Centre for Climate Change Economics and Policy

Grantham Research Institute on Climate Change and the Environment

A strategic approach to adaptation in Europe

Samuel Fankhauser and Raluca Soare

Policy paper

June 2012

Centre for Climate Change Economics and Policy

Grantham Research Institute on Climate Change and the Environment

The Grantham Foundation for the Protection of the Environment

E·S·R·C Economic & Social Research Council

University of Leeds

LSE The London School of Economics and Political Science

The Centre for Climate Change Economics and Policy (CCCEP) was established in 2008 to advance public and private action on climate change through rigorous, innovative research. The Centre is hosted jointly by the University of Leeds and the London School of Economics and Political Science. It is funded by the UK Economic and Social Research Council and Munich Re. More information about the Centre for Climate Change Economics and Policy can be found at: http://www.cccep.ac.uk

The Grantham Research Institute on Climate Change and the Environment was established in 2008 at the London School of Economics and Political Science. The Institute brings together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy-relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment, which also funds the Grantham Institute for Climate Change at Imperial College London. More information about the Grantham Research Institute can be found at: http://www.lse.ac.uk/grantham/

A Strategic Approach to Adaptation in Europe

Samuel Fankhauser [a, b] and Raluca Soare [b]

[a] Grantham Research Institute and Centre for Climate Change Economics and Policy
London School of Economics

[b] Vivid Economics

Abstract

Adaptation to climate change will be a permanent feature of decision making from now on. As such it is important to go about it in a strategic, rational way. This paper explores the key elements of a strategic approach to adaptation and applies them to Europe. A strategic approach to adaptation involves setting priorities, both spatially (*where* to adapt) and inter-temporally (*when* to adapt). The paper reviews the available evidence to indicate geographic adaptation priorities. In terms of inter-temporal priorities, it recommends fast-tracking two types of action: Win-win measures that yield an immediate return, such as water efficiency, and strategic decisions on infrastructure and planning that have long-term consequences for Europe's vulnerability profile.

A strategic approach to adaptation involves careful project design to ensure adaptation measures are cost-effective (*how* to adapt). An important complication in this respect is the deep level of uncertainty that still exists about future climate change at the local level. This puts a premium on flexible designs that can be adjusted when new information becomes available. The final element of a strategic approach to adaptation is division of labour between the state on the one hand, and private actors (households and firms) on the other (*who* should adapt). The paper argues that the traditional functions of the state – the provision of public goods, creation of an enabling environment and protection of the vulnerable – also apply to adaptation.

Key words: adaptation, adaptation economics, climate change vulnerability, Europe

Acknowledgements: This paper is based on a Vivid Economics report commissioned by the European Investment Bank. We are grateful to Sebastian Catovsky, Atanas Kolev, Nicola Ranger and Armin Riess for their comments and feedback. Fankhauser also acknowledges financial support by the Grantham Foundation for the Protection of the Environment, the UK Economic and Social Research Council (ESRC) and Munich Re.

1 Introduction

Policy makers are still struggling to make sense of the notion of adaptation to climate change. On the one hand, adaptation (unlike mitigation) is clearly in the self-interest of people and the human race has proven to be singularly adept at dealing with different climate conditions. It seems natural therefore to see adaptation as something people, in developed societies at least, will do without much help or encouragement.

On the other hand, adaptation will be a complex and pervasive task. Our socio-economic structures are finely tuned to the climate we find ourselves in. Adaptation to the current climate is reflected in consumption choices, cultural norms, production techniques and the design of buildings and infrastructure. Adaptation to future climate change will affect many, perhaps most, of these behaviour, consumption and investment decisions. On closer inspection it also becomes apparent that we are not as well adapted to the current climate as one might think. There are instances of maladaptation. The empirical literature on how people adapt in practice has identified multiple market, information and policy failures (Hanemann 2008).

So there is a case for policy intervention. But policy makers struggle to define how those interventions should look and how to respond rationally to the need for adaptation. The conceptual literature contains several methodologies and "how to" manuals for adaptation practitioners (Ranger et al. 2010; Swiss Re 2009; Parry and Carter 1998; Carter et al. 1994). They offer important pointers for practitioners on how to devise a sensible adaptation framework.

At the same time there is a need to adopt a more rational, strategic approach to the problem. Many climate change assessments to date have aimed at producing a comprehensive inventory of climate risks (e.g., DEFRA 2012 and, for that matter, Parry et al. 2007). This is impossibly ambitious. The purpose of an adaptation plan cannot be to produce a complete blueprint for future adaptive action. Rather it should highlight areas of likely risk, establish priority responses and set the principles of good adaptation.

To make headway on a more strategic approach to adaptation it is worth remembering what basic welfare economics teaches us on issues such as risk management, project appraisal, market failures and intertemporal optimisation. Public economics can inform on the role of the state and the extent to which adaptation is a public policy issue. The purpose of this paper is to tease out these basic principles and illustrate them using Europe as an example. Europe is perhaps not as vulnerable to climate change as other world regions, but its adaptation challenges should not be underestimated (Parry et al. 2007; PESETA 2009, ESPON 2011).

The paper is structured around four basic questions that are at the centre of a strategic approach to adaptation. Section 2 asks about spatial priorities (*where to adapt*).Where are the key climate change risks and vulnerabilities? What should therefore be the geographical and sector priorities for adaptation? Section 3 explores inter-temporal priorities (*when to adapt*). Given that climate change is a long-term issue, how can adaptation be sequenced? What type of activities needs to be initiated now? Section 4 looks into the design and appraisal of adaptation option (*how to adapt*). How should good adaptation projects be designed? How can adaptation respond to the high degree of uncertainty about future climate risks? Section 5 asks about responsibilities for adaptation (*who should adapt*). To what extent will adaptation be undertaken autonomously by the private sector? To what extent will private adaptation be hindered by policy, market and information barriers, and what is therefore the role of the state?

2 Where to adapt

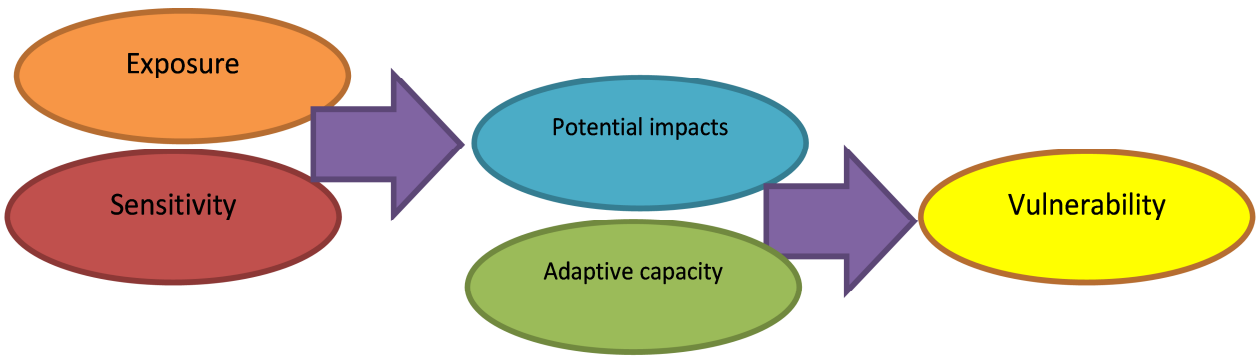
The first step in a strategic approach to adaptation is to develop an understanding of the main areas of vulnerability to climate change. A broad sense of the main vulnerabilities will help policy makers to set the right sector and geographic priorities.

Developing this sense of key vulnerabilities is not the same as adopting a traditional science-first approach to adaptation (Ranger et al. 2010). Science-first analysis starts with a study of the possible climate change outcomes and quantifies in some detail the likely effects of climate change under each scenario. The need for adaptation would then follow from the nature of these effects (see e.g. World Bank 2010a).

While science-first is the method of choice for impact assessments, it raises issues for adaptation analysis. First, it may lead analysts to underestimate the level of uncertainty. Given the analytical effort involved in developing local climate scenarios, studies typically have to restrict themselves to a small number of scenarios for which adaptation measures are fine-tuned. However, rational adaptation decisions will have to account for the full range of possible climate outcomes and not just one particular scenario. Second, there are problems with the timeframe. Most "science-first" studies focus on the period 2050-2100 for which climate models give the clearest results. However, the timeframe for adaptation decisions is rarely more than 10-20 years. Third, with the bulk of the effort devoted to getting the climate scenarios right, insufficient attention is paid to the actual adaptation decisions and the economic and institutional context in which they are made.

Ranger et al. (2010) therefore advocate a "policy-first" approach that puts adaptation decisions at the centre of the analysis. However, even under a "policy-first" approach it is important to develop at the outset a broad sense of the main areas of vulnerability. Vulnerability to climate change is a function of the potential impacts and the capacity of a society or system to adapt. The potential impacts are in turn determined by the system's exposure and its sensitivity (figure 1). That is, an assessment of climate vulnerabilities is broader than an impact assessment. It also takes into account the capacity to adapt. In the remainder of this section we use readily-available information on exposure, sensitivity and adaptive capacity in Europe to develop a high-level sense of what some of the main areas of vulnerability in Europe might be.

Figure 1. **Vulnerability is a function of exposure, sensitivity and adaptive capacity**



Source: IPCC.

2.1 Exposure

A picture of Europe's exposure to climate change can be drawn from various impact studies (e.g., Parry et al. 2007, PESETA 2009, ESPON 2011). They suggest that, in terms of temperature, and dependent on the emission scenario, Europe may see a rise in annual temperature of 0.1 to 0.4°C per decade to 2100, with warming greatest over Eastern Europe in winter and over western and southern Europe in summer. As an illustration, for a mean temperature increase of 2.5°C (expected by 2080), temperatures may increase by 1 to 2°C in the British Isles, whereas in the very northern part of Scandinavia and central Spain the temperature rise could exceed 3°C (PESETA 2009).

For all emission scenarios, mean annual precipitation generally increases in northern Europe and decreases further south, with substantial variation in seasonal precipitation across seasons and regions. Annual runoff is expected to increase in Atlantic and northern Europe, and decrease in the Mediterranean. The duration of snow cover at middle elevation in the Alps is expected to decrease by several weeks for each degree of warming. Low-lying coastlines with high population densities and small tidal ranges, such as the southern North Sea and coastal plains/deltas of the Mediterranean, Caspian and Black Seas are most exposed to sea level rise.

Warmer, drier conditions in the Mediterranean are likely to result in more frequent and prolonged droughts, heat waves, a longer wildfire season and increased fire risk. Winter floods are likely to increase in maritime regions. Flash floods are likely to increase throughout Europe, in particular in major river basins such as the Loire, Garonne and Rhone in France, the Po in Italy and the Danube in Central Europe .

2.2 Sensitivity

Sensitivity to climate events is a function of economic structure (e.g. reliance on sectors like agriculture), environmental management (e.g., the baseline stress put on the natural environment) and bio-physiological factors (acclimatisation, age of population). We may thus distinguish between economic, environmental and societal sensitivity.

In terms of economic sensitivity, countries with bigger agricultural sector (e.g. Romania, Greece, Slovakia, Slovenia, Italy, and France) will, all else equal, be more affected by climate change. The sign of the effect depends on the type of exposure. Crop productivity is projected to increase in northern Europe, but may fall elsewhere (Parry et al., 2007). Northern European countries with an important forestry and logging sector (e.g. Finland, Estonia, Latvia, Sweden) may also benefit as forests are projected to expand in northern Europe and retreat in the south (Parry et al. 2007). In addition to these direct effects there may be indirect sensitivities through higher crop prices for agribusiness and consumers. These are harder to ascertain as it depends on economic structure, market dynamics, and internal and external trade patterns.

Another sector that is sensitive to climate change is tourism (PESETA 2009). The Alpine region and the Mediterranean are two major touristic hotspots that are also exposed to climate change (ESPON 2011). In terms of gross value added, the countries with the biggest tourism industries in these regions, and thus the highest sensitivity, are Spain, Greece, Austria, Italy and France. Overall, the top five[1] tourist destinations in Europe, ranked by number of tourists, are Germany, France, the UK, Italy and Spain.

[1] based on EUROSTAT 2010 data (2009 for Italy)

One of the most important aspects of societal sensitivity is demographic trends, and in particular Europe's ageing population. Older people tend to be more sensitive to extreme weather events and often have a lower adaptive capacity (see below). Other factors that may affect sensitivity include migration patterns (e.g. towards or away from risk zones like coasts), public health issues, cultural habits and urbanisation, although the relative sensitivity of urban and rural areas is still poorly understood.

A key issue in terms of environmental sensitivity is water use, although there are broader concerns related to environmental mismanagement, including pollution (which can be exacerbated by climate conditions) and the overuse of natural resources, such as fish stock. High water stress areas could increase from 19 per cent in 2009 to 35 per cent by the 2070s (European Commission, 2009). The level of water extraction, relative to resources, varies, but is particularly high in Mediterranean countries (e.g., Croatia, France, Spain, Turkey), where climate change is expected to lead to a fall in precipitation. Irrigation uses a large part of water resources in Spain, Greece and Portugal, while France and Hungary have a high need for cooling water in their electricity sectors.

2.3 Adaptive capacity

Adaptive capacity, or the ability to respond to climate stress, is difficult to quantify. There is a strand of literature that aims to understand adaptive capacity at a global level (Brooks et al. 2005, Tol and Yohe 2007). It identifies factors such as income inequality, per capita income, the level of education, access to finance and insurance, and the quality of institutions as key determinants of adaptive capacity. There are also methods to determine adaptive capacity at the level of an institution, which assess factors like awareness of climate change, leadership, systems of reporting, the skills of individuals, the ability to learn and innovate and the ability to engage with stakeholders.[2]

It is hard to draw firm conclusions from the existing literature on adaptive capacity in Europe. Institutional assessments are too few to allow a credible extrapolation, while the global studies are not granular enough to determine differences in adaptive capacity among advanced countries. Most of them have uniformly high scores for indicators like education and institutional strength.

Nevertheless, the available evidence would probably suggest that there are differentials in adaptive capacity between Northern Europe on the one hand and southern and central Europe on the other. Adaptive capacity is strongly correlated with income, and it is therefore a reasonable conjecture that it will be lower in the southern and eastern parts of Europe.

3 When to adapt

While some impacts of climate change can already be felt, the most severe effects are not expected to become manifest for several decades. The speed with which adaptation measures are initiated and ramped up is therefore an important decision. The theory of adaptation timing has been set out in Fankhauser et al. (1999). They find two cases where it may be worthwhile to bring adaptation action forward:

- ***Early benefits***: Fast-tracking adaptation makes sense if the proposed measures have immediate benefits that would be otherwise be forgone. These early benefits could be related to the management

[2] See e.g. http://www.pact.co/pact_in_use

of current climate variability, efforts to reduce greenhouse gas emissions or the removal of broader market and policy failures.

- ***Costly lock-in***: Fast-tracking adaptation is also desirable if acting today costs less than acting tomorrow, even when taking discounting into account. This may happen if today's decisions lock society into a particular development or infrastructure path that would be costly to reverse later.

3.1 Early benefits

Not many studies systematically evaluate a wide set of adaptation options in terms of costs and benefits. Two recent examples are Swiss Re (2009) and ASC (2011). Both find substantial scope for adaptations that would be economically attractive even in the absence of climate change. Examples include:

- Improvements in ***water efficiency***, which would help to ease both current and future pressure on water resources. As shown in section 2 many European regions have high water abstraction rates and would be sensitive to a reduction in water availability. However, according to one study 20-40% of Europe's water is wasted and a 40% increase in efficiency is possible through known technological improvements (Ecologic, 2007). ASC (2011) identifies a number of attractive measures for residential water efficiency, such as low-flow taps, showers and toilets that are cost-effective when installed as part of an end-of-life replacement and may be mandated for new buildings. Efficiency improvements in hot water use would also have important emission reduction benefits.

- ***Flood protection*** measures either at the community or buildings level. For the latter, options include airbrick covers, door-guards, repointing of walls, drainage bungs and non-return valves, which ASC (2011) found to be cost-effective either as part of a wider renovation or in new buildings. Flood protection at the community level, even if cost-effective, can be expensive. According Britain's National Audit Office (2011), the annual spend on flood defences in the UK reached £664m in 2010/11. However, there are also cheap organisational measures that can improve flood risk management, such as awareness campaigns for local residents (e.g., risk profiles for individual homes, Swiss Re 2009) and improved emergency response training.

- Measures to deal with ***heat stress.*** The 2003 heat wave revealed shortcomings in heat management plans across Europe. Many of the response systems have since been upgraded, but better preparedness for heat waves can potentially be cost-effective. France, which suffered the highest casualty rates in 2003, has introduced a sophisticated new Heat Health Watch Warning System (Pascal *et al*. 2006), which is now replicated elsewhere. In buildings, additional no-regrets measures include window shading and investment in energy-efficient appliances that produce less waste heat (ASC 2011).

- Protection and better ***management of environmental resources***, as healthy ecosystems are more resilient and better able to adapt to climate stress. The management of European fish stocks is an obvious case in point , but there are also terrestrial examples, for instance related to agricultural practices.

This list is not exhaustive, but it illustrates the scope for adaptation measures that address both current policy issues and future climate risks.

3.2 Costly lock-in

Many decisions taken today have the potential to affect our vulnerability profile for decades. For these strategically important decisions it is important to factor in adaptation concerns right now. The most obvious cases are (Agrawala and Fankhauser 2008, Fankhauser et al. 1999):

- Long-lived ***infrastructure investments*** such as ports, water supply systems, flood protection schemes and coastal defences. These structures are both sensitive to the impacts of climate change and sufficiently long-lived to experience change during their economic life. The infrastructure needs in Europe are expected to cost trillions of euros over the coming decades (OECD 2006). Not all of the investments are sensitive to climate change. Indicative guesstimates suggest that the cost of "climate-proofing" those that are could add 5-20% to capital costs (Fankhauser 2010; Agrawala and Fankhauser 2008).
- A similar story holds for the design of ***buildings***, which are also long-lived. While some adaptive measures can be retrofitted cost-effectively (e.g., to save water, see above), others are best incorporated into the design of the building. In 2010 more than 1.5million housing permits were issued in the EU, and construction started on close to 1 million homes (European Mortgage Federation 2010).
- A third category of strategically important decisions is ***planning***, in particular whether or not to allow further economic development in potential hazard zones such as flood plains. The ASC (2011) found increased development in flood risk areas in eight of the nine UK localities studied, and along eroding coast lines in three of the four coastal communities studied.

  How climate risks are best taken into account in these decisions is not straightforward. Concern about climate change does not imply foregoing all development in risk areas, for example. If combined with appropriate defensive investment (such as flood protection) they may well be justified. However, it implies thoughtful decision making that weighs up development benefits, adaptation costs and climate risks. In the Netherlands, the Delta Commissie (2008) already recommends a cost-benefit analysis for new urban developments in flood-prone areas. The UK Green Book on public project appraisal also contains guidelines on adaptation. Overall, however, there is still considerable scope for improvement, including in international institutions (Sveiven 2010).

4 How to adapt

It is easy to maladapt. The careful design and thorough appraisal of adaptation projects are therefore important. A well-established set of tools is available to ascertain the value-for-money of adaptation investments, both from a societal (economic) and investors (financial) point of view, including cost-benefit analysis and cost-effectiveness analysis.

Although these techniques are used in a growing number of case studies, our understanding of the costs and benefits of adaptation is still patchy and concentrated in a few sectors, most notably agriculture and coastal zones (Agrawala and Fankhauser 2008). In agriculture there is evidence that low-cost adaptation measures like changes in planting dates, cultivars, fertilizer use and management practices will be able, when the time comes, to reduce the effect of climate change on crop yields by often more than half. A study on coastal protection in the European Union reports benefit-cost ratios of 1.1 – 2.6 by 2020, rising to 4.3- 6.5 by 2080 (European Commission 2007).

Since these studies focus on some of the most obvious low-regrets measures the high benefit / cost ratios are not unexpected. The question is how the return on adaptation changes as we move to less

straightforward and more costly adaptation measures. As seen above, Swiss Re (2009 and ASC (2011) found considerable scope for no-regret adaptations in areas like water efficiency. However, they also show that further up the 'adaptation cost curves' there are measures that fail the cost-benefit test.

Since they make sense independently of the expected climate change scenario, no-regrets options can be pursued without the need for complex uncertainty analysis. However, for other priority investments this will be essential. Adaptation decision makers have very high demands on climate information. They need to know climatic trends at a localised level, not just for temperature, but for precipitation, flood probabilities, wind speeds and much else. In addition to mean changes they need to know seasonal patterns, daily fluctuations and changes in extremes. Climate models cannot yet produce credible information at this level. Adaptation decisions are therefore inherently made under uncertainty; some would say deep uncertainty or ambiguity (Millner et al. 2010).

Several decision making methods are available to deal with this issue (Ranger et al. 2010). Expected value and expected utility maximisation are the standard tools if the set of possible climate outcomes can be quantified and their probabilities are known. Scientists have used ensemble forecasting (the distribution of results from several climate models and model runs) to approximate impact probabilities, thus potentially enabling the use of these standard tools. However, some scientists doubt the validity of the probabilities (Stainforth et al 2007). This would suggest the use of non-probabilistic approaches like maximin, which focuses on the worst possible outcome, or info-gap decision theory, which emphasises the robustness of a decision. Analysts who question whether impacts can be monetised would prefer multi-criteria analysis. Option theory becomes relevant if there is learning about the true state of nature.

While the theory of decision making under climate change uncertainty is complex, there are some straightforward practical implications. Adaptation measures should be flexible, that is, allow for revision at a later date when new information is available, or it should be robust to a wider range of climate scenarios (Fankhauser et al. 1999).

Flexibility intuitively means emphasis on behavioural and regulatory, rather than structural measures. A standard example is the superiority of water efficiency measures over investment in new supply infrastructure. Similarly, trade openness, labour mobility and the free flow of capital can increase the flexibility of economic systems to respond to climatic shocks, although openness can also amplify shocks, for example if it leads to capital outflows (Bowen et al. 2012). Even for structural measures it is possible to maintain a degree of flexibility, as the examples of the Thames Gateway in the UK (Reeder and Ranger 2010) and the Dutch approach to spatial planning (Deltacommissie 2008) show.

5 Who should adapt

Most adaptation will be undertaken by households and the private sector. Yet there is an important role for public policy, and much of the discourse in fact treats adaptation as a public policy issue. There are well-established principles in public sector economics on the role of the state, and they apply to adaptation. Accordingly, the state should involve itself in adaptation primarily for three reasons:

- ***Climate-resilient public goods***: Public goods like infrastructure are generally provided or at least commissioned by the state. There may be an increased demand for public goods specifically dedicated to adaptation, such as better sea defences. In addition, as the provider of traditional public goods like water supply networks, it may also fall to the state to ensure they are "climate proof".

- ***Barriers to adaptation***: Market imperfections, policy failures and behavioural barriers may prevent or distort the uptake of adaptation measures. It is a classic function of the state to remove such barriers and create an environment that is conducive to effective adaptation.
- ***Assistance to vulnerable groups***: Another key role of government is to assist population groups that cannot adapt sufficiently themselves. Public bodies will have an important role to play in protecting vulnerable segments of the populations against climate change, including through emergency services.

As European governments begin to grapple with these responsibilities (Swart *et al* 2009), this section reviews the case for public adaptation.

5.1 Public goods

Some adaptation measures are public goods, that is, they are non-rival and non-excludable. Typical examples include community-level flood protection, storm warning systems or coastal defence structures. Climate information – in the form of climate change model runs or impact scenarios, for example – can in principle be made excludable, but most analysts would agree that information has public good features. The same holds for research and development, for example in drought-resistant crops. It is possible to protect the intellectual property of innovators in these areas, but innovation clearly has aspects of a public good.

Public goods are underprovided by the market and governments intervene to correct this failure. In some cases government agencies become the provider of the goods – for example, in the case of state-owned infrastructure – in others the state commissions their provision from the private sector or overcomes the market failure through regulatory means, such as the granting of patents.

Public goods related to climate protection (and by extension climate change adaptation) are typically provided directly by the state. There are very few flood protection, coastal defence or climate information projects that are provided through public-private partnerships or PPPs (Agrawala and Fankhauser 2008). Rare exceptions are the Broadland scheme in East Anglia (UK), where flood risk management in an area of special interest has been outsourced to a private contractor (Environment Agency 2009), and the Border Meuse project, one of the biggest river flood defence projects in the Netherlands.[3]

There are several factors that make PPPs for adaptation difficult (Agrawala and Fankhauser 2008, World Bank 2010b). Governments are attracted to PPPs either because a private contractor can provide a superior level of service or because the cost of the scheme can be moved off the government's balance sheet. Neither possibility is likely in the case of adaptation. Once built, the operation of adaptation schemes is relatively straightforward, leaving little room for efficiency gains through private management. Moreover, the lack of an independent revenue stream means contractors have to be paid by the government, so the liability will remain on the government's balance sheet. For these reasons it is likely that dedicated adaptation measures of a public good nature will be the responsibility of the public sector.

Arguably the bigger task for the state, however, will be to "climate-proof" conventional public goods like national infrastructure. In cases where their provision has remained in state hands adaptation will also be a government responsibility. However, there are many instances where infrastructure services are provided by private contractors, such as private water utilities, energy companies or road concessionaires. In those cases, the onus of adaptation will fall on the private contractor. Some of their performance targets already

[3] See http://www.vanoord.com/gb-en/our_activities/project_selector/border_meuse/index.php

expose operators to climate risk, such as quality targets for water utilities, availability payments for road concessionaires or reliability targets for rail franchises.

5.2 Barriers to adaptation

The process of adaptation is neither smooth nor automatic. Case studies of adaptation behaviour with respect to both current and future climate risks reveal an abundance of institutional, policy and market failures (Hanemann 2008; Sobell and Leeson 2006). It is the role of government to address barriers to effective adaptation. Unlike the provision of public goods, which requires physical investment, the government's response to adaptation barriers is primarily institutional and regulatory. The main issues that will need government intervention can be grouped into three broad categories (Cimato and Mullen 2010; Productivity Commission 2011).

First, adaptation may be held back by shortcomings in the ***institutional and regulatory*** environment. In the UK, ASC (2011) hints at regulatory barriers (e.g. in the design of abstraction licences, limited water metering) that might hold back efficient adaptation in the water sector. Many of these problems are already manifest in the response to current climate risks. Sobell and Leeson (2006) detail how a layered bureaucracy, an incentive structure that rewards over-cautiousness and the political manipulation of relief aid, among other factors, hampered the response to hurricane Katrina.

Second, adaptation decisions may be affected by ***market failures***, some generic, others particular to adaptation. There may be asymmetric information, for example, between the buyer and seller of a property about its risk profile. There may be issues of moral hazard for people with insurance cover or with at-risk communities holding out for government assistance. Path dependence may affect the choice between protection and relocation, for example, for highly vulnerable, but unique locations like Venice.

A key market failure is externalities and more generally the lack of coordination, for example between upriver and downriver communities. In a world with multilevel governance the need for coordination may be international as well as national and local. Coordinated EU action may be needed, for example, in integrated sectors such as agriculture, water, biodiversity, fisheries and energy networks.

The third category are ***behavioural and information barriers.*** Complex, long-term adaptation decisions are knows to be affected by cognitive barriers. Hanemann (2008) talks about "the lack of perception of a need for action, and the lack of perception of a benefit from the action". Cimato and Mullen (2010) identify inertia, procrastination and implicitly high discount rates as potential behavioural problems. Millner et al. (2010) question the ability of decision makers to process rationally the available information.

The first challenge, however, is to provide good quality climate information. This is seen as a priority in many national adaptation strategies, in the UK for example through the work of the UK Climate Change Impacts Programme.[4] The European Commission too is very actively supporting climate change impact research. While addressing these barriers may require state intervention, governments themselves may be afflicted by information problems (Sobell and Leeson 2006).

5.3 Assistance to vulnerable groups

Addressing questions of fairness and equity is the purview of public policy, and adaptation raises many distributional questions. Climate change itself is an agent of redistribution (Hanemann 2008), as different

[4] See www.ukcip.org.uk

regions, sectors and population groups will be affected differently. More generally, people look to the state for basic protection, social safety nets and assistance in case of emergencies. As the impacts of climate change become more noticeable, demand for these essential public services will rise.

However, it remains an open (and highly political) question to what extent the costs of adaptation – for example, for a flood protection scheme – ought to be borne by the beneficiaries of the measure and to what extent they should be socialised across a larger population group. Different societies will come to different conclusions. Denmark's national adaptation strategy, for example, emphasises "autonomous adaptation", which implies the transfer of adaptation costs to stakeholders and communities. In contrast, the French system envisages the use of public funds to indemnify people in areas that are vulnerable to flooding. Portugal also requires the government to keep a high level of involvement (Swart et al. 2009).

Another critical element is solidarity with vulnerable populations abroad. Low-income countries will be hit much harder by the impacts of climate change and their capacity to adapt will often be limited (World Bank 2010b). Ensuring climate-resilient development in low-income countries, through both official development assistance and additional climate finance, will be an important responsibility of European governments and aid agencies.

6 Conclusions

Adaptation will become a permanent feature of future decision making, and given its ubiquity it is important to go about adaptation in a strategic way. A strategic approach to adaptation involves setting priorities, both spatially and inter-temporally. Not every sector and country is equally vulnerable and not all adaptation has to start now, even if ultimately everybody will have to adapt. There is a question of *where* and *when* to adapt.

The paper reviews the available evidence on Europe's exposure, sensitivity and adaptive capacity to climate change to identify where the spatial adaptation priorities might lie. Most studies point to the fact that Southern Europe (and the Mediterranean region in particular) would be most affected, whilst Northern Europe may gain in some areas and lose in others. The north-south climate change impacts gradient is likely to increase economic disparities that are already apparent and straining European cohesion. Although we have not attempted to measure the capacity to adapt, it is a reasonable conjecture that it will be lower in the southern and eastern parts of Europe.

In terms of inter-temporal priorities, adaptation theory recommends fast-tracking two types of action. The first are win-win measures that yield an immediate return. The second are strategic decisions that have long-term consequences and lock in an undesirable vulnerability profile. Win-win adaptations include measures such as water efficiency, improved flood protection, better emergency services and the careful management of the natural environment. Strategic decisions that should take climate change into account now include long-lived infrastructure investments, such as flood defences and water supply networks, which will be in use long enough to experience a change in climate. Other examples of strategic decisions include the design of buildings and planning – e.g. the development of areas prone to floods, water shortages or wildfires.

A strategic approach to adaptation also involves careful project design: the question of *how* to adapt. It is easy to mis-specify adaptation measures. A key complication particularly for long-lived, strategic adaptations is that we do not know the future climate to which long-lived assets need to be adapted. This deep level of uncertainty puts a premium on flexible designs that can be adjusted as new information

becomes available. Experience in the Netherlands and the UK shows that such flexibility can also be introduced even into large physical investments.

The final element of a strategic approach to adaptation is the allocation of responsibilities between the public and private sector: The question of *who* should adapt. Adaptation is to a large extent a private activity. Yet, there is an important role for the state. The paper identifies three core government responsibilities. The first is the supply of public goods, which includes both the provision of public adaptation goods like flood defences, and the climate-proofing of conventional public goods, such as roads and water networks. The second function of the state is to protect vulnerable population groups, for example by providing adaptation assistance or emergency services after extreme events. The third function is to remove market and policy barriers that may prevent effective adaptation. There are quite a few such barriers, including coordination problems between adapting communities, skill gaps and information asymmetries.

European countries are awakening to the challenge of adaptation. Several of them have commissioned climate change impact / adaptation studies or have put in place a national adaptation strategy. Organisations that are used to dealing with climate variations, such as water companies and environment agencies, are beginning to factor climate change into their approaches to current climate risk. However, there are still many instances where business and policy decisions lead to an increase in vulnerability. Adaptation to climate change is not yet a mainstream policy issue.

References

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

ASC (2011). *Adapting to Climate Change in the UK. Measuring Progress,* UK Adaptation Sub-Committee, London.

Bowen, A., S. Cochrane and S. Fankhauser (2012). "Climate Change, Adaptation and Growth", in: *Climatic Change,* DOI 10.1007/s10584-011-0346-8.

Brooks, N., Adger, W. N. and Kelly, P. M. (2005) "The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation", in: *Global Environmental Change* 15(2), 151-163

Carter, T.R., M.L. Parry, H. Harasawa, and S. Nishioka (1994). *IPCC Technical Guidelines for Assessing Change Impacts and Adaptations*, London: Department of Geography, University College London.

Cimato, F. and M. Mullen (2010). *Adapting to Climate Change: Analysing the Role of Government*, Defra Evidence and Analysis Series, Paper 1, UK Department for the Environment, Food and Rural Affairs, January.

DEFRA (2012). *Climate Change Risk Assessment*. UK Department for the Environment, Food and Rural Affairs, January.

Deltacommissie (2008). *Working together with water: findings of the Deltacommissie.*

Ecologic, Institute for International and European Environmental Policy (2007). *EU water saving potential (Part 1 – Report, Part 2 – Case Studies): final report*. July.

Environment Agency (2009). *Managing flood risk with a long-term contract.* Flood and Coastal Risk Management Case Studies, June.

ESPON (2011). *Climate change and territorial effects on regions and local economies: draft final report*. European Spatial Planning Observation Network, February.

European Commission (2009). *Adapting to climate change: towards a European framework for action*. White Paper, {SEC(2008) 386}{SEC(2008) 387}{SEC(2008) 388}.

European Commission (2007). *Accompanying Document to the Communication of the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee on the Regions on Limiting Global Climate Change to 2 degrees Celsius*, Brussels.

European Mortgage Federation (2010). *HYPOSTAT 2010: a review of Europe's mortgage and housing markets.*

Fankhauser, S. (2010). "The costs of adaptation", in: *Wiley Interdisciplinary Review Climate Change*, 1(1): 23 - 30.

Fankhauser, S., J. B. Smith and R. Tol (1999). "Weathering Climate Change. Some Simple Rules to Guide Adaptation Investments", in: *Ecological Economics*, 30(1): 67-78.

Hanemann, M. (2008). *Observations on the Economics of Adaptation: Uncertainty and Timing*, Presentation at the OECD Workshop on the Economics of Adaptation, Paris, April.

Millner, A., S. Dietz and G. Heal (2010) *Ambiguity and climate policy*, Grantham Research Institute on Climate Change and the Environment Working Paper No. 24, December.

National Audit Office (2011). *Flood risk management in England*. October.

OECD (2006). *Infrastructure to 2030 – Telecom, Land Transport, Water and Electricity*.

Parry, M., O. Canziani, J. Palutikof, P. van der Linden, and C. Hanson, eds. (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, UK.

Parry, M., and T. Carter (1998) C*limate Impact and Adaptation Assessment: A Guide to the IPCC Approach*, London: Earthscan.

Pascal, M., K. Laaido, M. Ledrans, E. Baffert, C. Caserio-Schönemann, A. le Tertre, J. Manach, S. Medina, J. Rudant, P. Empereur-Bissonnet (2006). "France's heat health watch warning system", in *International Journal Biometeorol*, 50:144-153, doi: 10.1007/s00484-005-0003-x.

PESETA (2009). *Climate change impacts in Europe: final report*. Project on Projection of Economic impacts of climate change in Sectors of the European Union based on boTtom-up Analysis, IPTS Seville.

Productivity Commission (2011). *Barriers to Effective Climate Change Adaptation.* Issues Paper, Productivity Commission of the Government of Australia, October.

Ranger, N., A. Millner, S. Dietz, S. Fankhauser, A. Lopez and G. Ruta (2010). *Adaptation in the UK: A Decision Making Process.* Grantham Research Institute on Climate Change and Centre for Climate Change Economics and Policy, London School of Economics.

Reeder and Ranger (2010). *How do you adapt in an uncertain world? Lessons from the Thames Estuary 2100 project*. Grantham Research Institute on Climate Change and Centre for Climate Change Economics and Policy, London School of Economics.

Sobel, R. and P. Leeson (2006). "Government's response to Hurricane Katrina: A public choice analysis," in: *Public Choice* 127(1): 55-73.

Stainforth, D., M.R. Allen, E.R. Tredger, L.A. Smith (2007). "Confidence, uncertainty and decision-support relevance in climate predictions", in *Philosophical Transactions of the Royal Society*, 365: 2145-2161, doi:10.1098/rsta.2007.2074.

Sveiven, S. (2010). *Are the European Financial Institutions climate proofing their investments. IVM Institute for Environmental Studies*. Report R-10/07. November.

Swart, R., R. Biesbroek, S. Binnerup, T.R. Carter, C. Cowan, T. Henrichs, S. Loquen, H. Mela, M. Morecroft, M. Reese and D. Rey (2009). *Europe adapts to climate change: Comparing National Adaptation Strategies*. PEER Report No 1 Helsinki: Partnership for European Environmental Research.

Swiss Re (2009). *Shaping Climate Resilient Development*, Economics of Adaptation Working Group, http://www.swissre.com/rethinking/climate/shaping_climate_resilient_development.html.

Tol, R.S.J. and G.W. Yohe (2007), 'The Weakest Link Hypothesis for Adaptive Capacity: An Empirical Test', *Global Environmental Change,* 17: 218-227.

World Bank (2010a), *The Economics of Adaptation to Climate Change. Synthesis Report*. The World Bank, Washington DC.

World Bank (2010b). *World Development Report 2010. Development and Climate Change*. World Bank, Washington DC.