

Defining response capacity to
enhance climate change policy □ □

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Summary

Adaptation and mitigation are usually in different policy domains and communities. Hence, despite the clear overlaps in policy responses, they are treated separately. We propose that a useful starting point to developing national climate policy is to understand what societal response might mean. First we frame the set of responses as a trade off between investment in the development and diffusion of new technology, and investment in encouraging and enabling society to change its behaviour and or adopt the new technology. We argue that these are the pertinent trade-offs, rather than those usually posited between mitigation and adaptation per se. The preference for a more technological response as opposed to a policy response that focuses on changing social behaviour will be influenced by the capacity of different societies to change the climate; perceived vulnerability to climate impacts and capacity to modify social behaviour and physical environment. Starting with this complete vision of response options should enable policy makers to re-evaluate the risk environment and the set of response options available to them. From here, climate policy has to consider who is responsible for taking response decisions and when actions should be taken. Institutional arrangements dictate social and political acceptability, they structure worldviews, and they determine the provision of resources for investment in adaptation and mitigation technology. The importance of focussing on the timing of the response is emphasised to maximise the potential for adjustments through social learning and institutional change at different policy scales. We argue that the ability to adapt is linked to, not separate from, the ability to mitigate as both depend on social and technological constraints. The resilience of society to climate change impacts and the need for technological change for both decarbonisation and for dealing with surprise in general, are central to concepts of sustainable development.

1. Introduction

Creating national climate policy is challenging; long time frames, scientific uncertainty about impacts and about social and economic futures conspire to test the abilities of existing decision making structures. Specific difficulties arise because national climate policy deals with climate change impacts generated through actions taken both within and outside most countries. The impacts could be seen as a form of externality generated across national boundaries. It is clear that there are many causes of climate change and there are many solutions which depend to a degree on how societies and individuals in the present day are willing to trade-off their consumption and lifestyles for speculative improvements in the well-being of future generations. Often the easiest decision is to postpone decision making until more information is available, although the costs or benefits of doing so are unknown, but could potentially be huge.

Government and non-governmental groups are looking to each other for direction and guidance on this complex and uncertain issue. At the international level, the UNFCCC annual Conference of Parties (COP) negotiations are working towards resolving conflicts of interests but are not necessarily making progress on tackling the causes of climate change. Some attribute this slow progress to scientific uncertainty coupled with the issue of assigning national responsibility for climate change impacts. The responsibility issue is crucial, since this ultimately has implications for the allocation of international compensation and makes countries more cautious in dealing with adaptation and mitigation together in international negotiations because of the possibility of liability at some time in the future (Barnett, 2001). Perhaps because of this impasse at the international level, perhaps because of the nature of

impacts and the avoidance of apparent liability for past action, there is a division of activities within the international institutions into adaptation and mitigation.

The dichotomy created by the initial division of climate change research and management into adaptation and mitigation has led, we would argue, to a proliferation of further false dichotomies in the area of climate change management: social versus physical sciences, victims and perpetrators, and bottom-up versus top-down decision-making. Each new dichotomy reduces the possibility of finding holistic responses that build macro-micro links, that consider sustainability, that are dynamic and learning based, that build on strengths rather than needs, and that put human well-being at the centre of the issue. Research in various related fields, from welfare economics to natural hazards has sought to bring cause and consequence of development processes together, (Blaikie, et al., 1994; Dasgupta, 1993; Rayner and Malone, 1998), although these insights, with some exceptions, have largely been missing from the climate change debates.

Decision making about climate change is difficult and individual disciplines offer little direction to decision makers. Microeconomic theory, for example, describes how individuals make decisions under uncertainty when dealing either with other people or with external hazards in nature, (see for example (Keeney and Raiffa, 1993). Unfortunately, due to the expected long times frames associated with climate change, these techniques are proving less than useful on guiding climate policy (Tol, 2003). Probability-based decision making frameworks are also of little use as there are no known probabilities of different climate impacts occurring at given times, places or in the form of specific hazards, and no evidence that nature will behave in a particular manner given a certain level of emissions or concentrations of greenhouse gases. Without the availability of such probabilities, planning for climate change will continue to be made in ignorance of potential impacts. As a result climate policy responses taken today more often depend on individual attitudes towards risk (Schneider, 2002).

The most commonly used framework for considering climate change issues separates the climate problem into two systems, mitigation and adaptation. Mitigation is usually framed as an anticipatory action, necessary now to avoid future climate change, while adaptation is depicted as a phenomenon which we can plan for now, but which will happen in the future. Wilbanks and colleagues (2003) argue that this false dichotomy has arisen because of the perception that raising adaptation options in policy circles reduces the requirement for mitigation. This may have been particularly true for policy communities in those countries where there are vested interests in not mitigating and where the costs of adaptation are not considered insurmountable. The US may be a case in point (Mendelsohn and Neumann, 1999; Wilbanks, et al., 2003). There are various critiques of the separation of mitigation and adaptation implied in the IPCC and other assessments (see for example (Barker, 2001); and recognition that there is a danger that setting up apparent trade-offs between adaptation and mitigation will lead to separate policies being developed in a vacuum from one another. Potentially this could lead to increased costs with little effect on climate risks (Kane and Yohe, 2000:2).

The use of a framework that depicts adaptation as an end-of-pipe solution to the climate problem by various institutions means that division of response options into adaptation and mitigation will remain the dominant paradigm for the foreseeable future. To understand and perhaps overcome the dichotomy we require insights into the structure and nature of both institutions and individual choices to explain the relationship between adaptation and

mitigation. Both choice theories and institutional theories dispel the notion that adaptation and mitigation should be approached separately. We do not deny that differences exist between the two concepts, but, following Lawson (2003:200), recommend a ‘less sharp, less categorical rendering of them’ (Lawson, 2003). As Peters (1987) notes, as a result of institutional complexity and inertia, models may continue to be used long after they have been rendered useless because they are embedded and rooted systems. She argues that ‘the power of models is such that the process of paradigmatic shift is long and painful’ (Peters, 1987): 177).

In the next section of this paper we consider the actual drivers of climate change response, i.e. technological innovation and societal change, and review the issues that are central to effective decision-making in the face of uncertainty. The third section develops the concept of a response space and response pathways as well as the idea of response capacity. The question of what drives response capacity is considered and the issue of how response capacity can contribute to a more flexible and sustainable approach to climate change is investigated. The focus here is on how response capacity may enhance societies’ ability to achieve more sustainable development. The paper concludes that the capacity of an individual, group or institution (at any scale) to learn and modify its response to climate change is important in generating sustainable outcomes. We propose that this can be best achieved through modification of the decision-making and decision support systems to encourage adaptive management and social learning.

2. The response set, risk and assets

The term ‘response’ has been used by the climate change community to refer to the adverse impacts from adaptation and mitigation measures. The debate about ‘responses’ has therefore tended to focus on how countries can be supported or compensated to deal with the impacts of their own or others’ responses to climate change. For example, the oil producing and exporting countries have expressed concern that climate mitigation actions in the developed world, such as investment in non-fossil fuel technology, will reduce global demand for oil resources, thereby reducing their export earnings and affect their ability to adapt to the new circumstances (Barnett and Dessai, 2002).

In this paper, a response is any action taken by any region, nation, community or individual to tackle or manage environmental change, in anticipation of those changes or after they have been experienced. This loose definition deliberately avoids tying ‘response’ to climate impacts as it is almost impossible to separate pressures exerted as a result of climate change from other economic, environmental or developmental pressures. Following Tompkins and Adger (2003) we propose that any response to climate change must factor in other development goals such as increasing economic, environmental and social well-being instead of focussing solely on environmental management.

Responding to climate change therefore requires consideration of factors that enable and constrain adaptation and mitigation. The availability and penetration of new technology and the ability of society to change have been identified as driving factors in constraining and enabling responses to other environmental and developmental pressures including: flood management, integrated coastal zone management, nature conservation, and common property resource management. Hence we propose that these same factors: the availability and penetration of new technology, and the willingness and capacity of society to change or

adopt this new technology are likely to drive responses to climate change. Figure 1 depicts the range of response options available in a ‘response space’.

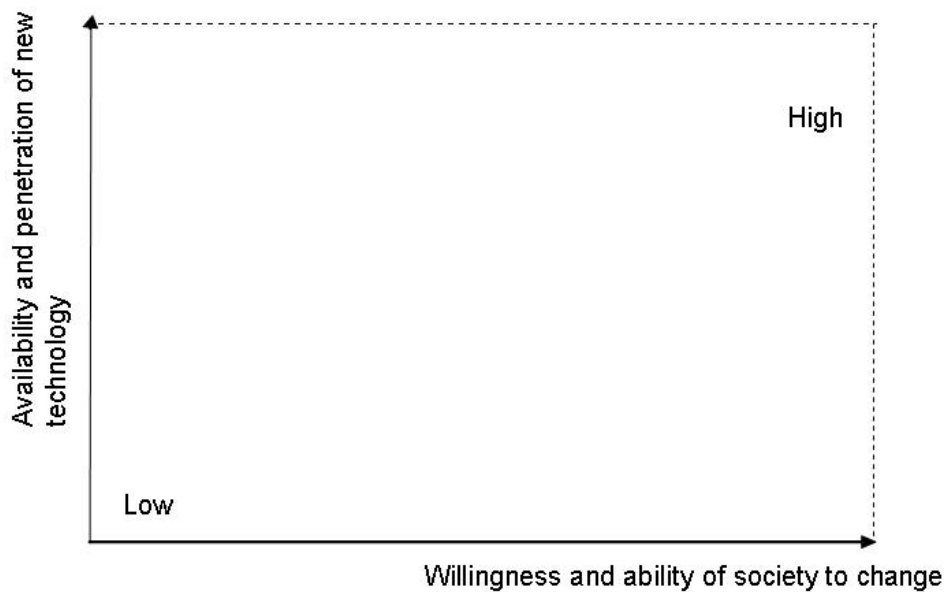


Figure 1 Elements of a response space

In Figure 1 decision makers choose between investment in new technology to manage the climate threats (such as carbon-neutral transport) or investment in processes to manage social change (such as the planned retreat of coastal communities) or a combination of the two. Using the UK as an example, public policy investments have been made in both education for the wider society on the potential impacts of climate change and societies role in creating and managing those impacts. These are implemented through agencies such as the UK Climate Impacts Programme (UKCIP) and the Energy Saving Trust (EST), see for example (Eppel and Eyre, 2002; UKCIP, 2003). Ultimately the purpose of such investment is to alter behaviour and increase social resilience to future impacts. Such investment is expected to enable individuals to start to respond to climate change, to enable them to internalise the costs of responding to climate impacts, and to reduce future investments in disaster management.

Governments also have to deal with the issue of how much to invest in research and development for new technology to reduce carbon emissions. How much to invest in these two areas over both the short term and the long term is one of the most difficult questions facing most governments at present. With a finite set of assets that can be allocated at all scales and in all countries, the bigger question is, how should assets be allocated to maximise the well being of society?

In other words, how can we move from the bottom-left hand corner, to the upper-right hand corner of Figure 1, under a specific budget? The ‘low’ response area of Figure 1 describes a situation of low capacity and desire to respond. Here there are limited resources allocated to enable access to technology and there is little perceived risk or vulnerability associated with climate impacts. Hence there is little support by the wider society to invest in response measures. Conversely, the ‘high’ area within Figure 1 suggests that there is a high degree of awareness of vulnerability/risk and that the need for adaptive actions is recognised. The path

taken to reach that top right-hand corner is determined by a much larger set of issues influencing attitudes to risk and uncertainty, access to capital assets (human, physical, natural, financial and social); the vulnerability context in which the society or group operates (including vulnerability to shocks or trends); the institutional context; and the strategies that individuals adopt.

Attitudes to risk and uncertainty are clearly important in explaining why regions of the world have adopted different approaches to managing the potential threats of climate change. Regions perceiving themselves at risk from impacts are investing in adaptation. In the Caribbean, the recently completed project Caribbean Planning for Adaptation to Climate Change (CPACC) had the remit to build capacity to reduce vulnerability to climate change, (World Bank, 1997). CPACC adopted an institutional strengthening approach through a monitoring, communication, training and information dissemination programme to provide guidance to country level managers (see for example (King and Clarke, 2000)). In the Maghreb region, another UNDP/GEF funded initiative ‘Capacity building of the Maghreb countries in climate change’ is focussing on building structures to manage climate change sustainably, to prepare adaptation strategies at the local level, and to engage the private sector to see how it can reduce its contribution to greenhouse gas emissions (see (Regional Coordination of the UNDP/GEF RAB/94/G31 Project, 2002)).

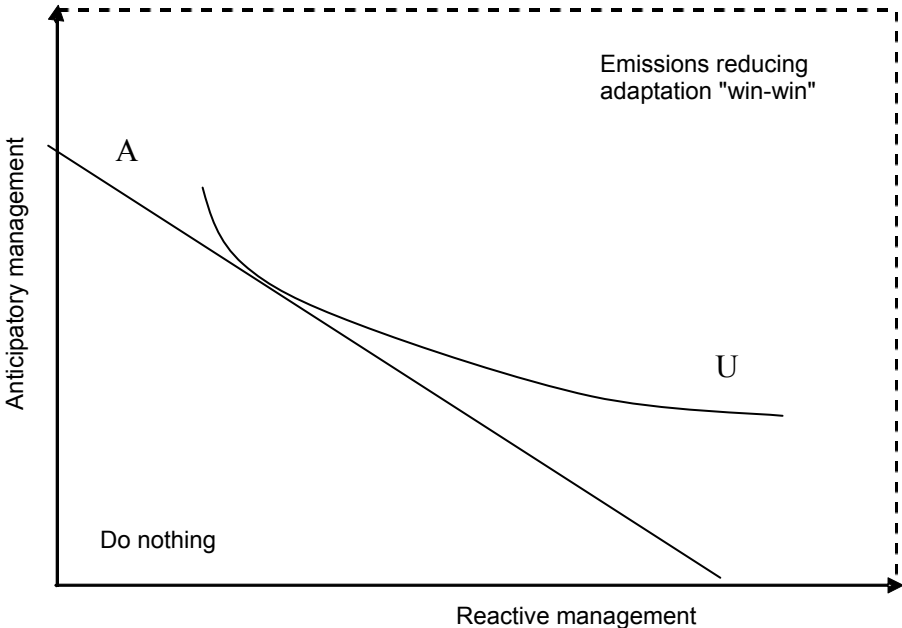
Nations with a different perception of the risk faced appear to be adopting decision rules that encourage them to invest in both adaptation and mitigating technology to ensure benefits are maximised from future climate changes. For example, in the Pacific, the Pacific Islands Climate Change Assistance Programme (PICCAP) has followed a community development approach to develop mitigative as well as adaptive capacity, wherein individual communities are being empowered to reduce their vulnerability to climatic variability and to focus on building resilience to their community. PICCAP’s six major capacity building objectives include: developing inventories of greenhouse gas sources and sinks; evaluating mitigation and adaptation options; and undertaking national vulnerability assessments, national climate change implementation plans and the first national communications under the UNFCCC, (SPREP, 2002). The UK has adopted an approach that focuses on drawing out the benefits that can be gained from climate change – including new business opportunities, as well as considering the risks that the businesses face (Clarke, et al., 2002; UKCIP, 2003). Clearly there are many different approaches being applied.

Access to capital assets (physical, natural, social, financial, human) directly affects society’s capacity to respond to climate change. The concept of capital assets is contested but most agree that human capital includes knowledge and effort. Physical capital includes innovation and technology as well as infrastructural development. Natural capital includes land, water and atmosphere and environmental goods and services. Social capital in this context is vested in the networks and associations underpinning collective or group action. Some types of capital assets may be specific to the climate change actions (e.g. physical capital in the form of decarbonising energy technologies) while other form of capital are more difficult to link to response capacity. Human capital in traditional economic models, for example, is usually measured in terms of aggregate educational attainment. Clearly general levels of education are important for implementing response strategies. But wider definitions of societal and individual capabilities (as espoused for example by (Sen, 1999) suggest that the instrumental definition of human capital as ‘useful knowledge’ is too narrow to capture the generic nature of and benefits of enhanced human well-being. Availability and access to assets clearly enables or constrains the set of response options. Figure 2 is a construct of the decision-

making process that explicitly portrays the role of assets and implicitly considers attitudes to risk. The total level of investment in responding to climate change depends on the availability of resources. The asset constraints faced by decision makers are described by the A budget constraint line. The slope of this line will change as more information becomes available on the relative costs of short term disaster management and longer term development planning objectives. The total assets available to be expended on the two options can be described as:

$$Z = p_a \cdot X + p_r \cdot Y$$

Where Z = total asset constraint, X = unit of anticipatory climate-impact response, Y = unit resource of reactive climate impact-response, p_a = cost per unit of anticipatory response action, p_r = cost per unit of reactive response. Both adaptation and mitigation activities could be short term or long term.



Source: Adapted from Tompkins and Adger (2003).

Figure 2 Trade-offs between anticipatory and reactive climate change response objectives

It is assumed, as is usual in economics that the social welfare function can be observed and is known, so the curve U represents the willingness of decision makers to trade-off quantities of longer term and shorter term investments in climate change management. In this simple characterisation the indifference curve is convex since the two levels of investment will most likely be undertaken at the same time. The curve is also convex because there is likely to be a positive level of investment in both areas - the need for action on climate change is well established and politically legitimate. Movement from the lower left hand area to the upper right hand area of the space reveals increasing levels of investment in both short term and long term climate change management and consequent increases in societal well being. Well-being is maximised at the intersection of the indifference curve (U) and the asset constraint (A).

What are the determinants of the shape of the indifference curves – what are decision-makers trading off? Both casual observation and public choice theory suggest that national level policy making, at least within democratic systems are constrained by a number of socio-political factors and a set of economic factors. The socio-political factors include a) the length

of political voting cycles (how long-term can investments be before politicians are held to account for them), b) the transmission of information from state to society on risk, c) lay perceptions of risk, and d) the length and nature of issue-attention cycles. The demand for action in the face of risk is mediated through voting systems, the media and other actors (see (Michaelowa, 2000) for an elaboration of a political economy approach to influence and demand for different strategies). In addition, public policy decision-making on climate change involves economic decisions that include formulation of expectations on the extent and cost of impacts, the cost of adaptation, the transactions costs of information (e.g. research), and the expected cost of misplaced foresight.

Both socio-political and economic factors manifest themselves in different ways in individual political cultures – they can be framed as trade-offs between legitimacy, equity and efficiency, or as a judgement on ‘dangerous’ climate change (Dessai, et al., 2003). But, ultimately, each of the elements, cost, risk and socio-political factors, are encompassed in the shape of the indifference curve between reactive and anticipatory management.

The response landscape and trade-offs between anticipatory versus reactive action is made of actors in government, civil society and individual agents. Figure 3 shows how the strategic level decisions by governments which involve trade-offs between investment in new technology or investment in social resilience (shown in Figure 1) are imposed through a set of institutions and policies on a society that makes individual decisions on the basis of individual social capital, assets and perceptions of vulnerability and risk. The outcome of these collective and individual decisions is the response to the climate change threat, a combination of adaptation and mitigation actions. Clearly this model of societal decision-making implies a linear progression from policy-making, to implementation, to policy outcome. Such a model is challenged in many theories developed in public administration and political science, which point to both the limits of the state in many policy areas, the breakdown or hollowing out of the state, the diverse nature of public policy formulation, and the interaction of social capital and state (Adger, 2003; Hall and Soskice, 2001; O’Riordan, et al., 1998; O’Riordan and Jordan, 1999).

The availability and penetration of environmentally sound technology is also an important element defining ability to respond. While it is received wisdom that “an umbrella is not important when it is not raining.”, (Metz, et al., 2001) suggest that technological uptake is influenced as much by circumstance as by market potential, economic potential, socioeconomic potential, technological potential and physical potential (see Figure 3).

The factors that influence technological uptake relate to the current levels of vulnerability of the individuals or societies, their access to assets, and the institutional structures and policies that can enable the uptake. In other words the factors influencing the uptake of new technology are very similar to the factors influencing whether individuals or societies are willing to embrace change. This understanding is described clearly by decision-makers themselves. An example is given by Turnpenny et al (2003) who interviewed a series of key agents in implementing climate strategies in the UK. One government decision-maker noted that adaptation and mitigation are often treated separately because different methods or analysis techniques are used with each; however adaptation and mitigation both ultimately occur as a result of behavioural change (Turnpenny, et al., 2003).

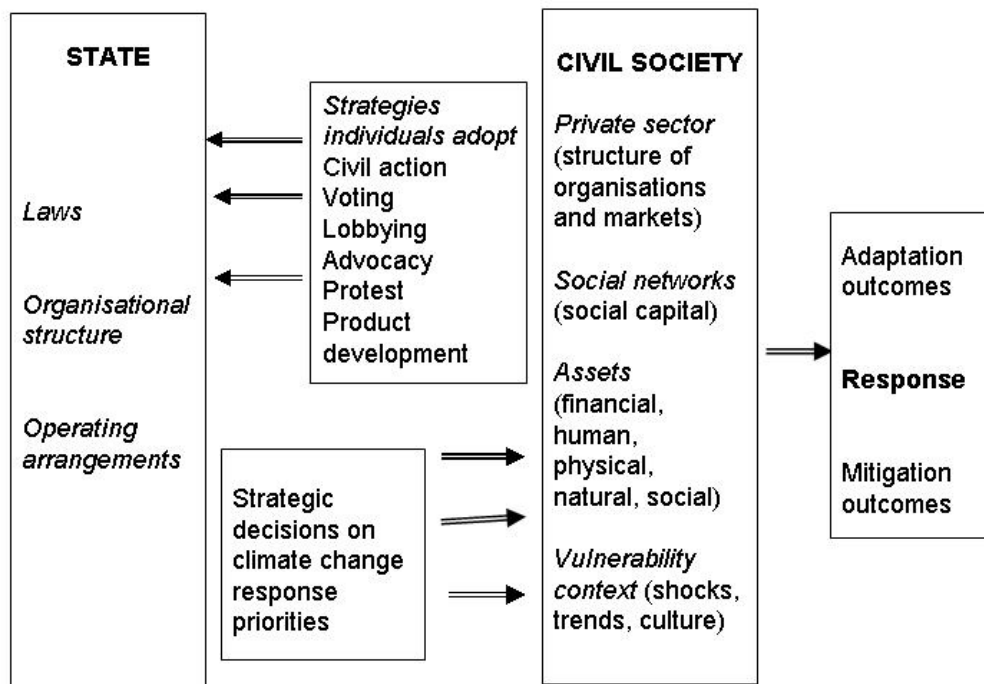


Figure 3 Relationships between assets, institutions and society

One of the most important features of both Figures 1 and 2, is that decision-makers make no explicit trade-off between adaptation and mitigation. It is assumed that a more accurate representation of the decision environment might reveal trade-offs between technological R&D and social resilience. Trade-offs also exist between reactive management and anticipatory responses, with different roles for the government, the private sector and individuals or wider society (see Table 1). In accordance with Article 3.3 of the United Nations Framework Convention on Climate Change (UNFCCC), anticipatory responses deserve particular attention from the international climate change community. Anticipatory responses are aimed at reducing a system's vulnerability by either minimising impact potential or maximising responsive capacity.

Table 1 portrays the benefits of responses as accruing in either the public or private domain. Some elements of investment in climate change response are ‘public’ and include conservation of nationally or internationally important habitats. Others are effectively private. If private firms in the water industry invest in knowledge of climate change risks, the costs and the benefits of this response are private. Climate change planning by governments at present tends to concentrate on providing public goods such as scenario information, risk assessments in the public domain, and public awareness campaigns, see (ERM, 2000; Hulme, et al., 2002; UKCIP, 2003). Hence many response programmes at present avoid providing subsidies to private adaptation decisions. But the public and private elements of responding to climate change are not fixed: they are shaped by institutional and regulatory features in each sector of the economy. Further, they can change from public, to private and back again over time (see Bakker 2003 on the UK water industry, for example).

This public-private issue is important to spell out, since it represents real trade-offs in policy. Governments in Europe, for example, continue to intervene in agricultural markets to reach public policy objectives of ‘food security’ through the Common Agricultural Policy even

though the benefits have leached from farmers income while capital values accumulate in land (Allanson and Hubbard, 1999). But there may be less willingness to invest in mitigation and adaptation to climate change if all the benefits are perceived to be ‘private’ – i.e. accrue to individual farmers, insurance companies and energy companies. The private and public nature of climate change response is determined by public policy and by underlying institutions and regulatory frameworks. Thus, similar responses in the water sector could accrue to the public or private sphere, and could change over time (Bakker, 2003).

Deciding how to allocate resources is not apparent from this conceptualisation of the response space. More resources may mean more action, but how can you prioritise different actions when the benefits and costs are unknown, or difficult to assess with any degree of accuracy. In the absence of a more appropriate decision making framework we suggest that consideration should be given to two specific elements of the decision problem: the timing of the investment (in anticipation of specific climate change impacts or after impacts have started to be experienced) and who should be making the decisions and taking actions (the government or non-government agents) as depicted in Table 1.

		Timing of response	
		Anticipatory (ex ante)	Reactive (ex post)
Responsibility for response	Private	Private insurance markets Private R and D and investments	Adjustments in insurance markets Identification of least-cost adaptation options
	Public	Public infrastructure provision (e.g. coastal protection) Risk communication to public Publicly available R and D	Post-disaster recovery Compensation for impacts Insurance underwriting

Table 1 Adaptation options by timing and by responsibility

By characterising the decision environment in this way, decision-makers are forced to explicitly consider their values and trade these off in the decision making process. Short-term gains or long term gains might be a more appropriate dichotomy to develop. Such value-focussed thinking, as suggested by (Keeney and McDaniels, 2001), is recognised as an important precursor to institutional policy-making under uncertainty.

3 Elements of response capacity: technology and society

As revealed in Figure 1, responses to climate change are expanded or constrained by societal willingness to change and access to technology appropriate for adaptation and mitigation. Understanding what the act of responding means is important, but so to are the pre-conditions that enable responses to occur. We propose that ‘response capacity’ is the human ability to manage the generation of greenhouse gases and the consequences of their production. Response capacity is time and context specific; over time, as the information about climate science changes and understanding of the climate futures change, perceptions of what factors

enhance the ability to respond are also likely to change. The factors are also likely to be culturally and regionally specific as different societies or groups will need different characteristics and tools to respond to different hazards and different types of climate change. Hence it may be that in the future when we look back and evaluate past responses we may find that we have in fact been developing inappropriate response capacity. With this knowledge, it becomes important to recognise that any capacity that is built or developed is able to change in response to new information or learning. We now explore the elements of a response capacity and consider the issues of social learning and adaptive management.

3.1 Institutions, agents and decisions

Response capacity can exist within institutions, individuals and groups, and it can be influenced by the institutional environment as well as individual choice and behaviour. New institutional economics and choice theory offer insights into how such capacity can be built.

Current research suggests that existing institutions are unlikely to be able to cope efficiently and equitably with climate change outside their range of experience (Kane and Yohe, 2000), particularly in developing countries (Kates, 2000). This is partly because climate policy decisions are most frequently made at the national level, although the consequences of those decisions are experienced at local, national, regional and international scales. How then can we develop institutions that can cope with these unusual policy dimensions? Various areas of study suggest through the promotion of institutional and social learning and more effective management through greater inclusion and integration.

Empirical studies on barriers to adoption of new forms of technology or to social change show that there is a clear need for integration among sectors, among government departments, and across different scales of management, from the international to the local. In coastal zone management, for example, much attention is devoted to concepts of horizontal and vertical integration, inclusion, systems management and learning based approaches (see for example (Gezon, 1997; Sorensen, 1997; Tompkins, et al., 2002). Other studies indicate that laws or regulations imposed without enabling a behavioural change will have little or no effect in changing either institutions or human behaviour. For example in energy policy Sorrell (2003) identifies institutional and behavioural barriers to energy efficient construction of non-domestic buildings in the UK. He highlights the presence of imperfect information, moral hazard in the relationships between agents in the energy services market, split incentives within organisations, bounded rationality limitations on decision making, and hidden costs of rational behaviour (Sorrell, 2003). Some of these impediments could be removed through better communication among those involved and a more integrated planning process.

The complexity of human relations and the social, economic and cultural context in which people operate are as important as the legal framework. Integrative approaches that recognise the institutional bounds placed on individual decisions instead of the dichotomous approach in much public policy would likely advance its effectiveness. New technology and social change have both positive and negative externalities associated with each resource allocation decision, whether undertaken by governments or individuals. For example, an adaptation to cope better with extreme heat could increase green house gas emissions. A mitigation action to reduce use of fossil fuels would impact on the economies of the OPEC countries. Since we can expect that anticipatory adaptation decisions will be undertaken by individual agents (adopting insurance cover, moving location from hazardous areas), government decisions need both to avoid the inefficiencies of subsidising stewardship likely to take place anyway, and to incorporate planning for adaptation in their mitigation strategies. In other words,

public sector decisions on responses also require consideration of implementation issues, as discussed above.

Finding balance between government investment in new technology and building societal resilience can be found through recognition of the efficiency, effectiveness, equity and legitimacy dimensions to response actions (Adger, et al., 2003). Efficiency relates to welfare-maximising use of scarce resources. The cost-efficiency elements of mitigation are well understood. In terms of adaptation, the cost-efficiency of adaptation actions involve estimating the costs of impacts avoided, the expected value of future impacts over time, the transaction costs of new information and the costs (and probabilities) of misplaced foresight.

Effectiveness relates to the capacity of a decision or alternative to achieve its expressed objectives. In terms of mitigation this is the effect on the carbon cycle. In adaptation effectiveness essentially has two elements: effectiveness in reducing impacts (exposure) and effectiveness in terms of reducing risk, avoiding danger and promoting security. There are emerging insights into the nature of risk management in adaptation stemming from the realisation of the role of expectations in formulating response options (see Dessai et al. 2003).

Equity usually focuses on the distributional consequences of environmental decisions - from the uneven spatial impacts of environmental change to the distribution and consequences of political and social change. There are numerous ways to frame equity, in terms of desert, equality or other criteria. For both new technology and social change, the simplest means to highlight equity dimensions, as in vulnerability assessment, is to highlight who gains and who loses from any reactive or anticipatory climate change policy decision or any impact.

Legitimacy relates to the extent to which decisions are acceptable to participants on the basis of who makes and implements the decisions. Legitimacy can be gained as well as compromised through the process of making environmental decisions. There are no universal rules for procedures that guarantee the legitimacy of policy responses because cultural expectations and interpretations define what is or is not legitimate (Brown, et al., 2002; Kasemir, et al., 2003). The social acceptability of the procedures for implementation of co-ordinated climate change responses (e.g. carbon taxes, land use zoning, or provision of floodplain zoning) are often the overriding parameters in governmental decision-making.

3.2 Learning to respond

Decision support tools, to facilitate public response to climate change, are needed to guide decision makers in their response. Keeney and McDaniels (2001) point out that due to the long time frames for decision making, the lack of information available and the uncertainty about impacts mean that the danger of locking into one path, i.e. becoming path dependent, is very high for climate change decision making. They propose that to overcome this problem, a shorter time frame (less than 20 years) is required within which preliminary policy objectives for climate change are developed, pursued, tested and evaluated. In their study in North America, they suggest that there are six objectives which should influence the decision makers values: learning; education; alternatives beyond the planned 20 year time frame; the severity of the threat; the consequences of the current options; and accountability for decision making. Each of these addresses the issues of social change and adoption of new technology, however, they are built around the premise that management capacity changes through learning.

In the area of natural resource management, social learning to promote resilience is increasingly encouraged through a range of approaches known collectively as adaptive management (Jager, et al., 2001; Jordan and O'Riordan, 1995; Parsons and Clark, 1995; Tonn, et al., 2000). Adaptive management recognises that decisions will be made that may be perceived as inappropriate with hindsight (Folke, et al., 2002; Lee, 1999; Olsen, et al., 1997; Olsson and Folke, 2001; Roling and Wagemakers, 1998; Tompkins and Adger, 2003; Walters, 1986; 1997). The adaptive management approach requires decision-makers to accept reflexive, evaluative decision making as part of the long term process of testing and refining appropriate responses to climate change. This approach has been recommended in the area of coastal zone management for many years (Hale and Lemay, 1994; Olsen, 1993; Olsen, et al., 1998; White, et al., 1994). Adaptive management builds learning into the decision making process. It recommends iterative decision making: start small, test the decision made, build up that decision, and constantly test and revise assumptions. Dynamic institutional structures, which have the capacity to be reflexive and adapt in response to new information, are more likely to facilitate change and development in a society than inflexible rigid institutions. As a caveat to this, it is important to remember that institutional flexibility can generate high operating costs, and that institutions are heterogeneous, so flexibility is not 'uniformly useful' (Kane and Yohe, 2000).

Nordhaus, 1994 applies a version of a normative decision making framework and suggests an 'act then learn' approach to decision making under uncertainty (Nordhaus, 1994) that links clearly with adaptive management promoted in ecological management (Folke, et al., 2002; Lee, 1999; Walters, 1986; 1997). Nordhaus proposes a sequential decision making process wherein decisions are revised as new information becomes available. As there is no useful information initially it is accepted that the first decision made may require complete transformation as learning takes place.

Learning by doing requires decision makers to accept that they make mistakes and bad decisions. If this acceptance is not present, then the institutions can not learn. As Keeney and McDaniels (2001) note, economists and systems analysts have recognised the significance of learning by doing for over 30 years, and this has a major influence on the attractiveness of repeated decisions. Social learning is a complex area and still largely unknown, learning can be active or passive, there are costs associated with both learning and gathering information, and the mechanisms by which learning occurs, whether through markets and prices or through other means such as social capital and networks (Adger, 2003; Allen, et al., 2001). The information asymmetries that exist along with the complexities of learning can mean that the potential benefits that can be gained from such approaches are reduced unless these issues are tackled (Cordes and Yezer, 1998). Unlike Keeney and McDaniels (2001) who suggest that 'path dependency' is synonymous with learning by doing, we suggest that learning by doing is actually the flip side of path dependency, it is about flexibility of decision making, occurring outside of the constraints imposed by inflexible institutional arrangements that might for example increase information asymmetries and high information transactions costs.

4. Conclusions

Developing climate policy is riddled with difficulty as its remit is to influence all sectors: transport, construction, agriculture, shipping, utilities, tourism, and so on. Each sector, while pursuing its own internal objectives, can be encouraged through regulation or social pressure to mitigate the impacts of climate change as well as adapt. As Keeney and McDaniels (2001) point out, 'the first step is for governments to understand what they want to achieve with climate change policy choices', (p.989). Locking into their values and their preferred states of

the world at a given time is critical to developing consistent horizontally integrated climate policy.

The interdependence between mitigation and adaptation is clear in the context of sustainable development, both are driven by the availability and penetration of new technology and the ability of society to change. But it should also be recognised that the existing constituencies (particularly in government) of adaptation and mitigation are only marginally overlapping. Energy planning and the carbon intensity of economic growth, for example, are usually high in the priorities of industry sectors, government and by consumers who are interested in security of energy. Adaptation within government will primarily be dealt with by spatial planners, different (non-energy) sectors of the economy. It will also involve different consumption and production decisions by households from those about energy use.

The divergence between the parties responsible for adaptation and mitigation poses a problem for policy integration. Yet the pre-conditions for enhancing adaptive capacity are similar to those that can lead to enhanced mitigation. Adaptive capacity and mitigative capacity jointly describe the ability to make use of the spectrum of options that is available in responding to climate change. The capacities are at present only hypothesised, though we have pointed to some key issues in this paper. They are driven by technology and societal factors in the form of individual or group behaviour, economic markets and institutions. Both sets of factors can expand or constrain the set of response options that exist, and both have implications for sustainable development. Experience in social justice and in economic development suggests that the capability to be adaptive, to be able to learn and to grow through that learning process, are beneficial for more than instrumental reasons. Social learning is a complex issue that itself is an evolving subject. A joint response capacity can be elaborated in terms of resource needs; the distribution of risk; and the institutions required for the social learning processes that enable ability to adjust to climate change.

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References

- Adger, W. N. (2003) Social capital, collective action and adaptation to climate change. **Economic Geography**, 79, 4, in press.
- Adger, W. N., Brown, K., Fairbrass, J., Jordan, A., Paavola, J., Rosendo, S. and Seyfang, G. (2003) Governance for Sustainability: Towards a 'Thick' Understanding of Environmental Decision-making. **Environment and Planning A**, 35, 1095-1110.
- Allanson, P. and Hubbard, L. (1999) On the comparative evaluation of agricultural income distributions in the European Union. **European Review of Agricultural Economics**, 26, 1-17.

- Allen, W., Bosch, O., Kilvington, M., Oliver, J. and Gilbert, M. (2001) Benefits of Collaborative Learning for Environmental Management: Applying the Integrated Systems for Knowledge Management Approach to Support Animal Pest Control. **Environmental Management**, 27, 2, 215-223.
- Bakker, K. J. (2003) From public to private to mutual? Restructuring water supply governance in England and Wales. **Geoforum**, 34, 359-374.
- Barker, T. (2001) Representing the Integrated Assessment of Climate Change, Adaptation and Mitigation. **Tyndall Working Paper**, 11, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.
- Barnett, J. (2001) The issue of 'Adverse Effects and the Impacts of Response Measures' in the UNFCCC. **Tyndall Working Paper**, 5, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.
- Barnett, J. and Dessai, S. (2002) Articles 4.8 and 4.9 of the UNFCCC: adverse effects and the impacts of response measures. **Climate Policy**, 2, 2-3, 231-239.
- Blaikie, P., Cannon, T., Davis, I. and Wisner, B. (1994) **At Risk. Natural hazards, people's vulnerability and disasters**, Routledge, London.
- Brown, K., Tompkins, E. L. and Adger, N. (2002) **Making Waves. Integrating Coastal Conservation and Development**, Earthscan, London.
- Clarke, S., Kersey, J., Trevorrow, E., Wilby, R., Shackley, S., Turnpenny, J., Wright, A. and Hunt, A. (2002) **London's warming. The impacts of climate change on London**. UK Climate Impacts Programme and Greater London Authority, Oxford.
- Cordes, J. and Yezer, A. (1998) In harm's way; does Federal spending on beach enhancement and protection induce excessive development in coastal areas? **Land Economics**, 74, 128-145.
- Dasgupta, P. (1993) **An Inquiry into Well-Being and Destitution**, Clarendon Press, Oxford.
- Dessai, S., Adger, W. N., Hulme, M., Köhler, J., Turnpenny, J. and Warren, R. (2003) Defining and experiencing dangerous climate change. **Tyndall Working Paper**, 28, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.
- Eppel, S. and Eyre, N. (2002) **Putting Climate Change at the Heart of Energy Policy. Energy Saving Trust Submission to the Energy White Paper**. Energy Saving Trust, London.
- ERM (2000) **Potential UK adaptation strategies for climate change**. H. M. Government, Department of the Environment, Transport and Regions, Wetherby, UK.
- Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S. and Walker, B. (2002) Resilience and sustainable development: Building adaptive capacity in a world of transformations. **Ambio**, 31, 5, 437-440.

- Gezon, L. (1997) Institutional Structure and the Effectiveness of Integrated Conservation and Development Projects: Case Study from Madagascar. **Human Organization**, 56, 4, 462-470.
- Hale, L. Z. and Lemay, M. H. (1994) Coral Reef Protection in Phuket, Thailand: A Step Toward Integrated Coastal Management. In **Collaborative and Community-Based Management of Coral Reefs. Lessons from Experience**, eds A. T. White, L. Z. Hale, Y. Renard and L. Cortesi, Kumarian Press, West Hartford, Connecticut.
- Hall, P. A. and Soskice, D. (2001) **Varieties of Capitalism: The Institutional Foundations of Comparative Advantage**. Oxford University Press, Oxford.
- Hulme, M., Jenkins, G., Lu, X., Turnpenny, J., Mitchell, T., Jones, R., Lowe, J., Murphy, J., Hassell, D., Boorman, P., McDonald, R. and Hill, S. (2002) **Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report**. Tyndall Centre for Climate Research, University of East Anglia, Norwich, UK.
- Jager, J., Eijndhoven, J. v. and Clark, W. C. (2001) Knowledge and action: an analysis of linkages among management functions for global environmental risks. In **Learning to Manage Global Environmental Risks: A Functional Analysis of Social Responses to Climate Change, Ozone Depletion and Acid Rain**, eds Social Learning Group, MIT Press, Cambridge.
- Jordan, A. and O'Riordan, T. (1995) **Institutional Adaptation to Global Environmental Change (I): Social Institutions, Policy Change and Social Learning**. Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia, Norwich, UK.
- Kane, S. and Yohe, G. (2000) Societal adaptation to climate variability and change: An introduction. **Climatic Change**, 45, 1, 1-4.
- Kasemir, B., Jager, J., Jaeger, C. C. and Gardner, M. T. (2003) **Public participation in sustainability science. A Handbook**, Cambridge University Press, Cambridge.
- Kates, R. W. (2000) Cautionary tales: Adaptation and the global poor. **Climatic Change**, 45, 1, 5-17.
- Keeney, R. L. and McDaniels, T. L. (2001) A Framework to Guide Thinking and Analysis Regarding Climate Change Policies. **Risk Analysis**, 21, 6, 989-1000.
- Keeney, R. L. and Raiffa, H. (1993) **Decisions with Multiple Objectives: Preferences and Value Trade-offs**, Cambridge University Press, Cambridge.
- King, I. C. and Clarke, J. (2000) **Implementation of SIDSnet internet training in the Caribbean: the CPACC approach**. Islands of the World VI Conference, Isle of Skye, 16 - 20 October 2000, Isle of Skye, UK.
- Lawson, T. (2003) Institutionalism: On the Need to Firm up Notions of Social Structure and the Human Subject. **Journal of Economic Issues**, 37, 1, 175-207.

- Lee, K. N. (1999) Appraising Adaptive Management. **Conservation Ecology**, 3, 2, (online) <http://www.consecol.org/Journal/vol3/iss2/art2/>.
- Mendelsohn, R. and Neumann, J. E. (1999) **The Economic Impact of Climate Change on the Economy of the United States**. Cambridge University Press, Cambridge.
- Metz, B., Davidson, O., Swart, R. and Pan, J. (2001) **Climate Change 2001: Mitigation. Contribution of Working Group III**. Cambridge University Press, Cambridge.
- Michaelowa, A. (2000) International trade and climate policies. **Journal of World Trade**, 34, 3, 157-159.
- Nordhaus, W. D. (1994) **Managing the Global Commons. The Economics of Climate Change**, MIT Press, Cambridge, Massachusetts.
- Olsen, S. B. (1993) Will Integrated Coastal Management Programs Be Sustainable: The Constituency Problem. **Ocean & Coastal Management**, 21, 1993, 201-225.
- Olsen, S. B., Tobey, J. and Hale, L. Z. (1998) A Learning-Based Approach to Coastal Management. **Ambio**, 27, 8, 611-619.
- Olsen, S. B., Tobey, J. and Kerr, M. (1997) A Common Framework for Learning From ICM Experience. **Ocean & Coastal Management**, 37, 2, 155-174.
- Olsson, P. and Folke, C. (2001) Local ecological knowledge and institutional dynamics for ecosystem management: A study of Lake Racken Watershed, Sweden. **Ecosystems**, 4, 2, 85-104.
- O'Riordan, T., Cooper, C. L., Jordan, A., Rayner, S., Richards, K. R., Runci, P. and Yoffe, S. (1998) Institutional frameworks for political action. In **Human Choice and Climate Change: Volume I: The Societal Framework**, eds S. Rayner and E. L. Malone, Battelle Press, Columbus, OH.
- O'Riordan, T. and Jordan, A. (1999) Institutions, Climate Change and Cultural Theory: Towards a Common Analytical Framework. **Global Environmental Change**, 9, 81-93.
- Parsons, E. A. and Clark, W. C. (1995) Sustainable Development as Social Learning: Theoretical Perspectives and Practical Challenges for the Design of a Research Program. In **Barriers and Bridges to the Renewal of Ecosystems and Institutions**, eds L. H. Gunderson, C. S. Holling and S. S. Light, Columbia University Press, New York.
- Peters, P. (1987) Embedded systems and rooted models: the grazing lands of Botswana and the commons debate. In **The Question of the Commons; the Culture and Ecology of Communal Resources**, eds B. J. McCay and J. M. Acheson, The University of Arizona Press, Tucson, Arizona.

- Rayner, S. and Malone, E. L. (1998) **Human Choice and Climate Change. The Societal Framework. Volume 1.** Battelle Press, Columbus, OH.
- Regional Coordination of the UNDP/GEF RAB/94/G31 Project (2002) **Vulnerability of the Maghreb Region to Climate Change and Needs for Adaptation (Algeria, Morocco, Tunisia).** Regional Coordination of the UNDP/GEF RAB/94/G31 Project, Ministere de l'Amenagement du territoire, de l'Urbanisme, de l'Habitat Et de l'Environnement, Rabat, Morocco.
- Roling, N. G. and Wagemakers, M. A. E. (1998) **Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty.** Cambridge University Press, Cambridge.
- Schneider, S. H. (2002) Can we estimate the likelihood of climatic changes at 2100? **Climatic Change**, 52, 4, 441-451.
- Sen, A. K. (1999) **Development as Freedom**, Oxford University Press, Oxford.
- Sorensen, J. (1997) National and International Efforts at Integrated Coastal Management: Definitions, Achievements and Lessons. **Coastal Management**, 25, 1997, 3-41.
- Sorrell, S. (2003) Making the link: climate policy and the reform of the UK construction industry. **Energy Policy**, 31, 865-878.
- SPREP (2002) **Pacific at Risk: Our Islands Our Lives.** South Pacific Regional Environment Programme, Apia, Samoa.
- Tol, R. S. J. (2003) Is the uncertainty about climate change too large for expected cost-benefit analysis? **Climatic Change**, 56, 3, 265-289.
- Tompkins, E., Adger, W. N. and Brown, K. (2002) Institutional Networks for Inclusive Coastal Management in Trinidad and Tobago. **Environment and Planning A**, 34, 1095-1111.
- Tompkins, E. L. and Adger, W. N. (2003) Building resilience to climate change through adaptive management of natural resources. **Tyndall Working Paper**, 27, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.
- Tonn, B., English, M. and Travis, C. (2000) A Framework for Understanding and Improving Environmental Decision Making. **Journal of Environmental Planning and Management**, 43, 2, 163-183.
- Turnpenny, J., Haxeltine, A. and O'Riordan, T. (2003) A scoping study of UK user needs for managing climate futures Part 1 of the pilot-phase interactive integrated assessment process (Aurion Project). **Tyndall Working Paper**, 31, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK.
- UKCIP (2003) **Building Knowledge for a Changing Climate. The impacts of climate change on the built environment.** UK Climate Impacts Programme and Engineering and Physical Sciences Research Council, Oxford.

- Walters, C. (1986) **Adaptive Management of Renewable Resources**, Macmillan, New York.
- Walters, C. (1997) Challenges in Adaptive Management of Riparian and Coastal Ecosystems. **Conservation Ecology**, 1, 2, (online) <http://www.consecol.org/Journal/vol1/iss2/art1/>.
- White, A. T., Hale, L. Z., Renard, Y. and Cortesi, L. (1994) **Collaborative and Community-Based Management of Coral Reefs. Lessons from Experience**. Kumarian Press, West Hartford, Connecticut.
- Wilbanks, T. J., Kane, S. M., Leiby, P. N., Perlack, R. D., Settle, C., Shogren, J. F. and Smith, J. B. (2003) Possible responses to global climate change. Integrating mitigation and adaptation. **Environment**, 45, 5, 29-38.
- World Bank (1997) **Report No. 15916 CRG. Caribbean Planning for Adaptation to Global Climate Change Project**. Natural Resources Management and Rural Poverty Division, Country Department III, Latin America and the Caribbean Regional Office, UNEP,

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