The Cost to Developing Countries of Adapting to Climate Change

New Methods and Estimates

The Global Report of the Economics of Adaptation to Climate Change Study

Executive Summary

Consultative Draft

EXECUTIVE SUMMARY

Even with global emissions of greenhouse gases drastically reduced in the coming years, the global annual average temperature is expected to be 2°C above pre-industrial levels by 2050. A 2°C warmer world will experience more intense rainfall and more frequent and more intense droughts, floods, heat waves, and other extreme weather events. Households, communities, and planners need to put in place measures and initiatives that "reduce the vulnerability of natural and human systems against actual and expected climate change effects" (IPCC 2007). Without such adaptation, development progress will be threatened—perhaps even reversed.

While countries need to adapt to manage the unavoidable, they need to take decisive mitigation measures to avoid the unmanageable. Unless the world begins immediately to reduce greenhouse gas emissions significantly, global annual average temperature will increase by about 2.5°–7°C above pre-industrial levels by the end of the century. Temperature increases higher than 2°C—say on the order of 4°C—are predicted to significantly increase the likelihood of irreversible and potentially catastrophic impacts such as the extinction of half of species worldwide, inundation of 30 percent of coastal wetlands, and substantial increases in malnutrition and diarrheal and cardio-respiratory diseases. Even with substantive public interventions, societies and ecosystems will not be able to adapt to these impacts.

Under the December 2007 Bali Action Plan, adopted at the United Nations Climate Change Conference, developed countries have agreed to "adequate, predictable, and sustainable financial resources and the provision of new and additional resources, including official and concessional funding for developing country parties" (UNFCCC 2008) to help them adapt to climate change.

Yet, existing studies on adaptation costs provide only a wide range of estimates, from $4 billion to $109 billion a year, and have many gaps. Similarly, National Adaptation Programs of Action (prepared by Least Developed Countries under the United Nations Framework Convention on Climate Change, UNFCCC) identify and cost only urgent and immediate adaptation needs, and countries do not typically incorporate adaptation measures into long-term development plans.

Putting a price tag on adaptation

To shed light on adaptation costs—and with the global climate change negotiations resuming in December 2009 in Copenhagen—the Economics of Adaptation to Climate Change (EACC) study was initiated by the World Bank in early 2008, funded by the governments of the Netherlands, Switzerland, and the United Kingdom. Its objectives are to develop an estimate of adaptation costs for developing countries and to help decision makers in developing countries understand and assess the risks posed by climate change and design better strategies to adapt to climate change.

The initial study report, which focuses on the first objective, finds that ***the cost between 2010 and 2050 of adapting to an approximately 2°C warmer world by 2050 is in the range of $75 billion to $100 billion a year.*** This sum is of the same order of magnitude as the foreign aid that developed countries now give developing countries each year, but it is still a very low percentage of the wealth of countries as measured by their GDP. A second report, based on seven country case studies (Bangladesh, Plurinational State of Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Vietnam) and expected by March 2010, will focus on the second objective.

Using a consistent methodology

The intuitive approach to costing adaptation involves comparing a future world without climate change with a future world with climate change. The difference between these two worlds entails a series of actions to adapt to the new world conditions. And the costs of these additional actions are the costs of adapting to climate change. With that in mind, the study took the following four steps:

- *Picking a baseline.* For the timeframe, the world in 2050 was chosen, not beyond (forecasting climate change and its economic impacts becomes even more uncertain beyond this period). Development baselines were crafted for each sector, essentially establishing a growth path in the absence of climate change that determines sector-level performance indicators (such as stock of infrastructure assets, level of nutrition, and water supply availability). The baselines used a consistent set of GDP and population forecasts for 2010–50.

- *Choosing climate projections.* Two climate scenarios were chosen to capture as large as possible a range of model predictions. Although model predictions do not diverge much in projected temperatures increases by 2050, precipitation changes vary substantially across models. For this reason, model extremes were captured by using the two model scenarios that yielded extremes of dry and wet climate projections. Catastrophic events were not captured, however.

- *Predicting impacts.* An analysis was done to predict what the world would look like under the new climate conditions. This meant translating the impacts of changes in climate on the various economic activities (agriculture, fisheries), on people's behavior (consumption, health), on environmental conditions (water availability, oceans, forests), and on physical capital (infrastructure).

- *Identifying adaptation alternatives and costing.* Adaptation costs were estimated by major economic sector—infrastructure, coastal zones, water supply and flood management, agriculture, fisheries, human health, and forestry and ecosystem services. Cost implications of changes in the frequency of extreme weather events were also considered. Cross-sectoral analysis of costs was not feasible.

Putting the methodology to work

The next step was adjusting and tailoring each step to the data and information available, a distinctive feature of the EACC study. The study used extensive global and national data sets, including World Bank projects and global economic indicators. In the process, several questions arose.

What exactly is "adaptation"? Is development adaptation? In reality, developing countries face not only a deficit in adapting to current climate variation, let alone future climate change, but also deficits in providing education, housing, health, and other services. Thus, many countries face a more general "development deficit," of which the part related to climate events is termed the "adaptation deficit."

There are two ways to estimate the costs of adaptation: with the adaptation deficit or without it. This study chose to make the adaptation deficit a part of the development baseline, so that adaptation costs cover only the additional costs to cope with *future* climate change. Thus, the costs of measures that would have been undertaken even without climate change are not included in adaptation costs, but the costs of doing more, doing different things (policy and investment choices), and doing things differently are.

Which adaptation measures? Adaptation measures can be classified by the initiating economic sector—public or private. This study includes planned adaptation (adaptation that results from a deliberate public policy decision) but not autonomous or spontaneous adaptation (adaptation by households and communities acting on their own without public interventions but within an existing public policy framework). Since the objective is to help governments plan for risks, it is important to have an idea of what problems private markets will solve on their own, how public policies and investments can complement markets, and what measures are needed to protect public assets and vulnerable people—that is, planned adaptation.

In all sectors, "hard" options involving engineering solutions were favored over "soft" options based on policy changes and social capital mobilization—except in the study of extreme weather events where the emphasis is on investment in human resources, particularly those of women. Although hard adaptation options are feasible in nearly all settings, while soft options depend on social and institutional capital and thus may not be available in many settings, this focus on hard options was largely to ease computation of adaptation costs and not to suggest that these are always preferable.

How much adaptation is appropriate? Countries have several options. They can try to fully adapt, so that society is at least as well off as it was before climate change. They can choose to do nothing—to suffer (or enjoy the benefits from) the full impact of climate change. Or they can decide to adapt to the level where the benefits from adaptation equal their costs, at the margin. The study assumes that countries will adapt up to the level at which they enjoy the same level of welfare in the (future) world as they would have without climate change. This is not necessarily the most economically rational decision, but it is a practical rule that greatly simplifies the exercise.

How should benefits be costed? What happens if climate changes lead to lower investment or expenditure requirements for some sectors in some countries—for example, changes in demand for electricity or water lead to lower requirements for electricity generating capacity, water storage, and water treatment? In such cases, the "costs" of adaptation are negative. For calculating global costs, this becomes a summation problem. Rather than making an explicit decision on whether to offset potential benefits of climate change against costs of adaptation, whether across sectors or countries, the study presents costs using three aggregation methods—gross (no netting of costs), net (benefits are netted across sectors and countries), and X-sums (positive and negative items are netted within countries but not across countries). The study opted to use X-sums in reporting most adaptation costs in the interest of space, although similar trends hold for the other aggregation methods.

The global price tag

Overall, the study estimates that the ***cost between 2010 and 2050 of adapting to an approximately 2°C warmer world by 2050 is in the range of $75 billion to $100 billion a year*** (table 1). This sum is the same order of magnitude as the foreign aid that developed countries now give developing countries each year, but it is still a very low percentage of the wealth of countries (measured by their GDP).

Total adaptation costs calculated by the gross sum method average $10 billion a year more than by the other two methods (the insignificant difference between the X-sum and net sum figures is largely a coincidence). The difference is driven by countries that appear to benefit from climate change in the water supply and flood protection sector, especially in East Asia and Pacific and South Asia.

TABLE 1

Total annual costs of adaptation for all sectors, by region, 2010–50 ($ billions at 2005 prices, no discounting)

Cost aggregation type	East Asia and Pacific	Europe and Central Asia	Latin America and Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa	Total
National Centre for Atmospheric Research (NCAR), wettest scenario							
Gross sum	28.7	10.5	22.5	4.1	17.1	18.9	101.8
X-sum	25.0	9.4	21.5	3.0	12.6	18.1	89.6
Net sum	25.0	9.3	21.5	3.0	12.6	18.1	89.5
Commonwealth Scientific and Industrial Research Organization (CSIRO), driest scenario							
Gross sum	21.8	6.5	18.8	3.7	19.4	18.1	88.3
X-sum	19.6	5.6	16.9	3.0	15.6	16.9	77.6
Net sum	19.5	5.2	16.8	2.9	15.5	16.9	76.8

Note: The gross aggregation method sets negative costs in any sector in a country to zero before costs are aggregated for the country and for all developing countries. The X-sums net positive and negative items within countries but not across countries and include costs for a country in the aggregate as long as the net cost across sectors is positive for the country. The net aggregate measure nets negative costs within and across countries.

Source: Economics of Adaptation to Climate Change study team.

The ***drier scenario (Commonwealth Scientific and Industrial Research Organization, CSIRO) requires lower total adaptation costs than does the wetter scenario (National Centre for Atmospheric Research, NCAR),*** largely because of the sharply lower costs for infrastructure, which outweigh the higher costs for water and flood management. In both scenarios, infrastructure, coastal zones, and water supply and flood protection account for the bulk of the costs. Infrastructure adaptation costs are highest for the wetter scenario, and coastal zones costs are highest for the drier scenario.

On a regional basis, for both climate scenarios, ***the East Asia and Pacific Region bears the highest adaptation cost,*** and the Middle East and North Africa the lowest. Latin America and the Caribbean and Sub-Saharan Africa follow East Asia and Pacific in both scenarios (figures 1 and 2). On a sector breakdown, the highest costs for East Asia and the Pacific are in infrastructure and coastal zones; for Sub-Saharan Africa, water supply and flood protection and agriculture; for Latin America and the Caribbean, water supply and flood protection and coastal zones; and for South Asia, infrastructure and agriculture.

Not surprisingly, both climate scenarios show ***costs increasing over time, although falling as a percentage of GDP***—suggesting that countries become less vulnerable to climate change as their economies grow (figures 3 and 4). There are considerable regional variations, however. Adaptation costs as a percentage of GDP are considerably higher in Sub-Saharan Africa than in any other region, in large part because of the lower GDPs in this region.

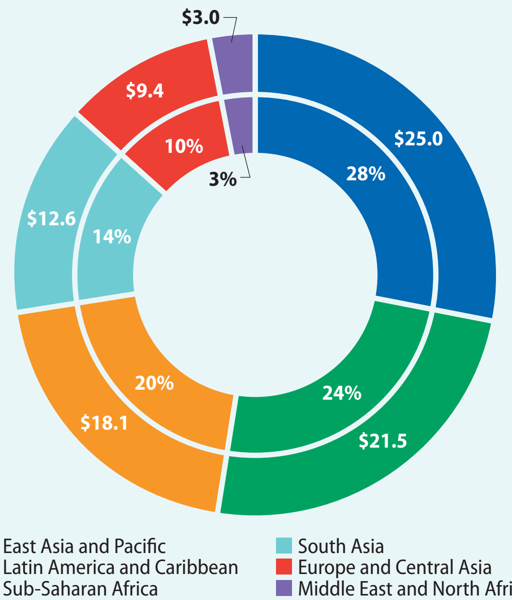
Turning to the EACC analyses of sectors and extreme events, the findings offer some insights for policymakers who must make tough choices in the face of great uncertainty.

Infrastructure. This sector has accounted for the largest share of adaptation costs in past studies and takes up a major share in the EACC study—in fact, the biggest share for the NCAR (wettest) scenario because the adaptation costs for infrastructure are especially sensitive to levels of annual and maximum monthly precipitation. Urban infrastructure—urban drainage, public buildings and similar assets—accounts for about 54 percent of the infrastructure adaptation costs, followed by

FIGURE 1

East Asia and Pacific has the highest cost of adaptation in the wetter scenario, followed by Latin America and the Caribbean

Total annual cost of adaptation and share of costs for National Centre for Atmospheric Research (NCAR) scenario, by region ($ billions at 2005 prices, no discounting)

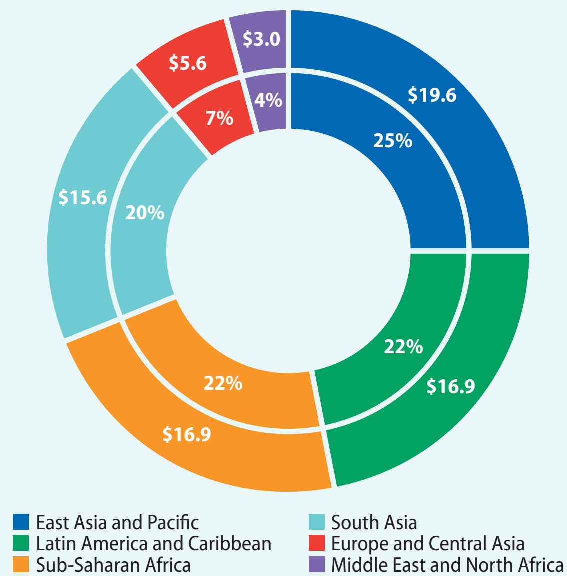


Source: Economics of Adaptation to Climate Change study team.

FIGURE 2

East Asia and Pacific has the highest cost of adaptation in the drier scenario, followed by Latin America and the Caribbean and Sub-Saharan Africa

Total annual cost of adaptation and share of costs for Commonwealth Scientific and Industrial Research Organization (CSIRO) scenario, by region ($ billions at 2005 prices, no discounting)



Source: Economics of Adaptation to Climate Change study team.

roads (mainly paved) at 23 percent. East Asia and the Pacific and South Asia face the highest costs, reflecting their relative populations. Sub-Saharan Africa experiences the greatest increase over time with its adaptation costs rising from $1.1 billion a year for 2010–19 to $6 billion a year for 2040–49.

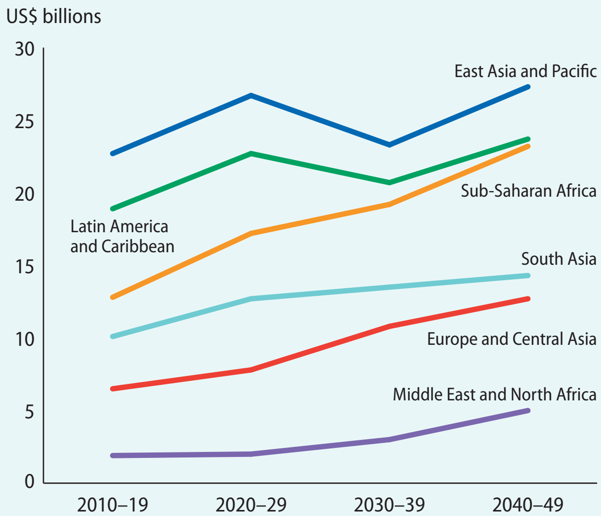
Coastal zones. Coastal zones are home to an ever growing concentration of people and economic activity, yet they are also subject to a number of climate risks, including sea-level rise and possible increased intensity of tropical storms and cyclones. These factors make adaptation to climate change critical. The EACC study shows that coastal adaptation costs are significant and vary with the magnitude of sea-level rise, making it essential for policymakers to plan while accounting for the uncertainty. One of the most striking results is that Latin America and the Caribbean and East Asia and the Pacific account for about two-thirds of the total adaptation costs (see figures 1 and 2).

Water supply. Climate change has already affected the hydrological cycle, a process that is expected to intensify over the course of the 21st century. In some parts of the world, water availability has increased and will continue to increase, but in other parts, it has decreased and will continue to do so. Moreover, the frequency and magnitude of floods are expected to rise, because of projected increases in the intensity of rainfall. Accounting for the climate impacts, the study shows that water supply and flood management ranks as one of the top three adaptation costs in both the wetter and drier scenarios, with Sub-Saharan Africa footing by far the highest costs. Latin America and the Caribbean

FIGURE 3

The absolute costs of adaptation rise over time . . .

Total annual cost of adaptation for National Centre for Atmospheric Research (NCAR) scenario, by region and decade ($ billions at 2005 prices, no discounting)

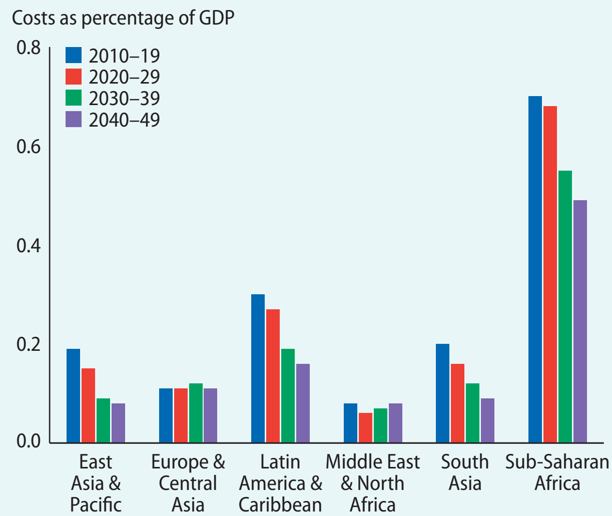


Source: Economics of Adaptation to Climate Change study team.

FIGURE 4

. . . but fall as a share of GDP

Total annual costs of adaptation for National Centre for Atmospheric Research (NCAR) scenario as share of GDP, by decade and region (percent, at 2005 prices, no discounting)



Source: Economics of Adaptation to Climate Change study team.

also sustain high costs under both models, and South Asia sustains high costs under CSIRO.

Agriculture. Climate change affects agriculture by altering yields and changing areas where crops can be grown. The EACC study shows that changes in temperature and precipitation from both climate scenarios will significantly hurt crop yields and production—with irrigated and rainfed wheat and irrigated rice the hardest hit. South Asia shoulders the biggest declines in production but developing countries fare worse for almost all crops compared to developed countries. Moreover, the changes in trade flow patterns are dramatic. Under the NCAR, developed country exports increase by 28 percent while under the CSIRO they increase by 75 percent compared with 2000 levels. South Asia becomes a much larger importer of food under both scenarios, and East Asia and Pacific becomes a net food exporter under the NCAR. In addition, the decline in calorie availability brought about by climate change raises the number of malnourished children.

Human health. The key human health impacts of climate change include increases in the incidence of vector-borne disease (malaria), water-borne diseases (diarrhea), heat- and cold-related deaths, injuries and deaths from flooding, and the prevalence of malnutrition. The EACC study, which focuses on malaria and diarrhea, finds adaptation costs falling in absolute terms over time to less than half the 2010 estimates of adaptation costs by 2050. Why do costs decline in the face of higher risks? The answer lies in the benefits expected from economic growth and development. While the declines are consistent across regions, the rate of decline in South Asia and East Asia and Pacific is more rapid than in Sub-Saharan Africa. As a result, by 2050 more than 80 percent of the health sector adaptation costs will be shouldered by Sub-Saharan Africa.

Extreme weather events. In the absence of reliable data on emergency management costs, the EACC study tries to shed light on the role of socioeconomic development in increasing climate resilience. It asks: As climate change increases potential vulnerability to extreme weather events, how many additional young women would have to be educated to neutralize this increased vulnerability? And how much would it cost? The findings show that ***by 2050, neutralizing the impact of extreme weather events requires educating an additional 18 million to 23 million young women at a cost of $12 billion to $15 billion a year.*** For the period 2000–50 as a whole, the tab reaches about $300 billion in new outlays. This means that in the developing world, neutralizing the impact of worsening weather over the coming decades will require educating a large new cohort of young women at a cost that will steadily escalate to several billion dollars a year. However, it will be enormously worthwhile on other margins to invest in education for millions of young women who might otherwise be denied its many benefits.

Putting the findings in context

How does this study compare with earlier studies? The EACC estimates are in ***the upper end of estimates*** provided by the UNFCCC (2007), the study closest in approach to the EACC (table 2), although not as high as suggested by a recent critique of the UNFCCC study by Parry and others (2009).

Why are the EACC estimates so much higher than those of the UNFCCC? To begin with, even though a comparison of the studies is limited by a number of methodological differences (in particular, the use of a consistent set of climate models to link impacts to adaptation costs and an explicit separation of costs of development from those of adaptation in the EACC study), the major difference between them is the sixfold increase in the cost of coastal zone management and defense under the EACC study. This difference reflects several improvements to the earlier UNFCCC estimates under the EACC study: better unit cost estimates, including maintenance costs, and the inclusion of costs of port upgrading and risks from both sea-level rise and storm surges.

Another reason for the higher estimates is the higher costs of adaptation for water supply and flood protection under the EACC study, particularly for the drier climate scenario, CSIRO. This difference is explained in part by the inclusion of

TABLE 2
Comparison of adaptation cost estimates by the United Nations Framework Convention on Climate Change and the Economics of Adaptation to Climate Change

		Economics of Adaptation to Climate Change study	
Sector	United Nations Framework Convention on Climate Change (2007)	National Centre for Atmospheric Research (NCAR), wettest scenario	Commonwealth Scientific and Industrial Research Climate (CSIRO), driest scenario
Infrastructure	2–41	29.5	13.5
Coastal zones	5	30.1	29.6
Water supply and flood protection	9	13.7	19.2
Agriculture,[a] forestry, fisheries	7	7.6	7.3
Human health	5	2	1.6
Extreme weather events	—	6.7	6.5
Total	28–67	89.6	77.7

Source: UNFCCC (2007) and Economics of Adaptation to Climate Change study team.

riverine flood protection costs under the EACC study. Also pushing up the EACC study estimate is the study's comprehensive sector coverage, especially inclusion of the cost of adaptation to extreme weather events.

The infrastructure costs of adaptation in the EACC study fall in the middle of the UNFCCC range because of two contrary forces. Pushing up the EACC estimate is the more detailed coverage of infrastructure. Previous studies estimated adaptation costs as the costs of climate-proofing new investment flows and did not differentiate risks or costs by type of infrastructure. The EACC study extended this work to estimate costs by types of infrastructure services—energy, transport, water and sanitation, communications, and urban and social infrastructure. Pushing down the EACC study estimate are measurements of adaptation against a consistently projected development baseline and use of a smaller multiplier on baseline investments than in the previous literature, based on a detailed analysis of climate proofing, including adjustments to design standards and maintenance costs.

The one sector where the EACC study estimates are actually lower than the UNFCCC study is human health. The reason for this divergence is in part because of the inclusion of the development baseline, which reduces the number of additional cases of malaria, and thereby adaptation costs, by some 50 percent by 2030 under the EACC study.

The bottom line is that calculating the global cost of adaptation remains a complex problem, requiring projections of economic growth, structural change, climate change, human behavior, and government investments 40 years in the future. The EACC study has tried to establish a new benchmark for research of this nature, as it adopted a consistent approach across countries and sectors and over time. But in the process, it had to make important assumptions and simplifications, to some degree biasing the estimates.

- Adaptation costs are calculated as though decisionmakers knew with certainty what the future climate will be, when in reality the current climate knowledge does not permit even probabilistic statements about country-level climate outcomes. In a world where decisionmakers hedge against a range of outcomes, the costs of adaptation could be potentially higher.

- Of the many global climate projections available for the baseline, only the set reporting maximum and minimum temperatures—and within that set, only the two yielding the wettest and the driest outcomes—were used. In addition, only one growth path was applied. A limited sensitivity analysis finds that a small number of countries face enormous variability in the costs of adapting to climate change given the uncertainty about the extent and nature of climate change. Moreover, the costs of managing these risks could be substantially higher.

- Climate science tells us that the impacts will increase over time and that major effects such as melting of ice sheets will occur further into the future. Even so, the study opted for projecting what is known today with greater certainty rather than making even less reliable longer-term estimates. Thus the investment horizon of this study is 2050 only. A longer time horizon would increase total costs of adaptation.

- The study looks only at additional public sector (budgetary) costs imposed by climate change, not the costs incurred by individuals and private agents. Similarly, the study generally opted for hard adaptation measures that require an engineering response rather than an institutional or behavioral response. Soft adaptation measures often can be more effective and can avoid the need for more expensive physical investment. But as a first-cut global study, it was not possible to know whether effective institutions and community-level collective action, which are preconditions for the implementation of soft actions, exist in a given setting. While incorporating private adaptation would increase cost estimates, including soft measures could potentially decrease them.

- Other limitations include not being able to incorporate innovation and technical change; leaving out local-level impacts, particularly the incidence on more vulnerable groups and the distributional consequences of adaptation; not examining migration; and only partially accounting for adaptation costs related to ecosystem services because of gaps in scientific understanding of the impact of climate change on ecosystems. Relaxing the first of these limitations could lead to significant reductions in adaptation costs, while a more comprehensive assessment of ecosystem services would lead to an increase.

Lessons and recommendations

Four lessons stand out from the study.

First, adaptation to a 2°C warmer world will be costly. The study puts the cost of adapting between 2010 and 2050 to an approximately 2°C warmer world by 2050 at $75 billion to $100 billion a year. The estimate is in the upper range of existing estimates, which vary from $4 billion to $109 billion. Although the estimate involves considerable uncertainty (especially on the science side), it gives policymakers—for the first time—a carefully calculated number to work with. The value added of the study lies in the consistent methodology used to estimate the cost of adaptation—in particular, the way the study operationalizes the concept of adaptation.

Second, the world cannot afford to neglect mitigation. Adapting to an even warmer world than the 2°C assumed for the study—on the order of 4°C above pre-industrial levels by the end of the century—would be much more costly. Adaptation minimizes the impacts of climate change, but it does not tackle the causes. If we are to avoid living in a world that must cope with the extinction of half of its species, the inundation of 30 percent of coastal wetlands, and a large increase in malnutrition and diarrheal and cardio-respiratory diseases, countries must take steps immediately to sharply reduce greenhouse gas emissions.

Third, development is imperative, but it must take a new form. Development is the most powerful form of adaptation. It makes economies less reliant on climate-sensitive sectors, such as agriculture. It boosts the capacity of households to adapt by increasing levels of incomes, health, and education. It enhances the ability of governments to assist by improving the institutional infrastructure. And it dramatically reduces the number of people killed by floods and affected by floods and droughts. But adaptation requires that we go about development differently: breeding crops that are drought and flood tolerant, climate-proofing infrastructure, reducing overcapacity in the fisheries industry, and accounting for the uncertainty in future climate projections in development planning.

Countries may have to shift patterns of development or manage resources in ways that take account of the potential impacts of climate change. Often, the reluctance to change reflects the political and economic costs of changing policies and (quasi-) property rights that have underpinned decades or even centuries of development. Countries experiencing rapid economic growth have an opportunity to reduce the costs associated with the legacy of past development by ensuring that future development takes account of prospective changes in climate conditions. The clearest, and probably most rewarding, opportunities to reduce adaptation costs lie in the water sector, with coastal and flood protection. But other sectors also stand to benefit.

Fourth, uncertainties are large, so robust and flexible policies and more research are needed. The imprecision of models projecting the future climate is the major source of uncertainty and risk for decision makers. Thus, it is crucial to undertake research, collect data, and disseminate information so that if climate change turns out to have worse impacts than anticipated in 20 or 30 years, countries can respond more quickly and effectively. In the meantime, countries should pursue low-cost policies and investments on the basis of the best or median forecast of climate change at the country level. At the same time, countries should avoid making investments that will be highly vulnerable to adverse climate change outcomes. For durable climate-sensitive investments, strategies should maximize the flexibility to incorporate new climate knowledge as it emerges. Hedging against varying climate outcomes, for example by preparing for both drier and wetter conditions for agriculture, would raise the cost of adapting well beyond what has been estimated here.

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The full report can be accessed at www.worldbank.org/eacc.