Part V
Policy Responses for Adaptation

Part V of the Review analyses adaptation as a response to climate change.

Climate is a pervasive factor in social and economic development – one so universally present and so deeply ingrained that it is barely noticed until things go wrong. People are adapted to the distinct climate of the place where they live. This is most obvious in productive sectors such as agriculture, where the choice of crops and the mode of cultivation have been finely tailored over decades, even centuries, to the prevailing climate. But the same is true for other economic sectors that are obviously weather-dependent, such as forestry, water resources, and recreation. It is also evident in how people live their daily lives, for instance in working practices.

Adaptation will be crucial in reducing vulnerability to climate change and is the only way to cope with the impacts that are inevitable over the next few decades. In regions that may benefit from small amounts of warming, adaptation will help to reap the rewards. It provides an impetus to adjust economic activity in vulnerable sectors and to support sustainable development, especially in developing countries. But it is not an easy option, and it can only reduce, not remove, the impacts. There will be some residual cost – either the impacts themselves or the cost of adapting. Without early and strong mitigation, the costs of adaptation rise sharply.

Part V is structured as follows.

- **Chapter 18** outlines key adaptation concepts and sets out an economic framework for adaptation.
- **Chapter 19** examines the barriers and constraints to adaptation identified in this chapter. It sets out how governments in the developed world can promote adaptation by providing information and a policy framework for individuals to respond to market signals.
- **Chapter 20** explores the particular issue of how developing countries can adapt to climate change. Developing countries lack the infrastructure, financial means, and access to public services that would otherwise help them adapt. The chapter shows the importance of support from the international community, and the need for investment in global public goods such as the development of resistant crops.

18 Understanding the Economics of Adaptation

Key Messages

Adaptation is crucial to deal with the unavoidable impacts of climate change to which the world is already committed. It will be especially important in developing countries that will be hit hardest and soonest by climate change.

Adaptation can mute the impacts, but cannot by itself solve the problem of climate change. Adaptation will be important to limit the negative impacts of climate change. However, even with adaptation there will be residual costs. For example, if farmers switch to more climate resistant but lower yielding crops.

There are limits to what adaptation can achieve. As the magnitude and speed of unabated climate change increase, the relative effectiveness of adaptation will diminish. In natural systems, there are clear limits to the speed with which species and ecosystems can migrate or adjust. For human societies, there are also limits – for example, if sea level rise leaves some nation states uninhabitable.

Without strong and early mitigation, the physical limits to – and costs of – adaptation will grow rapidly. This will be especially so in developing countries, and underlines the need to press ahead with mitigation.

Adaptation will in most cases provide local benefits, realised without long lag times, in contrast to mitigation. Therefore some adaptation will occur autonomously, as individuals respond to market or environmental changes. Much will take place at the local level. Autonomous adaptation may also prove very costly for the poorest in society.

But adaptation is complex and many constraints have to be overcome. Governments have a role to play in making adaptation happen, starting now, providing both policy guidelines and economic and institutional support to the private sector and civil society. Other aspects of adaptation, such as major infrastructure decisions, will require greater foresight and planning, while some, such as knowledge and technology, will be of global benefit.

Studies in climate-sensitive sectors point to many adaptation options that will provide benefits in excess of cost. But quantitative information on the costs and benefits of economy-wide adaptation is currently limited.

Adaptation will be a key response to reduce vulnerability to climate change. Part II highlighted the significant impacts of climate change around the world. The Earth has already warmed by 0.7°C since around 1900. Even if all emissions stopped tomorrow, the Earth will warm by a further 0.5 - 1°C over coming decades due to the considerable inertia in the climate system. On current trends, global temperatures could rise by 2 - 3°C within the next fifty years or so, with several degrees more warming by the end of the century if emissions continue to grow.

But adaptation is not an easy or cost-free option. This chapter outlines key adaptation concepts and sets out an economic framework for adaptation. It chapter highlights that adaptation is unlikely to reduce the net costs of climate change to zero – namely there will be limits. There will be often residual damages from climate change and adaptation itself will bring costs. The final part of the chapter outlines why policies may be required to overcome barriers and constraints to adaptation in anticipation of future impacts. These policy responses are outlined in more detail in Chapters 19 and 20 for developed and developing countries, respectively.

But even with a policy framework in place, there will be limits to or sharply rising costs of adaptation – for the most vulnerable at moderate levels of warming (e.g. ecosystems, the poorest regions), and for all parts of the world with higher amounts of climate change (4 or 5°C of warming). Developing countries are especially vulnerable to the negative effects of climate change. They are geographically vulnerable, located where climate change is likely to have often damaging impacts, and – as explained in Chapter 20 – are likely to have the least capacity to adapt. Chapter 26 in Part VI picks up this story and outlines how the international community can help developing countries deal with these impacts.

18.1 Role of adaptation

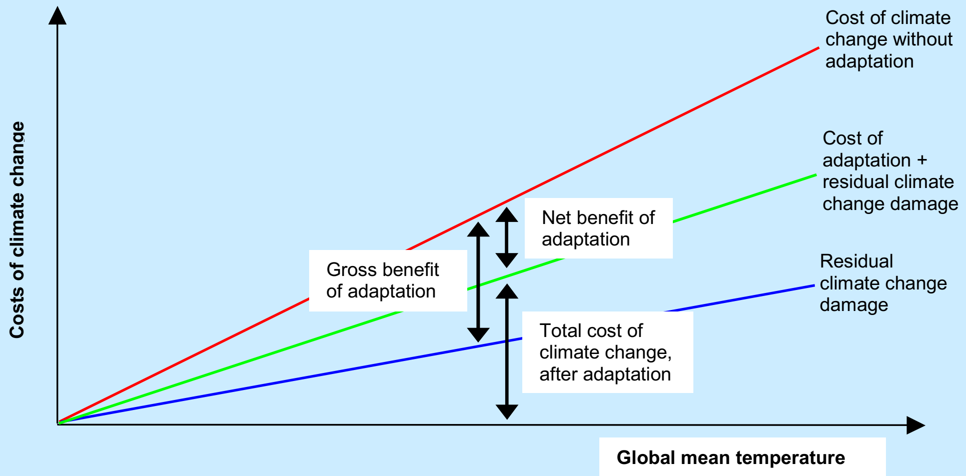
Adaptation is a vital part of a response to the challenge of climate change. It is the only way to deal with the unavoidable impacts of climate change to which the world is already committed, and additionally offers an opportunity to adjust economic activity in vulnerable sectors and support sustainable development.

A broad definition of adaptation, following the IPCC, is any adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.[1] The objective of **adaptation** is to reduce vulnerability to climatic change and variability, thereby reducing their negative impacts (Figure 18.1). It should also enhance the capability to capture any benefits of climate change. Hence adaptation, together with mitigation, is an important response strategy. Without early and strong mitigation, the costs of adaptation will rise, and countries' and individuals' ability to adapt effectively will be constrained.

Figure 18.1 The role of adaptation in reducing climate change damages

Adaptation will reduce the negative impacts of climate change (and increase the positive impacts), but there will almost always be residual damage, often very large. The gross benefit of adaptation is the damage avoided. The net benefit of adaptation is the damage avoided, less the cost of adaptation.

The residual cost of climate damage plus the cost of adaptation is the cost of climate change, after adaptation.



For the sake of simplicity, the relationships between rising temperatures and the different costs of climate change/adaptation are shown as linear. In reality, Part II and Chapter 13 demonstrated that the costs of climate change are likely to accelerate with increasing temperature, while the net benefit of adaptation is likely to fall relative to the cost of climate change.

Adaptation can operate at two broad levels:[2]

- **Building adaptive capacity** – creating the information and conditions (regulatory, institutional, managerial) that are needed to support adaptation. Measures to build adaptive capacity range from understanding the potential impacts of climate change, and the options for adaptation (i.e. undertaking impact studies and identifying vulnerabilities), to piloting specific actions and accumulating the resources necessary to implement actions.
- **Delivering adaptation actions** – taking steps that will help to reduce vulnerability to climate risks or to exploit opportunities. Examples include: planting different crops and altering the timing of

[1] Intergovernmental Panel on Climate Change (IPCC) (2001), Chapter 18
[2] UKCIP (2005) Measuring progress, Chapter 4

crop planting; and investing in physical infrastructure to protect against specific climate risks, such as flood defences or new reservoirs.

18.2 Adaptation perspectives

Some adaptation will occur autonomously, as individuals respond to changes in the physical, market or other circumstances in which they find themselves. Other aspects will require greater foresight and planning, e.g. major infrastructure decisions.

Adaptation is different from mitigation because: (i) it will in most cases provide local benefits, and (ii) these benefits will typically be realised without long lag times. As such, many actions will be taken 'naturally' by private actors such as individuals, households and businesses in response to actual or expected climate change, without the active intervention of policy. This is known as 'autonomous' adaptation.

In contrast, policy-driven adaptation can be defined as the result of a deliberate policy decision.[3] Autonomous adaptation is undertaken in the main by the private sector (and in unmanaged natural ecosystems), while policy-driven adaptation is associated with public agencies (Table 18.1) - either in that they set policies to encourage and inform adaptation or they take direct action themselves, such as public investment. There are likely to be exceptions to this broad-brush rule, but it is useful in identifying the role of policy. *The extent to which society can rely on autonomous adaptation to reduce the costs of climate change essentially defines the need for further policy*. Costs may be lower in some cases if action is planned and coordinated, such as a single water-harvesting reservoir for a whole river catchment rather than only relying on individual household water harvesting. The primary barriers to autonomous adaptation will be discussed in Section 18.5.

Table 18.1 Examples of adaptation in practice

Type of response to climate change	Autonomous	Policy-driven
Short-run	▪ Making short-run adjustments, e.g. changing crop planting dates ▪ Spreading the loss, e.g. pooling risk through insurance	▪ Developing greater understanding of climate risks, e.g. researching risks and carrying out a vulnerability assessment ▪ Improving emergency response, e.g. early-warning systems
Long-run	▪ Investing in climate resilience if future effects relatively well understood and benefits easy to capture fully, e.g. localised irrigation on farms	▪ Investing to create or modify major infrastructure, e.g. larger reservoir storage, increased drainage capacity, higher sea-walls ▪ Avoiding the impacts, e.g. land use planning to restrict development in floodplains or in areas of increasing aridity.

The distinction between short-run and long-run adaptation is linked to the appropriate pace and flexibility of adaptation options (Box 18.1). In the short run, the decision maker's response to climate change and variability is constrained by a fixed capital stock (e.g. physical infrastructure), so that the principal options available are restricted to variable inputs to production. For example, a farmer can switch crops and postpone or bring forward planting dates in response to forecasts about the forthcoming growing season. On the other hand, major investments in irrigation infrastructure cannot be made reactively on such a timescale. Evaluating such investments requires expectations to be formed on costs and benefits over several decades, which places a challenging requirement on

[3] This is sometimes referred to as "planned adaptation" in the literature.

climate and weather forecasting. If the climate changes faster than expected, infrastructure could become obsolete before its planned design-life or require a costly retrofit to increase resilience.

Adaptation will occur in practice in response to particular climate events and in the context of other socio-economic changes.

Responding to changed climate and weather (for example the appearance of stronger and more frequent floods or storms) is often an important first step for adaptation. Enhancing these responses to prepare for future impacts is the second step – for example, by using drought-resistant crops or improving flood defences. Many decisions to adapt will be made autonomously, within existing communities, markets and regulatory frameworks. This has important consequences for the way economists understand and appraise adaptation policy.

First, much adaptation will be triggered by the way climate change is experienced. Climate variability and in particular extreme weather, such as summer heat waves or storms, are likely to constitute important signals, alongside the dissemination of knowledge and information. Since adaptive capacity is related to income and capabilities, the most vulnerable in society will experience the same negative climate impacts more acutely.

Second, many adaptation decisions involve a measure of habit and custom, especially smaller decisions made by, for example, individuals, households and small businesses on short time-scales and with small amounts of resources. This effect may limit the extent to which such adaptations will be orientated towards maximising net benefits in an economic and social sense, since ‘custom’ may have been based on responding to past climate patterns.

Decisions about the timing and amount of adaptation require that costs and benefits are compared.

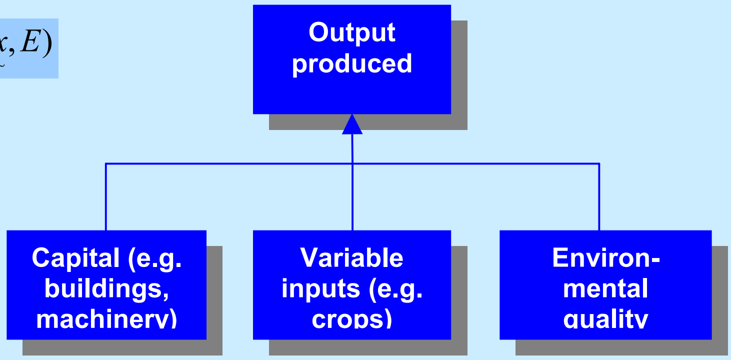
An appraisal of any particular method of adaptation should compare the benefits - which are the avoided damages of climate change - with the costs appropriately discounted over time (see Chapter 2 and Annex 2A for a discussion of discounting). The adaptation route that is chosen should be the one that yields the highest net benefit, having taken account of the risks and uncertainties surrounding climate change (see Box 18.2 for a risk management framework).[4]

[4] Callaway and Hellmuth (2006); Willows and Connell (2003).

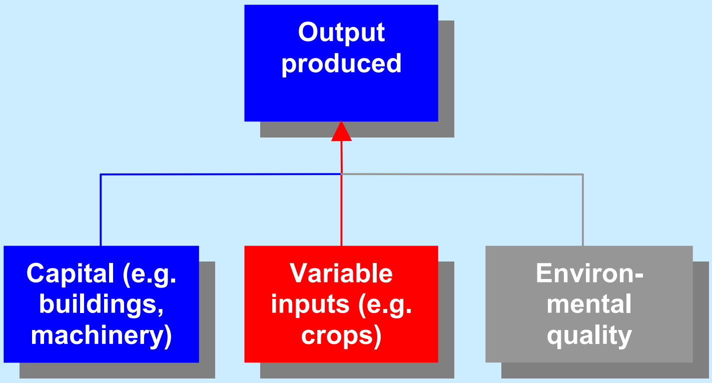
Box 18.1 Adaptation actions with fixed and variable capital stock

The difference between short-run and long-run adaptation decisions can be explained using the following illustrative diagram. In any given year, the output of an economy is generated using three types of inputs, capital *K*, variable inputs to production and environmental quality E.

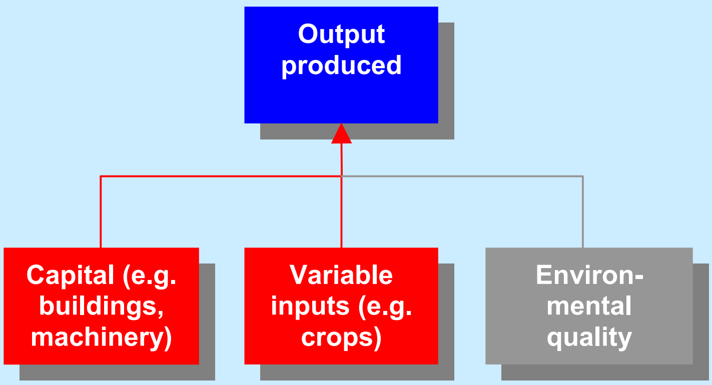
$$Y = f(K, \underset{\sim}{x}, E)$$



In the short run – and given a change in *E* due to climatic change and variability over a short period of time (e.g. one year) - the decision maker, who seeks to maximise the net profits of production, can respond only by changing variable inputs (shown as red in the diagram below).



In contrast, in the long run (e.g. over 30 years), the decision maker can respond by changing both variable inputs and the capital stock to maximise profits given a change.



Box 18.2 Adaptation costs and benefits.

The table below presents a simple framework for thinking about the costs and benefits of adaptation.[5] The columns reflect two climate scenarios, one with and one without climate change (T_0 and T_1 respectively). The two rows represent two adaptation options, one which is best to pursue without climate change and one which is best to pursue with climate change (A_0 and A_1 respectively).

The top left box represents the initial situation, where society is adapted to the current climate (T_0, A_0). The bottom right box represents a situation where society adapts (A_0 to A_1) to a change in climate from T_0 to T_1.

The top right box represents a situation where society fails to adapt to the change in climate. Finally, the bottom left box represents a counterfactual situation where society undertakes adaptation (A_0 to A_1), but the climate does not in the end change. This is an example of the type of situation that could arise if climate does not change in the anticipated way.

Adaptation costs and benefits

Adaptation Type	Existing Climate (T_0)	Altered Climate (T_1)
Adaptation to existing climate (A_0)	Existing climate. Society is adapted to existing climate: (T_0, A_0), or Base Case	Altered climate. Society is adapted to existing climate: (T_1, A_0).
Adaptation to altered climate (A_1)	Existing climate. Society is adapted to altered climate: (T_0, A_1).	Altered climate. Society is adapted to altered climate: (T_1, A_1).

The various costs and benefits of adapting to climate change follow from this, and can be thought of along the following lines:

- *Climate change damage* is the welfare loss associated with moving from the base climate (top left) to a changed climate without adaptation (top right): $W(T_1,A_0) – W(T_0,A_0)$.
- *Net benefits of adaptation* are the reduction in damage achieved by adapting to the changed climate (net of the costs of doing so), subtracting the top right box from the bottom right box: $W(T_1,A_1) – W(T_1,A_0)$.
- *Climate change damage after adaptation* is the difference between social welfare in the bottom right box and in the top left box: $W(T_1,A_1) – W(T_0,A_0)$.

Uncertainty over the nature of future climate change is implicit in this framework, and is one of the principal challenges facing climate policy. The second table below therefore modifies the framework to illustrate the trade-offs facing those planning adaptation under uncertainty.[6] The decision to implement an adaptation strategy should take account of the balance of risks and costs of planning for climate change that does not occur and vice versa.

Where the cost of planning for climate change is low, but the risks posed by climate change are high (top right box), there is a comparatively unambiguous case for adaptation. In contrast, where the costs of adaptation are high but the risks posed by climate change are low (bottom left box), the proposed adaptation responses may be disproportionate to the risks faced. Where the costs of planning for climate change and the risks of climate change are both low (top left box), there is little risk to the situation and the downsides are small, regardless of the choice made. In contrast, where the costs of both 'mistakes' are high, the stakes and risks are very high for the planner.

Cost of planning for climate change	Risks of climate change	
	Low	**High**
Low	Low risk	Plan for climate change
High	Don't plan for climate change	High risk

[5] Drawing on a framework originally presented by Fankhauser (1997) and modified by Callaway (2004).
[6] Callaway and Hellmuth (2006).

More quantitative information on the costs and benefits of economy-wide adaptation is required. For some specific sectors - such as coastal defences and agriculture – some studies indicate that efficient adaptation could reduce climate damages substantially.

As Chapter 6 explained, adaptation is an important component of integrated assessment models that estimate the economy-wide cost of climate change at the regional and global levels. However, these models are currently of limited use in quantifying the costs and benefits of adaptation, because the assumptions made about adaptation are largely implicit. Adaptation costs and benefits are rarely reported separately.[7]

However, for some sectors that are especially vulnerable to climate change, illustrative studies have been undertaken. As with the IAMs discussed in Chapter 6, many assumptions must be made to project costs and benefits over long periods of time. Assumptions about population and economic growth are especially important for evaluating the benefits of adaptation expressed in terms of avoided damage.

For coastal protection, the avoided damages of climate change can be calculated from the value of land, infrastructure, activities and so on protected by sea walls, while the cost of sea walls can be calculated by scaling up from engineering estimates of construction costs. Coastal protection should – in theory – occur up to the point where the cost of the next unit of protection is just equal to the benefit. In general, these studies suggest that high levels of protection may be economically efficient and reduce the costs of land loss substantially.[8] According to one recently analysis, the effectiveness of adaptation declines with higher amounts of sea level rise. This analysis found that for 0.5-m of sea level rise damage costs were reduced by 80 – 90% with enhanced coastal protection than without, while the costs were only reduced by 10 – 70% for 1-m of sea level rise.[9] For most countries, protection costs based on these calculations are likely to be below 0.1% of GDP, at least for rises up to 0.5-m. But for low-lying countries or regions, costs could reach almost 1% of GDP.[10] For 1-m of sea level rise, the costs could exceed several percent of GDP for the most vulnerable nations.[11]

In agriculture, adaptation responses could be even more diverse, ranging from low-cost farm-level actions – such as choice of crop variety, changes in the planting date, and local irrigation – to economy-wide adjustments – including availability of new cultivars, large-scale expansion of irrigation in areas previously only rain-fed, widespread fertiliser application, regional/national shifts in planting date. Some studies suggest that relatively simple and low-cost adaptive measures, such as change in planting date and increased irrigation, could reduce yield losses by at least 30 - 60% compared with no adaptation (Table 18.2).[12] But adaptation gains will be realised only by individuals or economies with the capacity to undertake such adjustments. The costs of implementing adaptation, particularly the transition and learning costs associated with changes in farming regime, have not been clearly evaluated.

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[7] Tol *et al*. (1998)
[8] Fankhauser (1995) assumes no population or GDP growth and finds that almost total protection of all coastal cities and harbours in OECD countries would be optimal (e.g. greater than 95% land area protected) and around 80% of open coastline. By allowing for population and GDP growth in line with IPCC scenarios, Nicholls and Tol (2006) find that protecting at least 70% of coastline in most parts of the world could be an optimal protection response.
[9] Anthoff *et al.* (2006) analysing data from Nicholls and Tol (2006) for the decade 2080 - 2089. Costs were calculated as net present value in US $ billion (1995 prices). Damage costs include value of dryland and wetland lost and costs of displaced people (assumed in this study to be three times average per capita income). The ranges represent results for different IPCC socio-economic scenarios with different population and per capita GDP growth trajectories over time.
[10] Analysis in Nicholls and Tol (2006)
[11] This analysis considers only protection costs required to manage loss of land from permanent inundation and not the costs of protection to deal with episodic flooding, which could cause damages an order of magnitude greater (Chapter 5).
[12] Reviewed in Tol *et al.* (1998)

Table 18.2 Benefits of adaptation in agriculture					
Study	**Climate scenario**	**Type of adaptation**	**Climate Impacts**		**Impact change of adaptation**
			without adaptation	**with adaptation**	
Easterling *et al* (1993) Missouri, Iowa, Nebraska, Kansas (MINK)	1930s climate analogue; base year 1980s	Change in planting date tillage practices, change in crops, improved irrigation and crop drought resistance	Yield change ($ bn)		% impact reduction
			-1.33 to –2.71	-0.53 to -1.92	29 - 60
Rosenzweig and Parry (1994) Developed countries Developing countries World	2 x CO_2 base year 2060	Small shifts in planting date (<1 month), change in crops, additional irrigation ('level 1 adaptation')	Change in cereal production %		% impact reduction
			-3.5 to 11.3 -10.8 to –11.00 -1.2 to –7.6	4.0 to 14.0 -9.0 to –12.0 0.0 to –5.0	24 - >100 9 - 17 34 - 100
Adams et al. (1993) United States	2 x CO_2 base year 1990	As Rosenzweig and Parry (1994)	Welfare change ($ bn)		% impact reduction
			2.15 to –13.00	10.82 to – 9.03	>100
Reilly et al. (1994)[a] Developing countries GDP/cap <$500 GDP/cap $500 – 2000 GDP/cap >$2000 E. Europe and former USSR OECD World	2 x CO_2 base year 1989	As Rosenzweig and Parry (1994)	Welfare change ($ bn)		% impact reduction
			-2.07 to –19.83 -1.80 to –15.01 -0.33 to –0.82 1.89 to –10.96 2.67 to – 15.10 -0.13 to –61.23	-0.21 to –10.67 -0.43 to –10.67 -0.60 to –1.02 2.42 to –4.88 5.82 to –6.47 7.00 to –37.62	26 - 90 41 - 76 20 - 46 29 - 56 57 - >100 39 - >100
[a] Based on Rosenzweig and Parry (1994) yield date					
Source: Table reproduced from Tol et al. (1998)					

18.3 Barriers and limits to adaptation

In many cases, market forces are unlikely to lead to efficient adaptation.

Broadly, there are three reasons for this:

- **Uncertainty and imperfect information**;
- **Missing and misaligned markets,** including public goods;
- **Financial constraints,** particularly those faced by the poor.

Policies can reduce these problems (see Chapters 19 and 20). But policy-makers themselves face imperfect information and have their own organisational challenges. Difficult policy choices may not always be tackled head-on.[13]

Uncertainty and imperfect information

Alongside an increase in global temperatures, climate change will bring increases in regional temperatures, changes in patterns of rainfall, rising sea levels, and increases in extreme events (heatwaves, droughts, floods, storms). High-quality information on future climate change at the regional scale is important for a market-based mechanism that drives successful adaptation responses. In particular, information is required for markets operate efficiently. Without a robust and

[13] Lonsdale *et al.* (2005) explored these challenges in the Atlantis Project, where key London decision-makers faced a collapse of the West Antarctic Ice Sheet beginning in 2030, and a 30% chance of a 5-metre rise in sea level by 2130. They found that a delay to approve construction of an outer barrier in the Thames by decision-makers meant that abandonment of parts of London became the only adaptation option.

reliable understanding about the likely consequences of climate change, it is difficult individuals – or firms – to weigh up the costs and benefits of investing in adaptation. Uncertainty in climate change projections could therefore act as a significant impediment to adaptation. The uncertainty will never be completely resolved, but should become more constrained as our understanding of the system improves.

As this understanding improves and develops, there may also be a role for markets in providing information to individuals. For example, better developed insurance markets would help to create clear price signals – for example through differentiated insurance premia - about the risks associated with climate change. Thus premia associated with buildings in high flood risk areas might be expected to be higher than those on buildings in less vulnerable locations.

Missing and misaligned markets, including public goods

Autonomous adaptation is more likely when the benefits will accrue solely – or predominantly – to those investing in adaptation. For sectors that are characterised by short planning horizons – and where there is less uncertainty about the potential impacts of climate change - successful adaptive responses may therefore be driven by autonomous decisions.

However, effective adaptation of long-term investment patterns (such as climate-proofing buildings and defensive infrastructure) could prove challenging for private markets, especially with uncertain information. Decisions that leave a long-lasting legacy require private agents to weigh the uncertain future benefits of adaptation against its more certain current costs (see also Box 18.2). Even if the benefits of adaptation can be realised over a relatively short time-horizon, unless those paying the costs can fully reap the benefits, then there will be a barrier to adaptation. For example, there will be little financial incentive for developers to increase resilience of new buildings unless property buyers discriminate between properties on the basis of vulnerability to future climate.

Evidence from the United States suggests that consumers often fail to adopt even low-cost protection against weather hazards. A report by the Wharton Center for Risk Management and Decision Processes cites major surveys of residents in hurricane- and earthquake-prone areas of the USA. It found that, in the majority of cases, no special efforts had been made to protect homes.[14] Willingness-to-pay research suggests that many property owners are reluctant to invest in cost-effective protection measures, because they do not make the implied trade-off between spending money on risk prevention measures now in return for potential benefits over time. Some may not be in a position to finance the investment. Some may expect the government to bail them out.[15] Others may believe that the benefits of investment will not be capitalised in the value of the home.

Some adaptive responses not only provide private benefits to those who have paid for them, they also provide benefits – or positive spillovers - to the wider economy. In such circumstances, the private sector is unlikely to invest in adaptation up to the socially desirable level because they are unable to capture the full benefits of the investment. In some cases, there may be little – or no – private adaptation because the necessary adaptative response is effectively a 'public good' in the technical economic sense[16]. Public goods occur where those who fail to pay for something cannot be excluded from enjoying its benefits, and where one person's consumption of a good does not diminish the amount available for others. In the case of climate change, relevant pubic goods include research to improve our understanding of climate change and its likely impacts, coastal protection and emergency disaster planning. These – and the appropriate policy response – are discussed more fully in chapters 19 and 20.

Financial constraints and distributional impacts

Upfront investment in adaptive capacity and adaptation actions will be financially constrained for those on low incomes. In many developing countries, financial resources in general are already extremely limited, and poverty already limits the ability to cope with and recover from climate shocks - particularly when combined with other stresses (Chapter 20 discusses the particular challenge faced by developing countries).

[14] Kleindorfer and Kunreuther (2000)
[15] Kydland and Prescott (1977)
[16] Samuelson (1954). That is, they are both non-excludable and indivisible.

Equally, across all countries, it will be the poorest in society that have the least capacity to adapt (Chapters 4 and 5 in Part II). Thus, the impacts of climate change could exacerbate existing inequalities by limiting the ability of poor people to afford insurance cover or to pay for defensive actions. Social safety nets that function in emergencies could be of great importance here: for example cash or food for work schemes, such as those involved in employment guarantee schemes in India, can play a very important role in droughts.

Even with an appropriate policy framework, adaptation will be constrained both by uncertainty and technical limits to adaptation.

An inherent difficulty for long-term adaptation decisions is uncertainty, due to limitations in our scientific knowledge of a highly complex climate system and the likely impacts of perturbing it. Even as scientific understanding improves, there will always remain some residual uncertainty, as the size of impacts also depend on global efforts to control greenhouse gas emissions. Effective adaptation will involve decisions that are robust to a range of plausible climate futures and are flexible so they can be modified relatively easily. But there will always be a cost to hedging bets in this way, compared to the expert 'optimal' adaptation strategy that is revealed only with the benefit of hindsight.

There are clear limits to adaptation in natural ecosystems. Even small changes in climate may be disruptive for some ecosystems (e.g. coral reefs, mangrove swamps) and will be exacerbated by existing stresses, such as pollution. Beyond certain thresholds, natural systems may be unable to adapt at all, such as mountainous habitats where the species have nowhere to migrate.

But even for human society, there are technical limits to the ability to adapt to abrupt and large-scale climate change, such as a rapid onset of monsoon failure in parts of South Asia. Sudden or severe impacts triggered by warming could test the adaptive limits of human systems. Very high temperatures alone could become lethal, while lack of water will undermine people's ability to survive in a particular area, such as regions that depend on glacier meltwater. Rising sea levels will severely challenge the survival of low-lying countries and regions such as the Maldives or the Pacific Islands, and could result in the abandonment of some highly populated coastal regions, including several European cities.[17]

18.4 Conclusions

There are many ways that people, governments and economic agents of all kinds can adapt to climate change. Indeed, adaptation has always occurred in response to changes in the climate system. However, adaptation by private individuals will have to be bolstered by government support in a variety of ways, if countries and regions are to rise to the challenge of climate change this century and beyond.

Uncertainty and imperfect information, missing and misaligned markets, and financial and distributional constraints, especially on the poorest in society, will present barriers to adaptation to climate change. Chapters 19 and 20 discuss the role of both markets and government in helping to promote effective adaptation in developed and developing countries.

In all cases, however, it is important to recognise the limits to adaptation. Although it can mute the impacts of climate change, it cannot by itself solve the problems posed by high and rapidly increasing temperatures. Even for relatively low amounts of warming, there are natural and technical constraints to adaptation – as is made vividly clear in low-lying coastal regions. Equally, without strong and early mitigation, the physical limits to – and costs of – adaptation will grow rapidly.

[17] Tol *et al.* (2006) investigated possible responses of society to 5 – 6 m of sea level rise following collapse of the West Antarctic Ice Sheet. The scenarios were developed from case studies based on interviews with stakeholders and experts. In the Rhone delta, the most likely option would be retreat. In the Thames Estuary, there could be a mix of protection and retreat with parts of the city turned into a Venice-style canal city. In the Netherlands, the initial response would be protection, followed by retreat from areas of low economic value, with eventual abandonment of some large cities, like Amsterdam and Rotterdam.

References

Developing an economic framework for examining adaptation was one of the primary objectives of a workshop hosted by the Stern Review in London on 9 May 2006. Several valuable papers were presented at the workshop, all of which are on the Review website (http://www.sternreview.org.uk). Sam Fankhauser summarised his previous work on developing an economic framework for adaptation (see Fankhauser 1997), while Molly Hellmuth presented her work with Mac Callaway (building on Callaway 2004). Frans Berkhout provided a valuable complement to these papers, discussing how we should understand adaptation by private individuals and the role of the public sector in that light (drawing on Berkhout, 2005). On the measurement of adaptation costs and benefits, Tol *et al.* (1998) reviewed evidence from a range of sources. Their discussion of estimates generated by global integrated assessment models is valuable.

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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 17). 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 17). 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 18.5). Government-funded research programmes have advanced our understanding of climate change substantially. A central challenge for adaptation remains

[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 3), 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.

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[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 6). 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.

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20 Adaptation in the developing world

Key Messages

Adaptation to mute the impact of climate change will be essential in the poorer parts of the world. The poorest countries will be especially hard hit by climate change, with millions potentially pushed deeper into poverty.

Development itself is key to adaptation. Much adaptation should be an extension of good development practice and reduce vulnerability by:

- Promoting growth and diversification of economic activity;
- Investing in health and education;
- Enhancing resilience to disasters and improving disaster management;
- Promoting risk-pooling, including social safety nets for the poorest.

Putting the right policy frameworks in place will encourage and facilitate effective adaptation by households, communities and firms. Poverty and development constraints will present obstacles to adaptation but focused development policies can reduce these obstacles.

Adaptation actions should be integrated into development policy and planning at every level. This will incur incremental adaptation costs relative to plans that ignore climate change. But ignoring climate change is not a viable option – inaction will be far more costly than adaptation.

Adaptation costs are hard to estimate, because of uncertainty about the precise impacts of climate change and its multiple effects. But they are likely to run into tens of billions of dollars. This makes is still more important for developed countries to honour both their existing commitments to increase aid sharply and help the world's poorest countries adapt to climate change. More work is needed to determine the costs of adaptation.

Without global action to mitigate climate change, both the impacts and adaptation costs will be much larger, and so will be the need for richer countries to help the poorer and most exposed countries. The costs of climate change can be reduced through both adaptation and mitigation, but adaptation is the only way to cope with impacts of climate change over the next few decades.

20.1 Introduction

It is the countries with fewest resources which are most likely to bear the greatest burden of climate change in terms of loss of life, adverse effect on income and growth, and damage to living standards generally. Developing countries - and especially the low-income countries in tropical and sub-tropical regions - are expected to suffer most, and soonest, from climate change. They are especially vulnerable to the effects of climate change, because of their existing exposure to an already fragile environment and their economic and social sensitivity to climate change. And their poverty reduces their capacity to adapt (discussed in Chapter 4).

As in developed countries, much adaptation will be a local response by individuals to a changing climate. Households, communities, and firms respond autonomously to climate change and extreme variability in ways that help to reduce its harmful effects. Yet these autonomous responses will be likely to fall far short of what is necessary, given current vulnerabilities and the scale of future impacts. Sections 20.2 and 20.3 set out the essential role that governments will have to play in reducing this vulnerability through good development practice, including better disaster risk management and use of social safety nets to protect the most vulnerable.

Governments will also have a specific role in establishing the policy frameworks to encourage adaptation by private individuals and firms – in particular to address information uncertainties, ensure transparency of transactions, and tackle financial/non-financial constraints that will reduce the capacity for autonomous adaptation (as discussed in Chapters 18 and 19). Three aspects will be especially important for governments:

- Providing high quality information;
- Effective land-use planning and performance standards; and
- Ensuring that major planning and public sector investment decisions take account of climate change.

The application of these principles is context specific and will vary from country to country. Developing countries face additional constraints and obstacles that will require even greater effort by governments, as discussed in Section 20.4. Section 20.5 sets out a range of estimated costs of adaptation in developing countries. The chapter concludes with a preview of the necessity of international assistance for adaptation (discussed in detail in Chapter 26).

20.2 Adaptation prospects in the developing world

Individuals, firms and civil society will respond to a changing climate as far as their knowledge and resources allow. But they will require support from their government to overcome barriers and increase adaptive capacity.

Individuals, firms, and civil society will have a central role in responding to climate change. People and local companies will typically have better information than governments about their own specific situations, as well as stronger incentives to act. This is testified by examples of autonomous action taken in response to extreme weather events. For example:

- In parts of the Mahanadi floodplains in India's Orissa state, farmers usually cultivate a local variety of paddy (Champeswar) that is tolerant to water stagnation to reduce agricultural output loss;[1] and
- In the Sahel, a drought in the 1980s was greater than one in the 1970s but the losses associated with the later drought were far less as people effectively adapted and increased their resilience to the impacts of a hostile climate.[2]

However, many poor people face a plethora of constraints – linked mainly to low-income levels and poverty – which limit their ability to react autonomously to climate change, as set out in Chapter 4. Unless action is taken, these constraints will be compounded as developing countries are exposed to more frequent and intense extreme weather events. As in developed countries, individuals and firms will naturally react in response to market signals. For example, if climate-induced water scarcity results in higher prices, firms and households are likely to become more efficient in their use of water. But in many developing countries public water utilities do not provide water services to poor people but only to firms and better-off consumers – and at artificially low, subsidised prices. In such cases, existing structures and price systems limit autonomous adaptation and actually increase the burden on the poorest.

Government capacity is also a major issue in most developing countries where human and other resources are already strained. But governments have an important potential role in helping people to build their adaptive capacity through good development practice. In addition, developing-country governments - as with developed - have an essential role in supplying information and ensuring that markets provide appropriate signals. This is in addition to providing necessary infrastructure and public services. But already stretched local and national administrations face additional burdens with the need to adapt governmental activities to climate change, and ensure that both public and private sectors exploit whatever comparative advantages they have in adapting to the stresses of climate change. Box 20.1 sets out a summary of the various measures that governments should take to strengthen adaptation, discussed in more detail below.

[1] Roy et al (2006). Champeswar can sustain almost seven days submergence

[2] Nkomo et al (2006) This resilience can be broadly attributed to a) reliance on local networks and groups, b) local savings schemes, many of them based on regular membership fees, c) a changing role of the state and linkages between countries and to global aid systems, and d) regional co-operation, such as the CILSS grouping (the Permanent Interstate Committee for the Fight against Drought in Sahelian countries founded in 1973 in the aftermath of the 1970s drought).

Box 20.1 Measures to strengthen adaptation

As discussed above, development itself is the most effective way to promote adaptation to climate change, because development increases resilience and reduces vulnerabilities. Beyond that broad development focus, fully integrating climate change will require ensuring that adaptation concerns are reflected across many aspects of government policy. Some of the required measures for strengthening adaptation include:

- **Ensuring access to high-quality information about the impacts of climate change and carrying out vulnerability assessment**. Early warning systems and information distribution systems help to anticipate and prevent disasters.
- **Increasing the resilience of livelihoods and infrastructure** using existing knowledge and coping strategies.
- **Improving governance,** including a transparent and accountable policy and decision-making process and an active civil society.
- **Empowering communities** so that they participate in assessments and feed their knowledge into the process at crucial points.
- **Integrating climate change impacts** in issues in all national, sub-national and sectoral planning processes and macro-economic projections. The national budget process is key here.
- **Encouraging a core ministry** with a broad mandate, such as finance, economics or planning, to be fully involved in mainstreaming adaptation.

Source: Adapted from Sperling (2003)

20.3 The foundations of the policy response: building on good development practice

Much of what governments should do in relation to adaptation is what they should be doing anyway - that is, implementing good development practice. This is key to reducing the vulnerability of developing countries to climate change and raising their capacity to adapt. Climate change concerns simply lend greater urgency to these core tasks of government and, as discussed in Chapter 26, the role of the international community in supporting adaptation in developing countries. This was noted in Chapter 4 where rapid growth, as being experienced in China and India for example, will equip these countries with the economic resources to invest in appropriate policies and tools to better manage the effects of climate change. In some circumstances, there may be additional costs, which the international community will have a role in helping to finance (see Chapter 26), bearing in mind the differences in income and historical responsibility for the bulk of past emissions.

If individuals and communities are empowered by development and rendered less vulnerable overall, they will be better able to adapt to climate change.

By empowering individuals with the tools to shape and improve their own lives and livelihoods - in other words, by promoting development broadly - governments will also strengthen individuals' ability to respond autonomously to climate change. Economic diversification, for example, is typically a core feature of development *and* is one of the best defences against economic shocks. It typically reduces the dependence of households, and the economy more broadly, on climate-sensitive sectors such as agriculture. It also increases the flexibility of the economy and individuals to adjust to sudden or gradual changes in the climate. Broad development measures will improve the lives of millions today and reduce individuals' vulnerability to climate change. In some cases it will also reduce the risks of these impacts occurring in the first place. For example:

- The control of malaria benefits millions of people today *and* will reduce the extent to which climate change will expose people to greater risk of malaria infection in the future;

- Greater access to education and reproductive health care for women will improve their lives and opportunities today *and* help control the rapid rate of population growth in developing countries, reducing pressures on existing resources.[3]

Good development practice will also serve to better equip people through building and developing their resilience. This is demonstrated in the case of Bangladesh where vulnerability to extreme weather events has been reduced in part through good development (Box 20.2).

Box 20.2 Reducing vulnerability in Bangladesh

Bangladesh has been identified as the "most disaster-prone" of all countries, having suffered 170 large-scale disasters between 1970 and 1998.[4] Substantial investments have been made in recent years to reduce vulnerability to extreme climate variability (with the recovery following the 1998 floods more rapid than predicted) including: a structural change in agriculture, with an increase in the planting of much lower risk dry season irrigated rice; better internal market integration; and increased private food imports. Bangladesh's dependence on agriculture has also been reduced by an increase in export-oriented garment manufacturing. These developments were aided by higher credit penetration, including micro credit, increased remittances from abroad, and increased donor assistance. General development support has contributed to reducing the economy's sensitivity to extreme climate variability.

Source: ODI (2005)

Key areas for development action that will help to reduce vulnerability to the effects of climate change include:

- Progress on achieving income and food security and on overcoming the structural causes of famine/insecurity;
- Building robust education and health systems, including eradication of malaria, cholera, and other diseases associated with water;
- Better urban planning and provision of public services and infrastructure; and
- Better gender equality.

Improving access to micro-finance to help create assets and income will also be important as much of the funding for autonomous adaptation in developing countries will have to come from domestic sources and much of the action will be by households and small firms. Access to insurance and reinsurance services, savings and credit facilities, and flows such as financing for disaster preparedness measures and remittances will also be important to help protect the most vulnerable from climate change (discussed in Chapter 26).

It is important to note, however, that not all development policies and practice will be beneficial from a climate change perspective, and in some cases will actually increase vulnerability to the impacts of climate change. This is known as maladaptation.[5] Maladaptation is commonly caused by a lack of information on the potential external effects of policies and practices on other sectors, or a lack of consideration given to these effects. The destruction of coastal mangroves is a prime example. Mangroves provide a wide range of services, including protecting against floods, coastal erosion and storm surges. Despite their importance, mangroves are being cleared in countries such as Bangladesh and Fiji to make way for agriculture, urbanisation and tourism. Shrimp-farming, for example, took-off in Bangladesh as an export industry in the mid 1980s. While this provided incomes it also encouraged the deliberate inundation of land with brackish water during periods of low salinity to increase shrimp production. As these fragile ecosystems are destroyed, so vulnerability to climate change is increased. More integrated planning and management is widely recognised

[3] For example, evidence suggests that educated women are more likely to seek medical care, improve sanitation practices and choose to have fewer children. For example, econometric studies have found that an extra year of female schooling reduces female fertility by between 5 to 10%. World Bank (2001); Summers (1992).
[4] World Bank's recent Water Resources Assistance Strategy report for Bangladesh
[5] Burton (1996, 1997)

as an effective mechanism for strengthening sustainable development, as discussed in Section 20.4 below.

Improving disaster preparedness and management saves lives, but it also promotes early and cost-effective adaptation to climate-change risks.

Natural disasters exact far greater economic costs in developing countries than developed countries, in relative terms, and can cause setbacks to economic and social development in developing countries. As a result, private, public and international resources and assistance is increasingly being diverted through humanitarian responses and reconstruction needs to deal with natural disasters, as discussed in Chapter 4. For example, OECD estimates, show that "emergency and distress assistance" from donors has risen from an average of 4.8% of total Official Development Assistance (ODA) in 1990 to 1994 to 7.2% in 1999 to 2003, reaching 7.8% of ODA (more than $6 billion) in 2003.[6]

It will typically be more effective - in terms of both lives saved and finances - to invest in better disaster preparedness and management. Macro-level assessments show that disaster risk reduction (DRR) measures have a high benefit-to-cost ratio. The US Geological Survey and the World Bank estimated that an investment of $40billion would have prevented losses of $280billion in the 1990s.[7] And the savings are not just hypothetical:

- *China*: the $3.15billion spent on flood control between 1960 and 2000 is estimated to have averted losses of some $12billion;[8]
- *Brazil*: the Rio flood reconstruction and prevention project yielded an internal rate of return exceeding 50%;[9]
- *India*: disaster mitigation and preparedness programmes in Andhra Pradesh yielded a benefit/cost ratio of 13.38;[10]
- *Vietnam*: a mangrove-planting project aimed at protecting coastal populations from typhoons and storms yielded an estimated benefit/cost ratio of 52 over the period 1994 to 2001.[11]

Thus a focus on climate change reinforces an earlier development lesson: not only do disaster preparedness and emergency planning save lives and property, they are also highly cost-effective. DRR measures can also bring significant developmental benefits in normal times. Raised flood shelters in Bangladesh are used on a day-to-day basis as schools or clinics, for example, and boreholes drilled to protect against drought provide water that is cleaner and easier to access than alternative sources.[12]

At the margin, it will be important to ensure that disaster risk assessments take new climate-change risks into account. Otherwise, mal-adaptation can be the result (as discussed above and in Chapter 18). This was the case in Bangladesh where flood defences had been designed for lower levels of floods. Because those defences were poorly maintained and were in any event inadequate for the higher flood levels of recent years, they became counter-productive, eventually trapping and prolonging the floods of 1999.[13]

Governments should also promote risk-sharing approaches, through insurance and pooling of disaster risks.

Insurance is another area - closely related to disaster preparedness - in which climate-change considerations reinforce what governments should already be doing on developmental grounds.[14] Well-functioning insurance markets share risk across individuals, regions, and

[6] OECD (2004) cited in ERM (2006). Note that a part of the increase in damages may be due to improved monitoring and reporting and increases in income.
[7] Cited in Environmental Resources Management (2006); Benson (1998). Figures are indicative as consistent methodologies were not used to prepare estimates.
[8] Benson (1998) cited in ERM (2006).
[9] ProVention (2005) cited in ERM (2006).
[10] Venton and Venton (2004), cited in ERM (2006).
[11] IFRC (2002) cited in ERM (2006).
[12] ERM (2006)
[13] Bangladesh is now integrating long-term climate risks into disaster management.
[14] A lot of work has been done on this by UNEP Finance Initiative (http://www.unepfi.org/).

countries, reducing the welfare effects of negative shocks of all types, whether climate-related or not. Risk-based insurance schemes can also reduce the costs of climate change by encouraging good risk-management behaviours, as discussed in Chapter 19. For example, by providing the incentives to meet standards on building design and construction, they encourage action to reduce risk. In addition, insurance may also act as a catalyst for autonomous adaptation by providing information through its measurement and pricing of climate risks. With the expected increase in climate-related shocks, governments now have even more reason to promote well-functioning insurance markets, as described in Chapter 18 and 19. Low-cost micro-insurance options, particularly weather derivatives, could be a mechanism for sharing risk in the poorest countries. Promoting private-sector involvement and investment in disaster risk management in developing countries should be high on the agenda for governments.[15] Box 20.3 provides examples of innovative programmes in this area.

Box 20.3 Pilot risk-sharing ventures in the developing world

A number of recent initiatives have pioneered micro-insurance and weather derivative instruments in the developing world:

- A weather insurance initiative was launched in 2003 in India by a group of companies called BASIX. It has already grown from 230 farmers in one state to 6,703 customers across six states for 2005, and it has generated much broader interest in weather-related insurance in India, with other insurance companies now beginning to offer the product;[16]
- The World Food Programme has a pilot drought insurance project in Ethiopia. The WFP secured contingency funding through a Paris-based reinsurer to set this up, and ensured data availability through capacity-building at the National Meteorological Agency. A drought index now tracks agricultural seasonal development through 26 weather stations reporting daily;[17]
- DFID is launching two pilot projects in Bangladesh to offer weather-based index insurance at the community level. These projects illustrate the possible convergence of micro-finance and complementary community-based programmes with more sophisticated market-based financial instruments;
- In Malawi, an index-based weather derivative is offered to groundnut farmers as part of a loan package organised by the National Smallholder Farmers Association (with technical assistance from the World Bank and Swiss development cooperation);
- In the coastal Andhra Pradesh region of India, micro-insurance services have been provided as part of the voluntary Disaster Preparedness Programme to groups of women with a minimum size of 250 members. The Oriental Insurance Company offers affordable cover to poor communities through cross-subsidy with the wider insurance market. In addition, Oxfam pays half the premium.

However, as noted in Chapter 4, these insurance markets will often fail to emerge autonomously in developing countries through poorly developed financial markets, low income levels with which to purchase the insurance and lack of robust information. While approximately a third of natural-disaster losses are insured in high-income countries, for example, less than 3% of such losses to households and businesses are insured in developing countries.[18] And only a small number of schemes offering weather derivatives or micro-insurance for disaster risks have been implemented in developing countries to date.[19] For insurance markets to work effectively, insurance companies need access to accurate forecasts of climate change effect and the damage it may cause. This is currently a major constraint in developing countries that will have to be addressed if insurance provision is to play an important role in disaster risk management. There is also a limit to the ability of insurance companies to spread risk as they will be unwilling or unable to insure against an event with a very high probability of occurring. In some cases the price of individual premiums will become unaffordable because of the high risks. At the same time, if risks increase in

[15] Mechler et al (2006)
[16] World Bank (2005b)
[17] WFP (2006)
[18] Munich Re (2005)
[19] The ProVention Consortium (http://www.proventionconsortium.org/) is actively pursuing this agenda.

several insurance markets at once, then insurance companies may find it harder to spread risks and therefore be less willing to provide insurance at affordable rates.

In addition, effective social safety nets will be important to protect those who are most vulnerable and cannot afford protection. One example is the set of safety net programmes that were announced in Indonesia in response to the economic, natural and political crisis between 1997-98. The employment creation programmes - which relied on self-selection targeting - were found to be far more effective in reaching the most vulnerable households than programmes based on health subsidies and subsidised rice sales.[20] Equally, the Employment Guarantee Scheme (EPG) in the Indian state of Maharashtra has provided wage labour opportunities since the 1970s that help buffer households from the effects of poor harvests and other negative shocks.[21]

20.4 New policies focused on climate change

Investing in climate resilience has implications for each country's investments in natural, physical, human, technological, and social capital.

While many of the policies that promote adaptation will already form part of national governments' priorities, others may not. Beyond reducing vulnerability through a broad suite of development activities, effective adaptation may also require governments to address specific market failures and barriers that limit effective adaptation.[22] Box 20.4 highlights a range of issues to consider. However, as the impacts of climate change are difficult to predict accurately, any adaptation strategy should be as flexible as possible, able to respond to new information, and robust enough to be cost-effective across a range of possible future scenarios.

Box 20.4 Investing in adaptation

- **By encouraging technology transfer and supporting flows of knowledge:** governments can deliver better climate forecasts, and spread information about climate-resilient crop varieties and irrigation schemes. Regional Climate Outlook Forums for example, provide guidance on the probabilities of rainfall to farmers in Africa and South America;
- **Human capital:** Investing in health and education raises the effectiveness of explaining to communities and individuals how their climate is changing, and why and how they should adapt in ways which effectively integrate climate risks into the development process;
- **Physical capital:** governments can make long-term infrastructure more climate resilient, for example through building codes and regulations, land-use zoning, river management, and warning systems. [23] Without increased climate resilience, people face shorter lives and will have to live with less reliable infrastructure. Some adaptation may require higher maintenance costs for basic infrastructure such as re-building or diverting dirt roads. Additional protective investments such as flood barriers and sea walls will also be required;
- **Social capital:** Supporting social networks, institutions and governance arrangements, to strengthen safety nets for poor people in response to natural disasters. Many traditional risk-sharing mechanisms based on social capital, such as asset pooling and kinship networks, are less likely to be effective when climate change simultaneously damages families and households in an entire region. The same is true of traditional coping mechanisms like selling assets;[24]

[20] Pritchett et al (2002)
[21] A problem with scaling up an EPG scheme is the lack of 'high value' works from local plans to provide employment. Sen (2004:11) discusses these challenges in the case of India and noted that "for any commitment of expenditure, the opportunity costs have to be scrutinised, and employment guarantee is no exception to this".
[22] Berkhout (2005)
[23] Climate norms including climate variability and extreme events should already be taken into account in infrastructure development. Climate is a factor in, for example, the design of domestic, industrial and commercial buildings, roads, bridges, drainage systems, water supply and sanitation systems, irrigation and hydroelectric power installations. Improving climate resilience will go a step beyond this. Burton and van Aalst (1999)
[24] In the jargon this is known as 'covariate risks' or 'correlated risks', as discussed in Chapters 5 and 19, Sections 5.5 and 19.6 respectively.

- **Natural capital:** governments can help protect the resilience of natural systems to support the livelihoods of poor people, for example by planting mangrove belts to buffer the coastal erosion impacts of sea level rise.

Source: DFID (2003); Sperling et al (2003)

Many of the interventions required in developed countries, as set out in Chapter 18 and 19, will also be needed by developing countries including:

- Better information on climate change and more accurate weather forecasting;
- Regulation to overcome market barriers to adaptation; and
- Incorporating climate change into long-term policies.

Whilst the principles may be similar, their application may be different. Development constraints – including high levels of illiteracy and poor governance – will present obstacles to the effectiveness of these policies. The significance of these constraints will vary from country to country, with low-income countries likely to face the greatest challenge. And additional adaptation measures will be required by developing countries that face acute threats of rising sea levels or desertification. Developed countries can play a strong leadership role on adaptation but these wide-ranging constraints have to be addressed to ensure early and effective adaptation in developing countries.

Governments have an important role to play in raising awareness. But there are barriers that should be addressed.

Individuals, firms, and civil society cannot adapt autonomously without reliable information and projections, especially since they should make some of their investment choices well before the effects of climate change are fully visible. A core responsibility of governments will be to see that it has access to, and disseminates domestically, good information on climate change. This will range from forecasts on the likely timing, extent and effects of climate change, to knowledge of drought and flood resistant crops and new crop planting techniques. Governments should provide these services given the public good nature of high quality climate information, noted in Chapters 18 and 19. The important role attributed to climate information is widely recognised. Tanzania's 1997 National Action Plan on Climate Change provides an example of a government focusing its efforts on raising awareness in the first two years of implementation.

Better information is a priority in many developing countries given the very low level of climate information currently available. The density of weather watch stations in Africa, for example, is eight times lower than the minimum level recommended by the World Meteorological Organisation, and reporting rates are the lowest in the world.[25] This low starting point indicates the size of the challenge compared to developed countries where government funded research programmes are already in place, such as UKCIP discussed in Chapter 19. Developing the necessary information is beyond the current capacity of many developing country governments. Many are not even able to monitor the climate, let alone forecast changes. Developing country governments will require international support in this area, as discussed in Chapter 26.

Effective communication of this information is also critical. Poor countries face barriers to free and easy communication such as:

- High illiteracy rates: in South Asia the female literacy rate is 46.3% and 53.2% in Sub-Saharan Africa, compared to 98.7% in developed countries;[26]
- Restricted access to electronic communication: while 70% of the population in North America are internet users, only 3.6% of Africans are, and only 10.8% of the population in Asia;[27]
- Inaccessibility of rural areas due to poor transport and road infrastructure.

[25] Washington et al (2004)
[26] UNESCO Institute for Statistics (2006) based on adult (15+) literacy rates on a regional basis, September 2006.
[27] Internet World Stats (2006)

Good development can go a long way in helping to overcome such barriers to effective information dissemination. However, it is important that governments take these issues into consideration in planning their communication strategies.

Government regulation can encourage private investment to take account of climate change. But its effectiveness will depend on the commitment and credibility of the government.

Land-use planning and performance standards can be important tools in encouraging private investment to consider the future risks and implications of climate change on their investment, as discussed in Chapters 18 and 19. However, the value of these interventions will be largely dictated by the commitment and credibility of the government. Poor governance is a problem in many developing countries, and indeed some developed countries, as demonstrated by the Corruption Perception Index.[28] This can lead to weak regulatory practices and poor enforcement of building standards. For example, while Iran adopted a seismic building code in 1989, legislation was not always enforced. As reported in the IFRC (2004), new buildings were sometimes certified as conforming to earthquake norms without thorough inspections being conducted, and laws were not in place to tackle municipalities that failed to retrofit infrastructure. Addressing problems with governance and weak enforcement will be crucial if regulation is to be fully effective.

Unclear property rights and the illegality of much slum housing also pose major problems which need to be overcome by changes to ownership and property laws and stronger law enforcement. Without property rights and civil protection householders put off making necessary home improvements since authorities would then have an incentive to evict the occupants once the work was done and rent out the dwellings to others willing to pay for protection.[29] Development itself can help to overcome these constraints, by educating civil society, promoting transparency and institutional checks on power, and encouraging accountability. Governments can then help by providing better technical guidance on building standards and encouragement of monitoring and enforcement.

Governments should integrate adaptation into their development projects but may require support to overcome technical capacity constraints.

Developing countries should integrate adaptation into development policy, budgets, and planning.[30] This cannot be an add-on or an afterthought, since some degree of continuous adaptation will be required across many sectors and regions. Governments - working alongside donors, the private sector, and civil society - should ensure national policies, programmes and projects take account of climate change and the options for adaptation.

National planning and policies

The importance of integrating adaptation into development policy and process through national economic planning and budgetary processes is an important first step towards effective adaptation. The budget is an important process for identifying and funding development priorities. Adaptive activities should be integrated into the budget framework and relevant sectoral priorities to help ensure necessary actions receive adequate funding over the long term and are balanced against other competing priorities.[31] Yet there is little evidence of progress on this score so far. Recent (draft) analysis by the World Bank found that while most of the Poverty Reduction Strategy papers (PRSPs) reviewed established linkages to climate change, such as by highlighting vulnerabilities to climate risk factors and impacts on economic productivity, further in-depth discussion of the issue was rare. They found a similar story with the Country Assistance Strategies (CAS).[32] Developing countries face two key constraints in integrating climate change into broader national development planning:

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[28] This is produced by Transparency International. This Index ranks more than 150 countries by their perceived levels of corruption, as determined by expert assessments and opinion surveys. http://www.transparency.org/policy_research/surveys_indices/cpi/2005

[29] IFRC (2004)

[30] Burton (2006)

[31] Sperling (2003)

[32] Jiminez (2006)

- Institutional constraints: Governments face numerous constraints, including competing demands on scarce public resources. At present the adaptation process is generally channelled through the UNFCCC focal points, which are normally based in Ministries of the Environment. Such ministries usually have limited influence with other line ministries and with the Ministry of Finance. An integrated response requires activities led by a strong core ministry with overall responsibility such as Finance, Planning, Economic Affairs, and other line ministries. Climate change faces the same challenges that other crosscutting issues, such as gender, HIV/AIDS, and rural livelihoods, have faced in the past. Given the importance of risk management in relation to climate change – and the potential impact on public sector investments – there are sound reasons for Finance and Economy Ministry engagement.

- Technical capacity: Many developing countries – particularly the poorest – have only recently begun preparing longer-term national development plans and budget frameworks. This planning capacity is essential for broader development, as well as for enabling the integration of climate issues, and is already being supported by many development programmes. This should also be supported by the process of preparing National Adaptation Plans of Action (NAPAs) in Least Developed Countries.[33] While NAPAs could help to fill this planning gap, it is essential that they be integrated within overall national planning. Otherwise they could become yet another issue without a strong championship ministry and therefore be ignored when budgets are prepared. So far, only five NAPAs have been completed, and there is no indication that any implementation has begun as a consequence of preparing a NAPA, so their effectiveness or otherwise is as yet untested.

Programmes and projects
At the programme and project level, climate change may reduce the efficiency with which development resources are invested and worsen outcomes. Hence the risks of climate change should be integrated into development programmes. This means, for example, using information related to climate-change risks in the design and construction of infrastructure and buildings. In addition to building the resilience of development programmes, integrating climate-change risks will also help to ensure action to achieve adaptation to climate change is consistent with action to reduce poverty. Several commentators have suggested how to incorporate climate change risks into their plans and programmes. Burton and van Aalst (2004), for example, have proposed a climate risk-screening tool for World Bank projects,[34] while the UNDP has compiled a series of technical papers to guide projects towards identification of appropriate adaptation strategies.[35] One crucial task will be for governments to manage public goods that may be sensitive to climate change through finance and investment decisions, for example by improving flood defences, public health and safety, and emergency planning and response. Some examples of adaptation in practice are given in Box 20.5 below.

Box 20.5 Adaptation in practice

(a) Climate resilience in the Pacific Islands
Several Pacific Islands are implementing climate risk management programmes:

- *Samoa*: community grants to strengthen coastal resilience and reconstruction of roads and bridges to cyclone-resilient standards. Such local initiatives may well be a fruitful approach since local people are usually able to identify more accurately points of vulnerability;
- *Tonga:* national programme to construct cyclone-resistant housing units and retrofit buildings to improved hazard standards;

[33] The Least Developed Countries have received funding from the Least Developed Countries Fund (discussed in Chapter 26), implemented by the Global Environment Facility (GEF), to assist them in preparing these documents.
[34] This includes (i) a web-based knowledge tool that sets out the nature, magnitude and distribution of climate risks by country and region; and (ii) a routine project risk-screening tool modelled on the widespread practice of environmental impact assessment, where high-risk "hotspots" undergo a full risk assessment, while low and medium-risk projects undergo a vulnerability appraisal.
[35] The UNDP Adaptation policy framework is designed to be flexible so that those at an early stage of understanding can begin to assess vulnerability to climate variability and change, and those at a more advanced stage can begin to implement adaptation in practice. The overall approach embeds adaptation into key policies for development and places substantial emphasis on stakeholder engagement.

- *Kiribati*: climate-proofing of major public infrastructure and promote effective water management;
- *Niue:* strengthening of early-warning system for cyclones, including satellite-phone back-up, solar-powered radios for isolated villages and email facilities. In addition, the government is promoting vanilla as a more resilient cash crop than taro that typically suffers heavy damage during cyclones.

Source: Bettencourt et al. (2006)

(b) Qinghai-Tibet Railway
The Qinghai-Tibet Railway crosses the Tibetan plateau with some 550 km of the railway resting on permafrost. About half of this permafrost is only 1°C to 2°C below freezing, and is therefore highly vulnerable to even moderate warming. Permafrost thawing could significantly affect the stability of the railway. To reduce these risks, design engineers have put in place a permafrost cooling system using crushed rocks. In the winter, the colder denser air above the rock layer will circulate downwards through the spaces between the rocks, forcing warmer air out and away from the ground. In the summer, the air will be warmer and lighter outside the rock layer, and the air within the rocks will cease to circulate, thus minimising the amount of heat absorbed by the permafrost. The technique could be applied to many types of infrastructure projects in permafrost zones around the world.

Source: Brown (2005)

(c) Adaptation of hydropower sector in Nepal
Glacier retreat and ice melt are adding to the size of Nepal's glacier lakes and increasing the risk of 'glacial lake outburst floods' (GLOFs), catastrophic discharges of large volumes of water following the breach of the natural dams that contain glacial lakes. The most significant flood occurred in 1985 when a surge of water and debris up to 15 metres high flooded down the Bhote Koshi and Dudh Koshi rivers for 90km. The flood destroyed the almost-complete Namche Small Hydro Project, which had cost over $1 million. Much more attention is now being paid to the GLOF risks in Nepal and the likelihood that such risks will increase as a result of rising temperatures. Some adaptation options being considered include:

- Siting of hydropower facilities at low-risk locations (although this may only be feasible for new facilities);
- Early warning systems that can save lives far downstream (likely to cost around $1 million per basin);
- Design of hydropower infrastructure to limit vulnerability, such as powerhouse placed under ground;
- Direct reduction of risk through (i) siphoning or pumping water out of dangerous lakes, (ii) cutting a drainage channel, and (iii) taking flood control measures downstream.

Source: Agrawala (2005)

(d) Shanghai Heatwave Warning Systems
With a population of over 17 million, Shanghai is vulnerable to the effects of dangerous heat waves. The original heat wave warning system was triggered whenever temperatures in the city reached an arbitrary threshold of 35°C. The new system monitors a range of weather variables known to affect human susceptibility to the heat. For example, 'moist tropical' conditions are associated with the highest average temperatures and humidity and lead to the greatest increase in daily average mortality (35-63 excess deaths on top of a baseline of 222). The system can predict dangerous conditions up to two days in advance. Such a forecast triggers a series of activities by the Shanghai Municipal Health Bureau to reduce the population's vulnerability – media announcements on TV and radio, preparation of hospitals and public services, visits to the elderly in the city centre, and measures to ensure an adequate supply of water.

Source: Acclimatise (2006)

In factoring climate-change risks into investment decisions, it will be important to make good use of information on the costs and benefits of various alternative investments in terms of the damages avoided through adaptation and the benefits gained. An example is given in Box 20.6. These can mostly be at the project level, as in the case of retro-fitting buildings and flood defences. A key element determining the appropriate response will be the lifespan of the project and the options, for example, to retro-fit buildings and flood defences – noting that designing in adaptation at the beginning of the project can reduce the cost of retro-fitting.

Box 20.6 Case-study of cost-benefit analysis for adaptation

Water supply in the Berg River Basin in South Africa

Runoff from the Berg River Basin provides a major source of water for Cape Town and the surrounding agricultural land. In the last 30 years, water consumption in Cape Town has increased three-fold, and is expected to continue to grow in the future, as a result of population growth (migration of households to the city from rural communities) and economic development. At the same time, climate models show that average annual run-off in the catchment could decrease by as much as 25% during the period 2010 - 2040 due to climate change. A dam for the basin was approved in 2004 to deal with these competing pressures, but the possible impacts of climate change were not taken into account. Similarly, arrangements for liberalising the market for water supply are also being discussed in order to provide an economically efficient and more resilient distribution of water.

A recent study has compared the net benefits of adjusting to development pressures and, additionally, adjusting to climate change under two strategies:

Strategy A: Constructing a storage reservoir to cope with development pressures and then adding capacity to cope with climate change.
Strategy B: Implementing water markets to cope with development pressures and then building a dam to cope with climate change.

Table showing present value estimates for costs and benefits of adjustments for increasing development pressures and climate change in the 2080s

Estimated benefit or cost measure	Strategy A	Strategy B
Development action (no climate change)	Construct dam, no water markets	Water markets, no dam
Net benefits of development action	15 billion	17 billion
Additional adaptation action (development + climate change)	Increase dam capacity, no water markets	Construct dam + water markets
Net benefits of adaptation (reduction in damages from adaptation minus costs of adapting)	0.2 billion	7 billion
Cost of not planning for climate change that does occur	-0.2 billion	-7 billion
Cost of planning for climate change that does not occur	-0.2 billion	-1 billion

Note: All monetary estimates are expressed in present values for constant Rand for the year 2000, discounting over 30 years at a real discount rate of 6%.

Both the dam and water market options individually have similarly large projected net present values, but adding the possibility of adaptation to climate change shows the benefits of adopting both simultaneously. Increasing the water storage capacity of the Berg Dam could have a significant benefit for welfare. The effect is particularly strong if efficient water markets are introduced (net benefit of 7 billion, discounted over 30 years). Under this flexible and economically efficient approach, the costs of not adapting to climate change that does occur are much greater than the costs of adapting to climate change that does not occur (-7 billion vs. –1 billion in the case of efficient markets).

Source: Callaway et al. (2006)

20.5 Adaptation costs in the developing world

Adaptation is projected to cost developing countries many billions of dollars a year, increasing pressure on development budgets.

Only a few credible estimates are now available of the costs of adaptation in developing countries, and these are highly speculative. In a world of rapid climate change, it is increasingly difficult to extrapolate future impacts from past patterns, so historical records are no longer reliable guides. Furthermore, the discussion above has shown that conceptually this is a difficult calculation to solve: adaptation is so broad and cross-cutting - affecting economic, social and environmental conditions, and vice versa - that it is difficult to attribute costs clearly and separately from those of general development finance. Adaptation should be undertaken at many levels at the same time, including at the household/community level, and many of these initiatives will be self-funded.

With these very important caveats, one can consider the range of estimates that is available. The most recent estimates come from the World Bank that show the additional costs of adaptation alone as $4-37 billion each year.[36] This includes only the cost of adapting investments to protect them from climate-change risks, and it is important to remember that there will be major impacts that are sure to occur even with adaptation.[37] The World Bank estimate is based on an examination of the current core flows of development finance, combined with very rough estimates of the proportion of those investments that is sensitive to climate risk and the additional cost to reduce that risk to account for climate change (5-20% as a very rough estimate).[38] See Table 20.1. Whilst there is considerable debate as to the value of these figures, they provide a useful order-of-magnitude estimate and reinforce the importance of further research in this area.

Table 20.1 World Bank preliminary estimates of the added costs necessary to adapt investments to climate-change risks

This table, based on World Bank analysis, examines the core flows of development finance and estimates the proportion of the investment that is sensitive to climate risk. An estimate of the additional cost to reduce that risk to account for climate change is given. The percentage figures relating to the estimated costs of adaptation require further research and revision.

Item	Amount per year	Estimated portion climate sensitive	Estimated costs of adaptation	Total per year (US$ 2000)
ODA and Concessional Finance	$100bn	20%	5 – 20%	$1 – 4bn
Foreign Direct Investment	$160bn	10%	5 – 20%	$1 – 3bn
Gross Domestic Investment	$1500bn	2 – 10%	5 – 20%	$2 – 30bn
Total International finance				**$2 – 7bn**
Total Adaptation finance				**$4 – 37bn**
Costs of additional impacts				**$40bn (range $10 – 100 bn)**

Source: World Bank (2006a), updated through discussions with the World Bank

Another source of information is the NAPAs, which five countries have completed so far. On the basis of these it is possible to get a preliminary indication of the funding required. The total estimated cost for these NAPAs is $133million, averaging $25million per country.

[36] World Bank (2006a) and subsequent revisions.
[37] As explained in chapter 18, adaptation will not fully insulate people or economies from climate change, rather it is a way of dampening the impacts. As such, there will still be residual costs.
[38] These estimates exclude flood risk and other categories for which no costs are available so can be considered an underestimate from this perspective

Extrapolating up to the 50 Least Developed Countries suggests adaptation costs of $1.3billion for these (mostly small) countries alone, and for only the 'urgent and immediate' action that is required.

Information and knowledge about the additional costs of adaptation is very limited. This knowledge is essential in facilitating countries to integrate climate change risks and adaptation needs into their longer-term plans and budgets. More work is needed to arrive at more precise measures.

20.6 International assistance for adaptation

Just as individuals, communities, and firms in developing countries will require help from their governments to adapt efficiently to climate change, so these governments may need support form the international community. Chapter 26 will discuss how the international community can help to promote adaptation in developing countries. Nonetheless, it should be clear from the discussion above that adaptation will require coordinated efforts on many fronts. Donors and other international development partners should reorient their strategies to match national efforts. Development assistance should aim to reorient current practices and remove barriers to interventions that prove cost-effective once climate risk management is integrated into development programmes. This would also help to mainstream adaptation into national development and planning processes and so promote sustainable development.

Equally, given that the most affected countries are often among the poorest, there is a real need for the international community to fully honour the commitments, made at Monterrey in 2002, the EU in June 2005, and at the G8 summit in Gleneagles in July 2005, to increase sharply the flows of aid to developing countries, with the EU confirming and setting a timetable to 0.7% of GDP for ODA. Chapter 26 explores in detail the question of international support for countries facing the challenge of adaptation.

20.7 Conclusion

The climate will continue to change over the next few decades, whatever the world manages to achieve on the mitigation side. But the costs of adaptation will rise exponentially if efforts to mitigate emissions are not successful. It is an unfortunate twist of fate that those affected most immediately and hardest are often the countries that contributed little to the problem and that are least able to afford the costs of adaptation. They can afford even less *not* to adapt, however. Adaptation efforts are already underway, but they must be accelerated. Much of the adaptation is and will have to be autonomous, driven by market forces and by the needs and devices of households and firms. Governments should assist this process.

This chapter argued that a first set of actions consists of policies that should already be high on each government's agenda, even in the absence of climate change. The first and best way for governments to accelerate adaptation is to promote development successfully. If individuals and communities are empowered by development and rendered less vulnerable overall, they will be better able to adapt to changes in their environment. Second, improving disaster preparedness and management saves lives, but it also promotes early and cost-effective adaptation to climate-change risks.

But, in addition, governments should adopt new policies targeted at the climate-change threat. One important new task for governments will be to provide firms and communities with high-quality information and tools for dealing with climate change. Governments will also have an important role in encouraging effective adaptation through the use of regulation. More generally, in light of the far-reaching implications of climate change, governments should integrate adaptation into their development projects and plans across the board. Investing in climate resilience has implications for each country's investments in natural, physical, human, technological, and social capital. There will be barriers and obstacles to these climate policies that will have to be taken into consideration – but development progress will help to address and overcome these constraints.

With all of these needs, the incremental investment costs of adaptation are projected to run into many billions of dollars a year for developing countries, including very poor countries that are already hard pressed to meet development goals. On top of those costs, these countries will have to bear the costs of the climate-change impacts that remain even after adaptation. Chapter 26 will return to the question of how the international community can best help developing countries adapt.

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