 2015 a country-wide assessment of the costs of climate change was published, detailing the significant financial implications of unmitigated climate change for public and private actors, amounting to about a billion Euro already today (Steininger et al. 2015).

In terms of policy engagement, in 2012, Austria developed its national adaptation strategy (BMLFUW 2012), which cogenerated options with a large set of stakeholders, and identified several possible alternatives for action. Protection from natural hazards and disaster risk management are two of 14 different activity categories which are detailed in the climate adaptation strategy and which we will examine here in the context of a more comprehensive discussion of CRM. Whether and how to link DRM and CCA strategically and the implications for implementing policy options however, had not been explored in detail.

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

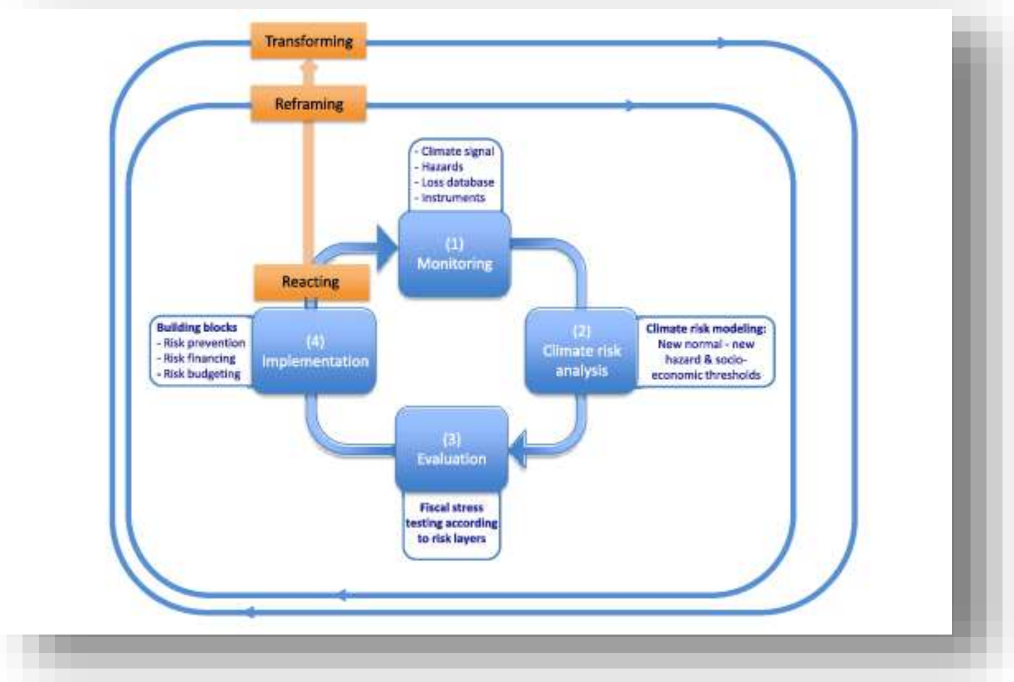

Figure 4: Iterative framework for climate risk management embedded in a triple loop learning process. Schinko et al., 2016

3.2 Lessons learnt, recommendations and guidance

The evidence generated addressing the above research question shows that there is important development, yet decision-making approaches have by no way settled yet: governments, government agencies and academic researchers are experimenting with approaches and are actively evaluating and developing the options.

In this context, the European Commission has rightly argued that in investment projects, climate change-related risk management should be integrated into existing project lifecycle appraisal approaches to manage the additional risk from climate change. These existing approaches can vary between countries and sectors. From a practical perspective it is important that risk management approaches complement existing project appraisal processes but not replace them.

Because the research in this report focussed on flood risk management, we should be careful in generalizing the conclusions to investments in adaptation to climate change in general. The most obvious generalization would be to adaptation of long-lived infrastructures in general (for example also with respect to mitigating public health risks from heatwaves). In addition, the high returns of investments in preparedness seem to offer some evidence that investments in preparedness to other climate-related extreme events (heatwaves, storms, droughts) might also offer comparable returns. Decision-making approaches on adaptation investments in general can benefit from the methods and tools that we found are currently being used and that are currently being developed in existing DRM domains.

Importantly, the complexity of decision-making on flood risk in light of climate change at national, regional and local levels depending on the specific context and decision-making level is to be acknowledged. Some countries are actively factoring-in the effects of future climate change into flood risk management strategies (e.g., Netherlands and United Kingdom). Others, focus strongly on addressing existing risks of extremes (e.g., Austria and Czech Republic). Sophistication and implementation of methodological approaches varies largely-from simple updates of protection design standards based on one 'most-likely' scenario of future (climate) changes, to complex applications of pathways analysis and iterative risk management. Climate change concerns to build on DRM investments: tackle today's adaptation deficits caused largely by exposure and vulnerability dynamics

In terms of guidance, we would like to submit that the iterative risk management cycle, as proposed generally and tested for the case of Austria can be of general relevance. As we see it, an iterative CRM approach, co-developed with key national-level decision makers, constitutes a useful framework in terms of serving as a reflexive-participatory framework to address the existing adaptation deficit and the uncertainties associated with future climate change impacts and losses in policy and practice. Moreover, as new knowledge on the complex dynamics of social–ecological systems and their interactions with a changing climate becomes available, this CRM framework can inform the required iterative update of current learning and CRM practice within a learning loop framework (Keen et al. 2005).

4 Public and fiscal climate risk management: tools for considering multiple stresses and criteria

4.1 Policy and research questions

Although comprehensive disaster risk management requires joint efforts by the private and public sector, to date, in addition to the insurance industry, it has been the public sector risk that has played a significant role in the application of proactive risk management approaches. Governments' central position in DRM is due to the fundamental role it plays in providing goods and services and redistributing income, particularly in times of need. While losses for extreme hazard phenomena can be high, for governments disaster risk usually constitutes a contingent liability, i.e., costs that accrue only in the case of an event. As a result, governments have often ignored catastrophic risks in their planning, and implicitly or explicitly exhibit risk-neutrality (Mechler 2004). This can be justified if risk neutrality prevails (i.e., risks can be absorbed and refinanced relatively easily (Arrow and Lind 1970). Nevertheless, in line with the global shift to a more pro-active approach, many developing countries have become more aware of their risk-averse position and started to plan and budget accordingly. Faced with increasing risk arising from climatic and non-climatic stressors, and being aware that contingent liabilities may cause considerable fiscal stress, OECD countries have also begun to take action (e.g., USA, Austria) (Mechler and Hochrainer-Stigler 2014). Progress in public sector risk-planning has been achieved by using analytical tools available to systematically assess and manage risks in the fiscal balance sheet. We examine a number of tools in terms of their applicability for a broad climate risk management approach as outlined above.

The suggestion for using a broad set of tools along a climate risk management approach is well in line with recent thinking, as e.g. brought forward by IPCC's 5th assessment report, which suggested there is evolution with regards to decision-support for adaptation and climate risk management: "Economic thinking on adaptation has evolved from a focus on cost-benefit analysis and identification of "best economic" adaptations to the development of multi-metric evaluations including the risk and uncertainty dimensions in order to provide support to decision makers (high confidence)" (Chambwera et al., 2014).

Building on this finding and studying the fiscal management of climate-related risks, work in this work package focussed on further testing and operationalising this suggestion and asked: **What are useful tools and methods to support iterative public sector risk management decisions in light of multiple stresses and criteria on public finance?**

We discuss the roles of risk layering, stochastic fiscal risk assessment as well as a fiscal scorecard approach as applied to the case of Austria as well as EU member states.

4.2 Analyses and key findings

Risk layering for understanding roles and responsibilities
Disaster and climate risk layering involves identifying efficient and acceptable interventions based on the recurrence of hazards and allocating roles and responsibilities to reduce, finance or accept risks. Disaster risk is complex, as it lumps together frequent events with minor impacts, and infrequent but devastating catastrophes. Not all disaster risk can be eliminated, and it is imperative to know which risks should be reduced, which insured against and which will require governmental or international aid efforts. To this effect, segregating risk according to risk preference via risk layering has raised general interest in several areas of risk policy and management in agriculture, finance and insurance, yet been operationalised exclusively so for instrumental debate in the insurance sector (Mechler et al., 2016).

Instead of relying on a single risk management measure, we suggest to employ a more comprehensive and integrative approach. As there are different kinds of climate related risks, some occurring frequently with only minor impacts while others rather infrequently but devastating (low and high return period events, respectively. It is recommendable that countries employ a varied portfolio of instruments, each carefully chosen to be applicable for a certain layer of climate related risk (Mechler et al., 2014) and iteratively adjusted over time with evidence. Risk layering involves targeting policy measures to the level of climate-related risk associated with specific return period, such as risk reduction measures for low layers of risk, potentially financed by a reformed disaster fund, risk financing, e.g. via insurance, for medium layers of risk, and national and internationally coordinated disaster relief in combination with alternative risk transfer mechanisms for high risk layers. Proactively engaging with all layers of risk and fostering explicit budgeting for contingent disaster risk liabilities is needed to reduce climate stress on public budgets and to ensure fiscal stability in the future.

Findings

Results of comprehensive risk layering for the case of Austria have been presented and discussed at a stakeholder workshop with DRM and adaptation experts as well as further experts active in this field. The main focus was on increasing participants understanding of the relevance of the various layers of risk and the implications in terms of specific responsibilities for private and public sectors in terms of risk prevention, insurance and budget absorption. Cumulated losses over the different return periods were estimated to increase from EUR 17 billion in 2015 to EUR 24 billion in 2030 and EUR 34 billion in 2050. It should be noted that the results are mainly driven by socioeconomic developments, leading to higher exposure of assets to flood risk, while climate change impacts are not found to be large in the near to medium future.

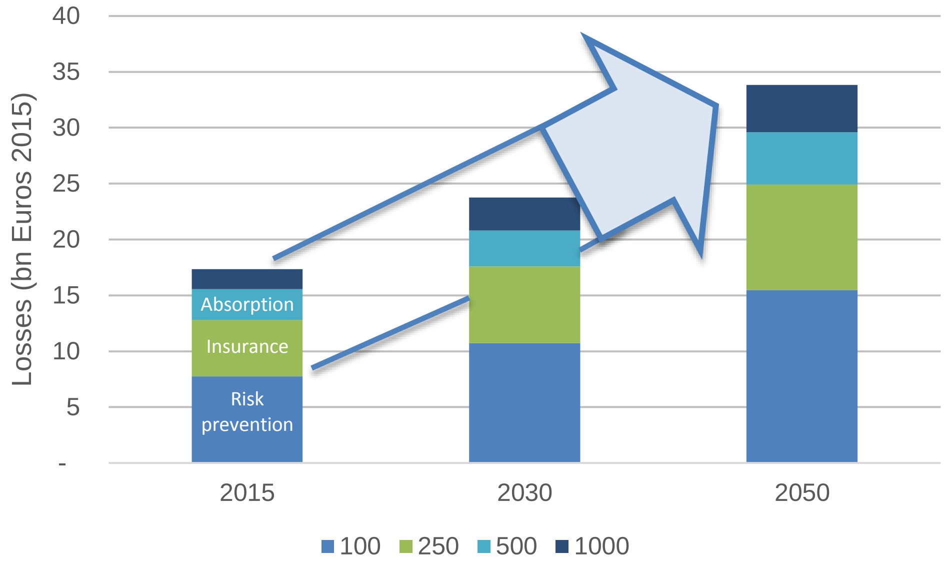

Figure 5: Risk layering approach to deal with probabilistic projections of flood losses (with flood protection measures) for different return periods in Austria (in billion 2012 EUR). Schinko et al., 2016

Stochastic fiscal risk assessment

Modelling future fiscal stress from climate-related events involves linking climate risk estimates (such as due to flooding) and climate scenario analysis building on the IIASA CATSIM model (see Hochrainer-Stigler et al. 2013). CATSIM employs probabilistic modelling of disaster risk to understand the current and future stress imposed on the fiscal position, and support the development and implementation of fiscal policy options.

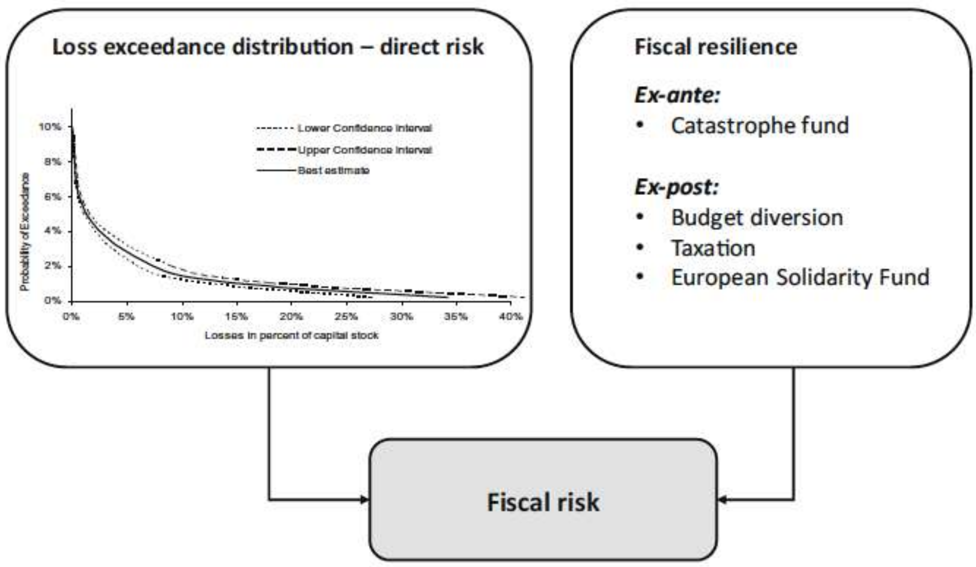

Fig. 6 Modelling fiscal risk as a function of losses (direct risk) and fiscal resilience based on the CATSIM framework. Adapted from Hochrainer-Stigler et al. 2013.

In order to introduce climate Scenarios*,* we build on the Shared Socioeconomic Pathway scenarios (SSP). In the current analysis, we used projected GDP and demographic composition in Shared Socioeconomic Pathway 2 (SSP2) as an illustrative example for medium-levels of warming. In a next step, the flood risk is linked up with an estimate of fiscal resilience to gauge fiscal risk. By integrating potential future economic losses due to climate risks with the public resources available for absorbing these risks, the relevant layer of risk at which a specific country might experience fiscal stress in the future, and concrete options to remedy this situation, can be identified.

Findings

The probabilistic modelling results give not only information about the changes in average losses but also about changes of the tails, i.e. extreme risk (see figure 7). Using baseline assumptions of macroeconomic, demographic projections, public debt under a business as usual scenario'' (i.e. no fiscal consolidation) is estimated to increase from 84.5 % in 2015 to 123% in 2030. Under the same assumptions, the total of disaster fund is expected to increase from its current level of 292 million/year to 330 million/year in 2030. While continuation of no fiscal consolidation is unlikely beyond the medium term, baseline assumptions suggest that total disaster fund will increase to 410 million/year by 2050.

The results of Monte-Carlo simulation shows how the Austrian fiscal position may deviate from the baseline debt-projections due both to macroeconomic variability and climate extreme events. The results indicate that variability due to macroeconomic variability is much higher than that of direct risk of climate extremes, suggesting that climate extreme in itself is unlikely to pose significant fiscal pressure on Austria. What is important, however, is the combined effect of macroeconomic- and climate-derived fiscal pressure on the Austrian fiscal stance: under increased pressure due to longer-term fiscal consolidation and macroeconomic variability, ad-hoc and ex-post oriented management of climate extreme events will likely become increasingly difficult.

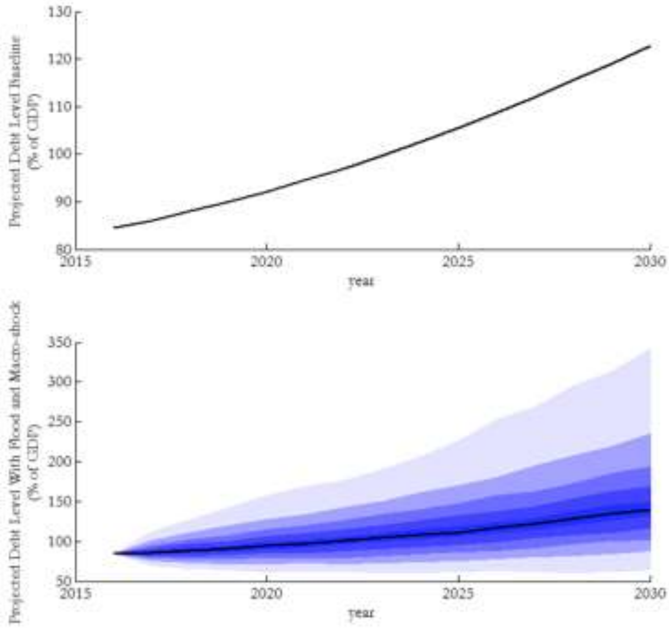

Figure 7: Baseline and stochastic debt trajectories for Austria under SSP2 scenario up to 2030 5th to 95th percentiles

Integrating disaster risk with fiscal risk more broadly: Scorecard

In addition to climate-related and other extreme event risk, there are many pressures on the fiscal position. To concurrently assess those, a scorecard approach is useful, which was applied and extended to the case of Austria and risks in the EU28 more broadly.

A policy scorecard is a common approach used in EU wide assessments in a variety of policy domains, including, more recently, its development for use in climate change adaptation. In this study the scorecard is developed to show data from the following three domains, capturing:

- Underlying fiscal pressure
- Macroeconomic & fiscal variability
- Climate change extreme risk (DRM Fiscal Capacity).

For underlying fiscal pressure, the scorecard shows four variables: current debt-to-GDP, the primary balance needed to stabilize debt at 60% in year 2030 (also known as the S1 indicator), the projected increase in fiscal burden due to demography-related costs (ageing, health, longer-term care, education), and projected changes in the fiscal burden as a result of climate change mitigation. This set of indicators illustrate the current fiscal health and consolidation requirements of each EU member country, along with the additional longer-term challenges posed by both climate and socioeconomic changes under the SSP 2 scenario.

For macroeconomic and fiscal variability, the scorecard shows the historical variability of three variables: growth adjusted interest rate, exchange rate and semi-budget elasticity parameters (describing how budgetary expense and revenue responded to a percentage change in the output gap). This set of indicators show how future debt burden may deviate from baseline projections (assuming past variability is indicative of the future variability of these variables). These variables are also used in the stochastic-debt assessment, described in the next section. For climate change extreme risk, the scorecard shows five variables: annual average loss (AAL) calculated for 2015, AAL projected for 2050 (relative to the size of projected government expenditure), current availability of reserve fund and budgetary allocation, historical observations of average insured losses, and availability of other budgetary mechanisms. This set of indicators show both direct risk posed by current and future risk of extreme weather events, together with the availability of fiscal and economic resources to cope with these kind of risks. To gather information on governments' ability to cope financially with current extreme weather events, this study sent out email surveys to relevant ministries (e.g. ministries of finance and disaster management agencies) in each EU member state. Results of applying the scorecard approach to EU 28 are shown in figure 8.

Findings

The results of the fiscal risk scorecard exercise indicate a variety of challenges facing EU member states with regard to longer-term costs as a result of climate extreme events. Figure 8 shows the estimates of fiscal pressure, variability and climate extreme costs, ranked according to 25th (Green), 50th (Yellow), 75th (Orange) and 100th (Red) percentiles respectively. For example, the first indicator, government debt as percentage of GDP, illustrates the wide range of fiscal consolidation needs that face these countries in coming years. This ranges from 10.6 % in Estonia to 177.1% in Greece (figure 8).

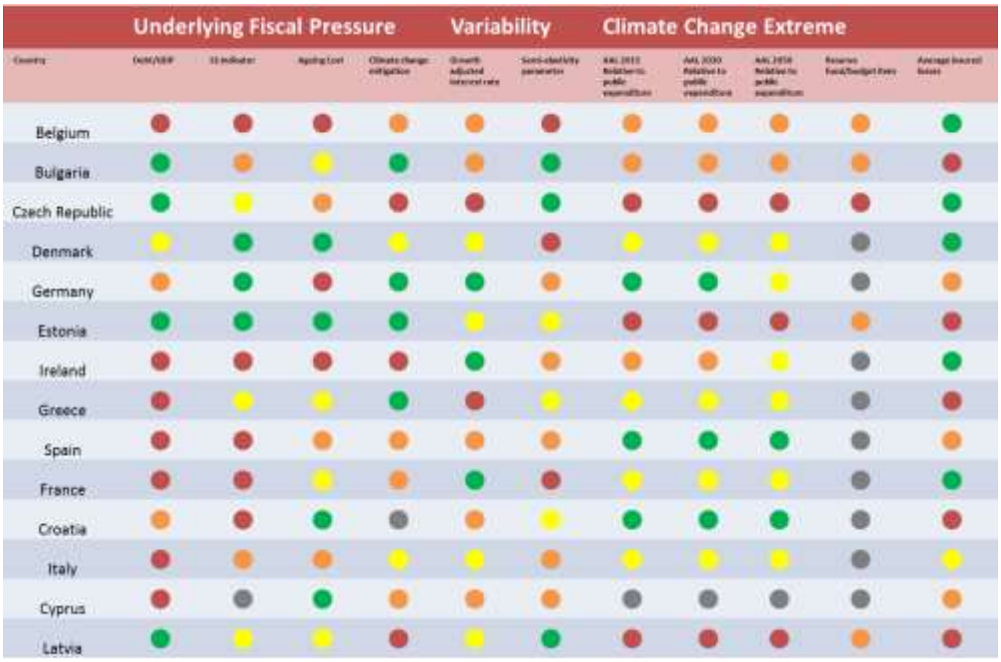

Figure 8: Fiscal Risk Scorecard applied to EU 28. Mochizuki et al., 2016

4.3 Lessons learnt, recommendations and guidance

We distil relevant lessons and guidance from our applications of innovative tools for fiscal climate risk management.

We find that the concept and method of risk layering integrated with a scenario-led participatory approach holds high appeal for many areas of disaster risk policy and management to work towards developing comprehensive risk management portfolios building on risk prevention, preparedness, risk financing and risk absorption. As well, applying the approach in a participatory environment can support negotiating roles and responsibilities public and private sector players through formalised dialogue or informal role-play and other participatory exercises.

Assessments of challenges related to extreme events have not been well linked to future scenarios of climate and socio-economic change in order to understand future risks and risk management options.

The climate risk scorecard and stochastic debt-assessment illustrate the importance of fiscal mainstreaming of climate risk in EU member countries. Focusing on increased flood risk in EU countries, economic risk of climate extreme events, relative to the size of economic and public finance resources available, is estimated to be high in a number of countries. At the same time, these countries also face the need for fiscal consolidation in the medium to longer-term, thus making proactive risk management especially important for these countries.

At the EU level, longer-term fiscal planning has thus far focused on incorporating the increased cost of ageing-related expenditure, whereas climate-related costs are only just beginning to be analysed. Unlike ageing cost estimates, which are projected using common underlying assumptions and shared widely with public and relevant institutions, climate related fiscal cost considerations still lacks such harmonized estimation methodology. As this report illustrates, shared socioeconomic pathways scenarios (SSPs) provide a useful framework for linking inter-related dimensions of demography, climate change and other socioeconomic trajectories, and this kind of approach will likely be effective in linking various fiscal policy concerns and designing appropriate fiscal risk managing policies under changing climate and socioeconomic trends. As EU member states strive for fiscal consolidation, sustainable growth and climate risk management in coming years, mainstreaming of climate risk into fiscal planning is becoming increasingly important.

5 Conclusions: an increasing role for climate risk management

Our research, conducted jointly with key stakeholders in some EU member states, has focussed on and identified DRM as an entry point for (early) climate adaptation. The analysis demonstrated that investment into climate-related risk (mostly, flood-risk) management has the potential to yield tangible and high economic returns across Europe. Currently, the level of sophistication in methodological approaches to disaster risk appraisal varies significantly, from simple updates of protection design standards (based on a 'most-likely' scenario of future climate changes), to complex applications of alternative climate and development pathways analysis.

The evidence generated shows that policy and scientific discussions are on-going, with government officials, academic researchers and stakeholders deliberating different aspects of iterative decision-making. The report also highlighted the complexity of decision-making and the interplay of local, regional and national actors. We worked out a number of analytical contributions, such as generation of database on investment, the role of risk layering in identifying roles and responsibilities, forward-looking fiscal risk modelling linked to climate scenarios, scorecard approach for considering climate-related fiscal side-side with other critical fiscal variables and stressors.

The issues analysed and presented in this synthesis are bound to remain of high importance. Over the last few years, public sector risk management and investment in many countries exposed to disaster risk has seen a step change. Based on experiencing and better understanding the large fiscal and economic burdens from disasters, fiscal and development planning has graduated from a perspective of risk ignorance to one of risk awareness. This effectively means that increasingly risk is explicitly taken into account in fiscal decisions and is being considered as part of contingency liability planning indicating a shift in perspectives from a risk-neutral to risk-averse planning stance.

Progress in fiscal risk planning has been achieved based on tools available to systematically assess and manage risks in the fiscal balance sheet (fiscal risk and hedge matrices). Better risk planning may lead to improved risk detection across sectors. Countries have started to develop broad risk matrices that chart out probability vs. impact for many diverse risks, which helps to consider measures that broadly enhance fiscal stability. Reduced budgetary uncertainty allows governments to focus less on crisis management and more on longer-term issues. Overall, there is increasing recognition that a broad-based perspective is necessary to incentivize risk reduction, avoid risk creation and generate additional co-benefits that go beyond the direct and indirect gains from reducing risk. Co-benefits can be achieved by better integration of disaster risk management with fiscal risk management, public debt management and development policy and planning.

Figure 9: Shifting perspective in the assessment of fiscal risks. Mechler, Hochrainer-Stigler and Mochizuki 2016.

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

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