Centre for
Climate Change
Economics and Policy

Grantham Research Institute on
Climate Change and
the Environment

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September 2009

Centre for Climate Change Economics and Policy
Working Paper No. 8

Grantham Research Institute on Climate Change and the Environment

Working Paper No. 7

The Grantham Foundation for the Protection of the Environment

ESRC Economic & Social Research Council

University of Leeds

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The costs of adaptation

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Abstract

Policy interest in the cost of adaptation is growing, but compared to the mitigation literature adaptation cost research is still in its infancy. Global adaptation cost estimates from more recent studies range from around $25 billion a year to well over $100 billion by 2015-2030. The wide range is symptomatic of the poor state of knowledge. Important knowledge gaps remain both in terms of scope (whether all relevant impacts are covered) and depth (whether, for a given impact all relevant adaptation options have been considered). The omissions introduce biases in both directions, upward and downward, but it is likely adaptation costs have been underestimated so far.

Adaptation is only one part of the overall response to (and therefore the costs of) climate change. The total burden of climate change consists of three elements: the costs of mitigation (reducing the extent of climate change), the costs of adaptation (reducing the impact of change) and the residual impacts that can be neither mitigated nor adapted to. The annual adaptation cost estimates reviewed here cannot be directly compared with the other two cost elements. Making that comparison would require an integrated model that takes into account the total impact of greenhouse gases over their lifetime in the atmosphere.

Keywords: Adaptation, Adaptation costs, Cost-benefit analysis, Aggregate impacts

1. Introduction

There is growing policy interest in the costs of adaptation. This has a lot to do with the role of adaptation in the negotiations for a post-2012 climate agreement. A commitment by developed countries to finance adaptation in developing countries is a key element of the new global climate change regime that is currently negotiated (Stern 2009), and negotiators would like to know what the magnitude of this transfer might be. Independently many governments are also beginning to worry what adaptation will mean for their own countries and their own budgets.

People have always adapted to the climatic conditions they found themselves in. Adaptation to the current climate is omnipresent in our everyday lives. It is embedded in the design and location of buildings, machinery and infrastructure and it is reflected in business decisions, consumption patterns and lifestyle choices.

In principle, adaptation to climate change has to be measured from this baseline of current adaptation. In reality it is not easy to delineate where current adaptation ends and adaptation to anthropogenic climate change begins. This is particularly the case for developing countries, where there is a well-documented adaptation deficit. There is evidence that socio-economic indicators like per capita income, literacy and institutional capacity are positively associated with lower vulnerability to climate events (Noy 2009; Bowen et al. 2009; Leary et al. 2008a, b). This has led Schelling (1992) to conclude that good development is one of the best forms of adaptation. More subtly, McGray et al (2007) identify a continuum of measures that address, to varying degrees, both development and adaptation needs. They include:

- Policies to reduce vulnerability to stress more broadly (whether climate-related or not), including human development objectives like health, sanitation and poverty eradication;
- Creation of “response capacity”, such as resource management practices, planning systems and effective public institutions;
- The management of current climate risks, including flood and drought prevention, disaster preparedness and risk management.
- Policies specifically addressing anthropogenic climate change, such as accelerated sea level rise and an increased incidence of extreme weather events.

These measures often build on each other, in the sense that certain development conditions have to be fulfilled before one can move to the next level. It therefore makes sense to think of adaptation not as incremental activity to deal with climate change, but as climate-resilient development or, in the words of Nicholas Stern, as “development in a hostile climate” (McKinsey 2009).

The adaptation cost literature usually ignores this overlap and focuses on incremental adaptation over and above a vaguely defined baseline that presumably includes climate-relevant development programs. But because the delineation is vague, some do include cost elements that could equally well be classified as the creation of response capacity or the management of current climate risk.

People using adaptation cost estimates also need to realize that adaptation is only one part of the overall response to (and therefore the costs of) climate change. The total burden of climate change consists of three elements: the costs of mitigation (reducing the extent of climate change), the costs of adaptation (reducing the impact of change) and the residual impacts that can be neither mitigated nor adapted way. For example, society may seek to limit the overall temperature increase to $2^{o}C$ (mitigation), invest in coastal protection to limit the negative impacts of $2^{o}C$ warming (adaptation) and accept the loss of certain coastlines because they cannot be defended at reasonable cost (residual damage). Finding the right combination between these measures is a complex economic and ethical question. The point to note here is that cost-effective adaptation is unlikely to reduce impacts to zero. There will be substantial residual damages that adaptation cannot avoid.

Bearing these caveats in mind, this paper reviews the existing literature on adaptation costs. It concludes that research on adaptation costs is still very much in its infancy. The earliest estimates emerged from various sector and country studies. They are discussed in section 2. A first generation of global estimates emerged around 2006, in response to growing interest from policy makers (section 3). They were refined in subsequent work commissioned by the UNFCCC Secretariat and a handful of follow-up studies. These are reviewed in section 4. Section 5 concludes.

2. The evidence from sector and country studies

Adaptation cost research started in the 1990s as part of early attempts to estimate the economic costs of climate change (Smith and Tirpak 1989, Cline 1992, Nordhaus 1994, Fankhauser 1995, Pearce et al 1995 and Tol 1995. A recent survey is Tol 2005). The objective at that time was not to measure adaptation costs per se, but to refine our understanding of climate change impacts. Modelers recognized that their impact estimates would be wrong if they did not include an adaptive response and overcame the "dumb farmer hypothesis" (the assumption that farmers and other actors would not react to a change in climate).

In a survey of adaptation in early impact models, Tol et al. (1998) concluded that many impact categories covered in the economic cost literature were actually adaptation costs, in particular coastal protection, space heating and cooling (an adaptive response to changing temperatures), defensive expenditures against air pollution and in some cases migration (an adaptive response if premeditated but arguably a residual damage in the case of climate refugees). Adaptation also featured prominently in the agriculture literature and to a lesser extent in health, but the adaptive measures considered there were rarely costed out. Overall, Tol et al. found that adaptation costs amounted to 7 – 25% of total impacts.

Over the years, the treatment of adaptation in global impact models was refined over a series of sector studies. However, a recent survey found that beyond coastal protection our knowledge of adaptation costs (and benefits) at the sector level was still fairly limited (Agrawala and Fankhauser 2008, see Table 1).

Table 1: The state of knowledge on adaptation costs and benefits

	Analytical coverage	Cost estimates	Benefit estimates
Coastal zones	Comprehensive	√√√	√√√
Agriculture	Comprehensive	-	√√√
Water	Isolated case studies	√	√
Energy	N. America, Europe	√√	√√
Infrastructure	Cross-cutting partly covered in other sectors	√√	-
Health	Selected impacts	√	-
Tourism	Winter tourism	√	-

Source: Agrawala and Fankhauser (2008). More ticks are associated loosely with a better knowledge base, but no attempt was made to quantify the rating scale.

A similar story holds for cost assessments at the country level. Some information about adaptation costs can usually be gleaned from country-level exercises to develop national adaptation strategies. However, they are rarely complete and the extrapolation of country-level information into a global estimate would be difficult.

Early examples of country studies include World Bank-sponsored work in Bangladesh (Smith et al 1998) and the Pacific (World Bank 2000). More recently, McKinsey, in collaboration with Swiss Re and the Global Environment Facility, have studied adaptation costs and adaptation priorities in eight case studies that cover both developed and developing countries (McKinsey 2009). World Bank (2009) also offers fresh case study evidence.

As significant in terms of actual adaptation planning are the National Adaptation Plans of Action (NAPAs). Sponsored by the Least-Developed Country Fund (a UNFCCC-supported adaptation fund, administered by the Global Environment Facility), NAPAs aim to identify priority adaptations and initiate a process of planning, preparation and implementation in vulnerable developing countries.

Some 40 NAPAs have so far been completed. They vary in quality and scope, with cost estimates ranging from less than $4 million in Madagascar, Comoros and the Central African Republic to several hundred million dollars in Ethiopia and The Gambia, the only two countries to include extensive infrastructure investments. Elsewhere, NAPA priorities predominantly concern preparatory measures and capacity building, most of it on agriculture and water. As such, NAPAs are a poor indicator of the ultimate adaptation expenditures in vulnerable countries, although they can give a rough indication of what the initial outlay (and sectoral priorities) may be.

3. First generation global estimates

Interest in global adaptation cost estimates increased sharply a few years ago when it became clear that a certain amount of climate change, and therefore adaptation, was unavoidable and international support for adaptation became a key aspect of the new global deal on climate change. In response to this demand a handful of aggregate adaptation cost estimates emerged in quick succession. Although they are often dubbed "global" they in fact only concern adaptation in the developing world. Moreover, rather than estimating lifetime costs, they generally deal with capital costs only.

Most estimates share a common method, first developed by the World Bank (2006). The World Bank estimated the fraction of current investment flows that is climate sensitive and then used a "mark up" factor that reflects the cost of "climate-proofing" future capital investment.

Investment flows to developing countries amounted to about $1.8 trillion at the time. The World Bank assumed that 2-10% of gross domestic investment, 10% of foreign direct investment (FDI) and 40% of official development assistance (ODA) would be sensitive to climate change. The mark up to climate-proof these investments was assumed to be 10-20% (see Table 2). Of these assumptions only the ODA figure had some empirical grounding. It was derived from earlier OECD work (Agrawala 2005) about climate risks in six developing countries (Bangladesh, Egypt, Fiji, Nepal, Tanzania and Uruguay)..

Nevertheless, subsequent work for the Stern Review (Stern 2006) and the Human Development Report (UNDP 2007) adopted the same approach, with some adjustments to parameter values. The Human Development Report also included some further adaptation costs to adjust poverty reduction strategies ($40 billion a year) and strengthen disaster response systems ($2 billion a year). This resulted in considerably higher numbers, although some of these measures are arguably as much development-related as adaptation-related (see discussion above)..

A fourth study by Oxfam (2007) also added new cost items to the original infrastructure estimates, viz. the extra cost of NGO work at the community level and the cost of implementing a NAPA-style programme. Both additions are based on strong assumptions. The costs of community-level adaptation were extrapolated from just three projects, while the cost of early adaptation was derived from the 13 NAPAs available at the time. Oxfam concluded that the cost of adaptation in developing countries was "likely to be at least $50 billion annually". Müller and Hepburn (2006) extrapolated NAPAs to arrive at an adaptation cost estimate of $ 5.4 – 9.2 billion.

Although the first-generation studies are mostly based on the same methodology, they resulted in a large range in estimates, with the lowest number at $4 billion and the highest one over $100 billion. Neither the time horizon nor the underlying climate scenario is usually specified, but the use of current investment flows as the basis implies that the numbers represent short-term adaptation needs.

The wide range points to a fundamental problem with the chosen estimation approach. There is not enough empirical information about the size of the mark ups for "climate proofing" and as a consequence the range of credible values is extremely large. Yet, because investment flows are so large, even small changes in parameters can change results by up to an order of magnitude. Parry et al (2009) were harsh, but not wrong when they disqualified the first generation studies as "not substantive".[1]

Table 2: First generation estimates of adaptation costs in developing countries

	Investment flow ($bn)	Of which climate sensitive (%)	Extra cost of climate proofing (%)	Adaptation costs ($bn)
World Bank (2006)				
- Domestic Investment	1,500	2-10		3 - 30
- Foreign Direct Investment	160	10	10-20	2 - 3
- Official Dev. Assistance	100	40		4 - 8
Total				*9 - 41*
Stern Review (2006)				
- Domestic Investment	1,500	2-10		2 - 30
- Foreign Direct Investment	160	10	5-20	1 - 3
- Official Dev. Assistance	100	20		1 - 4
Total				*4 - 37*
UNDP HDR (2007)				
- Domestic Investment	2,724	2-10		3 - 54
- Foreign Direct Investment	281	10	5-20	1 - 6
- Official Dev. Assistance	107	17-33		1 - 7
- Additional adaptation				42
Total				*86* - 109*

* The minimum level of "climate proofing" (the first three cost items) was arbitrarily set at $44 billion.
Note: The World Bank and Stern investment data are for the year 2000; UNDP uses 2005.
Source: Agrawala and Fankhauser (2008).

4. Second generation global estimates

In 2007 the Secretariat of the UNFCCC commissioned five sector studies to get a better handle of investment needs for adaptation both globally and in developing countries (UNFCCC 2007). The UNFCCC estimate is an important step forward. Although incomplete, the study adds considerably more sector detail to our understanding of costs. The estimates are for the year 2030 and cover:

- *Agriculture, forestry and fisheries:* The agriculture estimate consists of three distinct cost items: extra capital investment at farm level, the need for better extension services at country level and the cost of additional global research (e.g. on new cultivars).
- *Water supply*. The water estimate considers the effect of additional water demand and changes on the supply side. Investment decisions are made in anticipation of 2050 water needs.
- *Human health*. The health estimates includes the extra treatment costs for three health issues: malnutrition, malaria and diarrhea. Scenarios are based on the Global Burden of Disease study (McMichael et al. 2004).

[1] This article draws in part on the author's contribution to the Parry et al. study

- *Coastal zones*. Coastal protection costs are based on the DIVA model, which considers a limited set of adaptation options that are applied globally. Uniquely, the coastal estimate considers both adaptation costs and residual damages. Long-term investments are made in anticipation of sea level rise by 2080.
- *Infrastructure*: The infrastructure estimate adopts the World Bank (2006) method, using insurance data to determine the share of climate sensitive investment.

A sixth study was commissioned to look into ecosystem adaptation. Although its results were reported, they were not included in the total as they were not considered to be sufficiently robust. Overall, the UNFCCC consultants concluded that global investment needs for adaptation could amount to $49 – 171 billion per annum by 2030, of which about half would accrue in developing countries (Table 3). By far the largest cost item is infrastructure investment, which was again based on the old World Bank methodology. Costs are over and above what would have to be invested in the baseline to renew the capital stock and accommodate economic and population growth.

Table 3: UNFCCC estimate of global adaptation costs

Sector	**Global cost ($bn in 2030)**	**of which**	
		Developed countries	**Developing countries**
Agriculture	14	7	7
Water	11	2	9
Human health	5	0	5
Coastal zones	11	7	4
Infrastructure	8 – 130	6 – 88	2 – 41
Total	*49 – 171*	*22 – 104*	*27 – 67*

Source: UNFCCC (2007).

Like the World Bank work that inspired the first generation of global estimates, the UNFCCC report has become the basis of several follow up studies. Project Catalyst, a group of climate change thinkers assembled by ClimateWorks, an international philanthropic network, took the UNFCCC numbers to answer a subtly different question. Rather than estimating the global costs of adaptation, Project Catalyst asked how much additional international funding might be needed for adaptation under the post-2012 climate change architecture. That number is smaller than total adaptation costs if existing flows (e.g., private investment) can be leveraged for adaptation and/or if not all countries benefit from international adaptation assistance.

Project Catalyst also paid much more attention to the sequencing of adaptation measures and emphasised capacity building, planning, preparation and research in the early years during which structural ("hard") adaptation is ramped up. Again, this makes their adaptation strategy cheaper than an immediate focus on climate-proofing infrastructure. They estimated a need for incremental public adaptation funding of $8–14 billion a year through 2010-2020, rising to $15-37 billion a year by 2030 (Project Catalyst 2009). In subsequent, unpublished calculations the numbers increased to $13 – 25 billion (for 2010-20) and $25 – 76 billion (for 2030), once the constraint on country eligibility was relaxed and more UNDP-style social adaptation was included.

In a critique of the UNFCCC estimates Parry et al. (2009) list a number of shortcomings – in terms of scope, depth and costing – that leads them to believe the UNFCCC underestimated the true cost of adaptation. Without providing their own estimate, they speculate that actual adaptation costs in the sectors covered might surpass the UNFCCC figure by a factor of two to three. If omitted sectors were included, costs would be higher still. Ecosystem protection, for example, could add tens of billions of dollars to the adaptation tally, although the distinction between adaptation and baseline conservation is difficult to make. The report also points out that by solely focussing on adaptation costs, the UNFCCC neglects important issues like residual damages and the urgent need to close the adaptation deficit...

Another step forward in our understanding of global adaptation costs comes from a comprehensive World Bank study (World Bank 2009). The study, which is so far only available in draft form, takes a similar approach to the UNFCCC for sectors like agriculture and coastal protection, but aims to provide more detail on infrastructure – the sector with the highest costs estimates based on the original World Bank (2006) method. The study also breaks new ground in analysing the higher order effects of adaptation on the economy as a whole (the "general equilibrium effects"). Other studies looking at general equilibrium effects include de Bruin et al (2009) and Bosello et al (2007).

One problem with the World Bank study is that it defines adaptation as the measures needed to restore pre-climate change levels of welfare. That is adaptation is pushed to the point where there is no residual damage, rather than the point where marginal adaptation costs equal marginal adaptation benefits. This exaggerates adaptation costs and the numbers are better seen as a proxy for total climate change costs (adaptation costs plus residual damage)

5. Conclusion

Compared to the abatement cost literature, research on the global cost of adaptation is still in its infancy. Adaptation cost estimates from the more recent studies range from around $25 billion a year to well over $100 billion for the next two decades. The wide range is symptomatic for the poor state of knowledge. Estimates remain indicative and incomplete. The numbers refer to the annual cost of adapting to "median" climate change over the next 20 years. Adaptation costs are likely to grow further over the longer term as the impacts of climate change are increasingly felt. Similarly, if the extent of warming cannot be contained to the 2-3^{o}C assumed in the current generation of studies, adaptation costs will go up and probably exponentially so.

Most authors readily admit that adaptation cost estimates are still preliminary. Important gaps remain in terms of:

- the scope the analysis (whether all relevant impacts and countries are covered),
- the depth of analysis (whether, for a given impact / country all relevant adaptation options and needs are considered),
- the costing of measures (whether all relevant costs are included), and
- the treatment of uncertainty (how uncertainty about future change affects costs)

These shortcomings are a reflection of just how difficult it is to measure and cost adaptation. The question is to what extent the prevailing knowledge gaps lead to an upward or a downward bias in the existing estimates. There are omissions in both directions, but is likely that adaptation costs have been underestimated so far.

The main downward bias in existing studies comes from their limited scope. Only a handful of studies aspire to provide a complete global estimate and even the most comprehensive of these (UNFCCC 2007) is limited to five sectors. Some areas with clear adaptation needs – such as energy and tourism – were omitted, as were some adaptation strategies that are likely to feature prominently, such as migration. Another important omission, not least in developing countries, are institutional and administrative costs, including the costs of building planning capacity. Even in the areas that were considered, the analysis was not always comprehensive.

More subtly, most estimates focus on investment costs, rather than the lifetime costs of adaptation measures. Lifetime costs also include operating costs and perhaps decommissioning costs and as such could be substantially higher. As such most cost estimates are better described as estimates of investment and financing needs, something the UNFCCC study does explicitly.

There is a clear focus on public and planned adaptation at the expense of private adaptation. Certainly in terms of prevalence, and perhaps also in terms of costs, private measures may well dominate the adaptation response as people adjust their buildings, change space cooling and heating preferences, reduce water use, alter holiday destinations or even relocate. This is mostly neglected, even though UNFCCC (2007) includes measures that will ultimately be the responsibility of private actors, in particular in health and agriculture.

Neglecting uncertainty also leads to a potentially substantial underestimation of costs. Just as it was wrong to assume “dumb farmers” in the early days of impact modeling, it is wrong to assume “clairvoyant farmers” now, as all cost estimates do. Uncertainty means that there will be mistakes in adaptation strategies. Even if the response strategies are fully rational, the fact that agents have to hedge their bets and prepare for different possible outcomes will introduce extra costs.

On the other hand, the adaptation options considered in global studies are rarely subjected to a rigorous cost-effectiveness test, suggesting that other, more effective options might be identified once concrete options are being considered. The most obvious bias in this respect is a preference for “hard” structural adaptation measures over “soft” behavioral or regulatory adaptations (the UNFCCC agriculture estimate is an exception). Hard adaptation, such as the expansion of water supply systems are relatively easy to capture and generalize, but they are also potentially much more expensive than soft measures like changes in water demand (e.g., in response to price incentives). Similarly, changes in the maintenance regime may be a cheaper way to adapt infrastructure than changes in design.

While a credible estimate of global adaptation costs remains elusive there are several avenues how our understanding of adaptation costs may be improved. The first one is further country and sector case studies. Only at that level can adaptation options really be studied at the required level of detail. Important issues that have so far been overlooked – such as the distributional implications of adaptation – can the also be analyzed. A second avenue is more research on adaptation under uncertainty. Local climate scenarios will remain uncertain for quite some time and it is important to understand the optimal adaptation strategies in this situation and their implications on cost. Finally, it is important to move away from the study of incremental adaptation and integrate adaptation into development planning. Doing so would recognize that adaptation is in fact “climate-resilient development”.

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