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An economic approach to adaptation: illustrations from Europe

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Abstract Policy makers are still struggling to find a rational and effective way to handle adaptation to climate change. This paper discusses a more strategic, economic approach to public adaptation and compares it with adaptation practice in Europe. An economic approach to adaptation involves setting priorities, both spatially (*where* to adapt) and inter-temporally (*when* to adapt). The paper reviews what we know about Europe's geographic adaptation priorities. On 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 spatial planning that have long-term consequences for Europe's vulnerability profile. An economic approach to adaptation involves careful project design to ensure adaptation measures are cost-effective and flexible in the light of climate uncertainty (*how* to adapt). The final element of an economic approach to adaptation is the division of labour between the state and private actors (*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.

1 Introduction

Policy makers are struggling with adaptation to climate change. On a fundamental level they wonder what the role of public policy in adaptation might be. On an operational level they find it hard to formulate a public response strategy that is both effective and practical to implement.

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 will do without much help or

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encouragement from governments. However, on closer inspection we find that we are not as well adapted to the current climate as one might think. The empirical literature on adaptation in practice has identified multiple market, information and policy failures (Hanemann 2008; Repetto 2008).

There is therefore a need for policy interventions. The question is what form these interventions should take. Adaptation will be a pervasive task. Our socio-economic structures are finely tuned to the climate we face today. 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. Coordinating changes of such breadth and intricacy is neither a realistic nor a desirable role for public policy.

Yet, explicitly or implicitly many early adaptation strategies have gone down this road. Most climate change assessments start from an impacts perspective. They aim is to produce comprehensive inventories of the likely climate risks from which an equally complete set of adaptation measures can be derived (e.g., DEFRA 2012a; Parry et al. 2007). This is impossibly ambitious. Climate change is too complex and our evidence base too patchy to allow for a centrally planned strategy.

There are other issues with this kind of "science-first" approach (Ranger et al. 2010). First, it leads analysts to underestimate the level of climate uncertainty. Given the analytical effort involved, and to avoid ballooning uncertainties, studies typically restrict themselves to a small number of climate scenarios for which adaptation measures are fine-tuned. The problem is that rational adaptation decisions ought to account for the full range of possible outcomes and not just a few scenarios. The second problem is the timeframe. Studies naturally focus on the period 2050–2100 for which climate models give the clearest results. Yet the timeframe for adaptation decisions is rarely more than 10–20 years. Third, with so much effort devoted to getting the science right, insufficient attention is paid to the actual adaptation decisions and the economic and institutional context in which they are made.

This paper instead proposes a more strategic, economic approach to public adaptation. Under this approach the remit of public adaptation strategies is much less ambitious, but more suitable to practical application. Rather than providing a comprehensive blueprint for future adaptation, the role of an adaptation programme is to highlight areas of likely risk, establish adaptation priorities and set the principles of good adaptation. We illustrate this approach using Europe as an example.

The core principles of this approach are derived from what public sector economics teaches us about issues like risk management, project appraisal, market failures and inter-temporal optimisation. Public economics can also inform on the role of the state and the extent to which adaptation is a public policy issue. The approach is related to what Ranger et al. (2010) call "policy-first" adaptation, particularly in its emphasis on risk and the need to make good adaptation decisions in light of climate uncertainty (see also Dessai and Hulme 2007).

Public economics has been applied to adaptation before (e.g. Hallegatte et al. 2011a, b; Agrawala and Fankhauser 2008), although most adaptation economics has focused on the *cost* of adaptation (Fankhauser 2010),[1] rather than adaptation *policy*. Few of the adaptation methodologies found in the literature take an explicitly economic approach (e.g., Carter et al. 2007; Parry and Carter 1998; Carter et al. 1994), and those that do neglect key features such

[1] Another strand of literature deals with the economic cost (damage) of climate change more broadly (e.g. Tol 2008). Adaptation costs are one main component of total climate damages. The other main component is residual damage that cannot be avoided.

as climate uncertainty (Swiss Re 2009). This paper synthesises and extends the existing economic approaches to adaptation. Perhaps the main value of the paper is the bridge it builds between adaptation theory and practice. The paper distils the lessons of several years of practical adaptation policy, gained mostly in the UK (ASC 2010, 2011, 2012), and combines them with the insights of economics. The paper is aimed both at academic readers with an interest in practical application and adaptation practitioners, who have found insufficient hands-on guidance in the conceptual literature on adaptation.

The paper is structured around four basic questions that any adaptation strategy has to answer. Section 2 asks about spatial priorities (*where to adapt*). Where are the key climate change risks and vulnerabilities? Section 3 explores inter-temporal priorities (*when to adapt*). Given that climate change is a long-term issue, how can adaptation be sequenced? Section 4 looks into the design and appraisal of adaptation option (*how to adapt*). How should good adaptation projects be evaluated? Section 5 asks about responsibilities for adaptation (*who should adapt*). To what extent will autonomous private adaptation be hindered by policy, market and information barriers, and what is therefore the role of the state?

2 Where to adapt

Like traditional "science-first" methods, an economic approach to adaptation involves extensive risk screening to develop an early understanding of the main areas of vulnerability. But compared to science-first there is less focus on detailed quantification and more on the strategic exploration of regional or sector differences in vulnerability, the drivers of vulnerability and the range of possible climate outcomes (e.g. Ranger et al. 2010; McKenzie-Hedger et al. 2006).

Understanding vulnerability is not the same as setting adaptation priorities. In setting priorities factors other than vulnerability also matter, including the urgency of action (e.g. because of imminent decisions with long-term consequences, see Section 3) or the ease with which a risk may be reduced (reflected perhaps in a benefit / cost ratio, Section 4). But the identification of vulnerability hotspots is nevertheless important in setting priorities. "Bearing the loss" will rarely be an option in high-risk areas.

An assessment of climate vulnerabilities is broader than an impact assessment in that it takes into account adaptive capacity (Füssel and Klein 2006). Following the standard definition we interpret vulnerability as the combined effect of climate impacts and the capacity to adapt to those impacts (e.g. Füssel 2007).[2] Both are explored in more detail.

2.1 Physical impacts

There is no shortage of climate change impact studies. The literature is vast. In the case of Europe important sources of information include IPCC (Parry et al. 2007), the European Environment Agency (EEA 2008), the PESETA study (Ciscar 2011 and other papers in the same special issue), the ESPON programme (ESPON 2011), the ATEAM project (Schröter et al. 2005) as well as national impact assessments (e.g., DEFRA 2012a). Results are hard to compare because the studies use different methods, assumptions and scenarios. Gaining a high-level sense of the main climate risks is nevertheless possible.

[2] Note that in its recent report on extreme events the IPCC uses a different definition of vulnerability (Field et al. 2012). A disproportionate amount has been written about the *right* definition for concepts like risk, exposure, vulnerability and sensitivity. For practical purposes *clear* definitions are generally all that matters.

The sources quoted above show pronounced regional differences in climate exposure. As an illustration, for a mean temperature increase of 2.5°C (expected by maybe 2080), the studies report a regional temperature increase of 1°C to 2°C in the British Isles, whereas in the northern part of Scandinavia and central Spain the temperature rise could exceed 3°C. Mean annual precipitation are expected to increase in northern Europe and decrease further south, with substantial variation across seasons and within regions. Warmer, drier conditions in the Mediterranean could result in more frequent and prolonged droughts, heat waves and increased wildfire risk. 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.

The wealth of data masks a profound level of uncertainty. Much remains unknown, especially at the local scale. Sometimes we are uncertain even about the sign of expected changes. The 2009 UK Climate Projections (Jenkins et al. 2010), for example, include precipitation scenarios that entail both drier and wetter conditions. Perhaps more fundamentally, the available studies rarely do justice to the full set of possible climate outcomes, and in particular tend to ignore the tail end of the impact distribution.

Adaptation practitioners need to understand the sensitivity of systems to these changes, as this will determine the ultimate impact. It is also important to analyse how sensitivity might change with socio-economic developments. Too many studies still impose climate change on today's socio-economic structures. 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 (see also ESPON 2011).

In terms of economic factors, countries with important weather-exposed sectors—such as tourism (e.g. Spain, Greece, Italy, France, Austria and Switzerland) and agriculture (e.g. Romania, Greece, Slovakia, Slovenia, Italy and France)—will, all else equal, be more sensitive to climate risk. Not all change may be negative, however. Crop productivity in northern Europe is projected to increase in the short term, for example. Northern European countries with important forestry sectors (e.g. Finland, Estonia, Latvia and Sweden) may also benefit as forests in northern Europe expand (Parry et al. 2007).

Economic sensitivity is not just about local circumstances. In open markets local impacts will spread, which means global trends can be as important as local developments. There is an international dimension to adaptation even at the local level. Understanding sensitivity to the international impacts of climate change requires the analysis of industrial structures (e.g. supply chains), global market dynamics (e.g. price expectations) and internal and external patterns of trade.

The main issue on environmental sensitivity is environmental mismanagement, with problems from habitat loss to pollution and the overuse of natural resources. European fish stocks are grossly overexploited, for example, and the level of water extraction, relative to resources, is precarious in many countries where climate change may lead to a fall in precipitation (e.g., Croatia, France, Spain, Turkey). When it comes to environmental management, climate change is just one of many stress factors.

Key drivers of societal sensitivity include poverty levels and demographic trends. There is clear evidence that low-income households are disproportionately affected by extreme weather events, chiefly because of sub-standard housing, poor access to infrastructure services and social exclusion (Fothergill and Peek 2004). A problem particular to Europe may be its ageing population. Older people tend to be more sensitive to extreme weather events and often have a lower adaptive capacity. 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.

2.2 Adaptive capacity

Adaptive capacity is a popular concept in the theoretical literature, but it is proving to be an elusive notion in empirical analysis. Studies that aim to understand adaptive capacity at a global level (e.g., Tol and Yohe 2007) focus on aggregate indicators like income inequality, per capita income, the level of education, access to finance, and the quality of institutions. There are also methods to determine adaptive capacity at the level of an institution, by assessing factors like awareness of climate change, leadership, systems of reporting, skills, the ability to learn and innovate and the ability to engage with stakeholders (e.g., DEFRA 2012a).

However, it is hard to draw firm or strategically meaningful conclusions from this literature for 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 or within advanced countries. What evidence there is suggests that adaptive capacity is highest in northern Europe and lowest southern and central Europe. A regional assessment by ESPON (2011) found that the Nordic countries, Germany (except former East Germany), Austria, Belgium, the Netherlands and to a lesser extent Britain and parts of France to have the highest adaptive capacity. The calculations are only illustrative, but they are intuitive. Adaptive capacity is strongly correlated with income, so it is a reasonable conjecture that it will be lower in the poorer regions of Europe.

Adaptive capacity may change over time. If incomes converge, as they did in Europe before the financial crisis, the regional pattern may soften. If lessons are learnt, as happened in France after the 2003 heat wave (Pascal et al. 2006), adaptive capacity may increase. In contrast, if the current period of economic stagnation and fiscal retrenchment continues, Europe's capacity to manage climate risk may suffer. Local authorities in the UK have already started to scale back their adaptation teams in response to budget cuts. Adaptive capacity can be depreciated as well as accumulated.

3 When to adapt

While some impacts of climate change can already be felt, the most severe effects are not expected for several decades. The speed with which adaptation measures are initiated and ramped up is therefore an important decision. The theory of adaptation timing (Fankhauser et al. 1999) identifies two situations where it is advisable to bring adaptation forward[3]:

- ***Early benefits***: Fast-tracking adaptation makes sense if measures have immediate benefits that would be otherwise be forgone. These early benefits could be related to current climate variability (e.g. by building adaptive capacity), emission reduction efforts or the removal of broader market and policy failures. Because the merit of early-benefits adaptations is insensitive to future climate outcomes they are attractive also in terms of managing uncertainty.
- ***Costly lock-in***: Fast-tracking adaptation is also desirable if acting today costs less, in present value terms, than acting tomorrow. This may happen if decisions today lock

[3] Some policy makers may want to separate out adaptations with a long lead time as a third category. Examples would be research into better climate information, new medicines or drought-resistant crop varieties. However, they can without risk of omission be included in the other categories.

society into a development path that is costly to reverse later. Addressing costly lock-ins is complicated in practice, since locking in a response to the wrong climate scenario is also expensive. We return to this question in Section 4. What matters here is that decisions with long-term consequences require careful adaptation analysis already now.

3.1 Early benefits

Not many studies evaluate systematically 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. 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. Efficiency improvements in hot water use would also have carbon emission benefits.
- ***Flood protection*** measures either at the community or buildings level. For the latter, options like airbrick covers, door-guards, repointing of walls, drainage bungs and non-return valves are often attractive, although flood protection at the community level is generally more cost-effective (ASC 2011, 2012). 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—including in France, which suffered the highest casualty rates in 2003 (Pascal et al. 2006)—demonstrating the high benefit of better heat plans. In buildings, additional no-regrets measures include window shading and investment in energy-efficient appliances that produce less waste heat (ASC 2011).
- Better ***environmental management***. Ecosystems provide important services, including to societal adaptation, and in a healthy state they are better able to cope with 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, habitat fragmentation and the expansion of green infrastructure in urban areas.

This list is by no means exhaustive, but it illustrates the scope for adaptation measures that address both current issues and future climate risks.

3.2 Costly lock-in

Many decisions taken today will affect vulnerability profiles for decades. For these long-term decisions it is important to factor in adaptation right now. The most obvious cases are (Agrawala and Fankhauser 2008; Fankhauser et al. 1999):

- Long-lived ***infrastructure investments*** such as ports, roads, water supply systems and flood protection schemes. These structures are both sensitive to climate conditions and sufficiently long-lived to experience climate change during their economic life.

Indicative guesstimates suggest that the cost of "climate-proofing" potentially vulnerable infrastructure investments could add 5–20 % to capital costs (Agrawala and Fankhauser 2008).

- A similar argument holds for the design of ***buildings***. While some adaptive measures can be retrofitted cost-effectively (see above), others are best incorporated into the design of a 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 important case is ***spatial planning***, in particular decisions on further economic development in hazard zones, such as flood plains or areas prone to wildfires. ASC (2011, 2012) 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.

Accounting for climate risks in these decisions is not straightforward. Concern about climate change does not imply foregoing all development in risk areas. If combined with appropriate defensive investment (such as flood protection) it may well be justified (ASC 2012). What it does imply is a thoughtful decision making process. We turn to this question next.

4 How to adapt

There are well-established tools to ascertain the value-for-money of public adaptation investments. For low-regret adaptations, whose merit is insensitive to future climate scenarios, the main tools are cost-benefit analysis and cost-effectiveness analysis, which are well-known to all government agencies. In contrast, the analysis of long-term decisions requires more sophisticated, less often-used tools that factor in climate uncertainties. As yet, neither set of tools is used as a matter of course in adaptation decisions. Two exceptions are the Netherlands, where the Delta Commissie (2008) recommends a cost-benefit analysis for new urban developments in flood-prone areas, and the UK whose Green Book on public project appraisal contains guidelines on adaptation.

As a consequence our understanding of the costs and benefits of adaptation is still patchy and concentrated in a few sectors (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 from straightforward to more costly adaptations. As seen above, Swiss Re (2009) and ASC (2011) found considerable scope for no-regret adaptations in areas like water efficiency and flood protection. However, they also showed that further up the 'adaptation cost curves' there are measures that fail the cost-benefit test.

Climate models cannot yet, and will not for a long time, produce sufficient information for well-informed long-term decisions—for example localised, diurnal or seasonal data not just on temperature, but on precipitation, flood probabilities and wind speeds. Long-term adaptation decisions are therefore made under profound uncertainty.

There are several decision making methods to deal with this issue (Ranger et al. 2010; Dessai and Hulme 2007). Expected value and expected utility maximisation are the preferred tools if the set of possible climate outcomes can be quantified and their probabilities are known. Scientists use ensemble forecasting to calculate such probabilities, but doubts remain about their validity (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.

These tools are complex and time-consuming to apply, but fortunately they provide some fairly robust and straightforward practical insights. Adaptation measures should be flexible, that is, allow for revision at a later date when new information is available, or they 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). Engaging stakeholders can increase flexibility by ensuring risk and cost trade-offs are acknowledged and accepted by those that are affected. The UK, for example, takes a deliberately inclusive approach to its national adaptation programme, which is “co-created” though extensive dialogue with stakeholders (DEFRA 2012b). 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 is undertaken by private agents—households and firms. The literature offers some examples of how people deal with climate risk (e.g., Surminski and Oramas-Dorta 2011 on insurance, Subak 2000 on water supply), but the evidence base is surprisingly poor. Business views climate change both as a risk and an opportunity. The need for adaptation will create demand for new goods and services in climate-resilient food production, urban drainage solutions, water efficient appliances, risk management services and much else. Forward-looking entrepreneurs will pursue these opportunities.

However, many of the private adaptation responses we currently observe are either regulation-driven (e.g. in the water sector) or facilitated by public support programmes. This raises the question about the appropriate role of government in adaptation. There are well-established principles in public sector economics on the role of the state. They suggest that the state should involve itself in adaptation primarily for three reasons:

- ***Climate-resilient public goods***: There may be an increased demand for public goods specifically dedicated to adaptation, such as better sea defences, which are generally provided by the state. In addition, it will fall to the state to “climate-proof” the traditional public goods it already provides, such as transport infrastructure and water supply networks.
- ***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***: A 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.

5.1 Public goods

Many adaptation services are non-rival and non-excludable, that is, they are public goods. Typical examples include community-level flood protection, storm warning systems or coastal defence structures. Climate information—in the form of climate change models, for example—can in principle be made excludable, but information has many public good features. The same holds for research and development, for example in drought-resistant crops. As public goods are underprovided by the market government agencies step in to provide the service—in the case of state-owned infrastructure –, commission it from the private sector or overcome the market failure through regulation (e.g. by granting patents in the case of R&D).

Public goods related to climate protection are typically provided directly by the state. There are very few flood protection, coastal defence and climate information projects that are provided through public-private partnerships (PPPs). 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.[4]

There are several factors that make PPPs for adaptation difficult (Agrawala and Fankhauser 2008). 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 most adaptation schemes is relatively straightforward, leaving little room for efficiency gains through private management. The lack of an independent revenue stream means contractors would have to be paid by the government and the liability would thus 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 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 reveal an abundance of institutional, policy and market failures. It is the role of government to address barriers to effective adaptation. The main issues that will need

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

government intervention can be grouped into three broad categories (Cimato and Mullan 2010).

First, adaptation may be held back by shortcomings in the institutional and regulatory environment. In the UK, ASC (2011) hints at regulatory barriers in the water sector (e.g. the design of abstraction licences, limited water metering). Network externalities may create cascading risks in the provision of infrastructure services (e.g. the interruption of power supply during extreme weather events). Institutional competition, layered bureaucracy and entrenched rules and traditions can hamper the ability of organisations to respond to changing circumstances (Repetto 2008). In Europe, many of these problems have been manifest in the response to recent climate hazards, such as the 2003 heat wave and the Mediterranean wild fires of 2007.[5]

Second, adaptation decisions may be affected by market failures, some generic, others particular to adaptation. There may be asymmetric information 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 historic locations like Venice. There may be externalities, or more generally a lack of coordination, between upriver and downriver communities.

Both institutional problems and market failures require deeper coordination, clearer incentive structures and better governance at multiple levels (Corfee-Morlot et al. 2011), including, perhaps, dedicated new institutions. In the UK this has taken the form of an independent new committee with a legal mandate to scrutinise preparedness for climate change (ASC 2010, 2011, 2012). EU action may be warranted in areas that require transnational cooperation, such as shared water bodies, commercial fishing and energy networks.

The third category are behavioural and information barriers. Adaptation suffers from a general lack of awareness and institutional capacity, which means climate risks are under-managed. More profoundly, complex, long-term adaptation decisions may be affected by well-known cognitive barriers that lead to inertia, procrastination and implicitly high discount rates (Hanemann 2008; also Grothmann and Patt 2005).

The main role of government in overcoming such barriers is to raise awareness and perhaps encourage action through tax and regulatory incentives. This is a priority in many Eurpean adaptation strategies, in the UK for example through the UK Climate Impacts Programme (McKenzie-Hedger et al. 2006). The European Commission is actively supporting climate change impact research. However, while addressing these barriers may require state intervention, governments themselves may be afflicted by information problems (Sobel and Leeson 2006).

5.3 Assistance to vulnerable groups

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, adaptation also raises broader equity questions.

It remains an open (and highly political) question, for example, 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

[5] For a US example, the response to hurricane Katrina, see Sobel and Leeson (2006).

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. Finland's insurance-based compensation mechanism for extreme weather events strikes a balance, transferring the cost burden gradually from the government to the private sector (Swart et al. 2009).

6 Conclusions

Policy makers are awakening to the challenge of adaptation, but as yet there are few examples of good adaptation practice. The prevailing literature has perhaps not helped, with its emphasis on science-led impact assessments and a penchant for conceptual discussion. This paper proposes an economic approach to public adaptation that keeps an eye on practical implementation, drawing on the experience of European countries.

An economic 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.

An economic approach to adaptation also involves careful project design: the question of *how* to adapt. A key complication here is that we do not know the future climate to which long-lived assets need to be adapted. This puts a premium on flexible designs that can be adjusted as new information becomes available.

The final element of an economic 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, including in the provision of public adaptation goods like flood defences, the climate-proofing of conventional infrastructure, the protection of vulnerable population groups, and the removal of barriers that prevent effective adaptation.

Adaptation will become a permanent feature of future decision making. Given its ubiquity it is important to go about it in a practical, economically rational way.

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