The Economics of Adaptation

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Introduction

Unlike greenhouse gas mitigation, which has to be coordinated internationally, adaptation to climate change is essentially a local or, in some cases, a regional issue. This means that adaptation decisions will be made to a large extent based on well-established local decision making procedures.

Some adaptations will have a public good character[1] and as such may be provided by the state (local authorities or national governments). In making these adaptation decisions the authorities will apply traditional decision support tools such as cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis.

Other, perhaps most, adaptation decisions will be taken by private agents (individuals or firms). The more sophisticated actors among them will base their decision on the investment appraisal techniques of corporate finance. They may, for example, calculate the net present value of an adaptation investment, analyse its risks and returns or determine the return on capital employed.

What most of these decisions will have in common is that they will in some way be based on a comparison of the advantages and disadvantages of a certain course of action, that is, its economic, financial and/or non-monetary *costs and benefits*. In addition to the level and type of adaptation, decision makers will also have to determine the *timing* of their action. And at least for the time being, adaptation decisions will be taken under considerable *uncertainty*.

The costs and benefits of adaptation

There is a small methodological literature that has devoted itself to the definition of costs and benefits in the context of climate change adaptation (see Callaway, 2004; Callaway et al. 1997; Fankhauser 1996, 1998; Smith et al. 1997). While these concepts are straightforward in principle, there was a perceived need for more methodological clarity in light of provisions in the UNFCCC, which open up the potential for financial assistance to some parties in meeting the costs of adaptation.[2] While these papers cannot answer the political question of financial assistance, they helped to sharpen our conceptual understanding of adaptation costs and benefits.

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[1] Public goods are defined in economics as goods for which it is difficult to exclude non-paying consumers (non-excludability) and where consumption by one person does not diminishes availability for others (non-rivalry). A classic example would be macroeconomic stability.

[2] See in particular UNFCCC Article 4.4, but also some provisions in Article 4.3.

Table 1 helps to illustrate the main issues. The starting point is the recognition that adaptation to climate phenomena has been a part of everyday life since the beginning of mankind. Today's society is adapted to the current climate through measures ranging from farmland irrigation to the production of waterproof clothes. This current state of affairs is represented in the top-left quadrant of Table 1. In the illustrative example of Table 1, society is spending an amount of 90 on adaptive measures – say, a flood protection system. Included in these costs are both monetary components (e.g., capital costs) and non-monetary components (e.g., the impact on the environment). This level of adaptation is sufficient to prevent most adverse climate effects, but not all. There is a residual damage of 50, for example due to occasional extreme flooding. There is no climate change, and hence no climate change impact yet. Current adaptation is preferred over extended adaptation, because the additional cost of more comprehensive protection (150 – 90 = 60) are higher than the additional benefits of reduced flood damages at the margin (50 – 20 = 30).

The calculus changes with global warming (associated, say, with a higher frequency of storms and floods). Under a changed climate, the extra costs of adaptation (150 – 90 = 60) are more than offset by the reduced costs of climate change (200 – 120 = 80). In this particular example, the climate change benefits alone are sufficient to justify adaptive action, but the extra reduction in ordinary climate impacts (50 – 20 = 30) is an important ancillary benefit. The ancillary benefits occur because the extended protection system will mitigate the impact of both climate change-induced and ordinary floods.

Obviously, the example of Table 1 is simplistic and ignores important complications, such as uncertainty and continuous change. However, it helps to flesh out two important issues: The costs of adaptation have to be measured against current adaptive measures, and many adaptive measures may have climate change as well as non-climate change-related benefits.

Empirical studies

Studies looking at the costs and benefits of adaptation are still relatively rare. Most systematic studies were undertaken in the context of impact assessments, where adaptation costs form a significant part of total impacts (refs). In addition there are a number of case studies that look at adaptation options for particular sectors (e.g., IPCC, 1994, Fankhauser, 1994, and Shaw et al 2000, all for sea level rise); or particular countries (e.g., Smith et al. 1998 for Bangladesh; World Bank, 2000, for Fiji and Kiribati; Dore and Burton, 2001, for Canada).

The majority of studies concentrate on agriculture and sea level rise. In most cases they do not try to optimise the adaptive response, but study the costs or benefits (not always both!) of certain policy options (see the discussion in Fankhauser et al. 1998). A global vulnerability assessment (GVA) – a series of country studies – carried out for the IPCC, for example, found that coastal adaptation could reduce the number of people at risk from flooding (ie, the number of people living in risk areas times the probability of flooding) by almost 90 per cent, at an annual cost of around 0.06 per cent of GDP (see Table 2). Subsequent studies for Senegal (Dennis et al., 1995) and Uruguay (Volonte and Nicholls, 1995) tested whether adaptation costs of this magnitude are justifiable from an economic efficiency point of view. They conclude that the preferred strategy for Senegal would be "important area protection", with perhaps even a lower level of protection in Uruguay. Studies for US coastal areas, in contrast, generally find even quite comprehensive adaptation measures to be justified economically.

Farming studies tend to find similarly positive results (see Table 3). Relatively simple adaptive measures like a change in planting date and increased irrigation could reduce yield losses by at least 30 per cent. More comprehensive adjustments could eliminate the majority of losses and in some cases turn losses into gains. However, adaptation gains are very unevenly distributed. A global study by Reilly et al. (1994) found that adaptation would be less effective in developing countries, where adaptive and institutional capacity is more limited. Most of the adaptive measures studied in Table 3 are low and sometimes zero cost options. Nevertheless, it remains an important shortcoming of many studies of agricultural adaptation that the costs of adaptation are not clearly spelt out. As such, it is difficult to ascertain the economic efficiency at least of those measures that are known to be more costly.

The timing of adaptation decisions

The long-term nature of climate change makes timing an important part of adaptation decisions. This is particularly the case for strategic and anticipatory means of adaptation.[3]

In deciding the optimal timing for adaptation, decision makers will compare the present value costs of adaptation now (PV^N) with the present value costs of adaptation at a later stage (PV^L). Let us assume that adaptive measures taken now cost AC^N and will reduce annual climate damages to DC^N over the lifetime of the project. If damage is discounted at the rate δ, NPV^N can be written as

$$PV^N = AC^N + DC^N_0 + \Sigma\, DC^N_t\, \delta^t$$

If adaptation is undertaken a period later, the costs of adaptation can be discounted, but climate impacts in the initial period will not be mitigated. That is, they will reach a level of $DC^U_0 > DC^N_0$. It is also possible that adaptation costs (AC^L) and subsequent damage costs (DC^L) will change, for example because of innovations in adaptation techniques. NPV^L then becomes

$$PV^L = AC^L\delta + DC^U_0 + \Sigma\, DC^L_t\, \delta^t$$

The benefit of early adaptation can be expressed as the change in the two present value streams, as follows

$$(PV^N - PV^L) = (AC^N - AC^L\delta) + (DC^N_0 - DC^U_0) + \Sigma\, (DC^N_t - DC^L_t)\delta^t$$

The expression shows that the timing of adaptation will be driven by the relative magnitude of three cost components. The first is the difference in adaptation costs over time, ($AC^N - AC^L\delta$). The effect of discounting would normally favour a delay in adaptation measures, and so would the prospect of potentially cheaper and more effective adaptation techniques to be developed in the future ($AC^N > AC^L$). However, there is also a class of adaptations where early action is cheaper. They include adjustments to long-term development plans and long-lived infrastructure

3 See Smit et al. (2001) for a classification of adaptation measures.

investments such as water and sanitation systems, bridges and ports. In each of these cases, it will be cheaper to make adjustments early, in the design phase of the project, rather than incur the cost and inconvenience of expensive retrofits. This was, for example, the approach taken by the Canadian authorities in the design of the Northumberland Bridge that links Prince Edward Island with New Brunswick. To account for future sea level rise the bridge was build approximately one metre higher than originally planned (see Smith et al. 1998).

The second component concerns the short-term benefits of adaptation (DC^N_0 - DC^U_0). Early adaptation will be justified if it has immediate benefits (that is, $DC^N_0 < DC^U_0$), for example by mitigating the effects of climate variability. It has been argued that changes in weather extremes will be noticed earlier than changes in the mean climate (e.g., Downing et al., 1996; Fankhauser et al., 1998; Katz and Brown, 1992, Knox, 1993, and Kwadiji and Middelkoop, 1994), making adaptation to climate variability a potentially important early measure. The strong complementarity between climate change adaptation and current climate variability has also been highlighted by Burton and van Aalst (1999; 2004), who argue convincingly that learning how to deal with current climate variability is an important first step in adjusting to climate change, particularly for developing countries.

Also in the second category fall adaptations that have strong ancillary benefits, such as measures to preserve and strengthen the resilience of natural ecosystems. Another important example is health investments (for example, the development of a malaria cure), which have poverty-alleviation benefits that are at least as large as the climate change benefits (refs).

The third component has to do with the longer-term effects of early adaptation ($\Sigma(DC^N_t$ - $DC^L_t)\delta^t$). Early adaptation is justified if it can lock in lasting benefits (that is, $DC^N_t < DC^L_t$), for example by preventing long-term damage to ecosystems.

Dealing with uncertainty

Uncertainty about the exact nature of climate change impacts at the local and regional level (for example in terms of precipitation and storminess) makes it difficult to fine-tune adaptation measures. Adaptation decisions will be taken under uncertainty. Conceptually, this means that most of the adaptation benefits (avoided climate impacts) in Table 1 should be interpreted as *expected* benefits, that is, the probability-weighted mean over the range of possible outcomes. Risk averse decision makers may pay more attention to negative outcomes, and if the potential cost of inaction is substantial, adaptation decisions may be based on the *precautionary principle*.

One set of adaptation measures that are easy to agree on, even in the face of uncertainty, are win-win measures. That is, adaptations that would be justifiable even in the absence of climate change. Many measures to deal with climate variability (for example, long-term weather forecasting and early warning systems) may for example fall into this category. Schelling (1992) has argued that one of the best adaptation measures available would be (sustainable) economic development, and it is easy to agree that better health care, access to safe drinking water and improved sanitary conditions for the world's poorest households are clear win-win measures.

Fankhauser et al (1998) have argued that given the prevailing uncertainties, the best way to account for potential climate change in current investment decisions may be to increase the flexibility and robustness of systems – allowing them to function under a wide range of climatic conditions and withstanding more severe climatic shocks.

The call for increased flexibility and robustness applies to both for physical, natural and social systems. In the case of physical capital, the capacity of water storage systems may be increased in anticipation of future droughts, for example, or coastal protection measures may be strengthened to withstand more severe storms and floods. In the case of natural capital, measures to protect the environment may increase the ability of species to adapt to a changing climate. Institutionally, creating regulatory frameworks that encourage individual adaptability would help to increase the flexibility and robustness of economic systems. It has been argued, for example, that opening agricultural markets to competition and trade would help to dampen the negative shock of a bad harvest in individual regions.

Table 1 A classification of adaptation costs and benefits

	Current climate	Changed climate
Current adaptation	Adaptation cost: 90 Ordinary climate damage: 50 Climate change damage: 0	Adaptation cost: 90 Ordinary climate damage: 50 Climate change damage: 200
Extended adaptation	Adaptation cost: 150 Ordinary climate damage: 20 Climate change damage: 0	Adaptation cost: 150 Ordinary climate damage: 20 Climate change damage: 120
Net benefit of extended adaptation	Incremental adapt. cost: 60 Incremental adapt. benefit: 30+0 *Net benefit: - 30*	Incremental adapt. cost: 60 Incremental adapt. benefit: 30+80 *Net benefit: +50*

Source: IPCC after Fankhauser (1998)

Table 2 The impact of coastal protection on sea level rise damage
(Number of people at risk from a one-meter rise in sea level)

	People at risk[1] *w.o. measures* ('000 people)	*People at risk*[1] *with addit. measures* ('000 people)	*Cost of measures* (% GNP/year[2])
Country Studies			
Antigua	19.0	7.7	0.32
Egypt	30.0	120.0[3]	0.45
Marshall Islands	20.0	2.0	>7.04
The Netherlands	24.0	1.2	0.05
Poland	196.4	9.9	0.02
General Vulnerability Assessments			
North America	170	90	0.02
Central America	56	6	0.23
Caribbean Islands	110	20	0.21
South America, Atlantic Coast	410	48	0.25
South America, Pacific Coast	100	11	0.01
Atlantic Ocean Small Islands	0	0	0.07
North and West Europe	130	130	0.02
Baltic States	3	3	0.08
North Mediterranean	37	31	0.02
South Mediterranean	2,100	250	0.07
Africa, Atlantic Coast	2,000	220	0.25
Africa, Indian Ocean Coast	3,600	390	0.38
Gulf States	14	3	0.05
Asia, Indian Ocean Coast	27,360	3,040	0.52
Indian Ocean Small Islands	100	12	0.72
Southeast Asia	7,800	880	0.20
East Asia	17,100	2,200	0.06
Pacific Ocean Large Islands	17	4	0.17
Pacific Ocean Small Islands	34	4	0.77
Former USSR	52	52	0.02
World	61,300	7,380	0.056 (av.)

Notes:
[1] *Number of people living in the risk zone, multiplied by the probability of flooding per year.*
[2] *Undiscounted, assuming 100 years lifetime, i.e., annual costs are 1% of total costs.*
[3] *The number of people at risk increases because adaptation allows people to remain in risk areas that would otherwise be abandoned.*

Source: Fankhauser et al. (1998) based on IPCC (1994) and Delft Hydraulics (1993).

Table 3 The impact of adaptation by farmers on agricultural impact

Study/study area	*Climate scenario*	*Type of adaptation*	*Climate impacts*		*Impact change no adaptation to adaptation*
			without adaptation	*with adaptation*	
Easterling et al. (1993)			*yield change (bn$)*		*% impact red.*
Missouri, Iowa, Nebraska, Kansas (MINK)	1930s climate analogue; baseyear 1980s	change in planting date and tillage practices, change in crops, improved irrigation and crop drought resistance	-1.33 - -2.71	-0.53 - -1.92	29 - 60
Rosenzweig and Parry (1994)			*change in cereal prod. (%)*		*% impact red.*
Developed countries	$2xCO_2$ baseyear 2060	small shifts in planting date (< 1 month), change in crops, additional irrigation ("level 1 adaptation")	-3.5 - 11.3	4.0 - 14.0	24 - >100
Developing countries			-10.8 - -11.0	-9.0 - -12.0	-9[1]- 17
World			-1.2 - -7.6	0.0 - -5.0	34 - 100
Adams et al. (1993)			*welfare change (bn$)*		*% impact red.*
United States	$2xCO_2$ baseyear 1990	as Rosenzweig and Parry (1994)	2.15 - -13.00	10.82 - 9.03	>100
Reilly et al. (1994)[2]			*welfare change (bn$)*		*% impact red.*
Developing countries	$2xCO_2$ baseyear 1989	as Rosenzweig and Parry (1994)			
- GDP/cap < $500			-2.07 - -19.83	-0.21 - -14.59	26 - 90
- GDP/cap $500-2,000			-1.80 - -15.01	-0.43 - -10.67	41 - 76
- GDP/cap > $2,000			-0.33 - -0.82	-0.60 - -1.02	20 - 46
E. Europe & former USSR			1.89 - -10.96	2.42 - -4.88	29 - 56
OECD			2.67 - -15.10	5.82 - -6.47	57 - >100
World			-0.13 - -61.23	7.00 - -37.62	39 - >100

Notes:
[1] Worldwide adaptation alters terms of trade to the disadvantage of developing countries.
[2] Based on Rosenzweig and Parry (1994) yield data.

Source: Fankhauser et al. (1998)