19 Adaptation In The Developed World

Key Messages

In developed countries, adaptation will be required to reduce the costs and disruption caused by climate change, particularly from extreme weather events like storms, floods and heatwaves. Adaptation will also help take advantage of any opportunities, such as development of new crops or increased tourism potential. But at higher temperatures, the costs of adaptation will rise sharply and the residual damages remain large. The additional costs of making new infrastructure and buildings more resilient to climate change in OECD countries could range from **$15 – 150 billion each year (0.05 – 0.5% of GDP)**, with higher costs possible with the prospect of higher temperatures in the future.

Markets that respond to climate information will stimulate adaptation amongst individuals and firms. Risk-based insurance schemes, for example, provide strong signals about the size of climate risks and encourage better risk management.

In developed countries, progress on adaptation is still at an early stage, even though market structures are well developed and the capacity to adapt is relatively high. Market forces alone are unlikely to deliver the full response necessary to deal with the serious risks from climate change.

Government has a role in providing a clear policy framework to guide effective adaptation by individuals and firms in the medium and longer term. There are four key areas:

- **High-quality climate information** will help drive efficient markets. Improved regional climate predictions will be critical, particularly for rainfall and storm patterns.
- **Land-use planning and performance standards** should encourage both private and public investment in buildings, long-lived capital and infrastructure to take account of climate change.
- **Government can contribute through long-term polices for climate-sensitive public goods**, such as natural resources protection, coastal protection, and emergency preparedness.
- **A financial safety net may be required to help the poorest in society** who are most vulnerable and least able to afford protection (including insurance).

19.1 Introduction

Adaptation will reduce the costs and disruption caused by climate change. Governments can promote adaptation by providing information and clear policy frameworks to encourage individuals and firms to respond to market signals.

While those in developing countries will be hit hardest by the impacts of climate change, developed countries will not be immune, particularly from extreme weather events (Part II).[1] Adaptation will be required to reduce the costs and disruption caused by climate change in the long term and take advantage of any future opportunities. Much adaptation will be a local response by private actors to a changing climate. Individuals and businesses will respond to climate change – both by reacting to specific climate events, such as floods, droughts, or heatwaves, and also in anticipation of future trends. But incomplete information and other market imperfections mean that long-term policies will be required to complement these individual responses (Chapter 18). Failing to do so could incur large costs, especially from the very serious risks associated with larger amounts of warming. This chapter sets out key

[1] O'Brien *et al.* (2006)

economic principles to underpin a broad policy framework to promote sound adaptation in the public and private sectors, many of which also apply to developing countries (Chapter 20).

19.2 Adaptation costs and prospects in the developed world

At higher temperatures, the costs of adaptation will rise sharply and the residual damages will remain large. The additional costs of making new infrastructure and buildings resilient to climate change in OECD countries could range from $15 – 150 billion each year (0.05 – 0.5% of GDP), with higher costs reflecting the prospect of higher temperatures in future.

In the developed world, some sectors may experience benefits from climate change for moderate levels of warming up to 2 – 3°C, particularly in higher latitude regions. Here, adaptation may allow developed countries to enhance such benefits. Farmers could switch to crops more suitable for warmer climates, such as grapes for wine. And some regions may be able to develop their summer tourism industries, as traditional tourist areas in the Mediterranean, for example, suffer from extreme heat and increasing water shortages.

But the negative impacts will become increasingly serious with rising temperatures and a rising risk of abrupt and large-scale changes (Chapter 6). Growing water shortages in regions with an already dry Mediterranean-like climate (Southern Europe, California, Australia) will also require costly investment in reservoirs and other measures to manage water stress and shortages. The UK Environment Agency has estimated that 10 – 15% of increased reservoir capacity may be required to address potential water deficits could cost the UK $5.5 billion (£3 billion).[2]

Infrastructure is particularly vulnerable to heavier floods and storms, in part because OECD economies invest around 20% of GDP or roughly $5.5 trillion in fixed capital each year, of which just over one-quarter typically goes into construction ($1.5 trillion - mostly for infrastructure and buildings). The additional costs of adapting this investment to a higher-risk future could be $15 – 150 billion each year (0.05 – 0.5% of GDP), with one-third of the costs borne by the US and one-fifth in Japan.[3] This preliminary cost calculation assumes that adaptation requires extra investment of 1 – 10% to limit future damages from climate change. For temperature rises of 3 or 4°C, these calculations are likely to scale as a constant proportion of GDP, as GDP grows. But the costs will rise sharply if temperatures increase further to 5 or 6°C, as expected if emissions continue to grow and feedbacks amplify the initial warming effect.

Stronger flood defences to protect infrastructure from storm surge damage will form a significant part of the extra spending. In the UK, the Foresight study estimated that a cumulative increase in investment of $18 – 56 million (£10 – 30 million) each and every year for the next 80 years would be required to prevent the costs of flood damages escalating in the UK. Defending New Orleans alone from flooding during a Category-5 hurricane is expected to cost around $32 billion.[4]

Markets that respond to climate information will stimulate adaptation among individuals and firms.

Developed countries typically have well-established markets with individuals and firms modifying their behaviour in response to price signals. Markets that respond to changing climate risks will stimulate adaptation in the private sector ("autonomous" adaptation – see Chapter 18). Adaptation is likely to be most responsive to market signals in sectors dominated by traded goods, such as agriculture, timber and

[2] Environment Agency (2005) – cost at 2005 prices. This assumes some level of demand management.
[3] The $15 – 150 billion range for OECD countries comes from assuming that additional costs of 1 – 10% of the total amount invested in construction each year ($1.5 trillion) are required to make new buildings and infrastructure more resilient to climate change. The original analysis was carried out by Simms *et al.* (2004) who assumed adaptation costs of 1 – 5% of construction from initial research by ERM (2000). Higher estimates, such as 10%, are possible, particularly with the prospect of higher temperatures in the future. A similar calculation by the World Bank (details in Chapter 19) assumes that additional costs of 10 – 20% of investment portfolios may be required for adaptation, with the result that the total adaptation costs in developing countries of $9 – 41 billion are of a similar magnitude despite lower levels of overall investment.
[4] Hallegatte (2006)

energy. Government action may be required to set up more effective pricing mechanisms to encourage more efficient use of goods such as water where property rights are often poorly defined (Section 19.4).[5]

Insurance provides another important mechanism through which market signals can drive adaptation. Insurance has a long history of driving risk management through pricing risk, providing incentives to reduce risk, and imposing risk-related terms on policies.[6] By accurately measuring and pricing today's climate risks, insurance can help incentivise the first steps towards adaptation. The extra cost of insurance can act as a disincentive to build on high flood risk areas. Market signals of this kind encourage individuals or firms to reduce their present-day risk to weather damage, because of the cost saving associated with taking steps to manage climate risks. Encouraging action that improves society's resilience to current climate today should improve robustness to climate change in the future. Over time additional adaptation may be required to deal with longer-term effects of climate change.

In developed countries, progress on adaptation is still at an early stage, even though market structures are well developed and the capacity to adapt is relatively high.

Market forces alone, however, are unlikely to deliver the full response required to deal with the challenge of climate change (Chapter 18). This does not mean that government should manage each individual response to climate change. Rather governments should put in place a set of policies that provide individuals and firms with better information and the appropriate regulatory framework to help markets stimulate adaptation.

Many developed countries have conducted detailed studies on projected climate change impacts and vulnerability in key sectors, but only a handful of governments are moving towards implementing adaptation initiatives.[7] Some governments are beginning to create policy frameworks for adaptation.[8] But even in the UK, where awareness on adaptation is relatively high, practical measures to prepare for climate change are limited and remain largely confined to the public sector.[9]

19.3 Providing information and tools

High quality information on climate change will drive efficient markets for adaptation. Improved regional climate predictions will be critical, particularly for rainfall and storm patterns.

To make rational and effective adaptation decisions, organisations require detailed information about the full economic impacts of climate change in space and time (more detail in Chapter 18). Clear information will help ensure that climate risks are properly priced in the market. For example, production of flood hazard maps will increase house-buyers' awareness of flood risk and what individuals can do. They will also potentially influence land and house prices. In the UK, there is some evidence that house prices have decreased in areas that have flooded recently, because of concerns about lack of insurance cover and greater understanding of the risks.[10]

The scale and complexity of climate information make it unlikely that individual organisations will undertake basic research into future changes. Generic but high-quality information on climate change could be considered a public good (Section 19.5). Government-funded research programmes have advanced our understanding of climate change substantially. A central challenge for adaptation remains

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[5] Mendelsohn (2006) provides an interesting example of how autonomous adaptation may occur in the agriculture sector, and how a mixture of private and public adaptation may be required in the water sector where property rights are poorly defined in many parts of the world.
[6] Kovacs (2006); Lloyd's of London (2006)
[7] Gagnon-Lebrun and Agrawala (2005) – for example, in the Netherlands, the US and New Zealand
[8] For example, Adaptation Policy Frameworks in the UK http://www.defra.gov.uk/environment/climatechange/uk/adapt/policyframe.htm and in Finland http://www.ymparisto.fi/default.asp?contentid=165496&lan=en
[9] Tompkins *et al.* (2005) - a recent survey from the Tyndall Centre found evidence of relatively high levels of awareness of the need to adapt with UK stakeholders, particularly those in the public sector (e.g. government, local authorities, agencies), but very few, if any, specific adaptation actions that have been undertaken in response to expected climate change.
[10] Royal Institution of Chartered Surveyors (2004)

the uncertainty in climate predictions, particularly changing regional rainfall patterns (see Chapter 1), which are a key determinant of many likely adaptation requirements, for example the size and location of new sewers to cope with heavier downpours.[11] Improved regional climate predictions will help to integrate climate risk into long-term planning and provide a rationale for adaptation action.

High-quality climate information is an important starting point for adaptation, but effective communication to stakeholders will also be required. Information should not be too complex and should provide practical pointers without being excessively prescriptive, because local choice and flexibility are important.[12] The UK Climate Impacts Programme has developed an important tool for helping stakeholders deal with risk and uncertainty and incorporate climate change into project appraisal (Box 19.1). The programme overall has been instrumental in raising awareness of adaptation issues among a broad range of stakeholders in the UK and driving forward the first steps towards adaptation actions.

Box 19.1 UKCIP Adaptation Wizard

The Government has established the UK Climate Impacts Programme (UKCIP) to provide individuals and organisations with the necessary tools and information on climate impacts to allow them to adapt successfully to the changing climate. The UKCIP (2005) Adaptation Wizard has been set up to help organisations move from a simple understanding of climate change to integration of climate change into decision-making. The Wizard draws heavily on Willows and Connell (2003) and provides web-based tools for four stages of adaptation:

- Scoping the impacts
- Quantifying risks
- Decision-making and action planning
- Adaptation strategy review.

One of the most valuable UKCIP tools is an up-to-date set of climate change scenarios that are available free of charge and used by a wide range of stakeholders, including local authorities, public agencies, and businesses. New scenarios will be published in 2008 that quantify risks and uncertainties in a more robust and quantitative manner to help stakeholders plan adaptation strategies. UKCIP has further tools on handling uncertainty and costing the impacts.

Source: UKCIP (2005)

19.4 Is there a role for regulation in overcoming market barriers to adaptation?

Land-use planning and performance standards could be used to encourage both private and public investment in buildings, long-lived capital and infrastructure to take account of climate change.

Infrastructure should be an important focus of adaptation efforts, because decisions taken today leave a long legacy for future generations when the impacts of climate change will be felt most sharply. OECD countries currently invest $1.5 trillion each year in construction of new infrastructure and buildings. Effective adaptation of long-term investments is unlikely to occur through market dynamics alone when there is limited incentive to invest today to avoid future losses for the next generation.[13] Given the uncertainty and imperfections in property markets, the investor may lack confidence that extra resilience will be fully reflected in resale value in future. Decisions that leave a long-lasting legacy for future generations require private agents to weigh the uncertain future benefits of adaptation against its more certain current costs (Chapter 18). Individuals and firms will require sufficient information to build long-

[11] Heavy storms in London in August 2004 killed thousands of fish when more than 600,000 tonnes of untreated sewage was forced into the River Thames, because the sudden downpour overloaded the city's network of Victorian sewers.
[12] Chapter 17 considers the different ways that can be used to communicate climate change information to the public and how these link to regulation and standards.
[13] Mendelsohn (2000)

term horizons and make adaptation decisions that fully reflect the risks and net benefits over the lifetime of the decision.

Some market intervention may be required in order to promote the proper pricing of risks of climate change in long-term investment decisions. Regulatory measures are often less efficient and flexible than market mechanisms, but may have an important role to play in avoiding unanticipated early obsolescence of capital stock (more detail on capital “lock in” in Chapter 17). Policies will be more efficient if they encourage private individuals and firms to take explicit account of the economic costs of climate change in their decision-making, rather than simply imposing prescriptive design standards. A developer will make a rational decision about whether to increase the long-term resilience of infrastructure or to design buildings with shorter lifespan if required to consider the impacts of climate change over the lifetime of the property.

Where the risks of climate change are clear and substantial, a planned approach that allows for changes in line with natural replacement cycles avoids costly retrofits or the abandonment of infrastructure before the end of its otherwise useful life. Where there is less certainty and the risks are moderate, no-regrets options may be most appropriate - namely those actions that offer net cost savings today regardless of the eventual amount of climate change, for example reducing vulnerability to current climate variability such as floods and storms.[14] In some cases, even relatively simple structural measures could yield both short- and long-term benefits to climate variability and change, such as bracing and securing roof trusses and walls using straps, clips or adhesives to reduce hurricane damages.[15] Property-owners in the US Gulf States who implemented all the recommended hurricane protection methods suffered only one-eighth of the damages from Hurricane Katrina than those that did not implement such methods. The result was that investment by property-owners of $2.5 million avoided damages of over $500 million.[16] This is a prime example of cost-effective adaptation

Land-use decisions leave a substantial legacy. The costs for future generations may not be taken into account in market-based decisions today. There is also a moral hazard issue – private individuals may take greater risks if they think the government will bail them out because of political pressure.[17] Market signals alone, however improved, cannot carry the full weight of policy. The planning system will be a key tool for encouraging both private and public investment towards locations that are less vulnerable to climate risks today and in the future. Limiting construction of new developments in the floodplain may be an important element of a sustainable response to managing flood risk in the long term (Box 19.2).

In certain circumstances, performance standards that include headroom for climate change could reduce vulnerability to unpredictable weather, such as flash-flooding or storms. Whether and how such standards are introduced and implemented will depend on the size of the risk and the degree to which an individual’s action affects others in the community. When there is a significant negative externality, the case for market intervention will be stronger. For example, individual decisions to pave over front-gardens in London have led to a loss of permeable drainage surface equivalent to 22 times the size of Hyde Park, increasing the city’s vulnerability to flash-flooding substantially.[18] Each individual decision may be rational, but in aggregate this loss of permeable land will leave a legacy for future generations living in London.

[14] Fankhauser *et al.* (1999); “no regrets” describe projects that have a positive net present value across a range of climate change outcomes.
[15] Kleindorfer and Kunreuther (2000) considered how simple hurricane protection measures could reduce the annual expected hurricane damage costs for a sample of the population in Miami by 25% ($9 million without measures, $6.8 million), with concurrent decreases in annual cost to homeowners of $1.5 million (10% decrease in cost), measured as sum of insurance premium, expected deductible losses and annual cost of prevention measures (7% discount rate, 20 year time horizon).
[16] Mills and Lecomte (2006)
[17] Kydland and Prescott (1977)
[18] London Assembly Environment Committee (2005)

Box 19.2 Land-use planning and climate change: South East England housing case study

In February 2003, the UK Government set out its plans to provide 200,000 new homes above existing targets in the South East by 2016 to reduce the pressure on the country's housing stock. The Communities Plan identified four growth areas as the focus for the initial wave of additional housing in the South East – Thames Gateway, Ashford, the M11 corridor, and the South Midlands. These areas were chosen, in part, due to their high concentrations of brownfield sites close to existing urban centres, but face a growing risk of flooding associated with climate change.

Research by the Association of British Insurers (ABI) has shown that rigorous application of the Government's planning policy for floodplains[19] could be one of the most effective ways to control the risks from flooding and climate change.

- Moving properties off the floodplain and accommodating them in non-floodplain parts of development sites reduced flood risk by 89 - 96% for all growth areas except Thames Gateway.
- In Thames Gateway where more than 90% of the land targeted for development lies in the floodplain, a sequential approach that allocates housing to the lowest risks parts of the floodplain could reduce flood losses by 40 - 52% for the initial tranche of new housing.
- Overall, effective use of land-use planning could reduce annual flood losses from new housing by more than 50%.

The alternatives to land-use planning were more costly – increased investment in flood defences to offset the uplift in national flood risk, and adding to construction costs through building in flood-resilience.

Source: Association of British Insurers (2005b)

In many countries, government plays a role in financing long-term infrastructure investment. Here, the nature of the arrangement between public and private sector in the provision of infrastructure will influence the form of any market intervention that may be required.

- Where infrastructure is provided through targeted public investment, resilience to climate change can be established through direct government action, for example (i) locating winter roads off ice and onto land in Manitoba, (ii) upgrading the Thames Barrier, which protects London from flooding (details in Box 19.4)

- Where the regulatory framework allows for infrastructure provision through the private sector, the operation of the arrangements should be flexible enough to allow for consideration of climate change. For example, in the UK, water companies are responsible for reservoir provision,[20] energy companies are responsible for power lines, transport providers are responsible for track maintenance, and private firms now manage some public construction projects.

Public procurement could be a useful vehicle for highlighting best practice in incorporating adaptation in investment decisions[21] – and may also drive forward demand for adaptation services to help guide private sector decisions.

[19] Office of the Deputy Prime Minister (2005)
[20] Water companies in the UK are able to examine the impact of climate change on future headroom allowances for water supply. However, even here, action on climate change remains limited to research and impact assessment, rather than specific adaptation measures (Arnell and Delaney 2006).
[21] Acclimatise (2005) identify that a changing climate could affect income, operating costs and financing costs for PFI projects, with potential knock-on effects for investor and market confidence.

19.5 Incorporating climate change into long-term policies for public and publicly provided goods

Government's own long-term polices for climate-sensitive public goods, such as natural resources protection, coastal protection, and emergency preparedness, should take account of climate change to control future costs (Box 19.3).

As well as providing a clear policy framework for investment decisions, government sets long-term policies for public and publicly provided goods that supply community services (Chapter 18). Examples of specific relevance to climate change include: flood and coastal protection (Box 19.3); public health and safety (Box 19.4); and natural resource protection. The risks of not taking action could leave a significant public liability – either because the private sector will no longer carry the risk, for example by refusing to offer flood insurance, or because of sharply rising costs of disaster recovery and public safety. However, adaptation policies will require careful cost-effectiveness analysis before implementation to prevent any wasteful expenditure on remote risks and inadequate expenditure on present-day risks.

Protecting natural systems could prove particularly challenging. The impacts of climate change on species and biodiversity are expected to be harmful for most levels of warming, because of the limited ability of plants and animals to migrate fast enough to new areas with suitable climate (Chapter 3). In addition, the effects of urbanisation, barriers to migration paths, and fragmentation of the landscape also severely limit species' ability to move. For those species that can move rapidly in line with the changing climate, finding new food and suitable living conditions could prove challenging. Climate change will require nature conservation efforts to extend out from the current approach of fixed protected areas. Conservation efforts will increasingly be required to operate at the landscape scale with larger contiguous tracts of land that can better accommodate species movement. Policies for nature protection should be sufficiently flexible to allow for species' movement across the landscape, through a variety of measures to reduce the fragmentation of the landscape and make the intervening countryside more permeable to wildlife, for example use of wildlife corridors or "biodiversity islands".

Box 19.3 Public sector adaptation examples

(a) Winter roads in Manitoba, Canada

The province of Manitoba uses winter roads constructed from snow and ice to transport essential goods (fuel, food, and building supplies) to its remote northern communities. The extent of this network is equivalent to building a road from Winnipeg to Vancouver every winter, a distance of approximately 2,000 km^2. After an extremely warm winter in 1997-98 when the roads could not be opened. 1 million kg of food had to be airlifted to communities at a cost of $50 million (Canadian), so Manitoba began the process of moving 600 km of roads from ice-based routes. Instead, Manitoba located routes on land, shifted the main access points further north, and installed permanent bridges over critical river crossings. *Source: Manitoba Transportation and Government Services (2006)*

(b) Managing flood risk in London

Climate change will put London at greater risk from flooding in future years. Many floodplain areas are undergoing regeneration, putting more people, buildings and infrastructure at risk. Flooding would cause immense disruption to London's commercial activities, and could cause direct damage equivalent to around £50 billion (plus wider financial disruption). Climate change could increase the maintenance costs of flood defences in the Thames over 100 years from £3.8 billion without climate change (£1.1 billion, Green Book discounted) to £5.3 – £6.8 billion (£1.9 - £2.8 billion, Green Book discounted) with climate change. Following the 1953 East Coast floods the Thames Barrier and associated defences were planned and built over a 30-year period to protect London to a high standard from tidal flooding. The design of the Barrier allowed for sea level rise but did not make any specific allowance for changes in river flows or the height of North Sea storm surges. Although the defences offer a high level of protection from today's risks, they will only provide protection of 1-in-1000 years until 2030. After that, the risk increases, potentially reaching 1-in-50 years by the end of the century without any active intervention to upgrade capital defences. Slight modifications could extend the useful life of the defences by a few more years, but in the long term a more strategic approach is required. The Environment Agency has set up the Thames Estuary 2100 project to develop a flood risk management strategy for the next 100 years and explicitly factor in adaptation to climate change using a risk-based decision-testing framework. The project is developing decision pathways to retain flexibility over the timing and types of flood management measures as understanding about climate change increases. For example, introducing non-structural measures, such as flood storage, could delay more intrusive and expensive measures, such as construction of a new barrier, which could cost several billion. *Source: Environment Agency (2005)*

(c) Protecting Venice

Flood events in Venice have been increasing in frequency throughout the 20th century. At the beginning of this century, St Mark's Square flooded less than 10 times a year. By 1990 it was flooding around 40 times a year and in 1996 it flooded almost 100 times. Without further protection, sea level rise this century will lead to the flooding of St Mark's Square every day. In December 2001, the then Italian Prime Minister, Silvio Berlusconi, approved a $2.6 billion (€2.3 billion) scheme, known by the acronym of MOSE, to protect the city from the rising tides. The scheme consists of 78 metal gates placed across the three main inlets of the lagoon. These gates can be raised ahead of a storm surge to separate the city from the sea. The plans have been controversial. The current design is only able to cope with around 20 cm more of sea level rise, while many climate models predict around 50 cm by the end of the century. Environment campaigners have contested the design, arguing that the gates will disrupt the lagoon's delicately balanced ecosystem. *Source: Nosengo (2003)*

Box 19.4 Heatwave Adaptations

With the recognition that heat is a growing mortality risk factor, many cities around the world are developing sophisticated heatwave warning systems. Climate change effects in cities are compounded by the urban heat island effect, which can maintain night temperatures several degrees above the surrounding rural area (chapter 3). Several international organisations are collaborating to promote good-practice in warning systems that deal with the impact of extreme heat on human health.

(a) France heatwave plan ("plan canicule")

Following the summer 2003 heatwave (the hottest three-month period recorded in France), which caused an estimated 15,000 extra deaths, the French Government prepared a national heatwave plan (plan canicule). The plan consists of four different levels of intervention.

1. Vigilance – Active every year from June to September to monitor action plans and keep the public informed.
2. Alert – Trigger public services at national and regional level when temperatures exceed critical levels.
3. Intervention – Medical and social intervention when the heatwave is already underway.
4. Requisition – Reinforce existing plans and apply exceptional measures when a heatwave is long lasting, for example through use of government transport and calling in the army.

The national plan is supported by a series of action plans that focus on particular vulnerabilities – (i) care homes for the elderly; (ii) medical emergency services; (iii) emergency alert system; and (iv) Paris.

Source: ONERC (2005)

(b) Philadelphia Heat Health Warning System

The system forecasts periods up to two days in advance when there is a high risk of a weather-system associated with heat-related mortality (more than four deaths expected). Once a warning is issued, the city of Philadelphia and its public agencies put in place a series of actions to minimise the dangers of the heatwave, including:

- TV, radio stations and newspapers are asked to publicised the upcoming conditions, along with information on how to avoid heat-related illnesses.
- Promotion of a "buddy" system – media announcements encourage friends, relatives and neighbours to visit elderly people during the hot weather and make sure they have sufficient water and proper ventilation to cope with the weather.
- Telephone "Heatline" to provide information and counselling to the public on avoidance of heat stress.
- Department of Public Health mobile field teams make home visits to vulnerable households.
- Nursing homes advised on how best to protect their residents, supported by visits from field teams.
- Emergency services increase staffing levels.
- Homeless agency increases outreach activities to assist those on the streets.
- Air-conditioned shelter facilities set up for high-risk individuals.

Source: Acclimatise (2006)

19.6 Spreading risk and protecting the vulnerable

Risk-based insurance schemes will encourage good risk management behaviours, but may require a financial safety net to protect those who are most vulnerable and cannot afford protection.

Many developed countries have mature insurance markets that provide additional adaptive capacity by spreading the risks of extreme weather events across a large pool of individuals or businesses. Without any insurance system or state-backed compensation at all, the costs of weather disasters will lead to crushing personal and business liabilities. However for rapidly escalating costs, even insurance capacity may not be sufficient to cover the costs, leading to restricted coverage or the use of alternative risk transfer mechanisms, such as weather derivatives or catastrophe bonds.

In a world of identical individuals where everyone faces the same risk, full risk pooling maximises overall welfare because average utility in a world of risk pooling is greater than an individual's expected utility where in some years they may have to pay the full cost of an extreme event.[22] In reality, individuals in a population face different risks. In this case, the nature of the insurance model used affects the outcome.[23]

- If everyone contributes equally to the pool, the costs of extreme events for those at greater risk are cross subsidised by those at lower risk.[24] This could act as a social safety net to protect those in society who are most vulnerable to the impacts of climate change. Government-backed insurance systems may cause such a subsidy effect, because the premiums are drawn implicitly from tax income and are unrelated to the risk of extreme events.[25] But, if no deductibles or limits are included in program design, this model creates moral hazard by offering no reward for those who take steps to reduce their vulnerability to climate change.

- If those at greatest risk contribute most to the pool and those who avoid risk pay least, the risks are pooled in proportion to their size. Private insurance markets may lead to such segmentation (risk based pricing), because competition between insurance providers drives firms to match individual premiums to the expected payout.[26] Risk-based pricing is efficient – it distributes the costs of weather amongst the insured on the basis of risk and encourages behaviours that reduce the risks. However, such a market-based approach could leave the most vulnerable financially excluded. From an equity perspective, government may wish to create a financial safety net to protect those who are most vulnerable to climate change and cannot afford protection.

But insurance systems will face challenges with operation of risk-sharing approaches if the risks reach very high levels.[27] The capital required to support a functioning insurance market will rise sharply in line with the rising costs of extreme weather (Chapter 5). At a global level, risk sharing works effectively where the risks are independent, but climate change will raise the frequency of very serious weather events in all the large insurance markets.[28] As a result, there will be a greater chance of several large events in one year and the insurance industry may struggle to cope. Finding alternative sources of capital to diversify the risk may help to some degree,[29] but ultimately the costs may become too large for the industry to bear.

19.7 Conclusion

Adaptation could reduce the costs of climate change in developed countries, provided policies are put in place to overcome market barriers to private action. But at higher temperatures, the costs of adaptation will rise sharply and the residual damages remain large.

While some sectors of the developed world may experience benefits from climate change for moderate levels of warming (2 – 3°C), the costs will rise sharply with increasing temperatures. Adaptation can make an important difference to reducing some of these costs – but there will be limits, as the relative effectiveness diminishes. The residual damages after adaptation are likely to increase faster than the total costs, and adaptation itself will become more expensive. Preliminary estimates suggest that adapting

[22] In other words, individuals perceive a greater damage from a loss of $10,000 than a benefit from a gain of $10,000, and would refuse a 50/50 gamble of that amount. This is because of the (assumed) concavity of the income-utility function.
[23] US GAO (2005) and Association of British Insurers (2005a) both provide a useful summary of insurance for natural catastrophes in different markets.
[24] However, those not directly affected can still be materially influenced indirectly, e.g. through community-wide curtailment of economic activity or loss of jobs due to business interruptions.
[25] For example, the NatCat model in France or the National Flood Insurance Program in the USA
[26] For example, in the UK, insurers have complete freedom over pricing and terms of cover. As insurers develop more sophisticated tools for quantifying risk (e.g. flood maps down to individual properties), prices increasingly reflect weather risks.
[27] Dlugolecki (2004); Lloyd's of London (2006)
[28] Association of British Insurers (2005a)
[29] Salmon and Weston (2006)

infrastructure and buildings to climate change could increase costs by 1 – 10% taking the total for OECD countries to $15 – 150 billion each year.

These calculations assume 3 or 4°C of temperature rise, but the costs are likely to rise sharply if temperatures increase further to 5 or 6°C (as expected if emissions continue to grow and feedbacks amplify the initial warming effect). At this level, very serious risks of abrupt and large-scale change come into play. For human societies, absolute limits will be crossed once a region loses an essential but non-substitutable resource, such as glacier meltwater that supplies water to over a billion people during the dry season. Populations will then have little option but to migrate to another region of the world. At very high temperatures, the physical geography would change so strongly that the human and economic geography would be recast too. The full consequences of such effects are still uncertain, but they are likely to involve large movements of populations that would affect all countries of the world and present a new and very difficult dimension to adaptation.

References

Andrew Simms and colleagues from the new economics foundation produced one of the first assessments of the costs of adaptation for developed countries (Simms et al. 2004). The figures in the report are relatively (and necessarily) crude, but provide an indication of the scale of adaptation costs in the developed world. Few robust assessments of adaptation costs are available. More work has been undertaken to understand the relative roles of the public sector and private individuals in adapting to climate change in developed countries – for example carefully reasoned papers by the Australian Greenhouse Office (2005), Prof Frans Berkhout (2005) and most recently Prof Robert Mendelsohn (2006). This kind of analysis has been complemented by work to catalogue the extent of adaptation action in developed countries, including a recent paper on national government adaptation within the OECD (Gagnon-Lebrun and Agrawala 2005), a survey of public and private adaptation in the UK (Tompkins et al. 2005) and in Norway (O'Brien et al. 2006), and a review of adaptation in major world cities (Acclimatise 2006). The insurance industry has also produced several reports examining the role of insurance in promoting good risk management and protection against extreme weather through market signals and awareness raising (Dlugolecki 2004, Mills and Lecomte 2006, Lloyd's of London 2006).

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