Climate Change and Development Series

SHOCK WAVES

Managing the Impacts of Climate Change on Poverty

Stephane Hallegatte, Mook Bangalore,
Laura Bonzanigo, Marianne Fay,
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WORLD BANK GROUP

1818 H Street NW, Washington, DC 20433
Telephone: 202-473-1000; Internet: www.worldbank.org

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Foreword

Ending poverty and addressing climate change are the two defining issues of our time. Both are essential to achieving sustainable global development. But they cannot be considered in isolation.

This report brings together these two overarching objectives and explores how they can be more easily achieved if considered together. It demonstrates the urgency of efforts to reduce poverty and the vulnerability of poor people in the face of climate change. It also provides guidance on how to ensure that climate change policies contribute to poverty reduction and poverty reduction policies contribute to climate change mitigation and resilience building.

Our studies show that without action, climate change would likely spark higher agricultural prices and could threaten food security in poorer regions such as Sub-Saharan Africa and South Asia. And in most countries where we have data, poor urban households are more exposed to floods than the average urban population.

Climate change also will magnify many threats to health, as poor people are more susceptible to climate-related diseases such as malaria and diarrhea. As the report points out, poverty reduction is not a one-way street. Many people exit or fall back into poverty each year. The poor live in uncertainty, just one natural disaster away from losing everything they have.

We need good, climate-informed development to reduce the impacts of climate change on the poor. This means, in part, providing poor people with social safety nets and universal health care. These efforts will need to be coupled with targeted climate resilience measures, such as the introduction of heat-resistant crops and disaster preparedness systems.

The report shows that without this type of development, climate change could force more than 100 million people into extreme poverty by 2030. But with rapid, inclusive development that is adapted to changing climate conditions, most of these impacts can be prevented.

Over the longer term, we will face the limits of what good development and risk management can achieve. Only immediate emissions-reduction policies can limit the long-term impacts of climate change on the poor. This report shows that these policies need not burden, and can actually benefit, the poor, through the use of proven mechanisms such as social safety nets to mitigate the impact of higher energy prices. The international community must also support poor countries that cannot provide such protection.

The report combines the findings from household surveys in 92 countries that describe demographic structures and income sources with the most recent modeling results on the impacts of climate change on agricultural productivity and food prices; natural hazards such as heat waves, floods, and droughts; and climate-sensitive diseases and other health consequences.

Based on these findings and results, the report gives a renewed urgency to the objective of eradicating extreme poverty by 2030 while tackling climate change. Development and poverty alleviation reduce people's vulnerability to the effects of a changing climate. And ending extreme poverty will be more achievable now—with limited climate change impacts—than later, when impacts are likely to be larger.

The report shows us that the best way forward is to design and implement solutions to end extreme poverty and stabilize climate change as an integrated strategy. Such concerted action, implemented quickly and inclusively, can help ensure that millions of people are not pushed back into poverty by the multifaceted impacts of climate change.

John Roome
Senior Director
Climate Change
World Bank Group

Ana Revenga
Senior Director
Poverty and Equity
World Bank Group

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Abbreviations

4P(s)	Pantawid Pamilyang Pilipino Program (Philippines)
AFOLU	agriculture, forestry, and other land uses
BUL	Beneficiary Update List (Philippines)
Cat-DDO(s)	Catastrophe Deferred Drawdown Option
CatMex	catastrophe bond (Mexico)
CCRIF	Caribbean Catastrophic Risk Insurance Facility
CDCP	Citizen's Damage Compensation Program (Pakistan)
CRW	Crisis Response Window
DAFAC	Disaster Affected Family Assistance Card (Philippines)
DANIDA	Danish International Development Agency
DHS	Demographic and Health Surveys
DSWD	Department of Social Welfare and Development (Philippines)
EU	European Union
FONDEN	Natural Disasters Fund (Mexico)
FSP	Food Security Program (Ethiopia)
GDP	gross domestic product
GEF	Global Environment Facility
GFDRR	Global Facility for Disaster Reduction and Recovery
GFEI	Global Fuel Economy Initiative
GHG	greenhouse gas
GHI	Global Hunger Index
GLOBIOM	Global Biosphere Management Model
GRS	Grievance Redress System (Philippines)
GTAP	Global Trade Analysis Project
HABP	Household Asset Building Program (Ethiopia)

HDI	human development index
HSSF	Health Sector Services Fund
I2D2	International Income Distribution Data Set
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kWh	kilowatt-hour
MAgPIE	Model of Agricultural Production and its Impact on the Environment
MDB	multilateral or bilateral development bank
MoA	Ministry of Agriculture
MSME	micro-, small, and medium enterprises
NADRA	National Database Registration Authority (Pakistan)
NCDD	National Community-Driven Development program (Philippines)
NDRRMF	National Disaster Risk Reduction and Management Fund (Philippines)
NDRRMP	National Disaster Risk Reduction and Management Plan (Philippines)
NGO	nongovernmental organization
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
OSDMA	Odisha State Disaster Management Authority (India)
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PET	Temporary Employment Public Works Program (Mexico)
ppm	parts per million
PPP	purchasing power parity
PSNP	Productive Safety Net Program (Ethiopia)
PTSD	post-traumatic stress disorder
QRF	Quick Response Fund (Philippines)
RCP	Representative Concentration Pathway
RFM	Risk Financing Mechanism (Ethiopia)
SP	social protection
SRES	Special Report on Emissions Scenarios
SSP	Shared Socioeconomic Pathways
TCIP	Turkish Catastrophe Insurance Pool
tCO_2	tons of carbon dioxide
TWh	terawatt-hour
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children’s Fund
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
WCFC	Watan Card Facilitation Center (Pakistan)
WFP	World Food Program
WHO	World Health Organization

Overview

Introduction

Climate change threatens the objective of sustainably eradicating poverty. Poor people and poor countries are exposed and vulnerable to all types of climate-related shocks—natural disasters that destroy assets and livelihoods; waterborne diseases and pests that become more prevalent during heat waves, floods, or droughts; crop failure from reduced rainfall; and spikes in food prices that follow extreme weather events. Climate-related shocks also affect those who are not poor but remain vulnerable and can drag them into poverty—for example, when a flood destroys a microenterprise, a drought decimates a herd, or contaminated water makes a child sick. Such events can erase decades of hard work and asset accumulation and leave people with irreversible health consequences. Changes in climate conditions caused by increasing concentrations of greenhouse gases (GHGs) in the atmosphere can worsen these shocks and slow down poverty reduction.

Ending poverty will not be possible if climate change and its effects on poor people are not accounted for and managed in development and poverty-reduction policies. But neither can the climate be stabilized without acknowledging that ending poverty is an utmost priority. The goal of maintaining climate change below a 2°C increase in global temperature above preindustrial levels—the very goal the international community has committed to—will require deep structural changes in the world economy. These changes will affect the conditions under which poor people succeed or fail to escape poverty. Emissions-reduction policies can increase energy and food prices, which represent a large share of poor people's expenditures. But these same policies can be designed to protect, and even benefit, poor people—for instance, by using fiscal resources from environmental taxes to improve social protection.

Ending poverty and stabilizing climate change will be two unprecedented global achievements and two major steps toward sustainable development—that is, development that balances the economic, social, and environmental considerations. But these two objectives cannot be considered in isolation: they need to be jointly tackled through an integrated strategy.

This report brings together these two objectives—ending poverty and stabilizing climate change—and explores how they can more easily be achieved if considered together. It examines the potential impact of climate change and climate policies on poverty reduction. It also provides guidance on how to create a "win-win" situation so that climate change policies contribute to poverty reduction and poverty-reduction policies contribute to climate change mitigation and resilience building.

The key finding of the report is that climate change represents a significant obstacle to the sustained eradication of poverty, but future impacts on poverty are determined by policy choices: rapid, inclusive, and climate-informed development can prevent most short-term impacts whereas immediate pro-poor, emissions-reduction policies can drastically limit long-term ones:

- **Climate-related shocks and stresses, already a major obstacle to poverty reduction, will worsen with climate change.**

  Climate is involved in most of the shocks that keep or bring households into poverty—notably, natural disasters (such as floods that cause asset loss and disability); health shocks (such as malaria that results in health expenditures and lost labor income); and crop losses and food price shocks (due to drought or crop disease).

  Poor people are disproportionately affected—not only because they are often more exposed and invariably more vulnerable to climate-related shocks but also because they have fewer resources and receive less support from family, community, the financial system, and even social safety nets to prevent, cope, and adapt. Climate change will worsen these shocks and stresses, contributing to a decoupling of economic growth and poverty reduction, thereby making it even harder to eradicate poverty in a sustainable manner.
- **In the short run, rapid, inclusive, and climate-informed development can prevent most (but not all) consequences of climate change on poverty. Absent such good development, climate change could result in an additional 100 million people living in extreme poverty by 2030.**

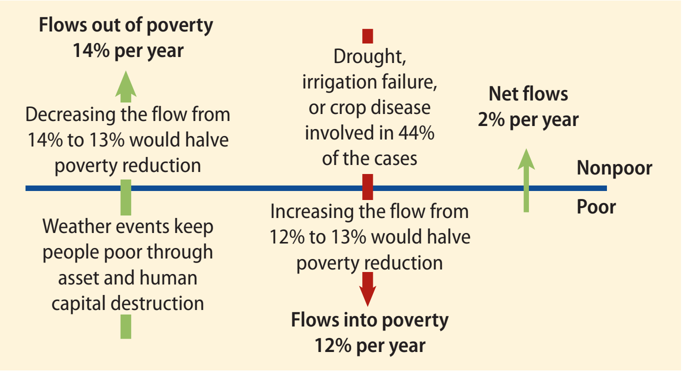
  Between now and 2030, climate policies can do little to alter the amount of global warming that will take place. The only option, therefore, is to reduce vulnerability through both targeted adaptation investments and improved socioeconomic conditions (higher incomes and lower poverty and inequality).

  Although development and adaptation cannot prevent all negative impacts from climate change, by 2030 they can prevent or offset most of its effects on poverty. But development must be rapid and inclusive to reduce poverty and provide poor people with social safety nets and universal health coverage. It also needs to be climate informed—meaning that investments and development patterns do not create new vulnerabilities and account for what we know about future climate conditions. And it needs to be accompanied by targeted adaptation (like upgrades in flood defenses or more heat-tolerant crops).
- **Immediate mitigation is required to remove the long-term threat that climate change creates for poverty eradication. Mitigation need not threaten short-term progress on poverty reduction provided policies are well designed and international support is available.**

  Our ability to manage increasing climate change impacts is limited. To keep long-term impacts on poverty in check, global temperatures need to be stabilized at a safe level—which implies that net global carbon emissions be brought down to zero before the end of the century. Such an ambitious goal requires that all governments act now to implement emissions-reduction policies. These policies will unambiguously benefit poor people over the long term, thanks to reduced climate change impacts, and they can be designed not to slow down poverty reduction over the short term.

  All countries should pursue options that provide local and immediate benefits (like less pollution, better health, improved energy access and efficiency, reduced energy expenditures, and higher agricultural productivity). Governments can protect the poor from the consequences of those mitigation policies that could impose net costs and create trade-offs—notably by strengthening social protection and cash transfers or reducing taxes, possibly using revenues from energy or carbon taxes or fossil fuel subsidy removal. In poor countries where domestic resources are insufficient to protect poor people, support from the international community is essential. This is particularly true for investments with high upfront costs that are critical to prevent lock-ins into carbon-intensive patterns (such as for urban transport, energy infrastructure, or deforestation).

FIGURE O.1 Flows in and out of poverty in Andhra Pradesh are larger than their net effect on poverty



Source: Based on Krishna 2006.

Climate change is a threat to poverty eradication

Poverty reduction is not a one-way transition out of poverty: many people exit or fall back into poverty every year. For instance, over a 25-year period, every year an average of 14 percent of households in 36 communities in Andhra Pradesh, India, escaped poverty and 12 percent of nonpoor households became poor—resulting in a net 2 percent annual decrease in poverty (figure O.1). The fact that, in practice, the net flow out of poverty is much smaller than the gross flows in and out of poverty means that a relatively small change in the gross flows in and out of poverty can significantly affect net flows and overall poverty dynamics. In the India example, if the flow into poverty increased from 12 to 13 percent per year or the flow out of poverty slowed from 14 to 13 percent per year, the pace of poverty reduction would be reduced by half.

Today, climate conditions or climate events are already involved in many cases where households fall into poverty. They include price shocks that can be linked to lower agricultural production (as occurred after the Russian droughts in 2010); natural disasters that destroy poor people's assets and affect health and education; and health shocks (such as death and illness) that are influenced by climate and environmental conditions (like higher rainfall and more malaria outbreaks, or higher temperatures and more frequent diarrhea). In addition, climate risks affect the behavior of people, who may reduce investments and asset accumulation because of the possibility of losses and select lower-risk but lower-return activities—a rational strategy to avoid catastrophic outcomes, but one that can keep them in poverty.

The key question then is: How much will climate change influence the flows in and out of poverty and affect poverty over time? This report reviews the evidence and provides new quantification on the issue. It does this by examining the impact of climate change on three interacting channels that are already affecting the ability of the poor to escape poverty—agricultural and ecosystem impacts, natural disasters, and health shocks—and then deriving policy implications. Here we should note that climate change will have other impacts (for example on tourism or energy prices) that are not reviewed and assessed in this report, and a comprehensive estimate of all climate change impacts remains out of reach. However, even a subset of all possible impacts reveals worrying patterns on how changes in climate conditions would threaten the objective of eradicating extreme poverty by 2030.

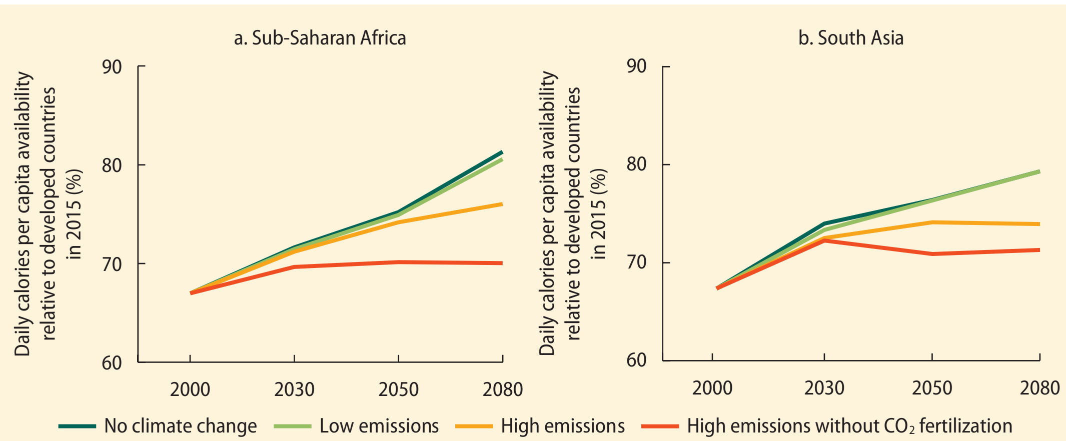
We find that climate change already worsens—and will further exacerbate—climate-sensitive shocks and negative trends in the three sectors that we consider, consistent with recent reports from the World Bank (2014a) and the Intergovernmental Panel on Climate Change (IPCC 2014; Olsson et al. 2014). We also show that there will be an impact on poverty and inequality because poor people (i) are more often affected by these negative shocks or trends (they are more *exposed*); (ii) lose more when affected, relative to their income or wealth (they are more *vulnerable*); and (iii) receive less support from family, friends, and community, and have less access to financial tools or social safety nets to help prevent, prepare for, and manage impacts.

Poor people are more vulnerable to spikes in food prices and more dependent on agricultural and ecosystem-related income

Impacts on agricultural production and prices—triggered by either gradual changes in long-term climate trends or more frequent and severe natural disasters—will affect poor people through food production impacts, higher consumption prices, and changes in rural incomes.

Lower crop yields and higher food prices. Modeling studies suggest that climate change could result in global crop yield losses as large as 5 percent in 2030 and 30 percent in 2080, even accounting for adaptive behaviors such as changed agricultural practices and crops, more irrigation, and innovation in higher yield crops (Biewald et al., forthcoming; Havlík et al., forthcoming). Over the short term, climate change will also create some benefits, but mostly in cold and relatively rich countries, while poorer regions will be the most negatively affected. The expected yield losses are likely to translate into higher agricultural prices; and climate change will make it more difficult, even with more trade, to ensure food security in regions like Sub-Saharan Africa and South Asia. In a world with rapid population growth, slow economic growth, and high GHG emissions (that is, a scenario in which global temperatures increase by approximately 4°C by 2100), food availability in these regions could plateau at levels far below current levels in developed countries (figure O.2).

FIGURE O.2 **Climate change can significantly reduce food availability in poor regions**



Source: Havlík et al., forthcoming.
Note: Results are based on simulations from the Global Biosphere Management Model (GLOBIOM) in a scenario with large population growth and little economic growth.

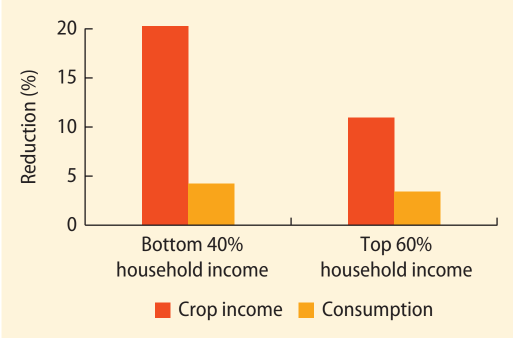
But these estimates come with a high level of uncertainty. They vary depending on the type of climate, crop, and economic model applied, as well as on assumptions about CO_2 fertilization (its presence should mean higher crop yields)—hence the −30 percent to +45 percent range in likely food price changes in 2050 that is reported by the IPCC (Porter et al. 2014). And they do not include local pollution and ozone, pests and crop diseases, food losses along the supply chain, or natural disasters that could result in temporary, but very severe, food price shocks.

In addition, emissions-reduction efforts could affect food prices and availability. The IPCC concludes that large-scale, land-based mitigation at the global scale, especially bio-energy expansion, can reduce the availability of land for food production, with implications for food security. In fact, new modeling simulations show that mitigation policies that do not consider food security could have price impacts that are larger than those of climate change (Havlík et al., forthcoming). However, more carefully designed mitigation policies could lead to price impacts that are smaller than those caused by unmitigated climate change (Lotze-Campen et al. 2014).

Changes in consumption and incomes. Losses in the agricultural sector and spikes in food prices can push vulnerable consumers into poverty—take, for example, the 2008 food price spike that caused about 100 million people to fall into poverty, or the 2010–11 episode that increased poverty by 44 million. Part of the problem is that poor people spend a larger share of their budget on food than the rest of the population, with nonagricultural rural households and urban residents the most vulnerable (Ivanic, Martin, and Zaman 2012).

In addition, farmers would directly suffer from production shocks that could reduce income and consumption. Data from Uganda between 2005 and 2011 suggest that a 10 percent reduction in water availability due to a lack of rainfall reduces crop income by an average of 14.5 percent—and almost 20 percent for the poorest households. Consumption also falls, but less so (figure O.3).

FIGURE O.3 Rainfall shocks in Uganda take a big toll on crop income, less so on consumption



Source: Hill and Mejia-Mantilla 2015.
Note: Values calculated based on Uganda National Household Survey UNHS 2005/6, UNHS 2009/10, UNHS 2012/13. Rainfall shock is represented by a 10 percent decrease in the Water Requirement Satisfaction Index, estimated for Uganda.

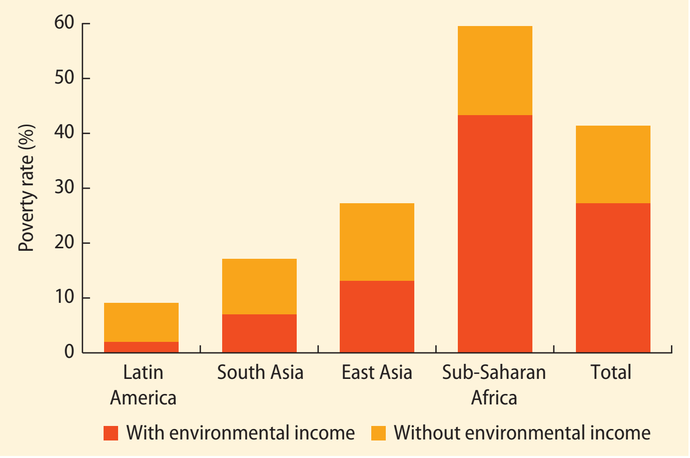
As for the rural poor, the situation could be mixed. If production shocks are accompanied by price rises, agricultural workers and farmers may benefit from higher wages and earnings (Jacoby, Rabassa, and Skoufias 2014). So the net effect on income depends on how food prices react to reduced global production and how demand and diets can adjust over the short term and the long term. It also depends on the balance between local changes (which affect farmers' production) and global changes (which affect global food prices). And it depends on institutions—especially labor markets—that determine how changes in revenues from agriculture are distributed between workers, landowners, and traders.

However, even if the net impact on income is positive, it is unlikely to offset the negative impacts of higher consumption prices on overall poverty. One study of 15 developing countries in various regions finds that climate-induced price rises increase extreme poverty by 1.8 percentage points (Hertel, Burke, and Lobell 2010). It also finds that, in parts of Africa and Asia, climate-related price adjustments could increase poverty rates for nonagricultural households by 20–50 percent. Similarly, another study shows that a once-in-30-year climate extreme could double the number of poor urban laborers in the most vulnerable countries, including in Malawi, Mexico, and Zambia (Ahmed, Diffenbaugh, and Hertel 2009). Our own simulations reach similar results (see below).

Another complicating factor is that climate change—especially when combined with local stressors such as pollution and overuse—threatens ecosystems, which provide subsistence production and safety nets for many people in rural areas. Poor smallholder communities across (sub)tropical landscapes depend on the extractive use of ecosystems for up to 30 percent of their income and often rely on ecosystem resources to keep themselves above the poverty threshold (figure O.4). Even though a precise quantification remains out of reach, a growing number of studies document how increasing climate stress threatens the livelihoods of poor people in a variety of rural contexts and forces them to pursue new livelihood strategies. Over the long term, climate change will even make some ecosystems (such as small island states or low-lying coastal areas) completely uninhabitable, forcing inhabitants to move.

FIGURE O.4 Without environmental income, poverty rates could be much higher in (sub)tropical forest landscapes

(Poverty rate in (sub)tropical smallholder systems)



Source: Noack et al., forthcoming.
Note: Figure shows share of sampled households below the extreme-poverty line. Based on the Poverty and Environment Network (PEN) dataset, including data from 58 sites in 24 countries. Environmental income describes income derived from ecosystem services (such as wood gathering or root and berry picking) rather than agriculture.

Natural hazards, to which poor people are often more exposed and almost always more vulnerable, will become more intense and frequent in many regions

We are already experiencing an increase in natural hazards. About 75 percent of the moderate hot extremes over land and 18 percent of moderate precipitation extremes are attributable to global warming (Fischer and Knutti 2015). Even though some positive impacts are expected—such as fewer cold spells—the frequency and intensity of many hazards are expected to increase in most places:

- Heat waves that are considered exceptional today will become common. In Europe, the summer of the 2003 heat wave, which led to more than 70,000 deaths, will be an "average" summer at the end of this century under a high-emissions scenario (a scenario in which the global mean temperature has increased by about 4°C by 2100).
- The number of drought days could increase by more than 20 percent in most of the world by 2080, and the number of people exposed to droughts could increase by 9–17 percent in 2030 and 50–90 percent in 2080.
- The number of people exposed to river floods could increase by 4–15 percent in 2030 and 12–29 percent in 2080 (Winsemius et al., forthcoming), and coastal flood risks can increase rapidly with sea level rise (Hallegatte et al. 2013).

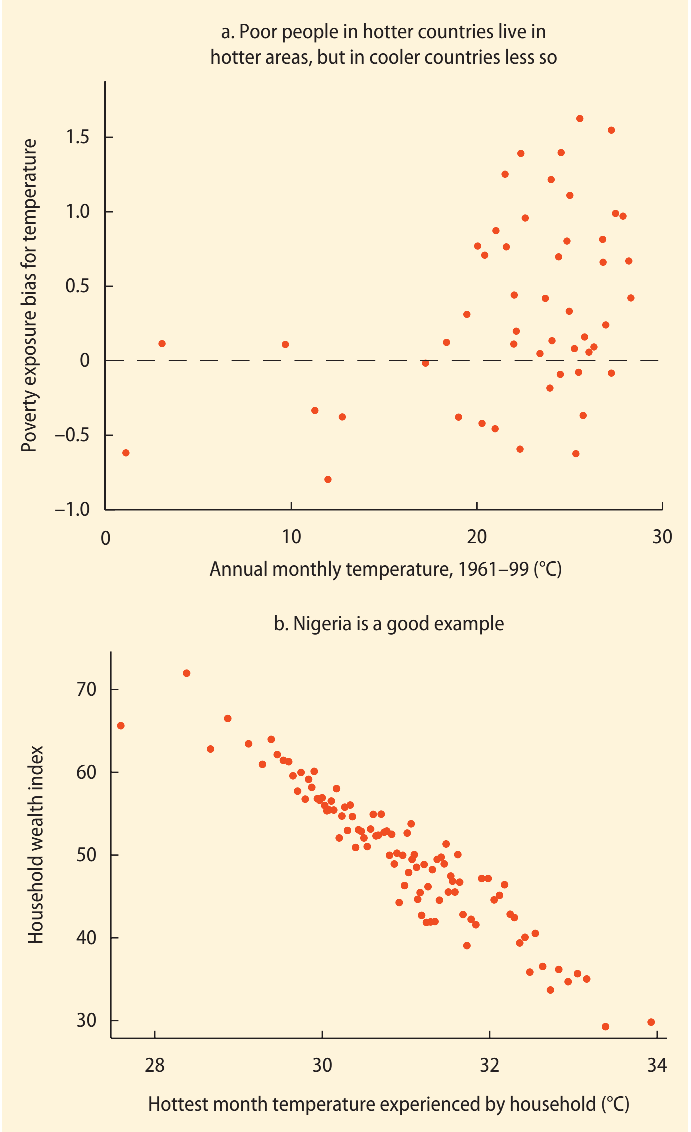
Will poor people bear the brunt of these climatic changes? Poor and nonpoor people settle in risky areas for many reasons. Sometimes, they lack information about the level of risk, or they do not account for this information in their decisions (World Bank 2013, chapter 2). But at-risk areas are often attractive in spite of the risk because they offer economic opportunities, public services or direct amenities, and higher productivity and incomes. In some rural areas, proximity to water offers cheaper transport, and regular floods increase agricultural productivity. People settle in risky areas to benefit from opportunities—such as coastal areas with export-driven industries or cities with large labor markets and agglomeration spillovers. While these factors apply to rich and poor alike, local land and housing markets (or the availability of land) often push poorer people to settle in riskier, but more affordable, areas.

To shed more light on this issue, we investigated poverty-specific exposure to flood, droughts, and extreme temperatures within 52 countries to obtain a first global estimate of the difference in exposure for poor and nonpoor people.

Our results show that *for drought*, most of the analyzed population (85 percent) lives in countries where poor people are more exposed to droughts than the average (Winsemius et al., forthcoming). Poor people are also more exposed to *higher temperatures*: 37 out of 52 countries (56 percent of the population) exhibit an overexposure of poor people, with this bias stronger in hotter countries where high temperatures are more likely to be detrimental (figure O.5). As for *river floods*, the results are mixed: poor people are more exposed than the average in half of the countries analyzed (60 percent of the population). In Africa, countries in the southwest exhibit a strong overexposure of poor people, as do those with large rivers in west Africa (like Benin, Cameroon, and Nigeria). Focusing on urban households, we find that in most countries (73 percent of the population), poor households are more exposed to floods than the average (map O.1). This might be because land scarcity is more acute in urban areas (than in rural areas), creating a stronger incentive for the poor to settle in risky areas due to lower prices. This higher exposure to flood risk for poor urban dwellers is also found using higher-resolution data on household location and flood hazards in Mumbai, India.

Given that the dynamics of disasters and poverty occur at a fine scale, studies of exposure at the national scale may miss important mechanisms and small-scale differences, from one city block to the next. An alternative way to examine whether poor people are more exposed to natural hazards is through in-depth case studies, analyzing household survey data from disaster victims. Here again we find that poor people are generally more exposed, although there are exceptions—such as hurricane Mitch in Honduras (figure O.6, panel a).

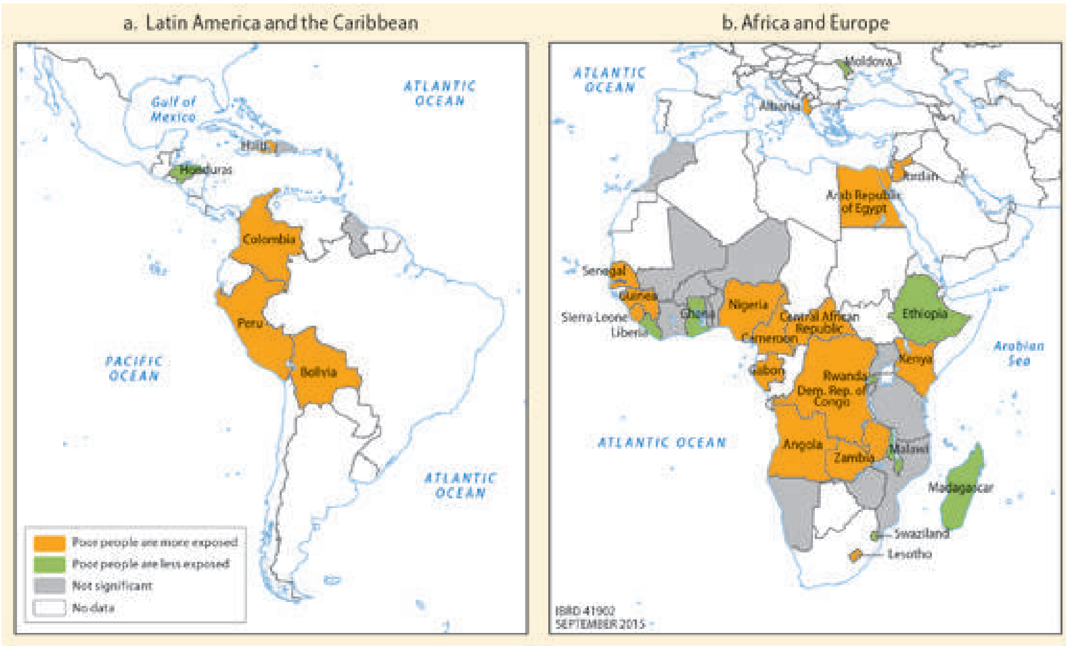
FIGURE O.5 Poor people in hotter countries—like Nigeria—live in hotter areas, but less so in cooler countries



Source: Park et al., forthcoming; World Bank 2015a.
Note: Panel a plots country-level poverty exposure bias for temperatures against each country's current climate. The poverty exposure bias is the share of poor people exposed to a hazard, divided by the share of the total population exposed, subtracted by 1. A positive bias means poor people are more exposed than the average. Panel b plots household-level wealth index and temperature within a country—Nigeria.

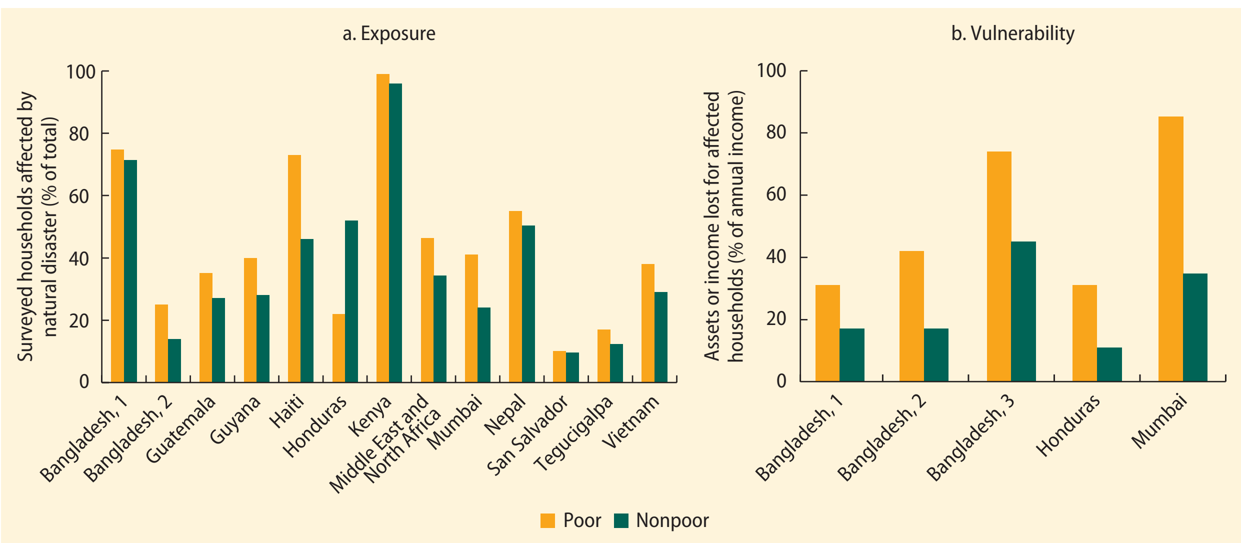
MAP O.1 The urban poor are more exposed to river floods in many countries

(Poverty exposure bias for floods in urban areas)



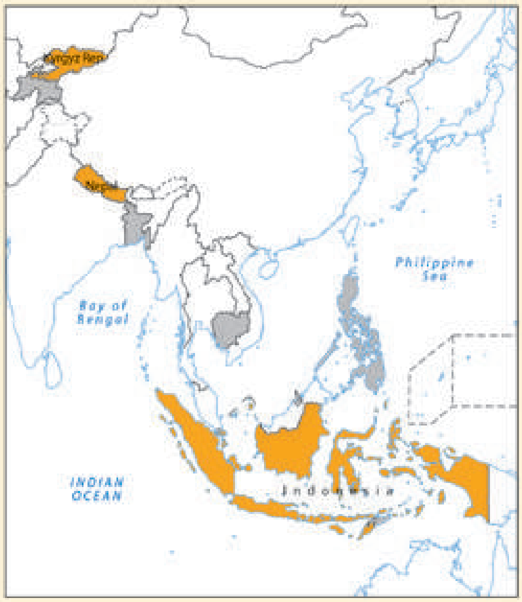
Source: World Bank (IBRD 41902, September 2015) based on Winsemius et al., forthcoming.
Note: Exposure was calculated for river floods.

FIGURE O.6 When disasters hit in the past, poor people were more likely to be affected (panel a) … and poor people always lost relatively more than nonpoor people (panel b)



Source: See sources in Chapter 3.
Note: Each Bangladesh case represents a unique study.

c. Asia



As for assets and income, nonpoor people lose a larger amount in absolute terms because they have more assets and higher incomes than the poor. But in relative terms, poor people always lose more than the nonpoor, according to the five surveys that report the magnitude of natural disaster losses, distinguishing by income classes (figure O.6, panel b). And it is these relative losses, rather than absolute ones, that matter most for livelihoods and welfare.

Poor people are losing relatively more to disasters for two main reasons. First, they often do not save at financial institutions, and they hold most of their wealth in vulnerable forms, such as housing for urban dwellers and livestock for rural households. Second, the quality of their assets—and the resistance of those assets to natural hazards—is often lower than average: typical houses found in a slum can be completely destroyed in a common flood whereas modern houses or multifamily buildings are much more resistant. And poor people's overall vulnerability is exacerbated by the dependence on ecosystems and the large fraction of their budget dedicated to food.

As a result of these differences in exposure and vulnerability, natural disasters increase inequality and may contribute to a decoupling of economic growth and poverty reduction. It is thus not surprising that natural disasters are found to worsen poverty. For instance, between 2000 and 2005, floods and droughts increased poverty levels in affected Mexican municipalities by 1.5 to 3.7 percent (Rodriguez-Oreggia et al. 2013). After Ethiopia's 1984–85 famine, it took a decade on average for asset-poor households to bring livestock holdings back to prefamine levels (Dercon 2004).

Poor people are strongly affected by diseases and health issues that climate change is likely to magnify

Climate change will magnify some threats to health, especially for poor and vulnerable people—such as children. The exact impacts are still highly uncertain in what is still an emerging research field. Past progress on medical treatment offers hope that some of these issues could be solved over the long term thanks to new drugs and better health infrastructure. But short-term impacts could still be significant.

Health shocks are important for poverty dynamics and the impact of climate change for three main reasons. First, the main diseases that affect poor people are diseases that are expected to expand with climate change (such as malaria and diarrhea). Second, health expenditures are regressive, with poor households largely uninsured—such outlays push an estimated 100 million people per year into poverty—and the loss of income for the sick or the caregiver can have a large impact on family prospects (WHO 2013). Third, children are most vulnerable to these shocks and can suffer from irreversible impacts that affect their lifetime earnings and lead to the intergenerational transmission of poverty.

Malaria. Even small temperature increases could significantly affect the transmission of malaria. At the global level, warming of 2°C or 3°C could increase the number of people at risk for malaria by up to 5 percent, or more than 150 million people. In Africa, malaria could increase by 5–7 percent among populations at risk in higher altitudes, leading to a potential increase in the number of cases of up to 28 percent (Small, Goetz, and Hay 2003). Further, climate change is projected to intensify malaria along the current edges of its distribution, where malaria control programs are often nonexistent and people have no naturally acquired immunity against the disease.

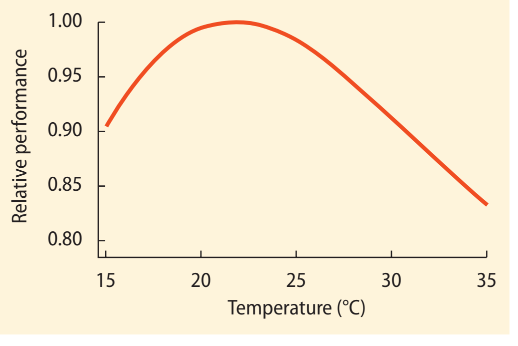
Diarrhea. Climate impacts could increase the burden of diarrhea by up to 10 percent by 2030 in some regions (WHO 2003). Indeed, higher temperatures favor the development of pathogens, and water scarcity affects water quality and the hygiene habits that can prevent diarrhea. An estimated 48,000 additional deaths among children under the age of 15 resulting from diarrheal illness are projected by 2030 (Hales et al. 2014). And climate change could contribute to outbreaks of other waterborne diseases such as cholera and schistosomiasis.

Stunting. In part because of its impacts on agriculture (figure O.2), climate change will increase undernutrition and could sharply increase severe stunting among children. By 2030, an additional 7.5 million children may be stunted (Hales et al. 2014). Climate change could even lead to an *absolute* increase in the number of stunted children in some parts of Africa, with the negative effect of climate change outweighing the positive effect of economic growth (Lloyd, Kovats, and Chalabi 2011). And recent evidence suggests that the nutritional quality of food (for example, its content in terms of micronutrients such as iron, iodine, vitamin A, folate, and zinc) could also be affected by climate change, even though little is known about potential impacts (Myers et al. 2014).

Even less is known about the combined effects of multiple health stressors. For instance, it is well known that undernourished children are more vulnerable to malaria and other vectorborne or waterborne diseases, but these interactions have not yet been investigated in the context of climate change. Also impossible to quantify is the impact on mental disorders and stress due to increased risk, disasters, or indirect impacts through physical health, household dynamics, or community well-being. And changes in climate and environmental conditions will interact with local air pollution and allergen distribution, exacerbating respiratory diseases. One estimate is that climate change could cause annually an additional 100,000 premature deaths associated with exposure to small particulate matter and 6,300 premature deaths associated with ozone exposure (Fang et al. 2013).

Another concern is that high temperatures will reduce labor productivity of those who are poorer and often work outside or without air conditioning (figure O.7). The impact on labor productivity could be large and reduce income by several percentage points. Moreover, this effect is not accounted for in any of the studies we reviewed on estimates of agricultural production, although it could magnify food security issues. In addition, new research suggests that extreme temperature stress in either direction—hot or cold—is suboptimal for economic activity, even when considering only nonfarm activities. These results imply that the temperature-related loss in performance observed in

FIGURE O.7 If it gets too hot, productivity falls
(Task performance under different temperatures)



Source: Based on Seppänen, Fisk, and Lei 2006.

laboratories and at the individual level may be observable at the macroeconomic level, and that climate change could hurt overall income through this channel (Deryugina and Hsiang 2014; Heal and Park 2013; Park et al., forthcoming).

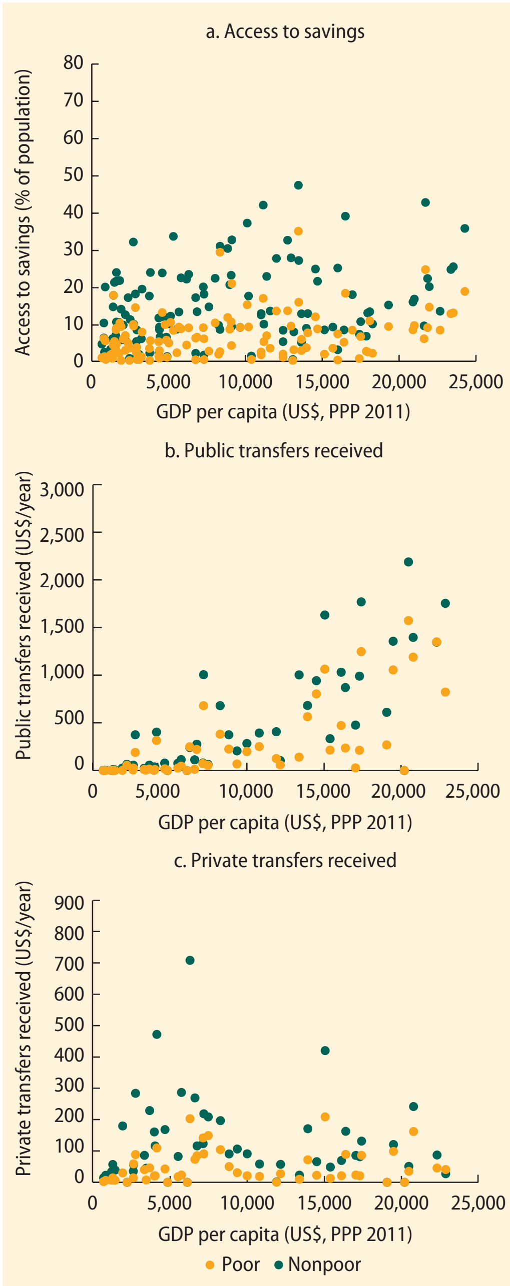
Poor people receive less support from friends and family and have more limited access to financial tools and social safety nets

Many policy instruments exist that could help poor people prevent, adapt to, and cope with climate shocks and changes (World Bank 2013), but poor people have only limited access to them (figure O.8). Take the case of financial inclusion—meaning access to formal savings, borrowing, and insurance products (figure O.8, panel a). People may lack access to these formal financial tools for several reasons, including the cost of bank accounts, distance and time to access a financial agent, lack of documentation, or mistrust in banks. Some people also prefer to stay in the informal sector, or are not aware of the benefits of using financial tools for risk management (Allen et al. 2012).

Poor people also receive limited support from social safety nets, ranging from cash transfers to work programs (figure O.8, panel b). In many countries, social programs cover less than half of the poorest quintile. In addition, even when poor households are covered by social protection schemes, amounts received are often too small to make a big difference and prevent negative coping strategies. In Bangladesh after the 1998 floods, poor affected households had to borrow an amount equal to six to eight times the level of government transfers (del Ninno, Dorosh, and Smith 2003).

Then, too, migration and remittances play a key role in managing shocks—but migration requires resources and assets that the poorest lack, and data show that remittances tend to benefit nonpoor people more than poor people (figure O.8, panel c). As a result, poor people are disproportionally affected by

FIGURE O.8 Poor people have less access to financial tools, social protection, and private transfers



Source: World Bank computation based on the FINDEX and ASPIRE databases.
Note: Panel a is based on data from FINDEX. Panels b and c are based on data from ASPIRE. Each country is represented with two dots. Poor people are those in the bottom 20% (ASPIRE) or bottom 40% (FINDEX). Nonpoor people are those in the top 80% (ASPIRE) or top 60% (FINDEX). PPP = purchasing power parity.

climate change and natural shocks, not only because they are more exposed and vulnerable to them but also because they receive less support.

By 2030, rapid, inclusive, and climate-informed development can prevent most (but not all) climate change impacts on poverty

Just how large might these impacts be on poverty by 2030 and how much can development help? We know that between now and then, climate policies will have minimal impacts on warming, given the long lag between the introduction of mitigation policies, their impact on emissions, and the effect of emissions reductions on the climate system (IPCC 2014). This means that, by 2030, the only way to reduce climate change impacts will be by lowering socioeconomic vulnerability to these impacts—which will require climate-informed development and specific actions to adapt to climate change.

The magnitude of future climate change impacts on poverty depends on today's choices

In this report, we try to get a sense of the magnitude of future climate change impacts—and how this magnitude depends on today's choices—by creating two scenarios for what the future of poverty could be by 2030 in the absence of climate change (figure O.9). The first one, "*Prosperity,*" assumes that the World Bank's goals of extreme poverty eradication and shared prosperity are met by 2030 (in particular, less than 3 percent of the world population remains in extreme poverty), and that access to basic services is quasi-universal. The second scenario, "*Poverty,*" is much more pessimistic in terms of poverty reduction and inequalities (for instance, 11 percent of the world population remains in extreme poverty).

We then introduce into each of these scenarios estimates of climate change impacts on food price and production, natural disasters, and health and labor productivity, based on the reviews and analyses presented in the report. But we do so with two climate change impact scenarios—a *low-impact* and a *high-impact* scenario—given that the physical and biological impacts will be highly uncertain, dependent on (i) how ecosystems adapt and physical systems (like glaciers and coastal zones) respond and (ii) how sectors spontaneously adapt (like adopting new agricultural practices or improved hygiene habits).

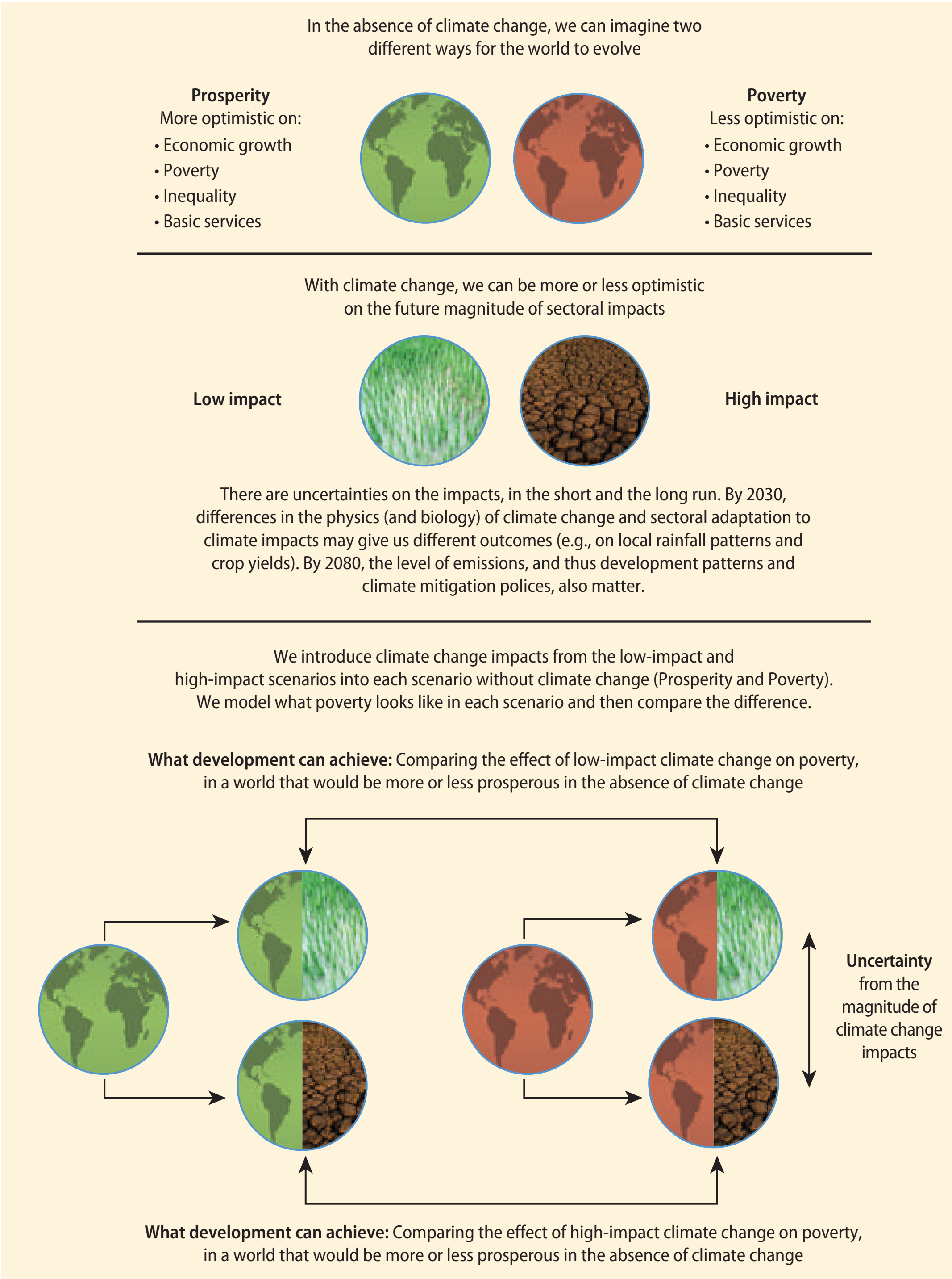
We do not attribute probabilities or likelihoods to the development and climate impact scenarios because we are not interested in forecasting the future of poverty (it is probably impossible). What interests us is the contrast across scenarios rather than the absolute numbers. That is why we focus on how the impacts of climate change on poverty would differ if development is rapid and inclusive ("*Prosperity*") as opposed to slow and noninclusive ("*Poverty*").

The bottom line is that, even though our analysis looks only at the short term with limited changes in climate conditions, it still finds that climate change could have a large effect on extreme poverty: by 2030, between 3 and 16 million people in the *prosperity* scenario and between 35 and 122 million people in the *poverty* scenario would be in poverty because of climate change.

That said, these estimates are likely an underestimate for several reasons. First, we follow a bottom-up approach and sum the sector-level impacts, assuming they do not interact. Second, we consider only a subset of impacts, even within the three sectors we focus on. For instance, we do not include losses in ecosystem services and reduced nutritional quality of food; we consider only consumption poverty, disregarding outcomes like the nonmonetary effects of disease; and we do not include secondary impacts of disasters (like the potential effect on migrants and refugees). Third, we cannot assess the poverty impact everywhere. Our scenarios are developed based on a household

FIGURE O.9 Our model for estimating the number of people in poverty due to climate change

(A schematic to represent the modeling undertaken to estimate the impact of climate change on extreme poverty in 2030 under different scenarios of future development, and thus in worlds with different levels of exposure and vulnerability)



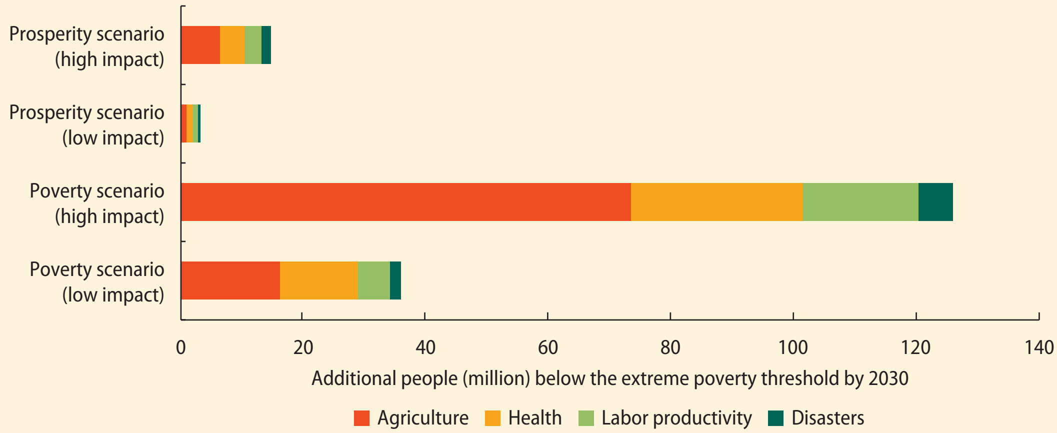
Note: Photos © Masaru Goto / World Bank (low impact image) and Arne Hoel / World Bank (high impact image). Further permission required for reuse.

BOX O.1 Agriculture is the key driver for climate change's impact on poverty

Which poverty channel is the dominant influence in our four scenarios? As figure BO.1.1 shows, agriculture is the main driver of the impact on poverty (in all four scenarios)—although its impact is possibly an underestimation because all climate scenarios assume CO_2 fertilization. Then, health impacts (diarrhea, malaria, and stunting) and the labor productivity effects of high temperature have a second-order but significant role. Disasters have a relatively limited role, but this may be because only the direct impact on income losses was taken into account.

FIGURE BO.1.1 Agriculture is the main sectoral driver explaining higher poverty due to climate change

(Summary of climate change impacts on the number of people living below the extreme poverty threshold, by driver)



Source: Rozenberg and Hallegatte, forthcoming.

database that represents only 83 percent of the developing world's population. Some high vulnerability countries (such as small islands) could not be included because of data limitations, in spite of the large effects that climate change could have on their poverty rate.

Although climate change has a significant impact on poverty up to 2030—working primarily through the agricultural channel (box O.1)—it remains a secondary driver, as evidenced by the nearly 800 million person difference between the two socioeconomic scenarios in the absence of climate change (table O.1). This does not mean that climate change impacts are secondary at the local scale: in some particularly vulnerable places (like small islands or in locations affected by large disasters), the local impact could be massive.

Note that the large range of estimates in our results may incorrectly suggest that we cannot say anything about the future impact of climate change on poverty. The main reason for this wide range is not scientific uncertainty on climate change and its impacts. Instead, policy choices dominate—particularly those concerning development patterns and poverty-reduction policies between now and 2030. While emissions-reduction policies cannot do much regarding the climate change that will happen between now and 2030 (because that is mostly the result of past emissions), development

TABLE O.1 Climate change threatens to worsen poverty, but good development can help

Policy choices	Climate change scenario: No climate change — Number of people in extreme poverty by 2030	Low-impact scenario — Additional number of people in extreme poverty due to climate change by 2030		High-impact scenario — Additional number of people in extreme poverty due to climate change by 2030	
Prosperity scenario	142 million	+3 million		+16 million	
		Minimum +3 million	Maximum +6 million	Minimum +16 million	Maximum +25 million
Poverty scenario	900 million	+35 million		+122 million	
		Minimum –25 million	Maximum +97 million	Minimum +33 million	Maximum +165 million

Source: Rozenberg and Hallegatte, forthcoming.
Note: The main results use the two representative scenarios for prosperity and poverty. The ranges are based on 60 alternative poverty scenarios and 60 alternative prosperity scenarios.

choices can affect what the impact of that climate change will be.

Also note that the range of possible impacts is even larger than the one represented by our four scenarios because there is an infinite number of possible socioeconomic pathways by 2030, even without climate change. To assess the robustness of our results, we create 60 alternative *prosperity* and 60 alternative *poverty* scenarios. We find that the range of possible impacts on poverty remains limited in the *prosperity* scenario: development not only reduces the impacts but also protects us from the uncertainty. In the *poverty* scenario, on the other hand, the range of possible outcomes is extremely large: the worst-case estimate increases up to 165 million, and some scenarios show a *decrease* in global poverty numbers—these are scenarios where climate change impacts remain moderate (low-impact) and where farmers benefit the most from higher agricultural prices.

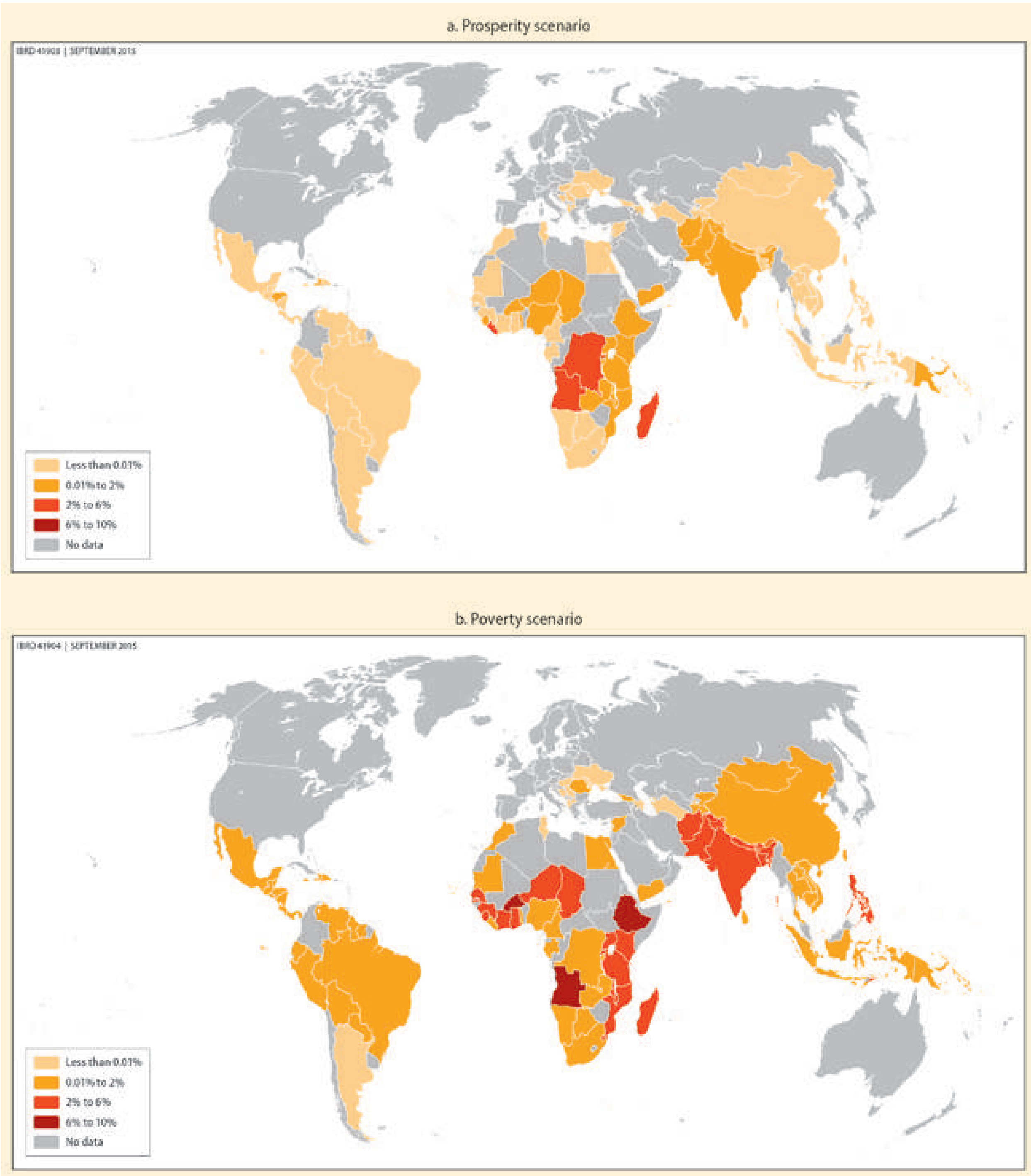
The lower vulnerability of the developing world to climate change in the *prosperity* scenario comes from several channels. First, people are wealthier and fewer households live with a daily income close to the poverty line. Wealthier individuals are less exposed to health shocks such as stunting and diarrhea, and are less likely to fall back into poverty when hit by a shock. And with fewer farmers, the population is less vulnerable to the negative impacts of climate change on yields. Second, the global population is smaller in the *prosperity* scenario in 2030, by 2 percent globally and by up to 20 percent in some African countries due to more migration. A smaller population mitigates the impact of climate change on food prices. In addition, the *prosperity* scenario assumes more technology transfers to developing countries, which further reduces the agricultural loss due to climate change. In the *prosperity* scenario, a more balanced economy and better governance also mean that farmers capture a larger share of the income benefits from higher food prices.

At the country and regional level, the hotspots are Sub-Saharan Africa and—to a lesser extent—India and the rest of South Asia (map O.2). Almost all countries are less vulnerable to climate change in the *prosperity* scenario, often dramatically: in India, the high-impact climate change scenario brings 2 million people into poverty in the *prosperity* scenario, compared to almost 50 million in the *poverty* scenario. One exception is the Democratic Republic of Congo, where climate change is found to bring more people into poverty in the *prosperity* scenario. This occurs because, in the *poverty* scenario without climate change, the poverty rate is extremely high (70 percent): climate change draws fewer people into poverty than in the *prosperity* scenario only because so many people are already in poverty.

Such a result warns us against using a poverty headcount as the unique indicator of the

MAP O.2 Climate change impacts on poverty vary greatly across scenarios, with Africa and South Asia the most vulnerable

(Increase in number of extreme poor people due to climate change in the high-impact climate scenario (% of total population))



Source: World Bank (IBRD 41903 and IBRD 41904, September 2015) based on Rozenberg and Hallegatte, forthcoming.

impact of climate change on poverty. Because it does not measure poverty depth, it does not capture the impact on people who are already poor. For instance, in a high-impact climate scenario, climate change reduces the income of the bottom 40 percent in 2030 by more than 4 percent in most of the countries in both the *prosperity* and *poverty* scenarios. And, in most Sub-Saharan African countries and Pakistan, climate change reduces the income of the bottom 40 percent by more than 8 percent.

Climate-informed development needs to be complemented with targeted adaptation interventions and a more robust safety net system

Rapid and inclusive development can prevent most of the impact of climate change on poverty, but only if new investments and developments are *climate informed*—that is, designed to perform well under changing climate conditions so that they do not create new vulnerabilities to climate impacts. For example, new water and sanitation infrastructure can make a big difference for diarrhea, but only if it can absorb the more extreme rainfall episodes that are expected in many regions. Similarly, new settlements in safe areas will reduce the long-term vulnerability only if the selected areas remain safe in spite of sea level rise and accelerated erosion.

However, even a rapid, inclusive, and climate-informed development will not cancel out the need for targeted actions that are aimed at lowering people's vulnerability to climate change impacts. Although some of them are pure climate change adaptation measures (like adapting building norms to new environmental conditions), others (like increasing financial inclusion) can be seen as "good development" and would make sense even in the absence of climate change.

Our report highlights potential options in the three sectors that we focus on (agriculture and ecosystems, natural disasters, and health) and emphasizes the potential of social protection and financial tools to boost the resilience of households and economies to all sorts of shocks, including those magnified by climate change (table O.2). Of course, each country can identify its own priorities, based on the impacts of climate change that are expected on its territory, but also on synergies and convergence with other policy priorities. For instance, where urban planning is a policy priority, mainstreaming natural hazards and climate change into its design is a low-hanging fruit waiting to be plucked.

Climate-smart agriculture and protected ecosystems. Climate-smart agricultural practices can increase productivity and resilience (Cervigni and Morris 2015). More productive and more resilient practices, however, require a major shift in the way land, water, soil nutrients, and genetic resources are managed to ensure that these resources are used more efficiently (FAO 2013). Crop improvement, smarter use of inputs, approaches to strengthen crop resistance to pests and diseases, and reduction of post-harvest losses can contribute to the sustainable intensification of agriculture—thereby leading to greater food production (Beddington 2010; Tilman et al. 2011).

For this to happen, innovation is needed to keep increasing yields, and the new techniques that result from innovation must actually be broadly adopted, including by poor farmers. These two conditions are challenging. First, yield increases have plateaued in recent years, even exhibiting abrupt decreases in some regions (Grassini, Eskridge, and Cassman 2013). The low and declining levels of investment in agricultural research and development in the developing world are a major constraint to realize further yield gains in poor countries (Pardey, Alston, and Chan-Kang 2013). Second, disseminating improved technologies and making them accessible to poor farmers is difficult, and even promising innovations sometimes have low or no uptake. High implementation costs, cultural barriers, and lack of access to information and education need to be overcome. Agricultural extension services can help farmers make better use of new technologies. In Uganda, extension visits increased household agricultural income by around 16 percent when new crop

TABLE O.2 Many targeted actions can lower poor people's vulnerability to climate change impacts

Sectoral options to reduce vulnerability	Private sector	Governments	International community
Agriculture, ecosystems, and food security			
Adopt climate-smart technologies and agricultural practices, with support from agricultural extension	X	X	
Develop higher yielding and more climate-resistant crop varieties and livestock breeds, adapted to developing country contexts and climate conditions	X	X	X
Develop transport infrastructure and facilitate market access (domestic and international)		X	X
Reduce non-climate stresses on ecosystems, including through conservation and ecosystem-based adaptation		X	X
Natural disasters and risk management			
Increase financial inclusion and participation in banking to reduce the vulnerability of poor households' assets	X	X	
Improve households' and firms' preparedness and ability to act upon warnings (contingency plans, regular drills)	X	X	
Improve access to risk information, invest in hydro-meteorological services—for observation and forecasting—and link with early warning and evacuation systems, and collect more data on disaster consequences		X	X
Enact risk-sensitive and enforceable land use regulation and building norms		X	
Improve tenure to incentivize investments in housing quality and resilience, and enforceability of building norms		X	
Invest more and better in infrastructure by leveraging private resources and using designs that account for future climate change and the related uncertainty	X	X	X
Health			
Increase R&D and eradication/control efforts toward health issues that affect poor people and are expected to increase with climate change	X	X	X
Invest in health infrastructure and access; train health workers		X	
Implement or strengthen effective surveillance and monitoring systems to detect emerging health risks		X	X
Increase health coverage to lower the share of expenses that are out of pocket		X	
Support systems: financial sector, social protection, remittances, and governance			
Develop market insurance for the middle class to concentrate public resources on poor people	X	X	
Enact well-targeted and easily scalable social safety nets designed to maintain incentives for long-term adaptation investments and grant portable benefits		X	
Manage the government's formal liability using reserve funds, contingent finance (such as Cat-DDOs), and insurance products, along with developing and scaling-up tools to share risks internationally		X	X
Facilitate flow of remittances and reduce cost burden on remitters	X	X	
Improve governance and give a role to poor people in the decision-making process		X	

Note: Cat-DDO = Catastrophe Deferred Drawdown Option; R&D = research and development.

varieties were available (Hill and Mejia-Mantilla 2015).

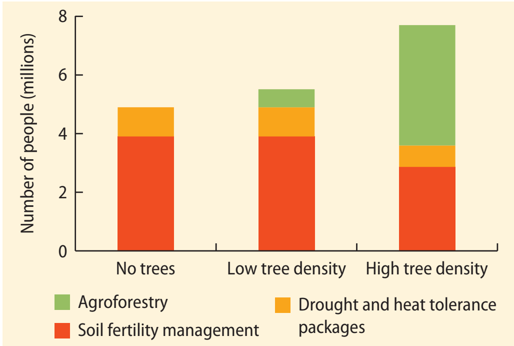
Poor people can become more resilient to shocks in agriculture thanks to trade and food reserves that can overcome local shortages in times of need, better access of poor farmers to markets, and improved technologies and climate-smart production techniques. Access to functioning markets, however, depends on better infrastructure and better institutions. In Ethiopia, the incidence of poverty decreased by 6.7 percent following farmers' access to all-weather roads (Dercon et al. 2009). In Burkina Faso, maize price volatility is found to be greatest in remote markets (Ndiaye, Maitre d'Hôtel, and Le Cotty 2015). Investments in transport infrastructure improve market integration, reduce price uncertainty for farmers, and improve food security.

For ecosystem-based income, the main option is to reduce the nonclimate stresses on ecosystems to make them better able to cope with changes in environmental conditions. Conservation and ecosystem-based strategies are critical for making ecosystems more resilient and for protecting the resources on which many poor people in rural areas depend. Healthy ecosystems are generally quite resilient, so protecting them and restoring degraded lands can increase their ability to withstand climate-related disturbances. Integrating trees in agricultural systems can also reduce vulnerability to drought and increase the store of carbon (figure O.10).

Land use regulations and better and more infrastructure for natural hazards. Land use regulations can ensure that new development occurs in places that are safe, or easy and cheap to protect using hard or soft infrastructure. But effective implementation of such regulations remains challenging. First, it requires appropriate data on risk and hazard, which remains limited in low-income environments despite recent progress (including the Global Facility for Disaster Reduction and Recovery's [GFDRR] Open Data for Resilience Initiative that makes risk data available for governments and the public).

FIGURE O.10 Drought vulnerability is reduced by agricultural techniques that integrate trees and store carbon

(Reduction in average annual number of drought-affected people)



Source: Cervigni and Morris 2015.

Second, strong institutions are needed to ensure that land use plans are actually enforced, and even the highest-capacity countries struggle to reduce flood exposure. Third, one needs to take into account the reasons why people decide to live in risky places, namely a trade-off between safety and access to jobs and services (Hallegatte 2012a). In a new survey, poor households in Mumbai say they would relocate to a safer place but only if they had access to cheap transport, health services, schools, and social networks (Patankar, forthcoming). Thus, land use planning can realistically function only if accompanied by investments in transport and other infrastructure to make it possible for people to settle in safe places while maintaining access to the same (or comparable) jobs and services.

Poor people lack the type of protective infrastructure that is common in richer countries. For instance, poor households are often exposed to recurrent floods due to the lack, or poor maintenance, of infrastructure (especially drainage systems)—even if these events do not attract media and policy maker attention, they can represent a large burden on poor people. Solving these problems requires investing *more* and investing *better*. Around $1 trillion per year would be needed in developing countries to close the infrastructure gap, with about $100 billion for Africa alone. Closing this gap is difficult, but it would go a long way toward reducing the vulnerability of poor people. Recommendations typically include leveraging private resources to make the most of available capital, which involves well-known steps like improving the investment climate, developing local capital markets, and providing a pipeline of "bankable" projects (Fay et al. 2015).

But infrastructure investments will reduce the long-term vulnerability of the population and contribute to long-term poverty reduction only if they serve poor people. In particular, investing where it is most cost-efficient would risk concentrating resources on wealthier populations at the expense of poor communities (Tschakert, forthcoming). New infrastructure also needs to be designed to remain efficient in spite of changes in climate and environmental conditions. Innovative methods for managing the uncertain risks of climate change and multiple (and sometimes conflicting) policy objectives can be applied to meet these challenges (Kalra et al. 2014). Several World Bank pilot projects using these methods have been completed or are under way, including on water supply in Lima, flood risk management in Ho Chi Minh City and Colombo, hydropower investment in Nepal, and adaptation of road networks in Peru and across Africa.

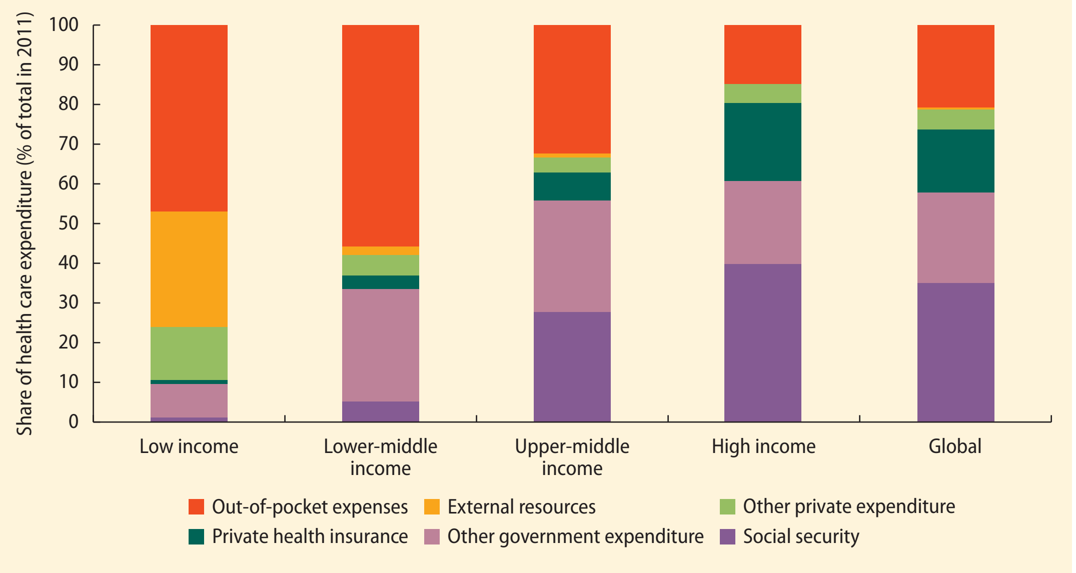
As discussed earlier, poor people lose a larger fraction of their assets and income because their dwelling is often their main asset and because they live in buildings with low resistance to natural hazards. In addition to financial inclusion—which could help people save in less vulnerable ways—improving tenure security could incentivize investment in housing, including in risk reduction, to make them more resistant. In Peru, the issuance of property titles to over 1.2 million urban dwellers encouraged households to invest more in their homes, thereby reducing their vulnerability (Field 2007).

Early warning systems—combined with observation systems and evacuation preparedness—can save many lives at a low cost. When Cyclone Phailin made landfall near Gopalpur, India, in 2013, it killed fewer than 100 people. While still a significant loss, it is much smaller than the 10,000 deaths that a similar storm caused in 1999. More generally, early warning systems are very cost-effective investments, with each dollar invested yielding more than $4 in avoided losses (Hallegatte 2012b). However, over the past 15–20 years, the situation of many hydrometeorological services in developing countries has worsened (Rogers and Tsirkunov 2013). As a result, the ability to monitor local climate change and increases in natural risks has eroded, making developing countries less able to detect, anticipate, and adapt to climate change.

Better health infrastructure and universal health care. Poor people in low- and lower-middle-income countries have limited access to health care, and face out-of-pocket expenditure exceeding 50 percent of health expenses—much higher than the less than 15 percent that is common in rich countries (figure O.11). But examples show that better health coverage is possible everywhere. In Colombia, thanks to a multilevel government scheme and cross-subsidization from contributory schemes, the poor are covered against primary care and catastrophic event costs—with coverage of the poorest quintile up to 47 percent in 1997 from only 3–8 percent in 1993. In Rwanda, the government invested in universal health coverage after the 1994 genocide, and today nearly 80 percent of its population is insured.

However, benefits from better access to care depend on the quality of care, and in most countries parallel efforts are required to develop and improve health infrastructure. Climate change makes this need even more important. Countries should have strong monitoring and surveillance systems able to detect new health issues that will periodically arise in response to changing climate conditions. They also need research and development on the diseases that affect poor people and that are expected to increase with climate change.

FIGURE O.11 In poorer countries, half of all health expenditures are paid out of pocket, unlike in richer ones



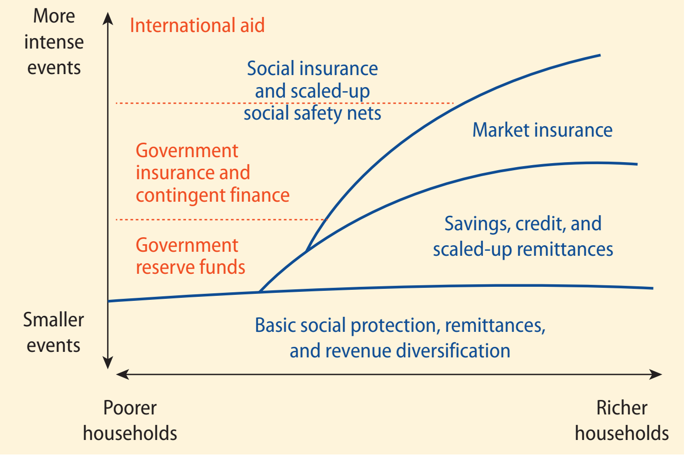
Source: Watts et al. 2015.

Social safety nets and financial tools. A growing body of evidence shows that insurance and social safety nets are efficient tools to support poor people when they are affected by natural disasters or environmental and economic shocks. In Mexico, beneficiaries of *Prospera*, the national cash transfer program (previously known as *Oportunitades* or *Progresa*), are less likely to respond to shocks by withdrawing their children from the classroom (de Janvry et al. 2006; Fiszbein, Schady, and Ferreira 2009; Gertler 2004).

To ensure that the financial sector and social safety nets provide instruments relevant to climate change, governments need to design a holistic risk management and climate change strategy, giving a voice to poor people and making their protection a priority. Such a strategy will necessarily include a range of instruments, targeted to specific disasters or social groups (figure O.12).

Basic social protection and revenue diversification can help households at all income levels cope with small and frequent shocks. But for larger shocks, additional tools are needed. For relatively wealthier households, savings and market insurance can offer efficient protection for larger losses. But the poorest households have minimal savings, and high transaction costs make it difficult to offer them private insurance. Instead, the government needs to provide social safety

FIGURE O.12 Poorer households need different types of solutions



nets that are well targeted and can be scaled up rapidly after a shock.

A key challenge is to strike a balance between providing rapid support when needed and precisely targeting those most in need. Case studies in Ethiopia and Malawi suggest that the cost of a drought to households can increase from zero to about $50 per household if support is delayed by four months, and to about $1,300 if support is delayed by six to nine months (Clarke and Hill 2013). This rapid increase, which is due to irreversible impacts on children and distress sales of assets (especially livestock), helps explain why most postdisaster responses have multiple stages. Typically, initial support is delivered quickly—even at the expense of targeting and accuracy—and larger recovery and reconstruction efforts are provided later with more emphasis on appropriate targeting.

Experience shows that countries at all income levels can implement social safety nets to protect their population, even though the appropriate instruments depend on local capacity. Preexisting social protection programs with large and flexible social registries help provide prompt support to affected people so that they do not have to resort to costly coping strategies. For instance, by using the preexisting conditional cash transfer system (the *4Ps*), the government of the Philippines was able to quickly release a total of P550.5 million (US$12.5 million) between November 2013 and February 2014 in emergency unconditional cash transfers to 4Ps beneficiaries affected by Typhoon Yolanda (Bowen, forthcoming). When droughts in Ethiopia caused food shortages and famine in 2011, the *Productive Safety Net Program* expanded its coverage from 6.5 million to 9.6 million people in two months and increased the duration of benefits from six to nine months per year (Johnson and Bowen, forthcoming). These safety nets remain affordable and reduce the need for costly humanitarian interventions.

However, adaptive social protection systems create an additional liability for governments, who may then need to turn to specific instruments such as reserve funds, regional mechanisms, contingent finance or reinsurance products (like the World Bank's Catastrophe Deferred Drawdown Option, or Cat-DDOs), or even international aid if local capacities are exhausted (Ghesquiere and Mahul 2010). In response to Cyclone Pam in March 2015, the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), a regional mechanism, provided Vanuatu with a rapid $1.9 million payment that supported the immediate response.

Social protection schemes also need to maintain incentives to invest in long-term adaptation to economic and environmental changes. Poorly designed social safety nets can reduce the incentive for people to quickly adapt and change occupation or activity when the first effects of climate change appear (Chambwera et al. 2014). This problem is not new and specific to climate change: efforts are already under way to ensure that social protection is a facilitator of—and not an obstacle to—long-term change and adaptation, for instance by facilitating migration (Brown, Zelenska, and Mobarak 2013; Bryan, Chowdhury, and Mobarak 2014) or making benefits more portable if the recipient decides to move to capture better opportunities (World Bank 2015b).

Combining rapid, inclusive, and climate-informed development with targeted interventions and stronger safety nets would largely reduce the *short-term* threat from climate change—and, fortunately, developing countries have a window of opportunity to go in that direction before most of the climate change impacts materialize. In parallel, the international community can do much to support them. This includes offering resources for climate risk analysis and project preparation, and ensuring that financial instruments and resources are available for development and poverty reduction investments—especially when higher resilience implies higher upfront costs. The international community can also build resilience by strengthening international risk-sharing mechanisms and generalizing access to contingent finance in emergency situations.

Emissions-reduction policies are required to remove the long-term threat from climate change, and need not threaten progress on poverty reduction

In the absence of mitigation policies, risks for development and poverty eradication will grow over time and only emissions reduction can limit long-term risks (IPCC 2014). While this report proposes options to reduce climate risks, it also points to the limits of these options: land use planning faces difficult political economy obstacles, financial constraints make it tough to invest in protection infrastructure, and the provision of health care in rural areas remains challenging. And, although social safety nets and health insurance help households cope with shocks, they do not reduce the direct and immediate impact on well-being and assets and will become increasingly costly—even unaffordable—if shocks become more frequent and intense (Carter and Janzen, forthcoming). There are clear limits to what adaptation can achieve, and these limits will be tested by climate change.

Moreover, some long-term risks could prove catastrophic—such as those related to the response of ice sheets and ecosystems—and remain impossible to quantify in terms of consequences or probability. Uncertainty is not a reason to delay climate change mitigation action. On the contrary, the need for climate stabilization arises from both a risk-management approach that accounts for threats created by long-term impacts and the fact that GHG emissions lock us into irreversible warming. Indeed, these long-term risks largely explain why the international community has committed to the goal of stabilizing climate change.

Maintaining global warming below 2°C, or even below 3°C, will require bringing emissions down to zero by 2100, a goal recognized by the leaders of the major industrial countries at the 2015 summit of the G7. And there is a consensus that current development trends are incompatible with these internationally agreed climate targets (IPCC 2014). Thus, policies are needed now to make development and climate change stabilization compatible: modern living standards will need to be supported in a more efficient and radically less carbon-intensive way, and residual emissions offset through natural carbon sinks like forests (Fay et al. 2015).

The first step is for all countries to enact comprehensive packages of emissions-reduction policies (IPCC 2014)—ranging from carbon pricing and innovation support to environmental performance standards, information labels, financing facilities, and land use and urban planning (Fay et al. 2015; NCE 2014; OECD 2015). Priority should go to implementing the policies and measures that are urgently needed to prevent irreversibility and lock-ins into carbon-intensive patterns (such as those regarding deforestation, energy infrastructure, or urban transport).

These policy packages must be designed in a way that does not threaten the objective of eradicating poverty by 2030. This can be done in three complementary ways: (i) building on no-regret options and cobenefits; (ii) protecting the poor and vulnerable populations against potential adverse consequences of emissions-reduction options; and (iii) in the poorest countries, using support from the international community to offset possible trade-offs between poverty reduction and climate change mitigation.

All countries should embrace the mitigation policies that generate short-term cobenefits that exceed costs—like lower air pollution and higher energy efficiency. Recent studies have found that, in all regions, the benefits for health and agricultural yields from less pollution alone could exceed the cost of mitigation, at least until 2030 (Shindell et al. 2012). For example, a pathway leading to lowering CO_2 concentrations would avoid 0.5 million premature deaths annually in 2030, 1.3 million in 2050, and 2.2 million in 2100, compared to a scenario with only the progress that can be expected from the historically observed uptake of pollution-control technologies.

Many other cobenefits are likely to occur in various sectors (World Bank 2014b).

Better public transit would reduce congestion and traffic accidents, and greater energy efficiency would bode well for productivity. Yet many countries, facing strong financing constraints, tend to favor technologies with lower upfront capital costs, at the expense of higher operation costs—in effect, favoring less energy-efficient technology and reducing overall productivity (World Bank 2012).

Governments need to enact policies to actively promote the adoption of no-regret options that reduce GHG emissions and accelerate development. A recent World Bank report reviews market and government failures that hamper the adoption of these no-regret options—such as incorrect pricing, split incentives, poor enforcement of existing regulations, lack of information, behavioral failures, and limits to the financing capacity of stakeholders—and offers solutions to overcome them (Fay et al. 2015). The international community can help developing countries by providing a combination of technical assistance and better access to green technologies (for instance to help them implement performance standards for vehicles, lighting, and appliances). It can also help them mobilize private capital to relax existing investment constraints and favor technologies with higher upfront costs but better efficiency, drawing on innovative financial instruments or the resources from bilateral and multilateral development banks.

In addition, all countries need to avoid negative impacts of mitigation policies on food security, since the resulting effects on global food prices could have a detrimental impact on the poor. Promisingly, many land-based mitigation options also provide an opportunity to strengthen the productivity of agriculture and ecosystems and to boost local incomes. They can be implemented through payments for ecosystem services, which can provide a source of income for the poor. An estimated 25–50 million low-income households could be benefitting from them by 2030 (Milder, Scherr, and Bracer 2010).

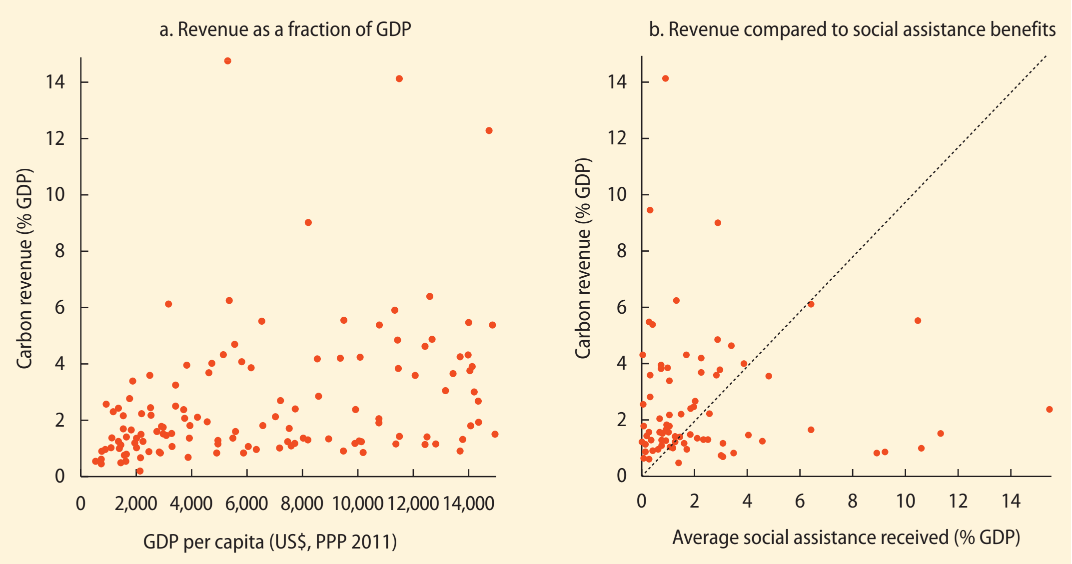
But to stay on a pathway compatible with the complete decarbonization of the economy before 2100, countries will have to do more than implement win-win options, sometimes creating net costs and trade-offs. Fortunately, governments can protect the poorest, using specific instruments or their existing social protection systems, possibly strengthened by the resources raised by climate policies. For instance, climate policies need to ensure that they do not slow down the switch from traditional biomass to modern cooking fuels, for example by subsidizing efficient cookstoves. This matters greatly because traditional cooking fuels not only are unhealthy but also worsen gender imbalances and affect educational opportunities, given the time women and children often spend collecting wood and other traditional fuels (WHO 2006).

There are many options to make climate policies pro-poor—such as introducing a carbon or energy tax and recycling the revenues through a universal cash transfer that would benefit the poor. An analysis of 20 developing countries shows that for each \$100 of additional energy tax collected and redistributed, the bottom quintile gains \$13 while the richest quintile loses \$23, and overall the bottom 60 percent would benefit from the measure (del Granado, Coady, and Gillingham 2012; Fay et al. 2015).

Similarly, we can estimate how the resources that could be raised by a carbon tax in one country (or an equivalent reform of energy subsidies) compare with current social assistance transfers. Based on current CO_2 emissions and without any international transfer, a \$30/tCO_2 (tons of CO_2) domestic carbon tax would raise resources amounting to more than 1.5 percent of national GDP in half of the 87 countries where data are available (figure O.13, panel a). And in 60 out of the 87 countries, a \$30/tCO_2 domestic carbon tax would provide the resources to more than double current levels of social assistance in the country (figure O.13, panel b). Even a low carbon tax at \$10/tCO_2 would make it possible to significantly scale up social assistance or other investments that benefit poor people (like connections to sanitation and improved drinking water or access to modern energy).

More generally, the impacts of climate mitigation policies on inequality can be corrected

FIGURE O.13 Using the revenue from a carbon tax could boost social assistance



Source: World Bank calculations using data from WDI and ASPIRE (World Bank 2015c, 2015d).
Note: Panel a: Revenue of a \$30/tCO_2 carbon price expressed as a fraction of GDP. Each dot represents a country. Panel b: How this revenue compares to current social assistance benefits in each country. In 60 out of 87 countries for which data are available, a \$30/tCO_2 tax would provide the resources to more than double current social assistance transfers (dots above the diagonal line for panel b). Calculations assume unchanged energy consumption. PPP = purchasing power parity; tCO_2 = tons of carbon dioxide.

using policies specifically designed to redistribute income in the economy—such as using income or consumption taxes to fund cash transfers or social safety net programs (Borenstein and Davis 2015; Gahvari and Mattos 2007; Lindert, Skoufias, and Shapiro 2006). A World Bank study based on household surveys reveals that countries with GDP per capita above \$4,000 (in purchasing power parity) have sufficient internal resources to redistribute poverty away, and thus can protect poor people against the possible negative effects of climate mitigation (Ravallion 2010). This is important because around 70 percent of people in extreme poverty live in these countries that are able to protect them.

But in very poor countries, it may be difficult for economic, political, or institutional reasons to accomplish this. In particular, the same World Bank study shows that countries with a GDP per capita below \$4,000 (in purchasing power parity) would find it nearly impossible to rely on internal resources for redistribution. In these countries, even if most of the cost of climate mitigation is paid for by the wealthier quintiles of the population, climate mitigation could still worsen poverty, because the top quintiles are still in, or close to, poverty. In these cases, international support will be essential to offset potential trade-offs between poverty reduction and climate change mitigation.

This is especially the case for investments that involve high immediate costs—and therefore large trade-offs with other investments—but are urgently needed to prevent irreversibility and lock-ins into carbon-intensive patterns. The typical example is urban transit. While transit-oriented development may require higher upfront costs than road-based low-density urbanization, there is now a unique window of opportunity to build efficient transit-oriented cities, because of high urbanization rates in many developing countries and the extended lifetime of urban forms and transit infrastructure.

In conclusion

Bringing together the short-run (up to 2030) and long-run views, this report emphasizes how climate change could set back poverty eradication efforts—including the risk that unabated climate change creates for the internationally agreed objective of eradicating extreme poverty. In parallel, it demonstrates that the future is not set in stone. We have a window of opportunity to achieve our poverty objectives in spite of climate change by pursuing both (i) rapid, inclusive, and climate-informed development, combined with targeted adaptation interventions, to cope with the short-term impacts of climate change and (ii) immediate pro-poor mitigation policies to limit long-term impacts and create an environment that allows for global prosperity and the sustainable eradication of poverty.

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From Climate Change to Poverty and Back: A Framework

1

Main Messages

- Climate-sensitive events are already a critical obstacle for people trying to escape poverty and those who are vulnerable to falling back into poverty.
- There are three major channels through which climate-sensitive events already affect the ability of poor people to escape poverty: (i) agricultural production, ecosystems, and food security; (ii) natural disasters; and (iii) health. All are likely to be significantly affected by climate change.
- The net impact of climate change on poverty and well-being will be mediated by socioeconomic trends (like demography, growth, and inequality) and non-climate change policies (like skills development and redistribution).
- Over the medium to long term, the impact of climate change on poverty will also depend on greenhouse gas emissions and thus on emissions-reduction policies.

Introduction

Despite substantial progress in reducing poverty rates, around 700 million people still live in extreme poverty (World Bank 2015a).[1] In addition, hundreds of millions hover close above the poverty line, vulnerable to shocks that could send them into poverty, or suffer from other dimensions of poverty—such as exclusion, powerlessness, and poor health—even if their consumption is above the poverty threshold (Bourguignon and Chakravarty 2003; Ferreira and Lugo 2013).

At the same time, the post-2015 Sustainable Development Agenda—which builds on the 2015 Millennium Development Goals—has reaffirmed the goal of ending extreme poverty or, as framed by the World Bank, bringing the number of people living on less than $1.90 per day to under 3 percent by 2030. Moreover, the agreed goal is not simply to eliminate poverty by 2030, but to eliminate it for good and ensure gains are not reversed after 2030.

How does climate change fit into this picture? We know that climate change affects the population, including the poorest, through changes in environmental conditions and the frequency and intensity of extreme weather events (O'Brien and Leichenko 2000; Olsson et al. 2014). While the magnitude of climate change is likely to be relatively limited between now and 2030, compared with what can be expected over the long term, its impacts may still be important in certain locations (like semi-arid areas where precipitation will decrease in response to climate change) or for certain people (like those already living close to subsistence levels). Moreover, anticipated warming by 2030 cannot be reduced much, as any action taken to reduce greenhouse gas emissions takes several decades to significantly affect climate change.

As we approach the end of this century, in the absence of ambitious climate-mitigation policies, global warming may exceed 4°C, and impacts are likely to become "severe, widespread and irreversible," threatening poverty reduction and development (IPCC 2014a; World Bank 2015b). But the good news is that we still have a window of opportunity to adopt and implement emissions-reduction policies that could slow down and stabilize long-term climate change, and in the process, usher in a more prosperous world.

One more wrinkle in this story is that the climate change–poverty link is actually two-way. Expected progress in poverty reduction and access to basic services has the potential to reduce vulnerability to climate change and reduce its impacts (Hallegatte, Przyluski, and Vogt-Schilb 2011; Wilbanks and Ebi 2013). But the future of poverty also matters for climate change. Development and economic growth, critical elements for reducing poverty, directly affect energy consumption and access to technologies—which, in turn, affect greenhouse gas emissions and the long-term pace and magnitude of climate change.

Against this backdrop—and the limited research done so far on this two-way relationship—this report sets out to explore the potential impact of climate change and climate policies on poverty reduction, and investigate whether climate change can represent a significant obstacle to the objective of ending extreme poverty. It also provides guidance on how to design climate policies such that they contribute to poverty reduction as well as on how to design poverty-reduction policies such that they contribute to climate change mitigation and resilience building. And it contributes to a series of reports that explore the complex relationship between development and climate change (box 1.1).

The report aims to answer the following questions:

- *Will the changing climate be a threat to ending poverty, at what time horizon, and under which conditions*? Would climate change make it impossible to end poverty only in the most pessimistic scenarios, or would it be a threat even in more moderate or optimistic cases? Will this impact be concentrated in highly vulnerable locations, or more broadly distributed globally? Is it a long-term trend, or is it also relevant over the shorter term?
- *What emissions-reduction policies and adaptation actions can reduce this threat?* In particular, how can we balance short-term actions (like reducing vulnerability to floods and droughts) with long-term goals such as stabilizing the climate? How should adaptation actions navigate across different options to reduce vulnerability—from poverty reduction and increased income to targeted adaptation policies and social protection? How can adaptation policies prevent lock-ins into activities and locations that will become increasingly unable to sustain rising standards of living?
- *How should poverty concerns be factored into mitigation and adaptation policies?* Are there trade-offs between mitigation and poverty goals, and if so how can these be managed? Can complementary policies cancel out potential negative effects on the poor? How can we design adaptation policies so that they benefit poor people and contribute to poverty reduction?
- *How should the existence of climate change modify poverty reduction strategies?*

BOX 1.1 Multiple reports explore the complex relationship between development and climate change

This report is just one of many produced by the World Bank Group in the past two years on climate change, mitigation, and development. The scope of this flagship report is on climate change and poverty, and it does not pretend to cover all the dimensions of the complex interplay between climate change and development. In particular, a number of other reports on mitigation, adaptation, and development, along with private-sector involvement, provide analyses that complement the findings of this report.

On mitigation, the recent report *Decarbonizing Development: 3 Steps to a Zero-Carbon Future* provides policy advice to help put countries on a path toward decarbonizing development. *On Thin Ice: How Cutting Pollution Can Slow Warming and Save Lives* reviews the scientific impacts of methane and black carbon and strategies to reduce emissions. And the annual *State and Trends of Carbon Pricing* report reviews the ever-changing landscape of country-level climate-mitigation policies.

On adaptation and development, this report relies on the *World Development Report 2014*, which focuses on managing risk (including natural risk, and opportunities for poverty reduction), and the three volumes of the *Turn Down the Heat* reports, which review the science of global climate change and provide detailed assessments on regional impacts. *Building Resilience: Integrating Climate and Disaster Risk into Development* explores solutions for both protecting lives and livelihoods and decreasing damages from natural disasters. *Climate-Smart Development* examines the many benefits of climate-smart development, including those for health, agricultural yields, and employment. And *Enhancing the Climate Resilience of Africa's Infrastructure* assesses the impact of climate change on infrastructure development in Africa, especially in the power and water sectors.

On the private sector, the report on *Mobilizing Public and Private Funds for Inclusive Green Growth Investment in Developing Countries* provides guidance on how to scale-up existing innovative mechanisms to mobilize private capital for green growth. And the report on an *Enabling Environment for Private Sector Adaptation* outlines how to create an environment for private sector participation in promoting climate-resilient development paths.

Other organizations have also recently produced major reports that contribute to the discussion on development and climate, including the OECD's *Aligning Policies for a Low-Carbon Economy*, the Global Commission on the Economy and Climate's *Better Growth, Better Climate*, the IMF's *Energy Subsidy Reform: Lessons and Implications*, and UNEP's *Adaptation Gap Report*.

Recognizing that poor people are more vulnerable, does climate change influence what should be the priority for poverty reduction? Is there a risk of a "global poverty trap" if people who are still in extreme poverty are unable to adapt to climate change and thus escape poverty? And how can we ensure that the goal of eliminating extreme poverty by 2030 is not achieved in a way that creates greater vulnerability post-2030?

This report builds on the existing literature—especially the review by the Intergovernmental Panel on Climate Change (IPCC)—on the links between climate and poverty, including the role of socioeconomic trends (like growth and demography) and patterns (like inequality and governance) in mediating impacts (Olsson et al. 2014).

It explores three main channels through which climate has always affected poverty: (i) agricultural production, ecosystems, and food security; (ii) natural disasters; and (iii) health. It fills in some gaps in the literature and uses data and modeling analyses to provide quantifications (or at least, orders of magnitude) for some of the qualitative statements that can be found in the literature. We combine, for example, large datasets on household characteristics and location with recent global flood and drought modeling to examine whether poor people are more exposed and vulnerable to natural disasters and how this is likely to change with climate change. We also explore whether lower agricultural yields will occur in places vulnerable to hunger, and the role that ecosystems play in reducing both poverty and risk in poor communities.

We then present the results of a new modeling exercise that builds on the collected knowledge in each main channel—agriculture, natural disasters, and health—to explore the potential impacts of climate change on poverty in 92 developing countries by 2030, investigating how these impacts are different in more or less optimistic scenarios of socioeconomic development. Finally, we explore policy options with an eye on the long term, and discuss how the stabilization of climate change can be made compatible with poverty eradication.

Our assessments—and quantification exercises—cannot be considered a comprehensive estimate of the impact of climate change on poverty. However, they are sufficient to demonstrate that climate change poses a significant obstacle to eradicating extreme poverty in the days and decades ahead. They also stress that we can act and reach poverty-eradication goals—in spite of climate change—by combining rapid, inclusive, and climate-informed development and targeted interventions (to cope with short-term impacts) with pro-poor mitigation policies (to avoid long-term impacts).

Climate change is an obstacle for people to escape poverty

Given that economic growth plays a critical role in reducing poverty, a key concern for poverty eradication is the impact of climate change on growth. Indeed, in the past, the income of the bottom 20 percent of the population has increased much more as a result of increases in the average income than from increases in the share of the income that goes to the bottom quintiles (Dollar, Kleineberg, and Kraay 2013; Dollar and Kraay 2002). This relationship could of course change in the future if governments implement substantial redistributive policies (Ferreira and Ravallion 2009; Robalino and Warr 2006). But substantial redistribution is not easy politically, and the poorest countries simply lack the resources to eradicate poverty through redistribution. Economic growth will thus be needed to bring people out of poverty (Ravallion 2010).

At this point, we know that climate affects economic growth, based on observations of past evolutions. Reduced rainfall in the 20th century partly explains Sub-Saharan Africa's slow growth (Barrios, Bertinelli, and Strobl 2010; Brown et al. 2010). And high temperatures in the second half of the 20th century may have slowed down growth in poor countries in both the agricultural and the industrial sectors (Dell, Jones, and Olken 2012). One study also finds that every 1°C warming reduces income by 1.2 percent in the short run, and by 0.5 percent in the long run (Dell, Jones, and Olken 2009). Other studies have found even larger impacts—including a 3.8 percent drop in income in the long run for every 1°C warming (Horowitz 2009).

But what should countries expect from global warming in the future? Here, the evidence is inconclusive, with estimates based on very simple, partial models that vary widely (Pindyck 2013; Stern 2013). Most studies find a relatively limited impact on GDP. The latest Synthesis Report of the IPCC states that "*incomplete estimates of global annual economic losses for additional temperature increases of [about] 2.5°C above pre-industrial levels are between 0.2 and 2.0% of income*" (figure 1.1), but adds that these estimates are likely to underestimate actual impacts. In particular, existing estimates have focused on limited warming (below 3°C) and do not include many sources of impacts that may prove consequential—such as the impact of ecosystems on economic activity, or the risk from surprises and tipping points. Studies including these elements, even in a simplistic manner, have found much larger potential impacts (Stern 2006; Weitzman 2014). As a result, the confidence in these estimates is limited, especially for warming that exceeds 2°C (IPCC 2014a).

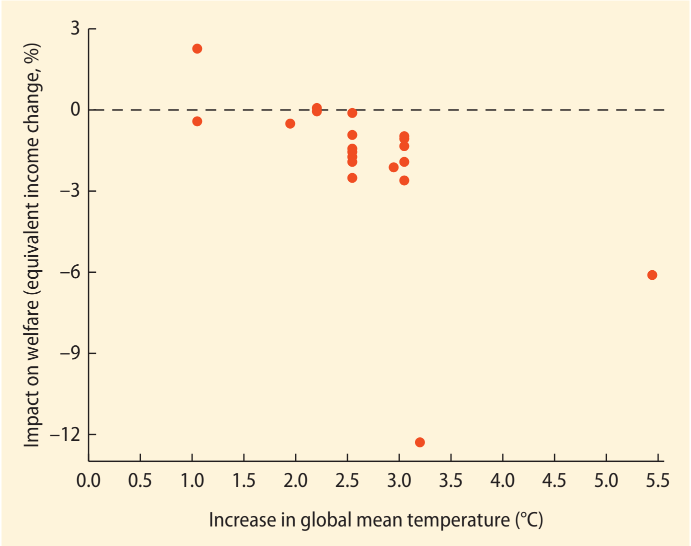
Based on these macroeconomic estimates of future aggregate impacts of climate change, the impacts on poverty via the GDP channel are small—possibly less than 1 percent by 2050 (Skoufias, Rabassa, and Olivieri 2011).

But of course, climate change does not only affect poor people via economic aggregates, it also can affect them directly. In fact, its direct impacts will likely be more significant than the growth-mediated one, and may not significantly affect aggregate GDP, since poor people represent a very small share of global income. This is because climate change can affect household consumption (and thus consumption-related poverty) through four channels almost independently of aggregate growth:

- *Prices*. Consumption in real terms is driven by price levels and relative prices, which can be affected by multiple trends, shocks, and policies. Spikes in prices of basic goods can have large impacts on poverty numbers (Ivanic, Martin, and Zaman 2012), and climate change may increase the level and volatility of food prices and thus hurt poor people who usually spend a large share of their income on food (chapter 2).
- *Assets*. Households escape poverty by accumulating assets (Moser 2008). For instance, they acquire education or information, improve their health, and invest in productive assets such as livestock or manufacturing equipment. Assets usually include the financial, physical, human, social, and natural capital that households own. They also include public goods, infrastructure, and institutions that households have access to. Climate change can affect asset accumulation and poverty reduction by destroying assets during disasters or affecting people's incentive and ability to invest in new assets (chapter 3), or by affecting people's health (chapter 4).

FIGURE 1.1 The bigger the climate change, the bigger the total impact

(Estimates of the total impact of climate change increases with the magnitude of climate change)



Source: IPCC 2014b.
Note: The magnitude of climate change is proxied by the increase in the global mean surface air temperature (x-axis). Each dot represents one study.

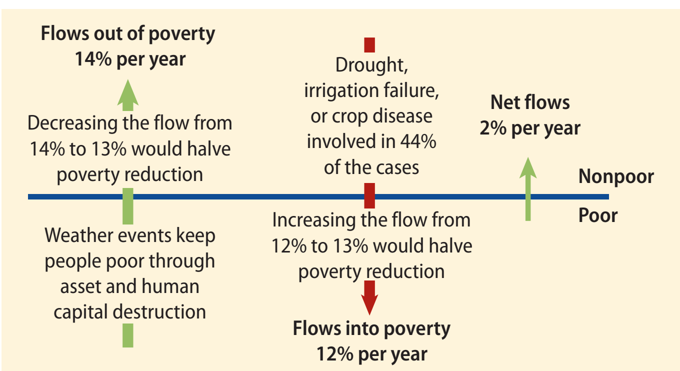
- *Productivity*. Households can increase the return on their assets (including labor) by being more efficient and improving production processes, although returns are often limited by economic inefficiencies (such as corruption, market failures, and inappropriate regulations). Returns are also affected by changes in the price of what households produce. Climate change can decrease these returns through lower agricultural yields (chapter 2) and labor productivity (chapter 4), or increase them through higher agricultural prices (chapter 2).
- *Opportunities*. Households can also increase their income by expanding their range of activities or migrating, typically to cities (Bryan, Chowdhury, and Mobarak 2014). This is possible thanks to new opportunities in new sectors and activities. But those opportunities are often limited by exclusion (for example, based on gender or ethnicity) and constraints on mobility. And climate

change can worsen the situation through more conflicts, increased competition for resources, higher risk aversion, or poorly designed adaptation policies (such as greater reliance on nonportable safety nets; chapter 5).

Of course, these channels interact closely. Lower agricultural productivity could lead to higher food prices, which can make it impossible for some households to continue saving and build their asset stock. Capturing new opportunities requires investments and sometimes migration, activities that are possible only with an appropriate asset base. And price changes will affect consumption (for net buyers) and income (for net sellers) simultaneously.

If poor people are disproportionally affected by climate change impacts through these channels, the impact of climate change on poverty will be larger than what is suggested by the macro impact on GDP—and climate change can lead to a decoupling of economic growth and poverty reduction. To explore this question, the report examines the impacts of climate change on poor and vulnerable people and draws implications for future poverty reduction. We start with current poverty dynamics to identify the obstacles to poverty reduction that are most likely to be affected by climate change.

FIGURE 1.2 Flows in and out of poverty in Andhra Pradesh are larger than their net effect on poverty



Source: Krishna 2006.

Climatic events already affect the dynamics of poverty, which will be worsened by climate change

Poverty reduction is not a one-way transition out of poverty. Recent data show that about a third of urban Indonesian residents moved in or out of poverty in less than a decade (Gentilini, forthcoming)—and such large flows are consistently found in surveys around the world (Baulch 2011; Beegle, De Weerdt, and Dercon 2006; Dang, Lanjouw, and Swinkels 2014; Krishna 2006; Lanjouw, McKenzie, and Luoto 2011).

Take the case of 36 communities in the state of Andhra Pradesh in India, over a 25-year period. As figure 1.2 shows, 14 percent of households in the 36 communities escaped poverty every year, while 12 percent of nonpoor households became poor—resulting in a 2 percent net annual decrease in overall poverty (Krishna 2007).[2] The fact that the net flow out of poverty is much smaller than the gross flows in and out of poverty means that a relatively small change in the gross flows can have a significant effect on the net flows and thus overall poverty dynamics. In this example, if the flow into poverty increased from 12 to 13 percent per year or the flow out of poverty slowed from 14 to 13 percent per year, that would cut the pace of poverty reduction by half.

Climate events and environmental degradation can make people fall in poverty. How can climate change affect these flows in and out of poverty? We know that natural hazards and climate conditions are involved in many cases where households fall into poverty, notably because of the shocks they create or contribute to. Table 1.1 shows the results of 15 household surveys in six developing countries—Afghanistan, India, the Lao People's Democratic Republic, Malawi, Peru, and Uganda—which ask people whether they have experienced a shock in the past year (Heltberg, Oviedo, and Talukdar 2015; World Bank 2013). Among the six categories of shocks, three of the most commonly reported can be directly

TABLE 1.1 Households in developing countries face many shocks
(Percentage of respondents reporting type of shock)

	Afghanistan		India	Lao PDR		Malawi		Peru		Uganda	
Shocks	U	R	R	U	R	U	R	U	R	U	R
Natural disasters (drought, flood)	10.6	42.2	57.3	5.6	36.0	10.4	47.2	2.6	21.5	19.9	52.1
Price shocks	0.2	3.0	—	4.4	4.9	21.1	42.0	—	—	1.7	3.2
Employment shocks	6.4	4.3	—	9.3	3.1	7.7	3.4	6.4	1.5	1.9	0.7
Health shocks (death, illness)	6.9	14.0	30.2	23.2	33.8	10.1	18.0	9.1	8.9	11.8	14.9
Personal and property crime	1.8	6.6	0.9	5.8	1.9	8.5	8.4	3.2	3.1	6.6	8.7
Family and legal disputes	—	—	1.9	0.0	0.9	1.7	4.3	0.7	0.3	—	—

Source: World Bank 2013, based on data from household surveys, various years 2005–2011.
Note: R = rural; U = urban; — = not available.

related to weather events and environmental conditions:

- *Price shocks* can be linked to lower agricultural production—for instance, following a shock like the 2010 Russian droughts or as a result of a long-term trend—and they can reduce poor people's consumption, pushing them into poverty and making it even tougher to save and accumulate assets.
- Many *natural disasters* are climate related. These include asset and crop or livestock loss that can be provoked by natural hazards such as droughts and water scarcity, and floods and storms. Natural disasters can bring people into poverty by destroying their assets—forcing them to either use their savings or borrow to repair or replace them—or by impacting health and education.
- *Health issues* (death and illness) are influenced by climate and environmental conditions, as shown by the relationship between rainfall and malaria outbreaks or the role of temperature in the number of cases of diarrhea. Moreover, health shocks remain the primary reason why people fall into poverty, owing to a combination of health expenditures, reduced income (for the sick or their caregivers), and long-term consequences on productivity (like disability).

TABLE 1.2 Weather shocks hit the poorer populations the hardest in the Middle East and North Africa region
(Percentage reporting economic impacts from weather shocks)

	Quintiles					
Percent	Poorest	Q2	Q3	Q4	Richest	All
Lost income	46	44	43	29	21	37
Lost crops	58	62	62	49	42	55
Lost livestock or cattle	24	25	30	23	15	23
Less fish caught	10	10	9	10	5	9

Source: Wodon et al. 2014.
Note: Households from five countries in the region are asked to report impacts from weather shocks in the last 5 years.

In addition, *employment* can be affected by climate events indirectly, because demand for work can decrease as a response to disasters (as when productive capital is destroyed by a storm) (Hallegatte 2008). It can also be affected by the degradation of natural resources and ecosystems, in which climate can play a role.

Climate change is expected to make many of these shocks worse (for an in-depth discussion, see chapters 2, 3, and 4). The effect of these shocks on poverty is all the more important given that people in lower income quintiles often appear more exposed and vulnerable to weather shocks than the rest of the population. In the Middle East and North Africa, a recent survey of five countries found that the bottom three quintiles are more exposed to weather shocks than the top two, especially in terms of income losses (table 1.2). Other household surveys show a similar story.

Climate-related shocks push people into poverty. In the Andhra Pradesh communities, among households falling into poverty, 44 percent cite "drought, irrigation failure, or crop disease" as one of the reasons for their descent. A household affected by droughts in the past is 15 times more likely to fall into poverty (Krishna 2006). In Bangladesh, of nearly 400 households falling into poverty, 15 percent cite natural disasters and 18 percent the loss of natural assets as the main reasons (Sen 2003). Changed weather patterns and modified rainfall may increase or decrease the frequency and intensity of such weather shocks and therefore change the flow of households into poverty.

Climatic and environmental conditions affect the ability of households to escape poverty. Climate change may make it more difficult for poor people to increase their income and accumulate assets, or may even lead in extreme cases to "poverty traps" (that is, when people own so little that they cannot invest to increase their income). While evidence on the existence of poverty traps is mixed, surveys do suggest that poor people experience slow income growth and slow recovery from shocks (Antman and McKenzie 2007; Carter et al. 2007; Kraay and McKenzie 2014; Ravallion and Jalan 2001). And a slowing down of income growth for the poor would result in slower rates of poverty reduction.

At the household level, we know that asset accumulation offers a way out of poverty, often over several generations. In Guayaquil, Ecuador, a study on asset-poor households found that they start by accumulating housing capital through improving their dwelling (Moser and Felton 2007). This improves the quality of life, but also helps build human capital through better health, safety, and security. Next, households consume more durable goods and diversify their asset base by investing in productive assets (like children's education and financial capital) to better cope with negative shocks such as illness or natural disasters. In Bangladesh, a recent study tells a similar story. Households that receive assets (such as livestock or a sewing machine, complete with income support and training) build and diversify their asset portfolio to increase their income and reduce vulnerability to negative shocks (Barrett et al. 2013).

Households also escape poverty because they have access to jobs with better wages, and in developing countries these jobs are largely created by private micro-, small, and medium enterprises (MSMEs), often in the informal sector. These firms therefore play a key role in reducing poverty, especially where many young people enter the job market (World Bank 2012). But recent studies show that these firms are particularly ill-equipped to anticipate and adapt to environmental change and prepare for natural disasters. In Turkey, more than 60 percent of the MSMEs interviewed in a recent study reported that they did not have enough understanding of climate risks and access to resources and financial and insurance instruments to manage climate-related risks (IFC and EBRD 2013). This lack of preparation translates into needless losses in economic activity and jobs, even in rich countries, as illustrated by case studies after (climate- or non-climate-related) disasters in the past (Groen and Polivka 2008; Kroll et al. 1991; Tierney 1997).

Climate and environmental shocks and degradation can also restrict asset accumulation and slow down poverty reduction (Carter et al. 2007; Dercon and Christiaensen 2011). Poor people who have little other means to cope with shocks may be forced to sell their productive assets, such as distress sales of livestock during drought periods (Little et al. 2006). They may also be forced to overextract environmental resources in a struggle for short-term survival (Reardon and Vosti 1995). Such strategies can lead to poverty traps when they undermine the resources poor people depend on for future income generation (Barbier 2010; Barrett, Travis, and Dasgupta 2011).

Climate-sensitive shocks can also have irreversible impacts on education and health, transmitting poverty from one generation to

the next. While households with enough assets can be expected to smooth consumption following a shock, asset-poor households may smooth assets and destabilize consumption in an attempt to preserve the small productive resources they still have (Carter et al. 2007). This interruption in postdisaster consumption can result in irreversible impacts for children. A review of the literature elicits many examples from Sub-Saharan Africa, but also in Asia, Latin America, and elsewhere (Baez, de la Fuente, and Santos 2010; Maccini and Yang 2009).

- Following weather shocks in Sub-Saharan Africa, asset-poor households typically provide children with lower-quality nutrition (Alderman, Hoddinott, and Kinsey 2006; Dercon and Porter 2014; Yamano, Alderman, and Christiaensen 2005) and are less likely to take sick children for medical consultations (Jensen 2000). These behaviors have short- and long-term impacts, especially for children under the age of two—like stunted growth (Yamano, Alderman, and Christiaensen 2005) and a greater tendency to get sick (Dercon and Porter 2014).
- After droughts in Côte d'Ivoire, school enrollment rates declined by 20 percent (Jensen 2000), and drought-affected households in Zimbabwe delayed the start of school for children on average 3.7 months, resulting in children completing 0.4 fewer grades (Alderman, Hoddinott, and Kinsey 2006).
- In Ethiopia, children younger than 36 months at the apex of the 1984 famine were less likely to have completed primary school, with calculations suggesting this led to income losses of 3 percent per year (Dercon and Porter 2014).

Moreover, health challenges are not limited to shocks: malnutrition can be a chronic condition that is expected to worsen in a future with climate change (see chapter 4). Considering the importance of child health and education for long-term prospects, productivity, and income, even a moderate impact of climate change on health and educational achievement could affect poverty visibly over the long term. And because poor households suffer disproportionately from climate impacts, it would reduce the chance for children from poor families to escape poverty, further harming social mobility and increasing the intergenerational transmission of poverty.

Increased risk can push poor households into low-risk, low-return strategies that keep them poor. Natural risk can affect people's prospects even before a disaster hits. Household choices on risk-return trade-offs depend on their ability to cope with potential negative futures (such as bad rainfall, reduced consumption, and lower demand). With less steady income, a larger percentage of total assets exposed, and reduced insurance coverage, poor people generally have a lower ability to adapt to bad outcomes than the rich. As a result, low-income households disproportionately choose low-risk activities, which are also low-return, perpetuating poverty (Bandyopadhyay and Skoufias 2013; Dercon and Christiaensen 2011; Elbers, Gunning, and Kinsey 2007; Mobarak and Rosenzweig 2013).

This effect can be as important as the actual impacts of a shock. In Zimbabwe, an agricultural study found that ex ante impacts from increased weather risk explain almost half of the reduction in income due to droughts (Elbers, Gunning, and Kinsey 2007). Such livelihood strategies often entail excessive and costly diversification of activities and less productive investments, thereby constraining wealth accumulation. This risk stance, in turn, discourages the adoption of new technologies and lowers incentives to invest in productive capital.

Risk exposure also reduces credit market willingness to lend—in other words, those with uninsured weather risk have limited access to credit and investments. Importantly, households consider their vulnerability to natural risks such as floods and droughts when making risk-related decisions in other domains—such as creating a business or migrating to a city. Research suggests that under fairly general conditions, the higher the background risk (due to floods or droughts), the less individuals are willing to take other risks (like innovation or entrepreneurship) (Gollier and Pratt 1996). Empirical evidence also provides support for this hypothesis in many places (Ahsan 2014; Cameron and Shah 2015; van den Berg, Fort, and Burger 2009), although not everywhere (Bchir and Willinger 2013).

Poor people can be protected by the support and tools they have access to. People rely on multiple support systems to manage risks and trends—like their household and family, the community, the socioeconomic system around them (including the financial system), and the government (World Bank 2013). How much support they receive will largely determine the impact of various shocks and stresses on their welfare and their ability to escape poverty (chapter 5). For instance, financial instruments (like bank accounts and insurance contracts) help households and firms adapt to climate change, prepare for natural shocks, and recover when affected. Protected savings and borrowing also make it possible for households to cope with income losses while maintaining consumption and avoiding detrimental coping measures (like reducing food intake or taking children out of school).

Social insurance and social safety nets are also efficient tools to support poor people when they are affected by natural disasters or environmental and economic shocks. When droughts in East Africa caused food shortages and famine in 2011, Ethiopia's *Productive Safety Net Program* expanded coverage from 6.5 million to 9.6 million beneficiaries in two months and extended benefits from six to nine months per year. In addition, migration and remittances help people manage temporary or permanent shocks and escape poverty. Migrants typically benefit, as do their family and area of origin, from remittances, enhanced social networks, and better information (Adger et al. 2002; Bryan, Chowdhury, and Mobarak 2014; Moser and Felton 2007).

Poverty reduction, socioeconomic trends, and non-climate policies affect climate risk

So we know that climate events and environmental degradation affect poverty reduction today. But the future impacts of climate change will depend on future conditions, including not only the magnitude and patterns of the change in climate but also the speed and direction of poverty reduction and future socioeconomic changes (Hallegatte, Przyluski, and Vogt-Schilb 2011). It is not hard to imagine that, in a world where everyone has access to water and sanitation, the impacts of climate change on waterborne diseases will be smaller than in a world where uncontrolled urbanization has led to widespread underserved settlements located in flood zones. Similarly, in a country whose workers mostly work outside or live and work without air conditioning, the impact of hotter weather on labor productivity and income will be stronger than in an industrialized economy. And a poorer household with a large share of its consumption dedicated to food will be more vulnerable to climate-related food price fluctuations than a wealthier household.

The impacts of—and risks from—climate change depend on the following three factors:

- *Hazard:* The physical event or trend (like a windstorm, a flood, or a trend in temperature), which is measured using physical metrics (like the maximum wind speed, the water level, or the temperature change over a decade) and is independent of any socioeconomic characteristics or human presence.
- *Exposure:* The population and the amount of assets that are located where the hazard can occur (like the population and houses located in a flood plain) or more generally that are potentially

affected by a hazard (like the population working in the agricultural sector and thus exposed to reduction in yields).

- *Vulnerability:* The expected amount of loss, if a hazard occurs. This depends on the physical strength of exposed assets (a mud house tends to be more vulnerable to flood than a brick house); the technologies used (some agricultural techniques are more vulnerable to a decrease in precipitation); and the role of exposed assets for the community's well-being (the loss of a critical bridge typically results in higher losses than the reconstruction value).

How these three factors evolve is uncertain, given our lack of full understanding about the climate system and impacts of climate change (for instance, on ecosystems)—as well as how socioeconomic systems evolve. But it is also uncertain because they can be affected by policies and therefore by our current and future choices. These two sources of uncertainty have very different implications: while the scientific uncertainty (for instance on how local climates will change and how physical and biological systems will respond) is a bad thing, because it impairs decision making and creates risks, the uncertainty due to our choices is good news, because it shows that our decisions can shape the future of climate change and its impacts.

These two sources of uncertainty also influence these factors differently at different time horizons. Emissions-reduction policies, even those implemented today, cannot significantly affect the rate and magnitude of climate change by 2030, so that the uncertainty about the hazard comes only from the scientific uncertainty: at this time horizon, reducing climate change impacts can be done only by reducing exposure and vulnerability. But for 2050 and beyond, greenhouse gas emissions and climate policies have a large impact on the climate change hazard: the scientific uncertainty *and* the policy uncertainty matter for the long-term climate change hazard. To account for these differences, this report uses different scenarios for the analyses at different time horizons:

- *Short-term hazard.* In our analyses of the short-term impacts of climate change, by 2030, we use two scenarios for the magnitude of climate change impacts (*low-impact* and *high-impact* scenarios) to represent the scientific uncertainty on how local climates will change in response to global climate change, and how physical and biological systems will respond (such as the effects of higher temperatures on ecosystems). These scenarios do not depend on emissions and extend to 2030.
- *Long-term hazard.* When analyzing the longer-term, beyond 2050, we use two scenarios for the future of global greenhouse gas emissions and climate change (*low-emissions* and *high-emissions* scenarios), which are driven by development trends and climate policies. Our low-emissions scenario is the Representative Concentration Pathway (RCP)2.6, which is consistent with the objective of stabilizing climate change at 2°C above preindustrial temperatures (Van Vuuren et al. 2011). Our high-emissions scenario is the RCP8.5, which represents a world of high population and economic growth combined with a growing use of fossil-fuel energy (Riahi et al. 2011). These scenarios extend to 2100, and are used for instance to discuss the long-term impact of climate change on agricultural production and food prices in chapter 2, or the future intensity of heat waves in chapter 3.
- *Socioeconomic scenarios.* To represent the uncertainty on the exposure and vulnerability, linked to development and adaptation policies, we also introduce two socioeconomic scenarios, the *poverty* and *prosperity* scenarios, which describe different possible evolutions of the world until the end of the century, *in the absence of climate change.* The *prosperity* scenario is optimistic, assuming that the World Bank's twin goals of extreme poverty eradication and

shared prosperity are met by 2030, that population growth is slow in developing countries, education levels and labor productivity increase rapidly, and the productivity gap between developing and developed countries decreases quickly. The *poverty* scenario is pessimistic, assuming high population growth, low economic growth, and greater inequalities between and within countries. Population and GDP growth in these two scenarios are based on two socioeconomic scenarios developed by the scientific community to support climate change research, the Shared SocioEconomic Pathways (SSPs), and we add projections for poverty until 2030 (chapter 6).[3]

The road map for our report

This report explores the impacts of climate change looking not only at varying intensities of climate change but also at how climate impacts will vary depending on progress made on poverty, inequality, and access to basic services and social protection. As such, chapters 2 to 4 present new analyses and provide a review of what we think are the three major channels through which climate-sensitive events already affect people's movements in and out of poverty, namely the following:

- *Agricultural production, ecosystems, and food security:* Chapter 2 looks at how climate change will affect food prices, agricultural incomes, and the nonmarket consumption that is provided by ecosystems, and the consequences these effects will have on poverty dynamics. New analyses from five background papers are presented here. Two of them explore the impact of climate change (and policies) on agricultural yields, food prices, and food security, using different modeling approaches and assumptions (Biewald et al., forthcoming; Havlík et al., forthcoming). Another study examines the global distribution of rural poverty in low-elevation coastal areas (Barbier, forthcoming). Two additional papers analyze the climate (rainfall and temperature) sensitivity of subsistence and cash incomes, and the relative vulnerability of poor households, using data from 58 sites representing smallholder production systems in (sub)tropical areas with good forest access (Angelsen and Dokken, forthcoming; Noack et al., forthcoming).
- *Natural disasters:* Chapter 3 reviews the changes that are expected in the distribution, frequency, and intensity of natural hazards, exploring the exposure and vulnerability of poor and nonpoor people to these shocks. While previous studies rely on self-reported shocks (which can be biased), this chapter provides ample evidence to support the finding that poor people are more exposed and more vulnerable. New analyses drawing on a variety of data sources (such as people's occupations and livelihoods, expenditures, location, housing types, asset portfolios, and the ability to cope with and react to shocks and economic or environmental change) from three background papers are presented in this chapter. Two papers investigate the relative exposure of poor and nonpoor people to floods, droughts, and extreme heat in 52 developing countries by combining hazard data with household surveys (Park et al., forthcoming; Winsemius et al., forthcoming). Another paper focuses on the city of Mumbai, India, and explores the exposure, vulnerability, and ability of poor urban dwellers to respond, based on survey data collected for this report (Patankar, forthcoming).
- *Health:* Chapter 4 discusses the effects of health shocks on poverty and explores how climate change can magnify already existing health risks that have consequences for people's ability to escape

or stay out of poverty. This chapter is a review of existing work, bringing together the literature on the economic impact of disease and poor health and what we know about the potential effects of climate change on health.

These three chapters also explore the policy options within each of these sectors that can help reduce impacts—a discussion that is expanded upon in chapter 5 to include cross-sectoral options such as social protection and migration. Chapter 5 investigates various tools and support systems, looking at whether poor people have access to them, and reviews recent innovations to make financial instruments, social safety nets, and remittances more efficient and useful for poor people. It also discusses the role of governance systems in designing these instruments and the policies that drive poverty reduction and risk management and adaptation to climate change. New insights from four background papers are presented here. The first explores the social inequalities that shape the ability to cope with and adapt to climate change, especially for the poor and nonpoor (Tschakert, forthcoming). The second models the performance of different designs of social protection schemes in protecting poor people under increasing climate change (Carter and Janzen, forthcoming). And two case studies examine how social protection can protect poor people against natural hazards and environmental changes, looking at Ethiopia and its *Productive Safety Net Program* and the Philippines and its response to Typhoon Haiyan (Bowen, forthcoming; Johnson and Bowen, forthcoming).

Chapter 6 brings all of the findings together to highlight the extent to which overall development patterns will condition how climate change affects poverty. Based on a background paper for this report, it presents the results of a novel modeling exercise that examines how climate change would affect extreme poverty in 2030 looking across different scenarios of future development, and thus at worlds with different levels of exposure and vulnerability (Rozenberg and Hallegatte, forthcoming). Encouragingly, it finds that, if socioeconomic trends and policies manage to minimize the exposure and vulnerability of poor people to climate change by 2030, a large fraction of the negative impact of climate change on poor people can be prevented. These results highlight the window of opportunity to act now to promote rapid, inclusive, and climate-informed development and reduce the future impacts of climate change that cannot be avoided through mitigation measures.

How development is done, and in particular how low carbon it is, will determine the longer-term impacts of climate change on poverty. This means moving quickly now to decarbonize development to make poverty reduction and climate change stabilization compatible (box 1.2). Multiple reports have been published on mitigation policies. The recent IPCC report reviews possible pathways toward zero net carbon emissions and discusses the policies that can be implemented to follow these pathways (IPCC 2014c). Three other reports—the World Bank's *Decarbonizing Development*, the OECD's *Aligning Policies for a Low-Carbon Economy*, and the Global Commission on the Economy and Climate's *Better Growth, Better Climate* (Fay et al. 2015; OECD 2015; NCE 2014)—also explore policy options, from carbon pricing to innovation, environmental performance standards, and land use and urban planning.

In this report, we do not present a detailed discussion of mitigation policies, but chapter 2 touches on the impact of land-based mitigation policies (like fighting deforestation) on poverty, and chapter 6 explores how to design mitigation policies that do not slow down poverty reduction—in particular by combining mitigation policies with measures to protect poor and vulnerable people against potential negative impacts.

BOX 1.2 A call for zero net CO_2 emissions by 2100

The scientific reality is that as long as human societies release CO_2 in quantities greater than natural carbon sinks (such as forests and other vegetation) can absorb, the climate will continue changing, with corresponding risks for well-being, development, and poverty reduction (IPCC 2014a). This is why the international community committed to the goal of keeping global temperature increases below 2°C, and thus to the full decarbonization of the global economy (UNFCCC 2010; G7 2015).

Because energy consumption and related emissions are unlikely to decrease by themselves, maintaining global warming below 2°C, or even 3°C, requires immediate action. This requires a radical change in development patterns. For instance, a background study for this report finds that it will be very difficult to remain below a 2°C warming if the carbon intensity of new development exceeds 73 gCO_2/$ (grams of carbon dioxide emitted per dollar of GDP) on average at the global level (Rozenberg et al. 2015). As a reference, the carbon intensity of global GDP today is around 360 gCO_2/$. There is no country—except those that outsource emissions (like Singapore or Hong Kong SAR, China)—whose carbon intensity of GDP today approaches 100 gCO_2/$. This is true even of countries that produce most of their electricity from nonfossil energy sources (such as Brazil and France).

Moreover, delaying action locks the global economy into a carbon-intensive pathway—where it becomes increasingly more difficult and expensive to reduce CO_2 emissions sufficiently to stay within a low budget of cumulative emissions—because of the long lifetime and relatively high capital cost of energy infrastructure. Each year that additional mitigation efforts are delayed (that is, we continue along the current path), the required carbon intensity of new production decreases by 20 to 50 gCO_2/$ for a 2°C budget.

Source: Fay et al. 2015; Rozenberg et al. 2015.

Notes

1. Until this year, extreme poverty was defined using the $1.25 poverty line, based on the 2005 PPP exchange rates. Since the publication of the Global Monitoring Report (World Bank 2015a), the poverty line is defined by a consumption threshold at $1.90, using the 2011 PPP exchange rates. These two poverty lines are consistent, and the country-level poverty headcounts calculated using the two definitions are close (Jolliffe and Prydz 2015).
2. Similar findings exist in many countries and regions, see for instance data for four other countries in Krishna (2007), for Bangladesh in Sen (2003), and for South Africa in Carter and May (2011).
3. The prosperity scenario uses population and GDP projections from SSP5 and the poverty scenario uses SSP4 (O'Neill et al. 2015). While we use the quantification of the SSPs for population and GDP, we do not retain the narratives associated to these SSPs, especially regarding the energy mix. For more information on the SSPs, see https://www2.cgd.ucar.edu/research/iconics. While the SSPs go to 2100, we can only add poverty projections until 2030 (see chapter 6 for details on the methodology and its limits).

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Bad Seed: Climate Change, Agriculture, and Food Security | 2

Main Messages

- Climate change impacts on agriculture are already evident in vulnerable regions, such as Sub-Saharan Africa and South Asia, even as they remain globally limited. Future impacts are highly uncertain, but are expected to be significant—even when accounting for adaptive behaviors and trade. Land-based mitigation can also bring risks for food production and prices.
- Production and price impacts—whether triggered by climate change or climate policies—significantly affect poor people. Net-consumers of food products will be harmed, while those who depend on agricultural wages and profits will experience mixed impacts.
- Climate change adds to the stress on ecosystems and makes them even more fragile. Impacts for poor communities dependent on ecosystem-based livelihoods can be large—cutting their subsistence production and removing one of their safety nets—but are still impossible to quantify.
- In the shorter term, food stocks, better access of poor farmers to markets, improved technologies, and climate-smart production practices can reduce climate impacts. Over the longer term, negative impacts can be avoided only through mitigation actions, including in agriculture, forestry, and other land uses. These actions can be designed to avoid negative impacts or even to benefit local production and incomes.

Introduction

What are the key obstacles hindering poor people from escaping poverty and making them vulnerable to falling back into poverty? Household surveys investigating this question reveal that changes in prices, employment shocks, or death of livestock and crop failures are among the chief culprits. And we know that many of these shocks can be triggered by climate-related events, whose frequency and severity will increase with climate change. In particular, the pace of poverty reduction could be affected by climate change impacts on agriculture and ecosystems.

This chain of events is expected to occur because climate change will seriously affect land and water productivity. This, in turn, will increase food prices and affect wages and incomes, especially in the agriculture sector. The impact of such changes in prices and earnings on households depends on their consumption basket and income sources. Food dominates the consumption basket of poor households, whose livelihoods—particularly in poor countries—are often derived from agriculture and other environmental goods and services.

This chapter explores how climate change and climate policies could affect poor people through these channels. Importantly, these effects can be triggered either by short-lived natural disasters or by more gradual, long-term changes in climate conditions. While natural disasters are discussed at length in chapter 3, this chapter focuses on long-term changes and trends that threaten poor people. But the line is often blurred between shocks and trends, and the two interact closely. For instance, tight agricultural markets—due notably to limited food stocks—make it more likely that a relatively small event in one region (such as a drought in a major exporting country) translates into a food price crisis, as illustrated by the consequences of the 2010 Russian drought.

We begin by reviewing the possible impacts of climate change and mitigation policies on food security—in terms of agricultural yields, food prices, and food availability—and the consequences for poor households of such changes and the associated impacts on ecosystems the poor depend on. We then examine how socioeconomic development, improved technologies, better infrastructure and market access, and well-designed land mitigation policies could help.

Our main message is that climate change can have significant impacts on agricultural yields and food prices, as well as ecosystem-based livelihoods, which will particularly affect poor consumers and rural people. However, impacts will remain globally limited (but locally significant) until 2030 and can be largely managed through good policies during this period. Beyond 2030, impacts can become large and well-designed mitigation policies are the only way to reduce longer-term risks.

Climate change and climate policies will impact food security

Agriculture is one of the most important economic sectors in many poor countries. It is also directly critical to households' food security. Unfortunately, it is also one of the most sensitive to climate change given its dependence on weather conditions, both directly and through climate-dependent stressors (pests, epidemics, and sea level rise). In fact, some of the most severe poverty impacts of climate change are expected to be channeled through agriculture.

In its latest report, the Intergovernmental Panel on Climate Change (IPCC) notes that there is high confidence that all aspects of food security will be negatively affected by climate change (IPCC 2014). However, the extent to which yields and prices will be affected is hard to predict. Uncertainty about future precipitation and temperature change are compounded by uncertainties regarding the likely response of crop growth to changes in climate conditions. Further, the magnitude of CO_2 fertilization (that is, the process through which higher CO_2 concentrations directly accelerate plant growth) is still unknown. As a result, climate change impacts on crop yields and prices are highly uncertain and vary across regions, crops, and adaptation scenarios, depending on crop models, economic models, and underlying assumptions (Nelson et al. 2014).

This chapter adds to the rapidly growing knowledge on climate change and agriculture by presenting the results of new modeling exercises undertaken for this report—one on hunger vulnerability (Biewald et al., forthcoming) and one on food prices (Havlík et al., forthcoming). These exercises combine a crop model for biophysical yield impacts with an economic and trade model to calculate production and price impacts under a variety of scenarios, including with and without CO_2 fertilization, and distinguishing between short-term (until 2030) and longer-term (until 2080) impacts.[1]

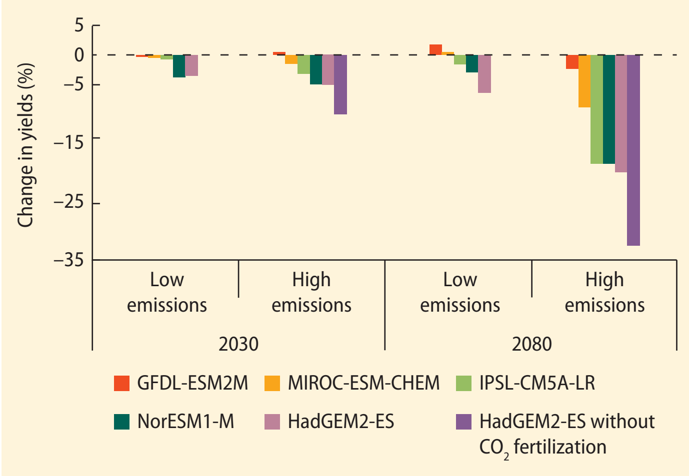
Climate change could reduce yields in many places, especially the poorest

As shown in the latest IPCC assessment, food production will be directly affected by changes in climatic conditions (Porter et al., 2014): Crop yields and harvest quality are susceptible to extreme events and changing precipitation and temperature. Livestock production can be impacted by grazing land productivity and quality, heat stress, and water availability. The distribution and abundance of aquatic species will change with negative impacts expected for fish production in developing countries in tropical areas.

Notwithstanding high uncertainties, the IPCC concludes with high confidence that crop production will consistently and negatively be affected by climate change in the longer term and in low-latitude countries (IPCC 2014). Projected impacts vary across crops, regions, and adaptation scenarios with positive and negative impacts being equally possible before 2050. Beyond that, risks of negative impacts become more severe.

Accordingly, Havlík et al. (Forthcoming) show that climate change is likely to have a detrimental impact although impacts remain limited in the shorter term. As figure 2.1 shows, in a high-emissions scenario, declines in average crop yields remain limited in 2030 once the positive effect of CO_2 fertilization is accounted for, and do not exceed 10 percent even without CO_2 fertilization. Beyond 2030, the severity of the damage will depend on the actions countries take to decrease their greenhouse gas (GHG) emissions. In a low-emissions scenario, overall crop yield losses could be stabilized at less than 8 percent by 2080 compared to a situation without climate change (and with CO_2 fertilization, net gains are even possible). But if GHG emissions continue to increase on an uncontrolled path (high-emissions scenario), yields could decrease by up to 20 percent (on average 14 percent across climate models) in 2080 even with CO_2 fertilization—and up to more than 30 percent without CO_2 fertilization.

FIGURE 2.1 Climate change could sharply reduce crop yields
(Change in yields compared to no climate change)



Source: Havlík et al., forthcoming.
Note: Results from Global Biosphere Management Model (GLOBIOM) based on 18 species aggregated on a dry matter yield basis. Climate change impacts are shown for 5 climate models (HadGEM2-ES, IPSL-CM5A-LR, GFDL-ESM2M, MIROC-ESM-CHEM, NorESM1-M) with CO_2 fertilization and HadGEM2-ES without CO_2 fertilization.

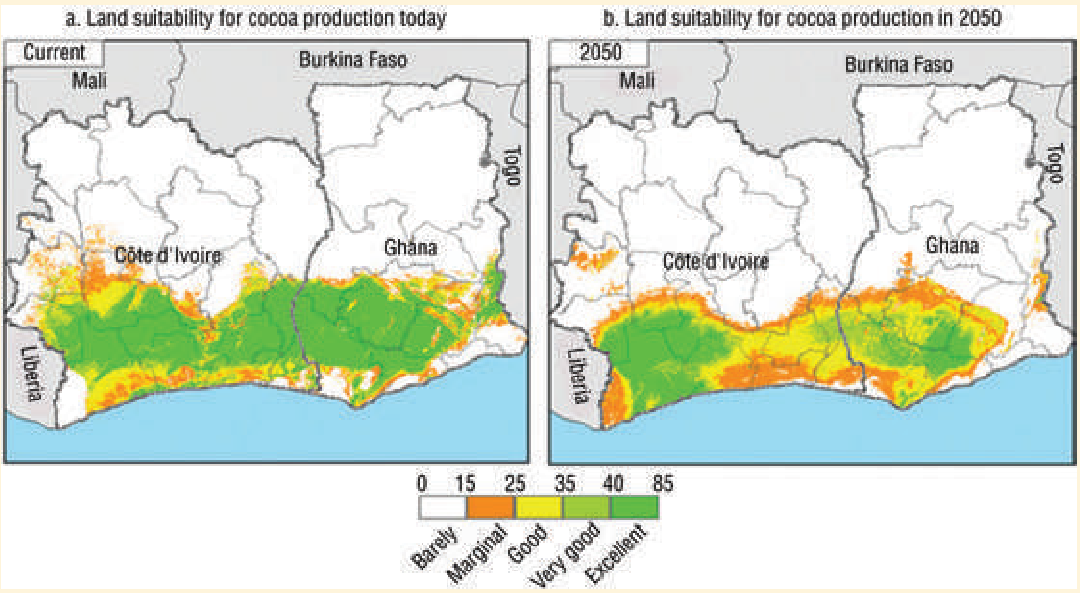
Climate-induced yield reductions are not homogenous. Climate change will benefit some cold regions in the short run, but these regions are relatively wealthy. In contrast, it will hit other regions especially hard, particularly the poorest ones. By 2080, the average yield declines estimated from all climate models could be as severe as 23 percent for South Asia, 17 percent for East Asia and the Pacific, 15 percent for Sub-Saharan Africa, and 14 percent for Latin America—even with CO_2 fertilization (Havlík et al., forthcoming). But if CO_2 fertilization effects do not materialize, overall impacts can be more severe, with all regions experiencing negative yield changes. Using another crop and economic model brings similar results (Biewald et al., forthcoming): its finer spatial resolution shows that yield impacts will also vary greatly within countries, with some regions benefiting while others lose much more than the regional or country average. Climate change could even make agricultural areas unsuitable for cultivation of key crops, resulting in large economic impacts for poor economies that are highly dependent on a few agricultural commodities (box 2.1).

BOX 2.1 Climate change could pose major hurdles for Africa's leading cocoa and coffee producers

Climate change can modify the suitability of particular locations for agriculture production, which could be a major challenge for agriculture-dependent economies. In Ghana and Côte d'Ivoire, areas suitable for cocoa production could be negatively affected by climate change—a major problem for two countries whose economies depend critically on employment and revenues from this export crop (map B2.1.1). Similarly, in Uganda, the leading coffee producer in Africa, significant declines in most areas suitable for coffee production are possible (Jassogne, Läderach, and van Asten 2013).

History suggests that specialized economies find it difficult to recover from the collapse of their main activity. For instance, one study shows that regions affected by the Dust Bowl in the United States in the 1930s never returned to their pre-drought production levels, with most adjustment taking place through outmigration toward other areas (Hornbeck 2012). Since production of such cash crops will be affected slowly, a well-prepared transition toward other production—in agriculture, manufacturing, or services—would be well advised.

MAP B2.1.1 Ghana and Côte d'Ivoire could experience a loss of area suitable for cocoa production by 2050



Source: Läderach et al. 2013.
Note: Maps show suitability predicted by Maximum entropy (MAXENT) model, which incorporates crop-environment interactions based on the current climatic conditions in cocoa growing areas (panel a) and changes in the climatic conditions according to climate change projections (panel b).

Biophysical impacts affect prices and food availability

The biophysical impacts on crop yields will also trigger changes in production and food prices. The impact of these changes will depend on how farmers and countries adapt to them. Farmers can adjust input use (fertilizer and irrigation) and cultivated area to compensate for some of the yield losses; and countries can buffer their production deficit by increasing their food imports. (These are the adaptation options used in the background modeling for this chapter.) Food prices will evolve depending on the interplay of demand and supply of food, which may be affected by public policies regarding food stock management and trade policies as well as management of losses during storage and transport.

What happens to agricultural prices is particularly critical for poverty given their impact on poor households' budget and income. According to the IPCC, changes in temperature and precipitation are likely to result in higher food prices by 2050, but the magnitude remains highly uncertain with increases ranging from 3 to 84 percent without CO_2 fertilization effects, and between decreases of 30 percent and increases of 45 percent with CO_2 fertilization (IPCC 2014). These estimates may be optimistic in that they do not account for impacts of pests, diseases, interaction with local pollution, and extreme weather events. Extreme events in particular could put global food systems at risk (U.K.–U.S. Task Force 2015).

Impacts also depend on socioeconomic trends, including technological change and population growth. This is why all simulations are performed under two socioeconomic scenarios—labeled *prosperity* and *poverty*—that represent different evolutions of the world's population and economy. The *prosperity* scenario is optimistic, assuming that the World Bank's twin goals of extreme poverty eradication and shared prosperity are met by 2030, that population growth is slow in developing countries, education levels and labor productivity increase rapidly, and the productivity gap between developing and developed countries decreases quickly. The *poverty* scenario is more pessimistic, assuming high population growth, low economic growth, and greater inequalities between and within countries (see chapter 1 for a discussion of the scenario approach used in this report).

Over the long term, the risks of harmful price impacts could be high, especially without CO_2 fertilization. The simulations carried out for this report (figure 2.2) suggest that in scenarios with continued high emissions and no CO_2 fertilization, climate change would increase world agricultural prices by 4 to 5.5 percent in 2030. Over time, these impacts increase and could be as large as 30 percent by 2080.[2] With CO_2 fertilization, impacts on global prices remain limited even with high emissions.

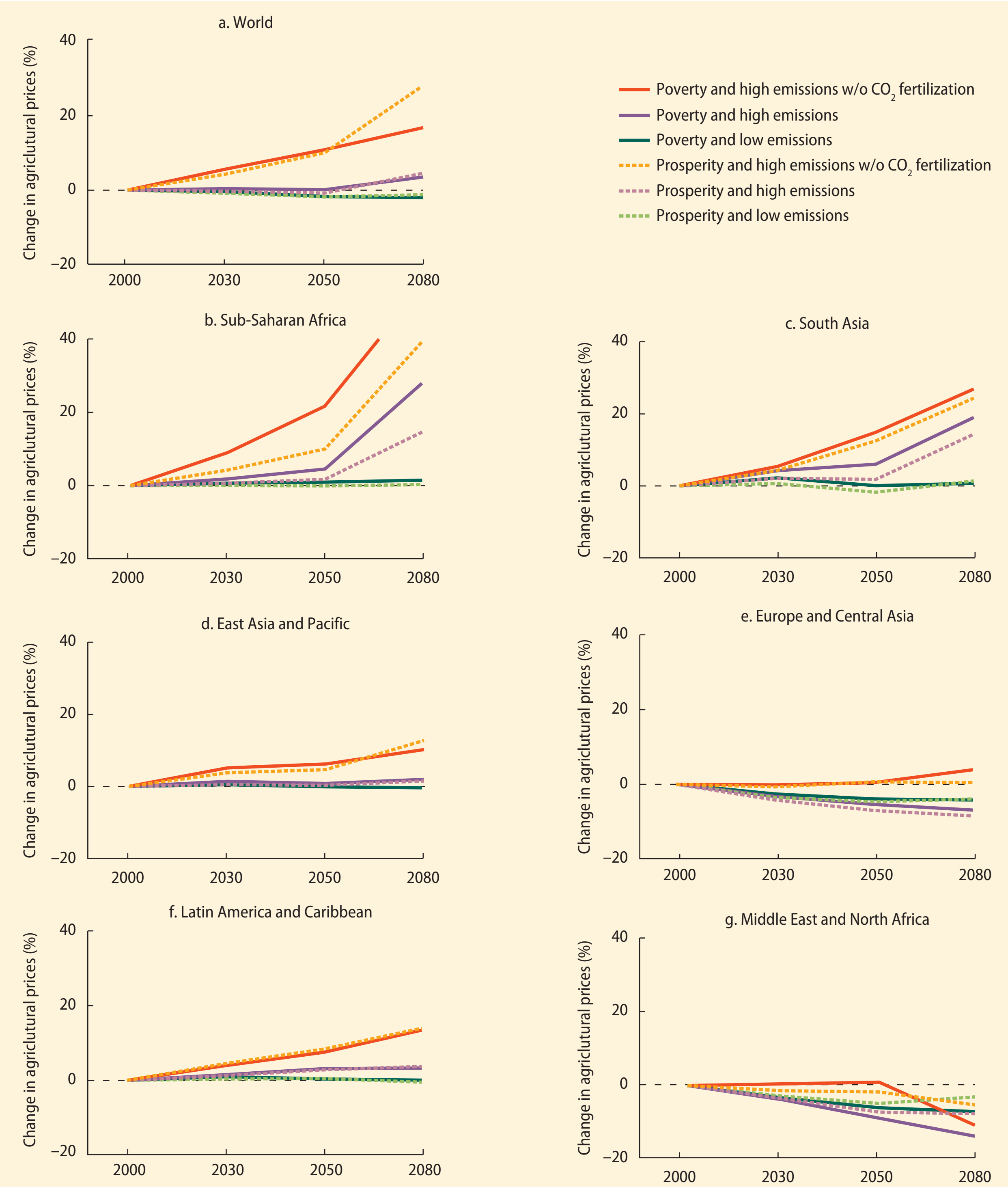
Regions are affected very differently by climate change induced price changes, with Sub-Saharan Africa and South Asia the most severely impacted (figure 2.2). Impacts on prices could be as high as 12 percent in 2030 and 70 percent by 2080 in Sub-Saharan Africa in a worst-case scenario (*poverty* and *high emissions* without CO_2 fertilization). In the same worst-case scenario, prices would rise by 5 percent by 2030 and 23 percent by 2080 in South Asia, 4 percent and 9 percent in East Asia and the Pacific, and 3 percent and 12 percent in Latin America. Even with CO_2 fertilization, in 2080 prices would be 29 percent higher in Sub-Saharan Africa and 16 percent in South Asia.

As for food availability, unmitigated climate change has the potential to cancel out a large fraction of the food security gains from technological change and economic growth and can be a threat in regions that already have low levels of food intake per capita and will experience high levels of population growth.

Sub-Saharan Africa and South Asia are particularly vulnerable. In those regions, without climate change, per capita food availability could increase at least to a level equivalent to 80 percent of the current food availability in developed countries by 2080,

FIGURE 2.2 Sub-Saharan Africa and South Asia are the most vulnerable to climate-induced increases in agricultural prices

(Climate change impacts on agriculture prices)



Source: Havlík et al., forthcoming.

Note: Results are based on simulations from *Global Biosphere Management Model* (GLOBIOM). The figure shows climate shock impact on agricultural prices by comparing the price level in the different emission and development scenarios with the price level without climate change for each year.

even in a *poverty* scenario (figure 2.3). However, in the *high-emissions* scenario, calories per capita grow until 2030 and then stagnate, remaining 7 to 10 percent lower than in the no climate change world even when adaptation and trade possibilities are accounted for. What is particularly worrisome about these simulations is that in Africa and South Asia, the increases in daily calories plateau at levels far below those of developed countries today. In other regions and in the *prosperity* scenario, impacts are much smaller and appear more manageable because of the much higher baseline levels.

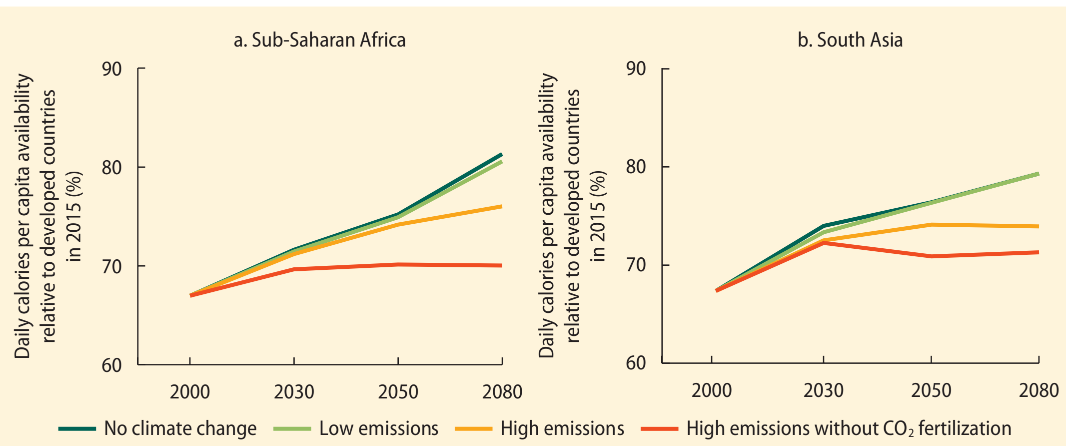
Ill-designed land-based mitigation policies can also be a threat for food security

In the longer term, countries will need to look into well-designed land-based mitigation policies to stabilize climate change (see chapter 6 for a discussion of mitigation needs and policies). Here, the agriculture, forestry, and other land uses (AFOLU) sector will be a key player, in addition to fulfilling its already critical role in providing food and supporting rural livelihoods.

It can contribute by reducing direct non-CO_2 emissions of existing agricultural production, and, even more important, by avoiding deforestation, increasing carbon sequestration through afforestation, and producing biomass for energy generation. The IPCC estimates that land-based mitigation, including bioenergy, could contribute 20 to 60 percent of total cumulative abatement up to 2030, and 15 to 40 percent up to 2100 (Smith and Bustamante 2014). Distributing mitigation efforts in a cost-efficient way across sectors could require a decrease in emissions from AFOLU by 64 percent in 2030, compared to their 2000 level (Havlík et al., forthcoming).

Yet such mitigation efforts could affect food prices and availability given the critical role of land in agricultural production. The IPCC concludes that large-scale, land-based mitigation at the global scale, especially bioenergy expansion, can reduce the availability of land for food production, with implications for food security (Smith and Bustamante 2014). Many studies show that regional and local commodity prices (like food, timber, and energy) could rise as a result (Chen et al. 2011; Golub et al. 2013; Kuik 2013).

FIGURE 2.3 Climate change can significantly reduce food availability in poor regions
(Impact on daily calories per capita)

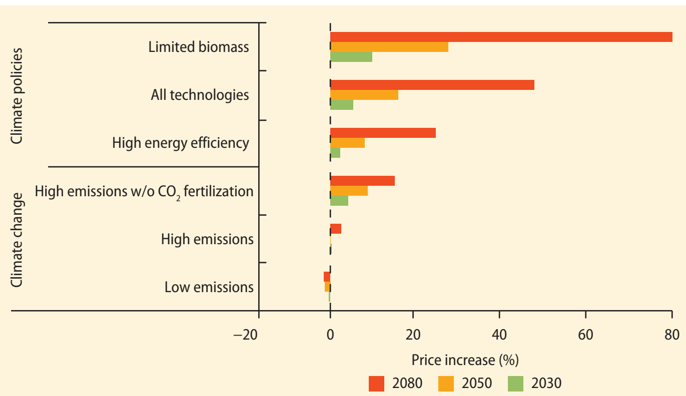


Source: Havlík et al., forthcoming.
Note: Results are based on simulations from Global Biosphere Management Model (GLOBIOM). The figure shows the aggregate daily calories per capita available in the Poverty scenario per region as percentage of the projected level of daily calorie consumption in developed countries in 2015. Data on calorie levels in developed countries in 2015—estimated at 3,390 kilocalories—are from Alexandratos et al. (2012).

Food price impacts could be severe for large-scale bioenergy deployment—especially when combined with protecting natural forests (Calvin et al. 2013; Popp et al. 2011; Wise et al. 2009).

The simulations carried out for this report show that mitigation policies implemented through a uniform global carbon price, which does not account for food production implications, would hurt crop and livestock production and result in lower food availability compared to a hypothetical baseline without climate change and climate policies (Havlík et al., forthcoming).[3] Such policies could even have price impacts that are larger than those of climate change (figure 2.4). Other, more carefully designed, policies, however, could lead to price impacts that are smaller than those caused by unmitigated climate change (Lotze-Campen et al. 2014). Nevertheless, these findings warn against climate policies that would not be sensitive to food security issues, and emphasize the need to protect poor people against the negative side effects of land-mitigation policies.

FIGURE 2.4 Ill-designed land-mitigation climate policies could sharply increase agricultural prices
(Impact on agricultural prices)



Source: Havlík et al., forthcoming.
Note: Results are based on simulations from Global Biosphere Management Model (GLOBIOM). The figure shows difference of agricultural prices between a baseline scenario (that is, no climate change and no climate policy) and different emissions and climate policy scenarios assuming a uniform global carbon price. "All Technologies" is a mitigation scenario in which all available technologies enter into the solution portfolio according to their relative competitiveness. "High Energy Efficiency" involves the same technologies but assumes higher investments in energy efficiency leading to final energy demand lower by 20 to 30 percent in 2050 and by 35 to 45 percent in 2100. "Limited Biomass" puts a limit on industrial biomass use for energy at 100 EJ/yr. All price impacts are shown for the poverty scenario. Results are similar under the prosperity scenario.

Poor people are vulnerable to climate impacts through prices and ecosystems

How are the poor affected by climate-related impacts on food production and prices? Increased agricultural prices will affect consumers through higher expenditure for basic goods, but will benefit net sellers and those who earn wages from agricultural employment. However, the increase in prices may be the result of a decline in productivity that would reduce returns from farm activities and agricultural wages, so that the net effect on sellers will depend on the interplay between prices and output. In addition, many poor people—especially those in rural areas—do not buy or sell consumption goods in markets, but produce them from ecosystems to meet subsistence needs (for example, nontimber products provided by forests, production of crops, or small fishery catches), which may be extremely climate sensitive.

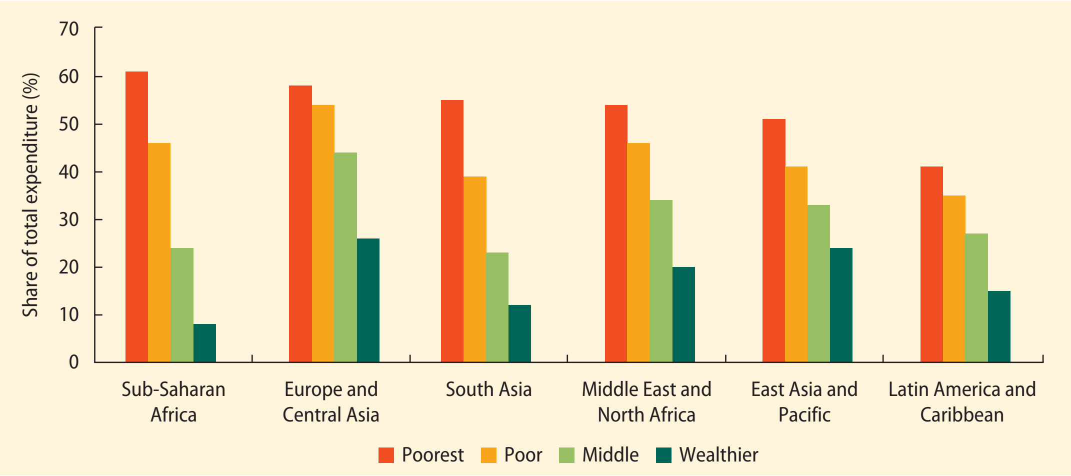
Poor people will be affected by higher agricultural prices as consumers and producers

Because climate change and climate policies are likely to affect the prices of basic goods—particularly food—they will alter the purchasing power and real income of households. However, the overall impact on poverty will depend on both how much the prices of these basic goods are affected and whether the households are net buyers or net sellers.

Poor consumers are highly vulnerable to food price hikes. The higher share of income that poor people spend on food makes them particularly vulnerable to rising prices or price volatility on food items. Across the developing world, the poorest households spend between 40 percent and 60 percent of their income on food and beverages compared to less than 25 percent of wealthier households (figure 2.5). In some African countries, such as Burundi, Chad, the Democratic Republic of Congo, Malawi, and Tanzania, food consumption of the

FIGURE 2.5 **Poor households spend a higher share of their expenditure on food than nonpoor households**

(Expenditure for food and beverages)



Source: World Bank Global Consumption Database. http://datatopics.worldbank.org/consumption/sector/Food-and-Beverages.
Note: Calculated based on total consumption value in 2010 ($PPP [purchasing power parity] Values) in developing countries. Consumption groups defined based on global income distribution data: poorest = $2.97 per capita a day; poor = between $2.97 and $8.44 per capita a day; middle = between $8.44 and $23.03 per capita a day; wealthier = above $23.03 per capita a day.

poorest households amounts to over 70 percent of their total expenditure. Poor people in urban areas often have even higher food expenditure than rural people, as the latter can also self-produce some of their food needs.

How poor people are affected by a particular food item's price rise depends on their ability to respond to price changes by modifying their diets toward cheaper foods. Overall, demand response for basic food products has been found to be limited, especially in the case of a generalized increase in food price levels (Ivanic and Martin 2008), or for staple foods (such as tortillas in Mexico) (Wood, Nelson, and Nogueira 2012). But poorer households are more likely to reduce food consumption in the face of higher prices, with a 10 percent increase in food price levels translating into a reduction in daily food intake by 301 kilojoules (72 kilocalories) in low-income countries (Green et al. 2013). Such impacts could lead to undernutrition, with potentially severe health impacts, especially on children (see chapter 4).

Price increases can benefit agricultural producers and laborers. A rise in agricultural prices is likely also to lead to an increase in agricultural profits and wages. The poverty impacts of price-induced changes in earnings depend on how vulnerable households make a living. In Sub-Saharan Africa, a recent study shows that almost all rural households are self-employed in farm activities, earning 63 percent of their income from these sources compared to only 33 percent in non-African developing countries (Davis, Di Giuseppe, and Zezza 2014). More generally, the share of poor people who declare agriculture as their main income source is highest in poorer countries, though with substantial variation (figure 2.6). In India, agriculture remains the main preserve of the unskilled and disadvantaged people (Lanjouw and Murgai 2009). These households will be highly sensitive to any change in agricultural profits or wages.

In spite of the benefits for farmers who are net sellers of food, existing studies using multicountry samples tend to agree that, in the absence of changes in production and wages, a rise in food prices increases poverty rates in most countries due to the negative impacts on consumers. Simulations suggest that a 10 percent price rise in food prices—with no change in agriculture productivity—leads on average to a 0.8 percentage point increase in extreme poverty headcount rates; a 50 percent price rise to a 5.8 percentage point poverty increase; and a 100 percent price rise to a 13 percentage point poverty increase (Ivanic and Martin 2014). The severity of poverty impacts will vary among countries—with Guatemala, Pakistan, Sri Lanka, Tajikistan, and Yemen being the worst hit (figure 2.7).

Accordingly, food price spikes in the past already had significant poverty impacts. In a sample of 28 developing countries the global price spikes between June and December 2010, which increased food prices by an average 37 percent, increased the number of people in extreme poverty by 44 million (Ivanic, Martin, and Zaman 2012). The 2008 food price shock, resulting in price increases of over 100 percent, even resulted in an additional 100 million people in extreme poverty (Ivanic and Martin 2008).

Poverty impacts will also depend on the specific food crops for which prices increase. A 10 percent price increase for rice would *increase* poverty in Bangladesh by 0.67 percentage points and in Côte d'Ivoire by 0.42 percentage points, but *reduce* poverty by 1.37 percentage points in Cambodia and 0.29 percentage points in Vietnam (Ivanic, Martin, and Zaman 2012). Similarly, as seen in figure 2.7, a 10 percent price increase in all crops could lower poverty rates in Albania,

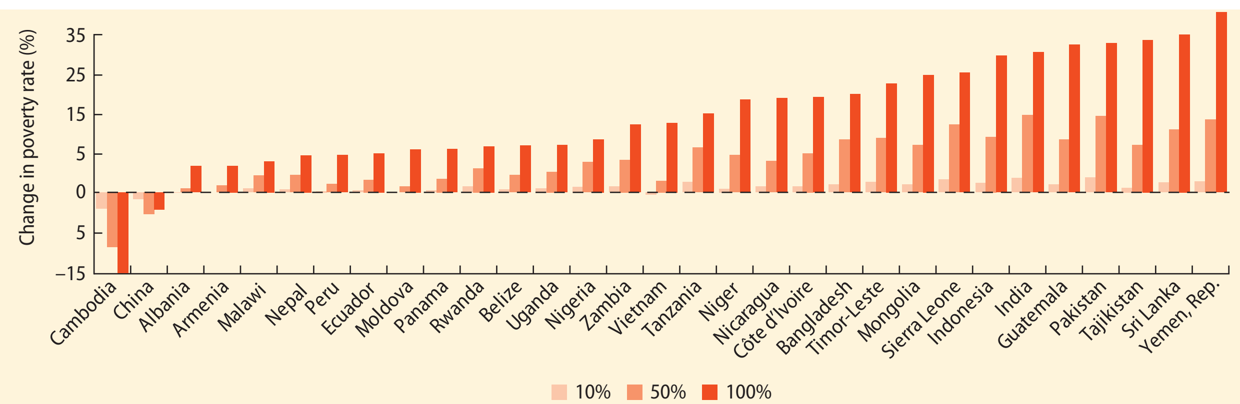
FIGURE 2.6 In poorer countries, agriculture plays a vital role for poorer households' incomes

(Agricultural participation of the bottom 20% and country GDP)

Source: World Bank calculation based on the International Income Distribution Data Set (I2D2).
Note: Values based on the number of people indicating agriculture as their main income-earning activity (including farm self-employment and wage-employment). PPP = purchasing power parity.

FIGURE 2.7 Food price rises could lead to big increases in extreme poverty in most countries

(Poverty change under 10%, 50%, and 100% food price increases)



Source: Ivanic and Martin 2014.
Note: Based on microeconomic simulations specified with the Global Trade Analysis Project (GTAP) general equilibrium model. Simulations measure the short-term impacts on poverty (without any supply or wage adjustments) of a uniform change in all food prices for 10, 50, and 100 percent (without productivity effects). Poverty is defined by the percentage of households living on less than $1.25 per day.

Cambodia, China, and Vietnam, while more extreme price shocks would have a poverty-reducing impact only in Cambodia and China. Modest price increases could lift a group of net-selling farmers out of poverty, while larger price rises would drop other groups into poverty.

In the longer run, wage and production adjustments are possible, but the net impact depends on productivity impacts. In the longer run, rising food prices will increase marginal returns from agriculture, which raises agricultural wages. While the effects of commodity price changes on rural wages could take some time to materialize, several studies have actually found that these adjustments could mediate poverty impacts of increased consumption prices (Devarajan et al. 2013; Ivanic and Martin 2014; Jacoby, Rabassa, and Skoufias 2014). The wage response depends on the elasticity of the agricultural wage with respect to land productivity. The more limited the supply of labor to agriculture, the more responsive the agricultural wage to price shock, as seen in India (Jacoby, Rabassa, and Skoufias 2014). Such responses may be observed if workers cannot easily move between sectors and if spatial mobility is limited.

Moreover, in the longer run, farmers respond to changing prices by adjusting their production. In some cases, they can switch land toward producing those items whose prices have risen relative to others or by increasing overall agricultural production through expansion of agricultural land or increases in other outputs. With these long-run adjustments and no change in productivity, extreme poverty could even decrease globally by as much as 1.4 percentage points under a 10 percent price rise and 8.7 percentage points under a 100 percent price rise (Ivanic and Martin 2014). However, these options are not always available to farmers.

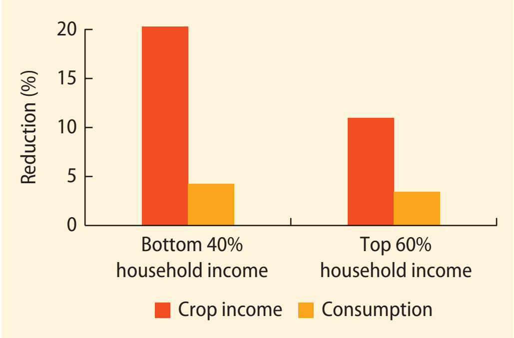
And farmers are also directly affected by changes in land and labor productivity. For instance, data from Uganda between 2005 and 2011 suggest that a 10 percent reduction in water availability due to a lack of rainfall reduced crop income by 14.5 percent in wealthier households, and by 20 percent in poorer ones (Hill and Mejia-Mantilla 2015 and figure 2.8). Interestingly, however, the average consumption decrease was the same in both sets of households—about 4 percent—suggesting the poorer ones made significant efforts to preserve consumption. Nevertheless, even small shocks can also push vulnerable households below the poverty line.

In addition, chapter 4 discusses the impact of high temperature on labor productivity. These effects are not accounted for in the agriculture models that are used in this chapter, but they could have significant effects on returns from all outdoor occupations, and especially agriculture.

The net effect of climate change on poverty, which is the combination of impacts on productivity, consumption prices, and incomes, is likely to be negative in many countries. In the 15-country sample used by Hertel, Burke, and Lobell (2010), climate-induced price rises increase extreme poverty by 1.8 percentage points—driven mostly by the negative impacts in countries with large populations (including Bangladesh and countries in Sub-Saharan Africa, such as Malawi, Mozambique, Uganda, and Zambia).

FIGURE 2.8 Rainfall shocks in Uganda take a big toll on crop income, less so on consumption

(Impact of rainfall shock on income and consumption)



Source: Hill and Mejia-Mantilla 2015.
Note: Values calculated using data from Uganda National Household Survey UNHS 2005/6, UNHS 2009/10, UNHS 2012/13. Rainfall shock is represented by a 10 percent decrease in the Water Requirement Satisfaction Index, estimated for Uganda.

Climate change modifies not only average climate conditions but also climate variability, with potential effects on poverty. One study estimates that by 2080, an increase in the intensity of extreme dry events would lead to a rise of extreme poverty by 0.53 percentage points in 16 developing countries with Bangladesh (1.35 percentage points), Mexico (1.76 percentage points), and Zambia (4.64 percentage points), most severely affected (Ahmed, Diffenbaugh, and Hertel 2009). Other significant effects would affect poor farmers through impacts on livestock, which are not only a source of income (box 2.2) but also used as an asset by poor households.

Nonagricultural households, which are net buyers of food—especially those in urban areas—will be the worst affected. A climate-induced rise in food prices could increase poverty rates of nonagricultural households by 20 to 50 percent in parts of Africa and Asia (Hertel, Burke, and Lobell 2010). Similarly, a once-in-30-year climate extreme would most severely affect urban laborers with a dramatic increase in poverty rates within this group in Bangladesh (31 percent), Malawi (111 percent), Mexico (95 percent), the Philippines (32 percent), and Zambia (102 percent) (Ahmed, Diffenbaugh, and Hertel 2009). With increasing urbanization rates, food price increases could have an even more severe poverty impact.

The analysis in chapter 6 also suggests that—even in the long run—the negative impacts through consumption prices and yields dominate the positive impacts on agricultural incomes in almost all scenarios, and the net effect of climate change is very likely to increase global poverty. A net decrease in poverty is not impossible, though, if many poor households stay in agriculture (the case in our *poverty* scenario) and if the impact of climate change remains moderate. That said, it occurs only in a small fraction of the scenarios—and only if institutions and labor markets are such that the extra revenue from higher prices is distributed fairly across workers and landowners. These results parallel those of a study on India, in which higher agricultural wages help poor households and, if the negative impacts of climate change on agricultural productivity impacts remain low, could even benefit them (Jacoby, Rabassa, and Skoufias 2014). But with greater productivity impacts, climate change will be increasingly likely to contribute to a global increase in poverty.

The poorest will be directly affected by impacts on ecosystems

Besides higher agricultural prices, the poorest people will also be directly affected by climate change through its impacts on

BOX 2.2 Climate-driven livestock diseases can have high economic costs

Livestock plays a vital role in the economies of many developing countries. Globally it accounts for 40 percent of agricultural production, employs 1.3 billion people, and creates livelihoods for 1 billion of the world's poor. Livestock products provide one-third of human protein intake.

Climate change affects many of the environmental variables that can lead to livestock diseases—and climate-sensitive livestock diseases already have high economic impacts (via income losses), as well as costs to prevent and control disease outbreaks. In Somalia, Rift Valley fever epidemics prevented 8.2 million small ruminants, 110,000 camels, and 57,000 cattle from being exported, corresponding to economic losses for the livestock industry estimated at $109 million in 1998–99 and $326 million in 2000–02. In Kenya, the annual cost of East Coast fever is estimated at $88.6 million; in Malawi, $2.6 million; in Tanzania, $133.9 million; and in Zambia, $8.8 million.

Source: Bouley and Planté 2014.

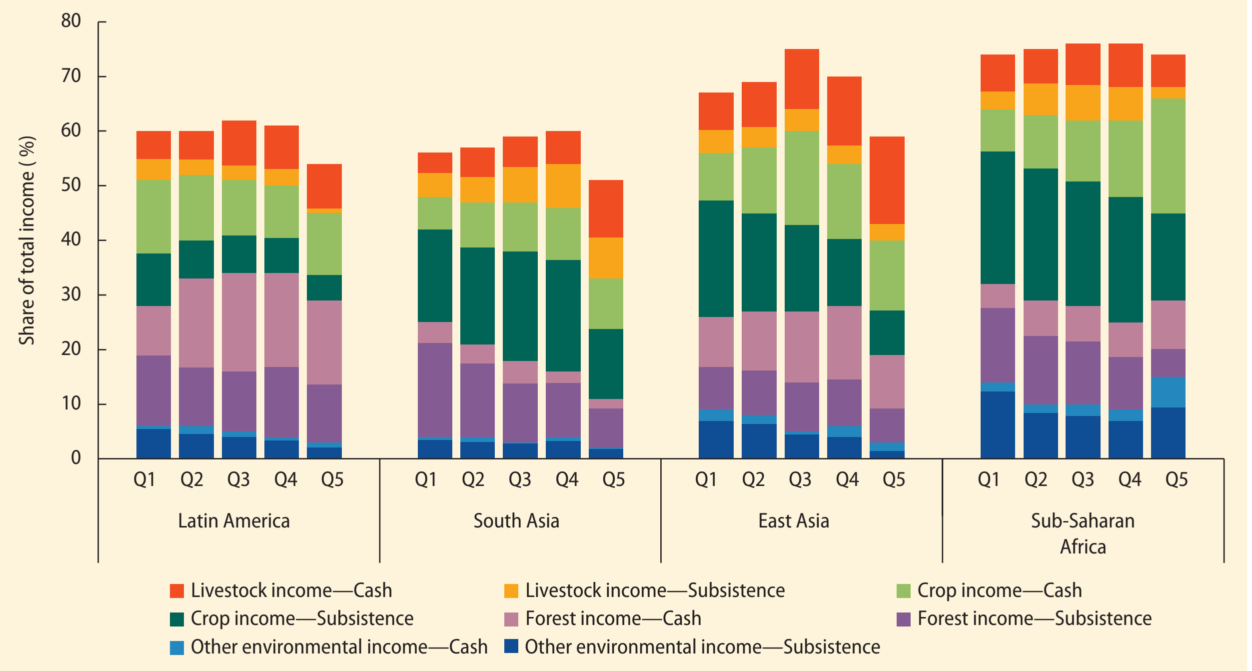
livelihood activities that fulfill subsistence and other needs. In the absence of functioning capital, labor, and land markets and with very few assets on hand, many poor rural households depend on access to ecosystems (Barbier 2010). They use them to produce or extract goods for self-consumption (like crops, timber, and fish) and to smooth income shocks. Climate change can add to the stress on ecosystems and reduce their ability to support livelihoods.

Many poor rural people depend on ecosystems for their base income and as safety nets. Many of them live in low-productivity and fragile ecosystems, making them highly vulnerable to climate risks, including natural disasters (see chapter 3). Data collected for a global comparative study of tropical and subtropical smallholder systems show that about 27 percent of the households included fall below the extreme poverty line—most of them in Sub-Saharan Africa (Noack et al., forthcoming). Out of the 424 million people living in the African drylands, 23 percent (or 40 percent of the 240 million agriculture-dependent individuals) are estimated to be below the extreme poverty line (Cervigni and Morris 2015).

In these areas, ecosystem-based activities provide poor people with incomes from intensive ecosystem management (like crop cultivation and livestock) and from the extraction of noncultivated ecosystem goods (like timber, plants, animals, and fish). These ecosystem-based incomes made up 55 to 75 percent of incomes in a cross-section of 58 sites representing smallholder systems, with 15 to 32 percent coming from forests or other noncultivated ecosystems (figure 2.9).[4] Among these typically poor households, the wealthier households derive a slightly lower share of their income from ecosystems and have a lower dependence on subsistence-based

FIGURE 2.9 Ecosystem-based incomes explain most rural income in (sub)tropical smallholder systems

(Income shares across income quintiles and regions)



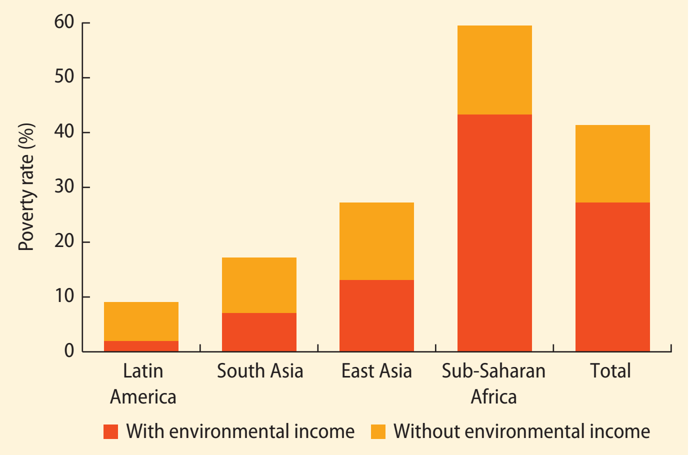
Source: Noack et al., forthcoming.

Note: Figure shows average share for households across income quintiles. Q1 is the lowest income quintile and Q5 is the highest. Income calculated as PPP (purchasing power parity) 2005 USD adult equivalent units. Based on Poverty and Environment Network (PEN) dataset, including data from 58 sites in 24 countries.

incomes. Similar to findings in Damania et al. (2015), ecosystems boost incomes of wealthier households, for example through cash crops or work on commercial plantations, and provide last resort incomes for poor households that have little other means to secure subsistence needs.

FIGURE 2.10 Without environmental incomes poverty rates could be much higher

(Poverty rate in [sub]tropical smallholder systems)



Source: Noack et al., forthcoming.
Note: Figure shows share of sampled households below the $1.25 per day poverty line based on incomes calculated as PPP (purchasing power parity) 2005 USD adult equivalent units. Based on Poverty and Environment Network (PEN) dataset, including data from 58 sites in 24 countries.

These subsistence incomes from ecosystems help to keep a considerable share of rural people above the poverty line. If smallholding households in (sub)tropical forest landscapes could not complement their income through forests and other environmental resources and were unable to find alternative income sources, an additional 14 percent of all sampled households would fall below the extreme poverty line (figure 2.10). Besides providing goods that directly contribute to cash or subsistence incomes, ecosystems can also indirectly benefit poor people (box 2.3).

Poor households have strategies to deal with climate variability. During the survey years, the poorest households in (sub)tropical smallholder systems were not subject to more weather or other livelihood shocks (such as income, asset, or labor losses), despite living in more extreme climatic conditions (Angelsen and Dokken, forthcoming). In addition, only a few of those households that were exposed to weather anomalies or shocks experienced a decline in income. As the survey years did not cover any major extreme events, this finding suggests that rural households can manage at

BOX 2.3 The wider functions of ecosystems and biodiversity in rural livelihoods

Ecosystems and biodiversity can support humans through nonprovisioning services (such as regulating, supporting, and cultural services) that are of critical importance for poor people in rural areas (MEA 2005). Studies that assess the links between such nonprovisioning ecosystem services and poverty have been very rare (Roe et al. 2014; Suich, Howe, and Mace 2015).

Ecosystem services can support incomes and livelihood activities in many indirect and often invisible ways. For instance, the establishment of a protected area in Costa Rica has increased tourism-based incomes and accounted for two-thirds of the poverty reduction achieved in the area (Ferraro and Hanauer 2014). Forests provide pollination services that benefit nearby farming activities (Olschewski et al. 2006; Ricketts et al. 2004). And intact watersheds support hydrological services that benefit local water supply for domestic use or agricultural activities (Klemick 2011; Pattanayak 2004).

In addition, ecosystems provide an important role in protecting livelihoods against climate risks. Trees on steep slopes protect rural villages from landslides when heavy rains fall, and mangroves provide protection to coastal livelihoods during storm surges (Badola and Hussain 2005; Das and Vincent 2009). Moreover, ecosystems can contribute to climate stabilization. For example, higher forest cover helps reduce the occurrence of droughts (Bagley et al. 2013; Davidson et al. 2012)

A new research agenda is emerging to better understand the services provided by ecosystems and who benefits from them (Bennett et al. 2012).

least modest weather and livelihood shocks without falling deeper into poverty.

One way to smooth income volatility is by extracting ecosystem resources. Incomes from resource stocks that grow continuously over years (like timber and fish) are less sensitive to weather fluctuations than those that depend on annual cycles (like crops). Hence forest resources can help smooth consumption between seasons and years (Locatelli, Pramova, and Russell 2012). Although environmental extraction was the primary coping strategy for only one out of 12 households in (sub)tropical smallholder systems, forest incomes are a substitute for agricultural incomes and can stabilize total income when weather anomalies hit (Noack et al., forthcoming).

As rural households are used to dealing with climate variability, weather anomalies are probably not perceived as shocks that require emergency responses, but as tacit changes in production conditions that require marginal adjustments of existing strategies. Thus, in India, households that have lower than predicted income, indicating a bad year, derive a higher income share from environmental resources (Damania et al. 2015). Unfortunately, such responses, as well as the general overextraction and overuse of ecosystems resources, can lead to increasing degradation of ecosystems, which undermines the sustainability of such strategies.

Climate change adds to the stress on ecosystems and undermines rural livelihoods. Despite the importance of ecosystems for poor people, the link between climate-induced ecosystem changes and poverty has not been systematically assessed. This is due in part to the difficulty in disentangling ecosystem changes driven by climate change from those driven by other factors. The existing peer-reviewed literature suggests that the ecosystem-related impacts of climate change will affect poor people mostly through hazard regulation, soil and water regulation in low elevation coastal zones, and dryland margins (Howe et al. 2013). In many regions, there are a number of risks that are relevant for the rural poor—such as local warming in the Sub-Saharan drylands, which can trigger shorter growing seasons and shifts in areas suitable for rain-fed agriculture (table 2.1). Moreover, although current knowledge does not allow for a

TABLE 2.1 Climate change risks for ecosystems and potential livelihood impacts across regions

Region	Ecosystem	Examples of long-term climate change risks	Potential livelihood impacts of relevance for poor people
Sub-Saharan Africa	Drylands	local warming, amplified by dry conditions leads to expansion of arid areas in Southern Africa and Western Africa	shorter growing season and shift in areas suitable for rain-fed agriculture will have negative impacts on farmers
	Grasslands	higher CO_2 concentration make trees better grow in savanna areas reducing grasslands	reduced availability of food for grazing animals with negative impacts for pastoralists
	Forests	more extreme temperature and rainfall conditions increase tree mortality in evergreen forests and woodlands	limited availability of timber resources for forest communities
	Freshwater	depletion of freshwater resources and wetlands	decrease area for flood recession agriculture, grazing for livestock and availability of freshwater fish for rural communities
	Coastal	sea-level rise increases coastal flooding	loss of land for coastal communities, increased salinization
	Oceans	warming and ocean acidification lead to bleaching of coral reefs and changes in fish species distribution	decrease in catch potential for coastal communities and fishery jobs

table continues next page

TABLE 2.1 (continued)

Region	Ecosystem	Examples of long-term climate change risks	Potential livelihood impacts of relevance for poor people
Middle East & Northern Africa	Drylands	warmer and drier climate shifts vegetation to the north and triggers desertification and soil salinization	increased water stress affecting livestock and crop production with negative impacts for smallholding farmers and herders
	Coastal	sea-level rise accelerates salinization of groundwater in the Nile Delta	damage to crop production with negative impacts of smallholder farmers
Europe & Central Asia	Forest	shift of boreal and temperate forests with heat waves, water stress, forest fires, and tree mortality in boreal forests in Russia	decline in timber harvest endangers jobs of workers in the forestry sector
	Drylands	expansion of arid areas and more frequent and intense droughts increase desertification	loss of area for rain-fed crop production and pressure on livestock with negative impacts for smaller agricultural producers
	Mountains	retreat of glaciers causing increased seasonal water variability and a significant water shortages in the long run	increased water stress affecting irrigated agriculture with negative impacts for workers on commercial farms
East Asia & Pacific	Freshwater	rising temperatures, salinity intrusion, and increasing tropical cyclone intensity exceeds tolerance for farmed fish species	damage to fish production with negative impacts for aquaculture farmers
	Coastal	sea-level rise and increased tropical cyclone intensity leading to increased coastal erosion and saltwater intrusion in river deltas and other low-lying areas, and loss of mangroves	loss of land for rice production in the Mekong Delta affecting farmers, reduced protection of coastal settlements and limited availability of mangrove forest resources for coastal communities
	Oceans	warming and ocean acidification lead to bleaching of coral reefs and changes in fish species distribution	reduction in fish catch potential with negative impacts for fishery jobs and coastal communities
South Asia	Mountains	glaciers loss in the Himalayas and Hindu Kush causes increased seasonal variability of water flows in glacier-fed river systems	reduced food production within river basins with negative impacts for smallholder farmers
	Terrestrial lands	changes in monsoonal precipitation increase river floods, number of dry days, severity of droughts, and reduction of groundwater resources	increased water stress affecting crop production with negative impacts for smallholder farmers
	Coastal	sea-level rise and increasingly intense tropical cyclones accelerate salinity intrusion in deltaic regions and wetlands	reduction in land that can be used for agriculture with negative impacts for farmers
Latin America & the Caribbean	Drylands	expansion of dryland areas and more extreme drought periods in Mexican dry subtropics and northeastern Brazil	increased water stress with negative impacts on local water supply and livestock and crop production affecting smallholder farmers
	Forest	dry season length, extreme drought, and forest fire cause tropical forest degradation	reduced availability of forest resources for indigenous people and other forest dwellers and forest-fringe communities
	Mountains	retreat of glaciers and changing snowfalls cause increased seasonal variability of river stream flows	negative impacts on water supply and crop production affecting smallholder farmers and indigenous communities in the Andes
	Coastal/Islands	sea-level rise, storm surge and tropical cyclones affecting small island states and low-lying coastal zones	loss of land and damages of tourism-related activities with negative impacts for coastal and island communities
	Oceans	ocean acidification and warming lead to coral bleaching in the Caribbean and fish species shift toward higher latitudes	decrease in catch potential in most waters with negative impacts for local fishermen

Source: Based on World Bank 2014b and World Bank 2014c.

quantification of these impacts, studies suggest severe livelihood impacts:

- Climate-related events have been shown to threaten livelihoods of poor people in a variety of rural contexts—such as precipitation variability in the Peruvian Andes (Sietz, Choque, and Lüdeke 2011); floods in Senegal (Tschakert 2007); drought in the West African Sahel (Sissoko et al. 2010) and in Northwest China (Li et al. 2013); and cyclone-related saltwater intrusion in coastal Bangladesh (Rabbani, Rahman, and Mainuddin 2013).
- Poor people can also be indirectly affected when climate change affects ecosystems that support their livelihoods, such as coastal and near-shore habitats (like wetlands, mangroves, coral and oyster reefs, and sea grasses) (Barbier, forthcoming). In Bangladesh, increased salinity linked to sea level rise reduced the suitability of land for rice farming (Dasgupta et al. 2014). In one Bangladeshi site, 70 percent of farmers partially or fully abandoned agriculture because of saline soils over a period of 10 years (Shameem, Momtaz, and Rauscher 2014).
- In the most extreme form of livelihood impacts, climate change could make ecosystems completely inhabitable, forcing out inhabitants—notably in small island states, some of which are at risk of disappearing before the end of the century (Burkett 2011). The low-lying Sunderbans, a coastal area between India and Bangladesh, are becoming a more difficult place to live for its mostly poor population, increasingly exposed to sea level rise, salinization of soil and water, cyclonic storms, and flooding (World Bank 2014a).

Conflict over environmental resources may exacerbate existing vulnerabilities of poor people. In Latin America, climate change and environmental degradation, along with the rapid growth of mining, could lead to greater competition for land and water resources. Smallholding farmers, indigenous communities, and other poor rural people are the most vulnerable because of their reliance on traditional systems built on ecosystems resources and their exclusion from formal policy making (Hoffman and Grigera 2013; Kronik and Verner 2010). In the high Andes, indigenous farmers face institutional marginalization and land scarcity compounded by delayed rainfalls, which lead to disputes over access to water and land (McDowell and Hess 2012). Similarly, after the 1998 floods, herders in northern Kenya tried to recover herd losses by raiding neighboring farms (Little, Mahmoud, and Coppock 2001).

Policies can avoid negative consumption effects and increase incomes

While climate change is quite likely to hurt agricultural yields and raise food prices, resulting negative impacts on poor people can be offset, at least partially, through socioeconomic development, better infrastructure and markets, improved farm practices and technological progress, and the preservation and strengthening of ecosystems. As for land-based mitigation policies, they can be designed to be pro-poor.

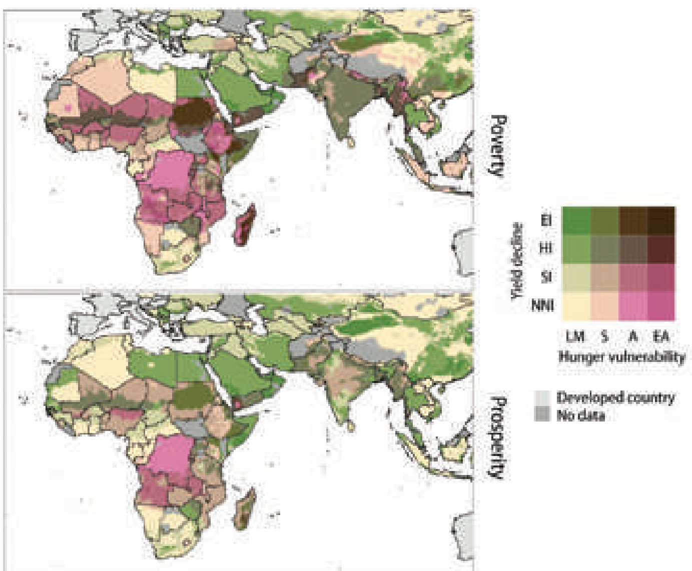
Negative impacts on food security can be reduced by development and poverty reduction

Food insecurity will be determined not only by yield declines but also by the socioeconomic conditions that make countries better prepared to respond to and adapt to such declines. Biewald et al. (Forthcoming) created a *hunger vulnerability* index, based on the Global Hunger Index (GHI) from von Grebmer et al. (2011).[5] This index represents in particular the fact that, as people get richer, they have better access to food markets and can buy their food instead of producing it. By 2030, development and increasing incomes reduce vulnerability to hunger in both the *prosperity* and *poverty* scenarios, with much greater progress in the *prosperity* scenario, thanks to its rapid reduction in poverty.

Socioeconomic vulnerability to hunger combined with climate-induced yield declines create potential food insecurity by 2030, especially in the *poverty* scenario. Map 2.1 shows where yields are expected to decrease, suggesting a reduced ability to produce locally, and where a high level of poverty may make it challenging to rely on food markets and imports. Most of the hotspots are in Sub-Saharan Africa. For example, most of Madagascar, Sudan, and Yemen suffer alarmingly high levels of yield decline and socioeconomic vulnerability to hunger in the *poverty* scenario. Angola and the Democratic Republic of Congo experience high socioeconomic vulnerability to hunger but only limited yield declines until 2030, while the opposite is true in the Middle East and North Africa. In India, where yield declines are modest, the socioeconomic vulnerability to hunger is serious in the *poverty* scenario, but decreases in parts of the country to moderate levels in the *prosperity* scenario.

The implication then is that development and poverty reduction can prevent some of the worst impacts of climate change on food security but do not replace targeted interventions to increase the resilience of the food production and distribution system.

MAP 2.1 Risks to food security would be much reduced in a more prosperous future



Source: Biewald et al., forthcoming.
Note: Risk to food security is indicated by the combination of potential yield declines and hunger vulnerability in a *Poverty* (upper panel) and *Prosperity* scenario (lower panel). Lighter colors indicate lower risks and darker colors represent higher risks. Results for yield decline are based on the Lund-Potsdam-Jena managed Land (LPJmL) model and results for hunger vulnerability are based on the spatial Vulnerability-to-Hunger Index (VHI) adapted from von Grebmer et al. 2011. Yield decline results compare a scenario with climate change to a scenario without climate change. The legend values are as follows: EI = Extremely high impact: decline of 10 percent or more, HI = High Impact: –10 to –2 percent, SI = Strong Impact: –2 to 0 percent; NNI = no negative impact: >0 percent. The Hunger Vulnerability index ranks spatial units on a 100-point scale. Zero is the best score (no hunger), and 100 is the worst: EA = Extremely alarming: ≥30, A = Alarming: 20 to 29.9, S = Serious: 10 to 19.9, LM = Low to moderate: below 9.9.

Better infrastructure and market access help cope with production shocks

As observed during the 2010 food price crisis, countries where global price increases are matched by high rises in local prices also experienced higher poverty increases (Ivanic, Martin, and Zaman 2012). Countries can insulate domestic markets from global prices by reducing import protection or increasing export restraints. But by doing so they both increase average domestic food prices and contribute to global volatility—for example, export bans, such as those imposed by a number of large exporters in 2008, reduced availability on international markets and contributed to higher prices (Anderson, Ivanic, and Martin 2013).

Well-functioning markets can help countries cope with production shocks, although the ability to rely on markets depends on many socioeconomic conditions—especially institutional barriers (like trade barriers) and transportation costs. Rural road development offers a strong potential to lower transport costs and spur market activity. In Ethiopia the incidence of poverty decreased by 6.7 percent after farmers gained access to all-weather roads (Dercon et al. 2009).

A productivity shock at the local level can lead to much greater price fluctuations if local markets are isolated. For example, a recent study examines the statistical effect of road quality and distance from urban consumption centers on maize price volatility in Burkina Faso (Ndiaye, Maitre d'Hôtel, and Le Cotty 2015).

It finds that maize price volatility is greatest in remote markets, suggesting that enhancing road infrastructure would strengthen the links between rural markets and major consumption centers, thereby also stabilizing maize prices in the region.

In addition, between 2006 and 2008, low food stocks may have exacerbated food price volatility (Gilbert and Morgan 2010), although an empirical analysis only confirms this effect for wheat since 2000. The absence of impact for other crops suggests that food stocks alone do not have a direct impact on price volatility but can amplify the effects of other factors (Tadesse et al. 2014). But while adequate food stocks can help to reduce price volatility and food insecurity, they can be costly and difficult to manage. And building food stocks can lead to increased grain scarcity and thus even higher prices in the short run. In the case of a large importing region—the Middle East and North Africa—one study shows that a strategic storage policy at the regional level could smooth global prices but is much more costly than a social protection policy that dampens the effects of price increases on consumers, like food stamps (Larson et al. 2013).

Thus, one solution appears to lie in coordinating measures aimed at limiting price volatility with actions to make farm practices more resilient. Together, these actions can significantly mitigate the impact of a shock, as occurred in Bangladesh in 1998 (box 2.4). Countries can also implement social protection schemes to ensure that vulnerable people are protected against food price volatility (see chapter 5).

Improved farm practices and technologies can mediate negative impacts

Climate-smart agricultural practices can increase productivity and make agricultural production more resilient. In countries most exposed to climate variability and change, disaster preparedness and resilient and diverse farming systems go hand in hand (World Bank 2011). For instance, Vietnam is improving its water resource management to make its cropping and aquaculture regimes

BOX 2.4 Mitigating losses from the 1998 flood in Bangladesh

The large-scale floods that hit Bangladesh in 1998 had the potential to cause a major food security disaster, but short-term and long-term policies played key roles in preventing such a disaster. Starting in the 1980s, public sector investment in agricultural research and extension, combined with private sector investments in small-scale irrigation, substantially increased yields of wheat and boro rice. These investments reduced vulnerability to floods by increasing total food grain production, reducing the length of time between major crops from 12 months to 6, and shifting away from flood-susceptible cultivation practices.

Furthermore, long-term investments in public infrastructure (including roads, bridges, electricity, and telecommunications) made agricultural markets more efficient and enabled traded grains to reach markets throughout the country after the floods.

In addition to infrastructure, government policies encouraged private-sector participation in the grain market. In the early 1990s, the liberalization of rice and wheat imports enabled private sector imports to quickly supply domestic markets and stabilize prices following the floods. Other policies—such as the removal of the import tariff on rice in 1998 and better port clearance of private sector food grain imports—also provided clear signals of government support for the private grain trade. These private sector imports proved a far less costly way of maintaining food grain availability than the distribution of government commercial imports or public stocks. And the inclusion of the private sector in general greatly increased food supply and stabilized food prices in the aftermath of the shock.

Source: Adapted from del Ninno et al. 2001.

better adapted to increasing flood risk and salinity levels. But more productive and more resilient practices require a more efficient use of land, water, soil nutrients, and genetic resources (FAO 2013).

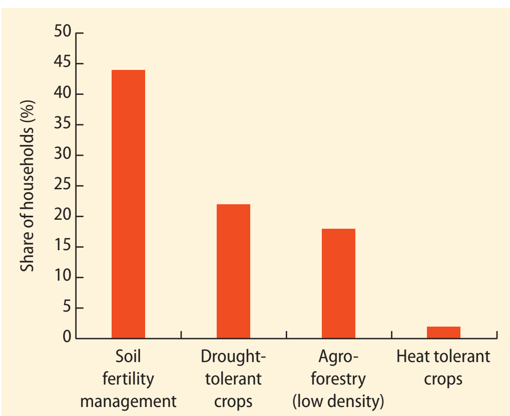
Better technologies will also be needed to tackle future food security challenges (FAO, IFAD, and WFP 2014). These might include improvements in crop varieties, smarter use of inputs, methods to strengthen crop resistance to pests and diseases, and reduction of postharvest losses (Beddington 2010; Tilman et al. 2011). Improved crops and better use of water and soil can increase both farmers' incomes and their resilience to climate shocks (figure 2.11).

One key way to make agricultural systems more climate resilient is by developing and adopting higher yielding and more climate-resistant crop varieties and livestock breeds (Tester and Langridge 2010). In a randomized control trial in Orissa, India, a recent study shows the benefits of using a new, flood-resistant variety of rice, which offers a 45 percent yield gain relative to the current most popular variety (de Janvry 2015). After a first good experience, these varieties motivated farmers to take more risks and adopt more profitable techniques.

But the overall potential of technology to increase resilience remains uncertain. Although many studies have shown that technological progress can limit climate change impacts on yields and food production costs (see figure 2.12), they usually assume sustained and very rapid yield gain, at odds with past yield trends. Empirical evidence reveals plateaus or even abrupt decreases in the rate of yield gain—for rice in eastern Asia and wheat in northwestern Europe (Grassini, Eskridge, and Cassman 2013). Further, another study points to a general decrease in the growth rate of yields for maize, wheat, rice, and soybeans at a global level, although with more optimistic trends in poorer countries (Alston, Beddow, and Pardey 2010). The low and declining levels of investment in agricultural research and development in the developing world can be a major constraint to realize further yield gains in poor countries (Pardey, Alston, and Chan-Kang 2013; Pardey and Pingali 2010).

FIGURE 2.11 Improved cropping technologies increase resilience in the African drylands

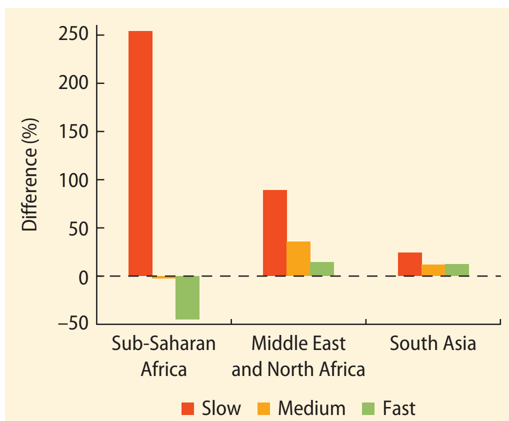
(Households made resilient)



Source: Cervigni and Morris 2015.

FIGURE 2.12 Faster technological progress would dampen long-term increases in food production costs

(Food production costs under varying assumptions regarding technological progress)



Source: Biewald et al., forthcoming.

Note: The values show the regional average changes in food production costs for Poverty and High Emissions Scenario without CO_2 fertilization compared to a no climate change scenario for the year 2030 based on results from the Model of Agricultural Production and its Impact on the Environment (MAgPIE). Food production costs used in MAgPIE account for all costs, including infrastructure (irrigation systems) and research, and thus can differ from the prices faced by consumers. Slow, medium, and fast in the legend refer to the speed of technological progress, which is assumed to translate directly into increase in yields.

Moreover, disseminating improved technologies and making them accessible to poor farmers will be critical for the gains from such technologies to materialize. Adoption of new technological packages is often slow and limited (box 2.5). Such technologies can be costly or difficult to access. For instance, in Africa, fertilizer application remains low because of high transport costs and poor distribution systems (Gilbert 2012). Furthermore, cultural barriers, lack of information and education, and implementation costs need to be overcome. Agricultural extension services can help to make better use of new technologies. In Uganda, extension visits coupled with the introduction of new crop varieties increased household agricultural income by around 16 percent (Hill and Mejia-Mantilla 2015). Secure tenure rights, smart subsidies, and access to long-term finance can also provide farmers with incentives to adopt climate-smart technologies and practices (World Bank 2012).

Conservation and ecosystem-based adaptation increase the resilience of ecosystems

The vulnerability of ecosystems to climate change impacts will also depend on nonclimate human-made impacts. For example, in the Amazon, self-amplifying feedbacks between reduced forest cover and extreme droughts resulting from a combination of global warming and forest cover loss puts the forest at risk for large-scale dieback (World Bank 2014c). Similarly, fishing-dependent countries in South and East Asia (such as Bangladesh, Cambodia, India, Indonesia, the Philippines Sri Lanka, and Vietnam), where fishing activities are poorly regulated, are very vulnerable to the combined impact of climate change and overexploitation (Barange et al. 2014).

This interdependence means that reducing nonclimate stresses on ecosystems can make them better able to adapt to climate change and continue to support livelihoods. Consequently, any measures that reduce or avoid land or forest degradation, depletion of natural resource stocks (such as fish), or pollution of water and soils can protect the ecosystems poor people depend upon and increase their resilience to climate change.

Targeted measures to foster ecosystem-based adaptation are a critical way to help ecosystems and poor people better prepare for climate change. They seek to strengthen ecosystem processes and services, as well as the human systems that maintain them, in order to make them more resilient to climate

BOX 2.5 Despite significant benefits, adoption rates of conservation agriculture remain limited

Technological packages, which have been successfully tested in demonstration fields, are available to help farmers better prepare for climate change. For instance, conservation agriculture has been promoted to address poor agricultural productivity and environmental degradation, particularly in semi-arid areas that are characterized by frequent droughts and dry spells (Giller et al. 2009; Kassam, Derpsch, and Friedrich 2014). Because of its potential to increase yields, reduce labor requirements, and improve soil fertility, it could be a powerful adaptation strategy (Kassam, Derpsch, and Friedrich 2014).

Nevertheless, despite these benefits, adoption is still uneven. In Brazil, millions of hectares are cultivated with conservation agriculture (Triplett and Dick 2008). But in Morocco, after two decades of demonstration, only 5,000 hectares are cultivated with these techniques—almost exclusively on large farms (ICARDA 2012). Low adoption rates are the case for most countries in the Middle East and North Africa and Sub-Saharan Africa, where the available evidence suggests virtually no uptake of conservation agriculture (Giller et al. 2009).

stress and other environmental degradation. Such approaches include better protection and management of natural habitat or vegetation, such as restoring and protecting mangroves and dunes in coastal areas; management of flood plains in larger river basins; managing forests sustainably through selective logging, forest buffers, and fire prevention; and farming systems that integrate natural vegetation through fallow systems or agroforestry (McKinnon and Hickey 2009). Many of these strategies also provide carbon sequestration benefits.

Land-mitigation policies can be designed to benefit local incomes

Land-mitigation policies can be designed to avoid—or at least minimize—harmful impacts on agricultural production and food security and poor people. Although calibrating general mitigation policies to local contexts or introducing complementary measures may increase the overall cost of mitigation (possibly because more efforts would be required in nonagricultural sectors), it could actually bring significant benefits in terms of improved local livelihoods and ecosystems.

Careful land use planning—such as using designated degraded or less-productive areas for storing and sequestrating carbon stocks—could minimize negative impacts on food production and even result in more productive landscapes. Restoring degraded forestlands and landscapes, as called for by the 2014 New York Declaration on Forests,[6] could yield net benefits in the general order of $170 billion per year from watershed protection, improved crop yields, and forest products if an area of 350 million hectares was restored by 2030 (NCE 2014). And most of the potential for energy crop production on degraded land is located in developing regions (Nijsen et al. 2012).

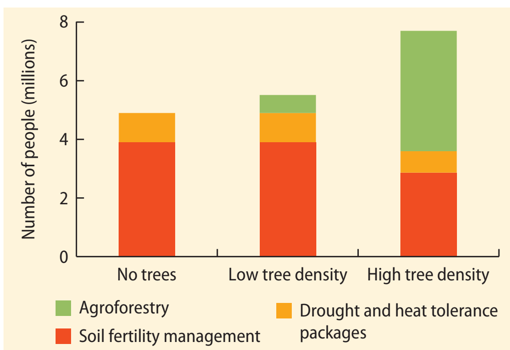
Adaptation and mitigation benefits can be reaped at the level of the plot (through reduced tillage), farm (soil terracing combined with tree management), and landscape (thanks to agroforestry and silvopastoral systems) (Harvey et al. 2014; FAO 2013; World Bank 2011). For example, the inclusion of trees in the farming system dramatically increases the potential to store carbon, while increasing yields—as shown in Africa, where farmers who have adopted evergreen agriculture are reaping impressive productivity gains of up to 30 percent without the use of costly fertilizer (ICRAF 2012). In Ethiopia, the Humbo Assisted Natural Regeneration Project has helped restore 2,700 hectares of biodiverse native forest, which has boosted carbon sequestration benefits and income generation based on forest products.[7] Improved tree coverage also reduced drought vulnerability (figure 2.13).

Some land-mitigation options can be implemented through payments for ecosystem services, which compensate land users for any forgone production benefits and provide them with financial incentives for preserving or increasing carbon stocks in soil or forests. More than 300 such payment schemes have been established worldwide to support carbon sequestration, biodiversity, watershed services, and landscape beauty (NCE 2014).

Even if trade-offs are likely to occur between social goals and project efficiency, many programs target poorer land users.

FIGURE 2.13 Drought vulnerability is reduced by agricultural techniques that integrate trees and store carbon

(Reduction in average annual number of drought-affected people)



Source: Cervigni and Morris 2015.

BOX 2.6 Securing local benefits from harnessing the forests to lower emissions

Increasing international attention and funding have been raised for reducing emissions from deforestation and forest degradation and for other land-related mitigation activities. At the 2010 Cancún meeting of the United Nations Framework Convention on Climate Change (UNFCCC), member countries agreed to establish an international mechanism, whereby developed countries would pay low-income and middle-income countries in the tropics for five types of forest-related mitigation activities, called REDD+: (i) reducing emissions from deforestation, (ii) reducing emissions from forest degradation, (iii) conservation of forest carbon stocks, (iv) sustainable management of forest, and (v) enhancement of forest carbon.

Concerns about negative social and environmental impacts—such as restricting access for local people to forests and harming biodiversity—led to the establishment of REDD+ "safeguards" within the UNFCCC decisions. These safeguards require countries to put procedures in place to ensure that social and environmental risks are minimized and benefits enhanced (UN–REDD 2013a).

Fair benefit-sharing systems that allow poor people to receive direct (like monetary gains) and indirect benefits (like better governance infrastructure provision) from REDD+ play a key role in operationalizing safeguards (Brockhaus et al. 2014). A precondition for such benefit sharing is tenure security and clarity that ensure access to ecosystems and participation rights for local people, which has become a key element of many national policies (UN–REDD 2013b). Under the Terra Legal program, Brazil has started a formal process of recognizing indigenous lands and granting land titles to about 300,000 smallholders conditional on compliance with the Brazilian Forest Code (Duchelle et al. 2014). The number of studies that illustrate how REDD+ can increase benefits for poor people is rapidly growing (Groom and Palmer 2012; Berry, Harley, and Ryan 2013; Luttrell et al. 2013).

Brazil's Bolsa Floresta program offers a monthly payment to low-income households if they commit to zero deforestation and enroll their children in school. Guatemala offers forest incentive programs, which aim to support forestry activities by poor smallholders without land title. In Colombia and Nicaragua, mainly poor land users receive payment for ecosystem services (Pagiola, Rios, and Arcenas 2008 and 2010). In Costa Rica, payments for reducing deforestation go mainly to poor areas (Pfaff et al. 2007). If participation constraints (like a lack of land titles, high transaction costs, or poor connections to government institutions) can be overcome, such payments could be an important livelihood element for poor people (Bremer, Farley, and Lopez-Carr 2014; Jindal et al. 2013; Zbinden and Lee 2005).

In other cases, mitigation actions need to be accompanied by complementary measures. Promoting modern energy for cooking can reduce the use of traditional wood biomass—which contributes to emissions through forest degradation and poor health—but often clean energy solutions are not affordable for poor people. Financing efficient cookstoves, introducing cash transfers, and enhancing social protection schemes can help to protect poor people against some of the negative impacts in the short term (chapter 5).

If done properly, land-based mitigation actions can create direct employment benefits for local people. Climate-smart agriculture practices, land restoration, selective logging, and forest protection are labor intensive and thus can provide jobs and revenues to poor rural households (see box 2.6). One study finds that over half of some 40 REDD+ projects reviewed provided benefits in terms of employment and incomes for local communities, although these benefits have been modest (Lawlor et al. 2013).

In conclusion

This chapter has shown how climate change can affect agricultural production systems with significant implications for food prices and food security. While these impacts may remain limited until 2030, they can become considerable in the longer term—especially in poorer regions. The only way to avoid this longer-term outcome is with mitigation policies that include agriculture, forestry, and other land uses, which are often the main sources of emissions in poor countries. But these policies must be designed in a way that avoids negative impacts, or that even benefits local production or incomes—or these policies risk adding pressure on food production and prices.

While increases in agricultural prices—triggered by climate change impacts or mitigation policies—will hurt all consumers, poor nonagricultural and urban households will be hit the hardest. In rural areas, farmers and agricultural laborers will experience mixed impacts. On the one hand, production shocks result in a direct drop in incomes. On the other hand, over the longer term, higher prices and wages could increase earnings, although this effect is more likely to reduce the negative impacts than to reverse them, especially if impacts are large. As for the resulting impact on poverty, our calculations (discussed in chapter 6) suggest that, in almost all possible scenarios, the net effect of the agricultural impacts of climate change will be to increase global poverty.

At the same time, climate change can add to existing stresses on ecosystems, which could undermine subsistence production, a critical safety net for the rural poor. Although such impacts remain difficult to quantify, case studies from various contexts show that climate stress coupled with ecosystem degradation forces households to alter their livelihood strategies.

The bottom line is that long-term climate change trends are likely to affect agriculture and ecosystems, with severe consequences for poor people and their livelihoods. These threats will be further amplified by the increasing frequency and severity of natural disasters, which will exacerbate production and price shocks in the short term, and could sharply increase poverty in the longer run—the topic of the next chapter.

Notes

1. These papers explore possible impacts in two *socioeconomic* scenarios: (i) a *prosperity* scenario (low population growth, high GDP growth, and low poverty and inequality) and (ii) a *poverty* scenario (high population growth, low GDP growth, and high poverty and inequality). See chapter 1 for a discussion of the scenarios and how they were chosen. The papers also explore possible impacts in two *climate* scenarios: (i) a *low-emissions* scenario (likely to result in a warming of 2°C by the end of the century compared to pre-industrial levels with limited impacts) and (ii) a *high-emissions* scenario (likely to result in a warming of 4°C with high impacts). The low-emissions scenario is consistent with the Representative Concentration Pathway (RCP) 2.6 of the IPCC, while the high-emissions scenario is based on the RCP8.5.
2. Impacts were calculated by comparing the agricultural price level (including crops and animal products) in the different emission scenarios—and thus with different magnitudes of climate change—with the prices that would occur without climate change.
3. In this model prices per tCO_2 (ton of carbon dioxide) increase to between $17 and $84 in 2030 and are between $200 and $1,000 in 2080.
4. Based on the first globally comparable data from 58 sites representing smallholder systems in (sub)tropical landscapes. These data over-represent sites with high forest cover and low population densities so that these numbers are not representative for all rural areas, but they provide an estimate for some of the most marginal environments.
5. The GHI is computed using three equally weighted indicators that are combined in one index, namely the proportion of people who are undernourished, the prevalence of underweight children younger than five, and the mortality rate of children younger than five. All three index components are expressed in percentages and weighted equally. Higher GHI values indicate more hunger; lower values indicate less.
6. http://www.un.org/climatechange/summit/wp-content/uploads/sites/2/2014/07/New-York-Declaration-on-Forest-%E2%80%93-Action-Statement-and-Action-Plan.pdf.
7. https://wbcarbonfinance.org/Router.cfm?Page=Projport&ProjID=9625.

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Threat Multiplier: Climate Change, Disasters, and Poor People 3

Main Messages

- Natural disasters push people into poverty and prevent poor people from escaping poverty.
- An increase in natural hazards is already observed and will worsen in the next decades. Some events considered exceptional today will become frequent in the long term, threatening current living conditions.
- These changes in hazards will affect poor people and our ability to eradicate poverty. Because poor people are often more exposed to natural hazards than the rest of the population, and almost always lose a greater share of their assets and income when hit by a disaster, natural disasters increase inequality and may contribute toward a decoupling of economic growth and poverty reduction.
- There are many options to reduce risks for poor people; and, although none are easy to implement, they do help reduce poverty and make the population more resilient to climate change. Examples include risk-sensitive land use regulation, more and better infrastructure, better housing quality and formal land tenure, air-conditioning, financial inclusion, and early warning and evacuation.

Introduction

Across the globe, on top of stresses on agriculture and ecosystems, shocks from natural hazards—from droughts to floods and storms—are a major reason why people become and stay poor. Indeed, evidence suggests that disasters increase poverty (Karim and Noy 2014). Consider the following examples:

- In Peru over the 2003 to 2008 period, one extra disaster per year increased poverty rates by 16 to 23 percent at the provincial level (Glave, Fort, and Rosemberg 2008).
- At the municipal level in Mexico, floods and droughts increased poverty levels by 1.5 to 3.7 percent between 2000 and 2005 (Rodriguez-Oreggia et al. 2013).

- In Bolivia, the poverty incidence rose 12 percent in Trinidad following the 2006 floods (Perez-De-Rada and Paz 2008).
- For coastal communities in the subdistrict of Shyamnagar in the southwest of Bangladesh, after Cyclone Aila hit in 2009, unemployment skyrocketed (from 11 to 60 percent between 2009 and 2010) and per capita income decreased sharply (from $15,000 before the storm to $10,000 after). The poverty headcount rate increased from 41 to 63 percent between 2009 and 2010 (Akter and Mallick 2013).

Moreover, recovery is not straightforward for poor people. After Ethiopia's 1984–85 famine, it took a decade on average for asset-poor households to bring livestock holdings back to prefamine levels (Dercon 2004). While a prolonged shock such as a drought can have long-term impacts, so too can temporary shocks on human capital and poverty (Rentschler 2013). In Mexico, once children have been taken out of school, even just for a temporary shock such as a flood, they are 30 percent less likely to proceed with their education compared to children who remain in school (de Janvry et al. 2006). Temporary spending adjustments by low-income households can result in permanent shifts—at the expense of the child's human capital and future productivity.

Further, poor households exposed to uninsured weather risk have been shown to reduce investment in productive assets and select low-risk, low-return activities, perpetuating poverty (Cole et al. 2013; Elbers, Gunning, and Kinsey 2007; Shenoy 2013). In terms of the impact of disaster risk on poverty, these ex ante impacts can dominate ex post impacts, that is, the losses caused by a disaster (Elbers, Gunning and Kinsey 2007). This link from natural hazard exposure to poverty may create a negative feedback loop, in which poor households have no choice but to settle in at-risk zones (with cheaper rents) and as a result face increased challenges to escaping poverty.

Natural disasters are thus one of the critical channels through which climate-sensitive events already affect, and can increasingly affect, the ability of poor people to escape poverty. An increase in the frequency or intensity of natural disasters is expected because of climate change—which is likely to push more people into poverty and increase poverty headcounts. Another key channel, agriculture and ecosystems, was covered in chapter 2, and a third, health, will be explored in chapter 4.

How can we explain the specific impacts of natural hazards on poor people? And what policy options are available to reduce this vulnerability of poor people, especially in light of climate change? Keep in mind that we are referring to all climate-related natural disasters, regardless of whether they are caused by natural climate variability or man-made emissions, as the two are closely linked and call for integrated risk management strategies that account for climate change.

This chapter tries to shed light on these questions. It begins with a short review of how climate change will affect natural hazards globally, then explores how these changes will impact poor people and affect the evolution of poverty. It draws on results from original studies that investigate—for the first time at the global level—the exposure differential between poor and nonpoor people, looking at droughts, floods, and high temperature. It also reviews several case studies on past disasters, deriving insights on the greater exposure and vulnerability of poor people, along with policy options to reduce this vulnerability.

Our main message is that the measures and policies that could be mobilized to help poor people manage natural risks in a changing climate amount to "good development," which would make sense even in the absence of climate change—with the important caveat that the design of such measures and policies needs to take into account climate change and the uncertainty it creates.

Climate change will worsen natural hazards in most regions of the world

The large-scale changes in temperature, precipitation, and other meteorological variables that models project as a result of climate change suggest that all extreme events related to these variables (droughts, floods, heat waves, and cold spells) will be affected. These impacts have been reviewed in many studies recently, including in the latest report of the Intergovernmental Panel on Climate Change (IPCC 2013) and in the three volumes of the *Turn Down the Heat* reports (World Bank 2015a). This section briefly reviews the changes in hazards to be expected.

Heat waves and cold spells. Climate change will not make all extremes worse in the future. Cold spells have serious consequences and are expected to decrease both in frequency and in intensity. However, it is almost certain that heat waves will become more frequent and intense in the future in most regions of the world. For instance, in North Africa, temperatures considered exceptional today (and that have significant harmful effects on ecosystem function and people's well-being) will become a new normal under a high-emissions (4°C) scenario (World Bank 2014) (map 3.1). In Europe, the summer 2003 heat wave, which led to more than 70,000 deaths, would become an "average" summer at the end of this century under a high-emissions scenario—meaning that by 2100, every other summer would be warmer than the 2003 one.

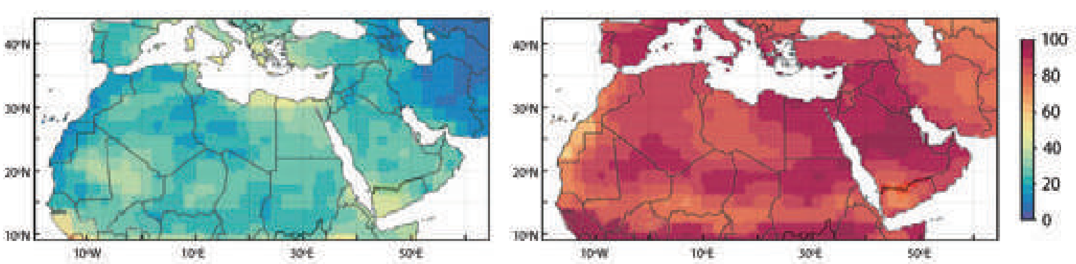
In many regions, such massive changes would threaten everyday living conditions—like the ability to work outside or in non-air-conditioned facilities during the summer. While no single heat wave or extreme event is "caused" by climate change, the effect of climate change on heat waves' frequency and intensity is already detectable and is growing over time (box 3.1).

Droughts. Water availability depends on more than just precipitation—seasonal cycles, snow packs, and evaporation rates also matter. Because of the variability in local changes in climate, the evolution of droughts will vary depending on location. Overall, however, droughts are likely to become more common—and it is likely that in many locations where droughts already are an issue the situation will worsen (like the Mediterranean basin, Southeast Europe, North Africa, Southern Africa, Australia, South America, and Central America). A background paper for this report estimates that under a high-emissions scenario, the number of people exposed to droughts could increase by 9 to 17 percent in 2030 and 50 to 90 percent in 2080 (Winsemius et al., forthcoming). Even so, some regions that currently experience regular water stress (like East Africa) are expected to see an improvement in water resources (map 3.2).

Tropical and extratropical storms. With higher temperatures, atmospheric circulations are modified, influencing winds and storms globally. But tropical storms (present in the tropics, the strongest of which are referred to as hurricanes in the North Atlantic and typhoons in the Pacific) and extratropical

MAP 3.1 Continued high emissions will mean many more "broiling" summer months

(Percentage of summer months with extreme temperatures by 2100, for a low-emissions (left) and high-emissions (right) scenario)



Source: World Bank 2014.
Note: Extreme temperatures are defined as temperatures that occur today less than once every 700 years.

BOX 3.1 Climate change makes extreme weather events more likely or more intense

Granted, *individual* events can never be fully attributed to climate change—even the most dramatic events of recent years would have been possible in a climate with no human influence, simply due to the natural variability of the climate (Hulme 2014). But recent *trends* in extreme temperature and precipitation can now be linked with climate change.

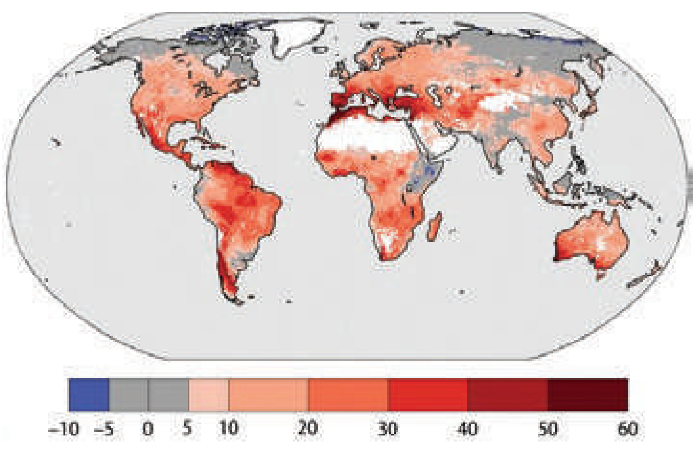
One recent study estimates that about 75 percent of the moderate daily hot extremes over land and 18 percent of moderate daily precipitation extremes are already attributable to warming (Fischer and Knutti 2015). And the probability of the occurrence of the 2003 European heat wave is estimated to have been doubled by the human influence on climate (Stott, Stone, and Allen 2004). About half the analyses of extreme events in 2012 find some evidence that human-caused climate change was a contributing factor, even though natural fluctuations also were key (Peterson et al. 2013). Heat waves, like the one that affected the U.S. midwest and northeast in July 2012, are now four times as likely because of climate change.

As for the current increase in disaster losses, they can be explained by socioeconomic evolutions—especially by the increase in population and wealth located in coastal and other at-risk areas. While an impact of climate change on economic losses probably exists, for now it remains undetectable (IPCC 2012).

Given the close interplay between natural climate variability and man-made climate change, disaster risk management cannot be separated from climate change adaptation.

MAP 3.2 With unmitigated climate change, total days under drought conditions will increase by more than 20 percent in most regions

(Change in the number of days under drought conditions by 2100 under a high-emissions scenario)



Source: Prudhomme et al. 2014.
Notes: Drought days are defined as days during which the river runoff is below 10 percent of the 1976–2005 average. Regions in white are those that experience very low runoff today and in the future.

storms (present in the mid- to high-latitude regions) may be impacted differently.

For tropical storms, a best guess today is that their overall number may decrease, even as the most intense storms may become more frequent, especially in the North Atlantic (IPCC 2013; Knutson et al. 2010; Ranson et al. 2014). In addition, tropical cyclones may start affecting new regions that are likely to be less prepared and more vulnerable (Hallegatte 2007; Kossin, Emanuel, and Vecchi 2014). A review of 11 studies concludes that economic losses from tropical cyclones could increase from 9 to 417 percent by 2040, depending on the region and the methodology applied (Bouwer 2013).

For extratropical storms, there is little agreement on how they will evolve, although models suggest that their intensity will increase and their mean trajectory will shift toward higher latitudes (Ranson et al. 2014). A review of seven studies finds that economic losses from extratropical cyclones could increase from 11 to 120 percent by 2040, depending on region and methodology (Bouwer 2013). And these studies do not account for sea level rise, which could make extratropical storms even more destructive (Hallegatte et al. 2013).

Coastal floods. Climate change will cause a global rise in sea level, with widespread consequences on coastal risks. This global rise combined with local mechanisms—including changes in water currents and local geological dynamics—will increase land loss from erosion, water salinization, and flood risks from storm surges in most coastal areas (World Bank 2014). Coastal flood risks are already large, as illustrated by the disastrous consequences of Tropical Cyclone Sidr in Bangladesh in 2007 or the destruction caused by Hurricane Katrina in New Orleans in 2005, and they will only increase over time (box 3.2). Multiple studies have shown how even a limited rise in sea level can significantly increase the likelihood of very destructive coastal floods (Jongman, Ward, and Aerts 2012; Wong et al. 2014).

Heavy precipitation and floods. As precipitation changes, so will river runoff—a development that may have large consequences on flood risk, with increases in some places and decreases in others. Averages are weak proxies for changes in risk, as extreme rainfall or river runoff can rise even in a region where average precipitation and runoff fall. Climate change is likely to exacerbate the most intense precipitation events (Min et al. 2011), with serious consequences for urban flash floods. Under a high-emissions scenario, the number of exposed people could increase by 4 to 15 percent by 2030 and 12 to 29 percent by 2080, according to a background paper for this report (Winsemius et al., forthcoming). Under current vulnerability levels, the total number of global fatalities may well double between now and 2080, based on the latest projections of climate change, population, and GDP (Jongman et al. 2015). Economic losses from river floods could increase by 7 to 124 percent by 2040, depending on the methodology applied and region considered (Bouwer 2013).

While climate change matters for the future of these hazards, nonclimate factors will also affect future risks. These include physical changes (like land subsidence for coastal risk), socioeconomic changes (like higher population and wealth in at-risk areas), and disaster preparedness. These changes will have large impacts and are likely to dominate the effect of climate change on economic losses from natural hazards in the next few decades (Bouwer 2013; Hallegatte et al. 2013; Mendelsohn et al. 2012).

Poor people are often—but not always—more exposed to hazards

Areas at risk of natural hazards have always attracted people and investment. Globally, there is a trend toward increased risk-taking: from 1970 to 2010, the world population grew by 87 percent, while the population in flood plains increased by 114 percent and in cyclone-prone coastlines by 192 percent. Further, the GDP exposed to tropical cyclones increased from 3.6 percent to 4.3 percent of global GDP over the same period (UNISDR 2011). The same trends hold at the country-level (Jongman et al. 2014; Pielke et al. 2008).

At-risk areas may be more attractive—in spite of the risk—when they offer economic opportunities, public services or direct amenities, and higher productivity and incomes (Hallegatte 2012a). In some rural areas, proximity to water offers cheaper transport, and regular floods increase agricultural productivity (Loayza et al. 2012). People may settle in risky areas to benefit from opportunities with industries driven by exports in coastal areas (box 3.2). Agglomeration externalities may attract people to cities, even if cities are more exposed than rural areas and newcomers have no choice but to settle in risky places. In a background paper prepared for this report, households in flooded areas in Mumbai, India, report that they are aware of the flood risks but accept them because of the opportunities offered by the area (such as access to jobs, schools, health care facilities, and social networks) (Patankar, forthcoming).

BOX 3.2 Large coastal cities: Wealthier places at risk of floods

The world's 136 largest coastal cities are examples of relatively wealthier places with large flood risks. A World Bank and Organisation for Economic Co-operation and Development (OECD) study (Hallegatte et al. 2013) estimates that average global flood losses today are about $6 billion per year, despite existing flood defenses. Even though these cities host pockets of deep poverty in slums and informal settlements, they are usually wealthier than the rest of the country, thanks to a concentration of export-led industries and skilled services. But they are also hotspots for flood risks, with widely varying protection levels. While cities in rich countries have the largest levels of risk in absolute terms, cities in developing countries experience higher relative risk levels (in percentage of local GDP), largely driven by lower protection. As map B3.2.1 shows, the 20 cities with the highest relative risks are almost all located in developing countries, especially in South and Southeast Asia.

Current trends in urbanization and economic growth alone are expected to increase flood losses in these cities, from $6 billion per year today to $52 billion per year by 2050. Environmental changes—climate change and land subsidence—would make losses soar rapidly if present protection is not upgraded. Even a moderate sea level rise (20 cm) combined with subsidence would make it necessary to invest massively in protection to avoid losses that could otherwise quickly reach levels of more than $1 trillion per year. Existing protection can rapidly prove ill-adapted to changing environmental conditions and generate very high risks, which are invisible until a disaster happens.

But even if adaptation investments (like higher dikes and seawalls) keep the probability of coastal floods constant, subsidence and sea level rise could increase global flood losses by 2050 to $60–63 billion per year. Further, since more population and assets would depend on protection, the consequences of a dike failure or of an event that exceeds protection design would become much higher. While better protection can reduce risk, it also raises the potential for larger-scale disasters if protections fail or are overwhelmed by an exceptional event—making it essential to develop early warning and evacuation systems, crisis-management preparedness, and reconstruction plans (Hallegatte 2012b; Hallegatte et al. 2013).

MAP B3.2.1 Most cities with the highest relative coastal flood losses are in South and Southeast Asia

(Average annual losses from coastal floods (relative to local GDP) in the 20 riskiest cities in the world)

Source: World Bank (IBRD 41909, September 2015) based on Hallegatte et al. 2013.

Within a country or region, the attractiveness of risky places means that people living there need not be poorer than the rest of the population. For instance, urban dwellers are, on average, wealthier than their rural countrymen. Since many cities are more exposed to floods than are rural areas, the urban-rural divide may make poorer people less exposed to floods than the wealthier urban population. However, at a more local scale and especially in urban areas, land and housing markets often push poorer people to settle in riskier areas. Where markets factor in hazard risks, housing is cheaper where risk is higher. And, because poorer people have fewer financial resources to spend on housing and a generally lower willingness and ability to pay for safety, they are more likely to live in at-risk areas.

The bottom line is that the "opportunity effect" attracts both rich and poor people to risky areas, even though land markets push poor people into riskier areas within a city. Whether poor people are more or less exposed than nonpoor people is an empirical question on which so far there has been little research. That is why this report explores the differential exposure of poor and nonpoor people, drawing on national studies and local surveys.

One of our background papers examines poverty-specific exposure to floods and droughts in 52 countries (Winsemius et al., forthcoming). It provides new insights by assessing if and where poor people are more exposed, and how this may change with a changing climate. Using the same socioeconomic data, another background paper examines the exposure of poor people to extreme temperatures (Park et al., forthcoming).

To understand whether poor people are more exposed to floods, droughts, and extreme temperatures we need "georeferenced" information (where people live, their income levels) and hazard maps—which have only recently become available at the global level and at high resolution (Ward et al. 2013 and Winsemius et al. 2013 for floods; Prudhomme et al. 2014 and Schewe et al. 2014 for drought). Our flood and drought hazard data come from a global model (GLOFRIS), which produces gridded indicators of inundation depth (for flood, 1 km resolution) and water scarcity (for drought, 5 km resolution). For temperature, we use observed spatial data on the maximum monthly temperature for each grid cell (at the 1 km resolution) from the Climatic Research Unit of the University of East Anglia, which provide gridded estimates of temperature extremes from 1960 onward.

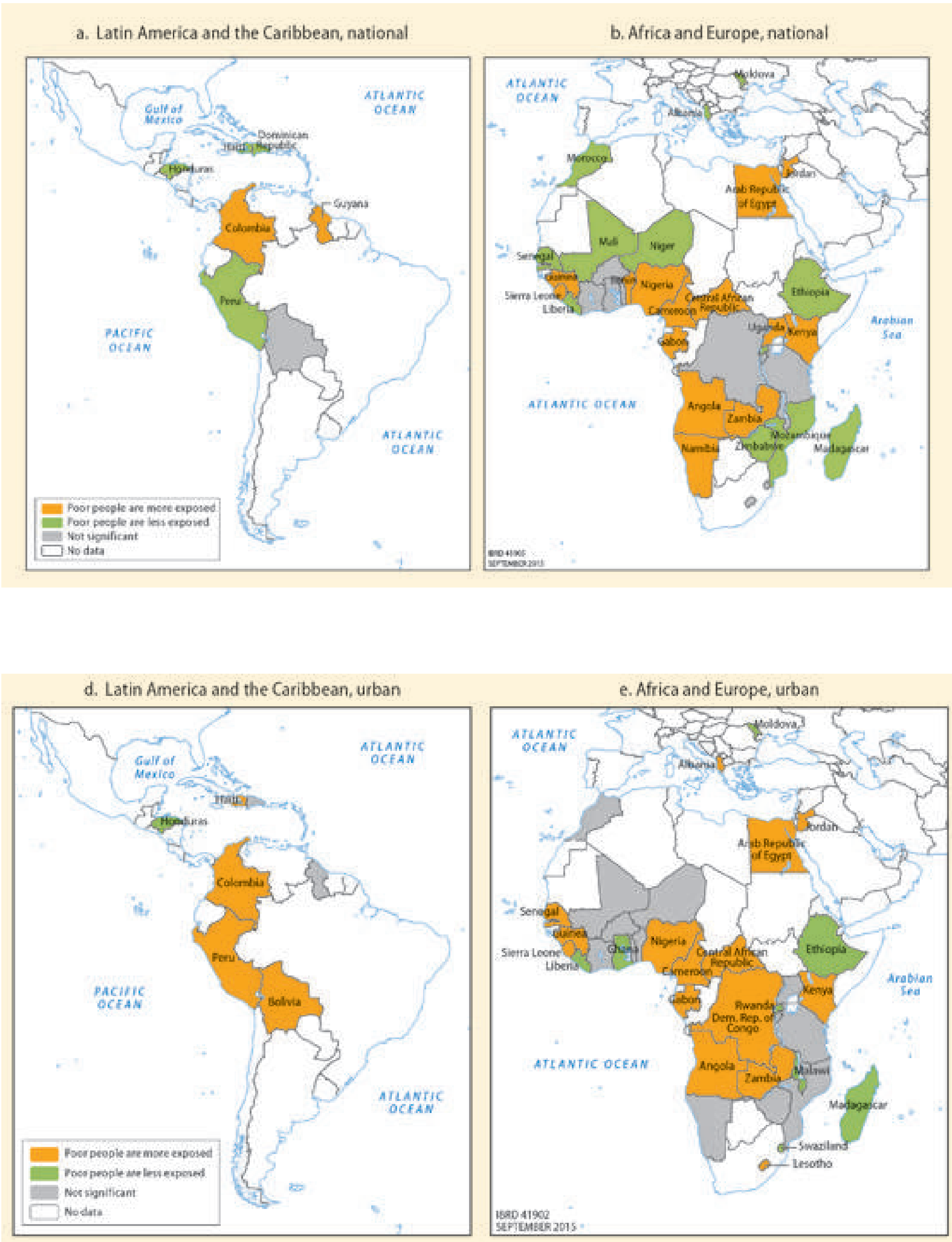
This state-of-the-art hazard data were combined with spatially explicit poverty data using a global dataset of household surveys in 52 countries from the Demographic and Health Surveys (DHS). These surveys contain data on each household's location and wealth status. By calculating the flood, drought, and temperature indicator at the household level, it is possible to examine whether and how this exposure is different for poor and nonpoor households. Poor people are defined as those in the lowest quintile of the population in terms of the "wealth index" provided in the surveys, which is a measure of the assets that a household owns.

Combining hazard and socioeconomic data, a *poverty exposure bias* can be used to measure whether poor people are more exposed to a hazard. For a given area, the poverty exposure bias is the share of poor people exposed to a hazard, divided by the share of the total population exposed, subtracted by 1. A positive bias means poor people are more exposed than average; a negative bias implies poor people are less exposed than average. With this definition in hand we ask whether poor people are more exposed to floods, droughts, and high temperatures within the 52 countries for which we have data.

Floods. For river floods at the country-level, we find mixed results as illustrated in map 3.3, panels a, b, and c, which show the poverty exposure bias for floods with a return period (or 10 percent annual probability of occurrence) of 10 years (other return periods show similar results). In Latin America and the Caribbean and Asia, no pattern emerges: some countries exhibit a positive bias (poor people

MAP 3.3 Poor people are more exposed to river floods in many countries, especially in urban areas

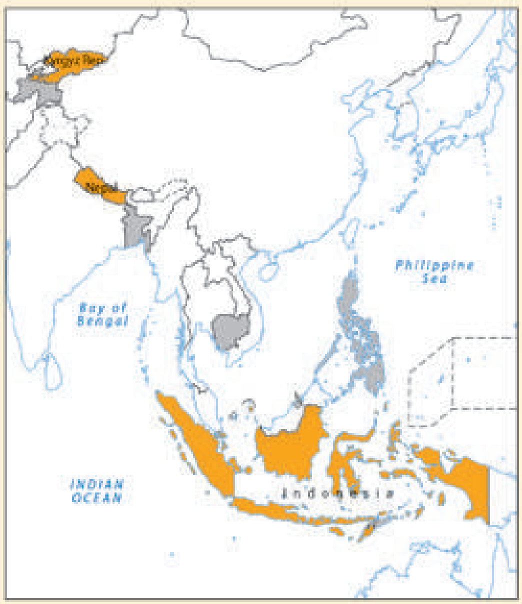
(Poverty exposure bias for floods at national level (top) and in urban areas only (bottom))



Source: World Bank (IBRD 41905 and 41902, September 2015) based on Winsemius et al., forthcoming.
Note: Exposure was calculated for the 10-year return period (results are similar for other return period events for floods).

c. Asia, national

f. Asia, urban



more exposed than average) and others exhibit no bias or a negative one (poor people less exposed than average). But in Africa, regional patterns appear. In the southwest, countries exhibit a strong overexposure of poor people, as do those with larger rivers in the west (like Benin, Cameroon, and Nigeria). Among the countries analyzed, about half (representing 60 percent of the analyzed population) live in countries where poor people are more exposed to floods than average.

What if we focus only on urban households? Land scarcity is more acute in urban areas (compared to rural areas), and thus might create a stronger incentive for poor people to settle in risky areas due to lower prices. The results for urban households demonstrate a clear difference between the exposure of poor and nonpoor people, as can be seen in panels d, e, and f of map 3.3. In most countries (about 73 percent of the analyzed population), poor urban households are more exposed to floods than the average urban population. There is no such pattern for rural households, suggesting that land scarcity is a driver of flood risk in urban areas. This phenomenon of high exposure to flood risk for poor urban dwellers is also found using micro-level data on household location and flood hazard in Mumbai, India (box 3.3).

Droughts. Results for droughts at the country level show a more prominent poverty exposure bias, as illustrated in map 3.4. In most Asian countries and in southern and eastern Africa, poor households are more exposed to droughts (the definition of drought here is based on surface flows only and does not include groundwater and artificial water storage). In western Africa, coastal countries (Benin, Cameroon, Ghana, Nigeria, and Togo) exhibit a positive bias, with the exception of Niger. In Latin America, poor people appear underexposed in Bolivia and Peru, but overexposed in Colombia, Guyana, and Honduras. Importantly, a number of Sub-Saharan African countries show a positive poverty exposure bias for both droughts and floods. When examining the total population, the

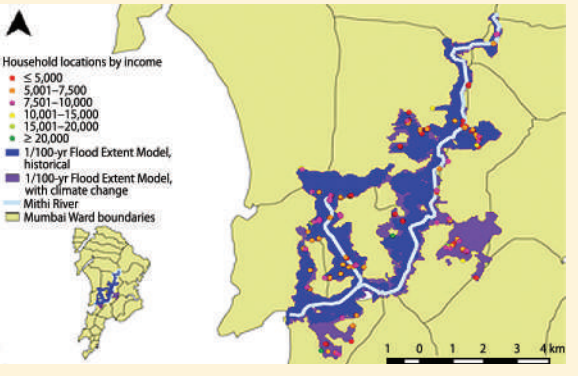
BOX 3.3 In Mumbai, poor people are disproportionately exposed to floods

In July 2005, Mumbai experienced an unprecedented flood, causing 500 fatalities and direct economic damages of $2 billion (Ranger et al. 2011). The flood took a toll on low-income and marginalized people—with their losses estimated at about $245 million, of which almost $235 million came from household asset losses and the rest from informal business losses (Hallegatte et al. 2010). While these impacts are large in and of themselves, they are likely an underestimate. Actual impacts on marginalized populations, especially health impacts and out-of-pocket expenditures, were probably much larger.

Are Mumbai's poor people more exposed than nonpoor people to current and future floods? To answer these questions we explore the exposure of poor and nonpoor people to similar floods in the Mithi River Basin flood zone, drawing on a city-level household survey (containing each household's location and income) and two flood maps (one based on today's climate and the other based on the climate projected in a high-emissions scenario by 2080), as illustrated in map B3.3.1.

Three results stand out. First, under both scenarios, households in lower-income levels are disproportionately exposed, with 75 percent of those exposed reporting a monthly income of 7,500 rupees or less (table B3.3.1)—and the richest households almost completely absent from at-risk areas. Second, more households overall are likely to be exposed to flood risks under the climate change scenario. Third, the distribution of exposure across poor and nonpoor people is similar for both scenarios: additional exposure (of climate change) has the same distribution as current exposure.

MAP B3.3.1 Mumbai's poor are over-represented in the Mithi River Basin flood zone



Note: Dots represent households (with associated monthly income in Indian rupees), overlaid with flood extent (blue is historical; purple is climate change impacts for 2080).

TABLE B3.3.1 Poor people tend to be more exposed to floods in Mumbai

Household income Rs./month	Share of population in survey (%)	Share of population exposed in 2005 (%)	Share exposed with 2080 climate (%)
< 5,000	27	44	43
5,000–7,500	28	33	34
7,501–10,000	22	16	17
10,001–15,000	12	5	5
15,001–20,000	6	1	1
> 20,000	6	1	1

Source: Calculations based on Baker et al. 2005 and Ranger et al. 2011. Thanks to Risk Management Solutions for production of flood maps. Household income shown in Rs. (rupees). The share of population exposed in 2005 and 2080 is based on modeling exercises.

poverty exposure bias is more evident: most people (85 percent of the analyzed population) live in places with an overexposure of poor people to droughts.

Temperatures. We find that poor people are often more exposed to higher temperatures: 37 out of 52 countries (representing 56 percent of the population) exhibit a positive bias (map 3.5). In Africa, most countries have a positive poverty exposure bias, with regional patterns similar to those found for floods and droughts, with the positive bias particularly strong in western Africa (Benin, Cameroon, and Nigeria) and southern Africa (Angola, Namibia, and Zambia). In Asia, the results for temperature are regionally consistent, with most countries exhibiting zero or negative bias; in Central America, results are again sporadic.

Also worrying is that many of the 37 countries that exhibit a poverty exposure bias for temperature are already hot. If we plot the poverty exposure bias against a country's average annual temperature from 1961 to 1999 (to represent average climate), we find that hotter countries have a higher exposure bias (figure 3.1, panel a). At the same time, cooler countries exhibit a smaller bias, and in some cool countries, a negative bias. This occurs because, in these cool countries, nonpoor people tend to settle in areas with higher temperatures because they are climatically more desirable.

The results for temperature suggest a sorting of the population into desirable and less-desirable areas within a country, with wealthier households typically living in desirable areas and poorer households in less-desirable ones. This is investigated in Nigeria, one of the hottest countries in our sample. We run a regression to estimate a household's wealth index conditional on the hottest monthly temperature a household experiences. Including socioeconomic and climatic controls, we find a clear signal that poorer households within Nigeria tend to live in hotter (less desirable) areas (figure 3.1, panel b).

One problem with studies of exposure at the national scale is that they may miss important mechanisms and small-scale differences, from one block to the next. Another way to examine whether poor people are more exposed to natural hazards is through in-depth case studies of actual past events, analyzing household survey data. While many studies of disaster impacts are available, only a few look at the exposure of poor and nonpoor people separately. We provide the first systematic review of their findings.

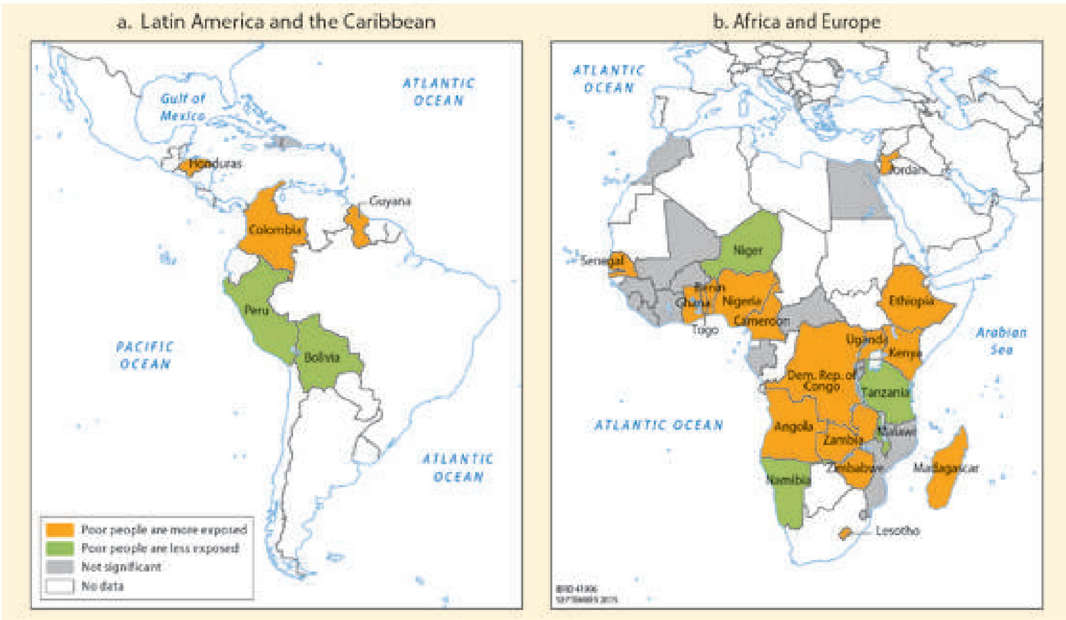
At the local scale, poor people seem much more likely to be affected by natural hazards. In Bangladesh, after Cyclone Aila hit in 2009, a postdisaster survey of 12 villages on the southwest coast finds that 25 percent of poor households in these villages were exposed to the cyclone while only 14 percent of nonpoor households were (Akter and Mallick 2013). In Vietnam, a similar pattern emerges for the Mekong Delta: 38 percent of the region's poor but only 29 percent of the region's nonpoor live in frequently flooded areas (Nguyen 2011).

However, this pattern is not universal. A postdisaster survey after the 1998 Great Flood in Bangladesh finds similar exposure: 75 percent of poor people and 71 percent of nonpoor people were affected (del Ninno et al. 2001). After the 2011 floods in Kenya, almost everyone in the Bunyala District was affected (Opondo 2013). In the Middle East and North Africa, a study of five countries finds that the percentage of households reporting being affected by a disaster in the last five years is high at 90 percent, but does not vary based on poverty status (Wodon et al. 2014). And in at least one documented case, poor people were less exposed: after Hurricane Mitch struck Honduras in 1998, more than 50 percent of nonpoor households were affected, but only 22 percent of poor households were (Carter et al. 2007).

Our conclusion is that most studies find that poor people are more exposed (figure 3.2). However, the relationship between poverty and disaster exposure is context specific and depends on the type of hazard, local geography, institutions, and other mechanisms.

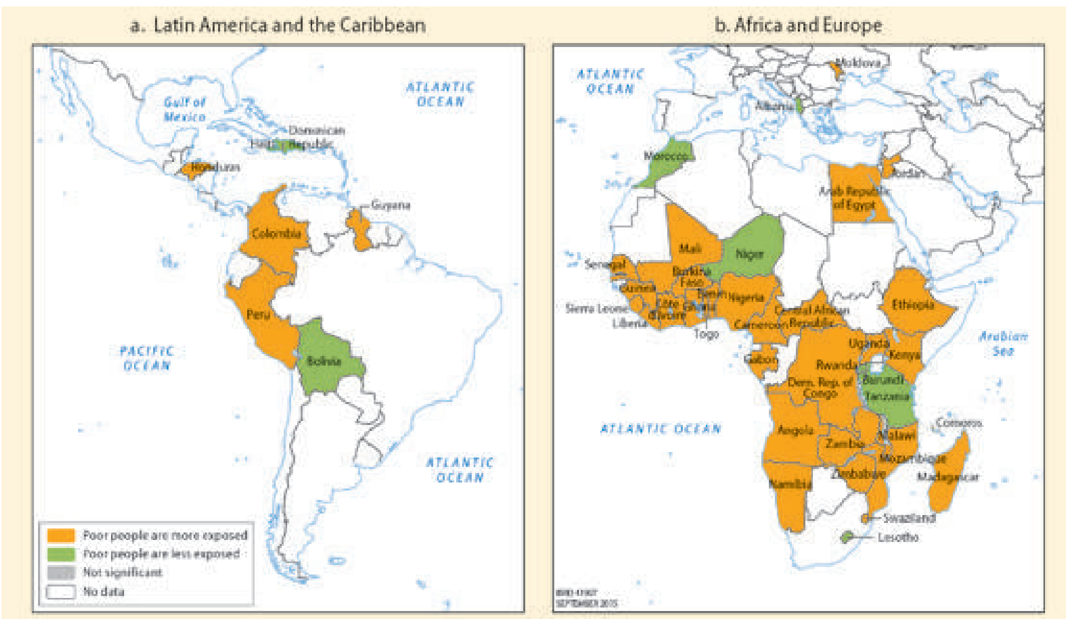
MAP 3.4 Sub-Saharan Africa's and Asia's poor tend to be more exposed to droughts than the nonpoor

(Poverty exposure bias for droughts at national level)



Source: World Bank (IBRD 41906, September 2015) based on Winsemius et al., forthcoming.
Note: Exposure was calculated for the 100-year return period (results similar for other return period events for droughts).

MAP 3.5 Poor people in most countries are more exposed to higher temperatures than nonpoor people



Source: World Bank (IBRD 41907, September 2015) based on Park et al., forthcoming.

c. Asia

c. Asia

Poor people lose relatively more to disasters when affected

Poor people are often—but not always—more exposed to natural hazards. But what about vulnerability? Do poor people lose more as a result of a disaster?

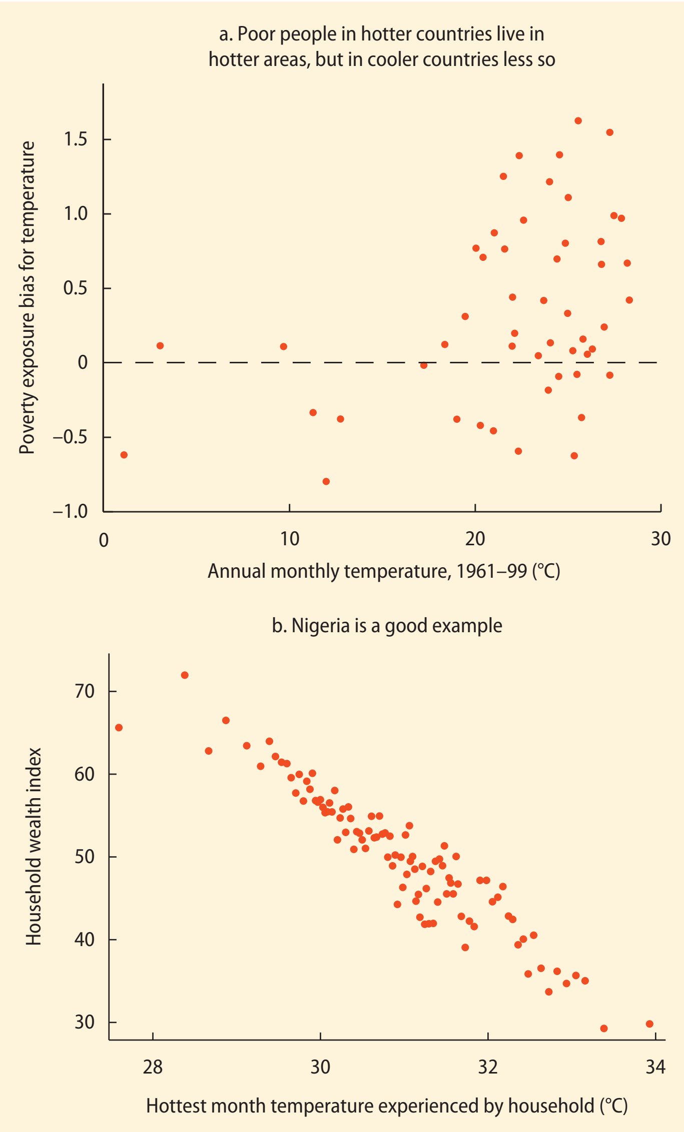
Answering these questions is challenging because of data limitations. While global data are sufficient for examining exposure, they cannot provide an estimate of vulnerability since that also depends on asset portfolios and livelihoods. However, out of the 13 local case studies that examine exposure to a disaster by poverty status, five (on Bangladesh, Honduras, and Mumbai) also examine losses for poor and nonpoor people separately (calculated as income losses, asset losses, or both) and provide insight on the difference in vulnerability.

The results show that in absolute terms, wealthier people lose a larger amount of assets or income because of a flood or storm, which is expected as they have more assets and higher incomes. But in relative terms, poor people always lose more than nonpoor people from floods and storms (figure 3.3). It is these relative losses, rather than absolute numbers, that matter more for livelihoods and welfare.

In Bangladesh, one study surveyed 700 floodplain residents living without protection along the Meghna River (Brouwer et al. 2007). The authors collected data on the average flood damage experienced because of floods for households above and below the poverty line. In absolute terms, households above the poverty line lost more: $240 per year, compared to $191 for those below the line. However, poor people lost much more in relative terms: 42 percent of household income compared to 17 percent for nonpoor people.

In Honduras, following Hurricane Mitch in 1998, a study investigated losses across wealth quartiles based on a survey of 850 rural households (Carter et al. 2007). Affected households in the bottom quartile lost nearly three times as much in relative terms as other households: 31 percent of their assets for

FIGURE 3.1 Poor people in hotter countries—like Nigeria—live in hotter areas, but in cooler countries, less so



Source: Park et al. forthcoming; World Bank 2015b.
Note: Panel a plots country-level poverty exposure bias for temperatures against each country's current climate. Panel b plots household-level wealth and temperature within a country—Nigeria.

the poor compared to 11 percent for the nonpoor.

In Mumbai, the 2005 floods not only caused direct losses to households' assets but also meant that the inhabitants lost income and spent large amounts on repairing or reconstructing their homes (Patankar and Patwardhan, forthcoming). A survey of 1,168 households shows that, while nonpoor people had higher absolute losses, poor people lost more as a percentage of income, across all three loss categories (table 3.1). When combining income, asset, and repairs, the total losses from the event reached 85 percent of the average annual income of the poorest people. These impacts obstructed the ability of households to recover in the aftermath—not least because the loss of assets meant many poor households found themselves unable to borrow or repay previous loans (Rentschler 2013).

Why is it that poor people lose relatively more? For asset loss, poor people hold lower-quality assets and keep the assets in a more vulnerable form. For income loss, poor people tend to be more dependent on lower-quality infrastructure and natural capital to earn an income. They also are vulnerable to food price rises, and women and children are especially vulnerable to health impacts. We review each in turn.

Poor people hold more vulnerable and lower-quality assets

The typical asset portfolio of a poor and a nonpoor person are very different. Poor people tend to have less diversified portfolios: they hold a larger percentage of their assets in material form and save "in kind." The first "savings" of poor urban dwellers are often through investments in their home, which are very vulnerable to floods (Moser 2007), while many rural poor use livestock as savings in spite of their vulnerability to droughts (Nkedianye et al. 2011). Nonpoor people, with higher financial access, are able to spatially diversify and save in financial institutions, and their savings are thus better protected from natural hazards.

In addition, the quality of assets owned by poor people is lower. Take for instance housing stock. Households living in slums or informal settlements made out of wood, bamboo, and mud on steep slopes will suffer more damage compared to individuals in housing made out of stone or brick. In coastal communities in southwest Bangladesh, following Cyclone Aila, 76 percent of households in "kacha" houses (traditional homes built with mud and bamboo) reported structural damage—far above the 47 percent for those in "pucca" houses (built with concrete and wood). In terms of economic damage, the average for kacha houses, $400, was also well above the $133 for pucca ones. Further, households in kacha houses were significantly more likely to experience fatality or physical injury—on average, 0.28 people per kacha house were injured or killed from the cyclone, compared to 0.13 per pucca house.

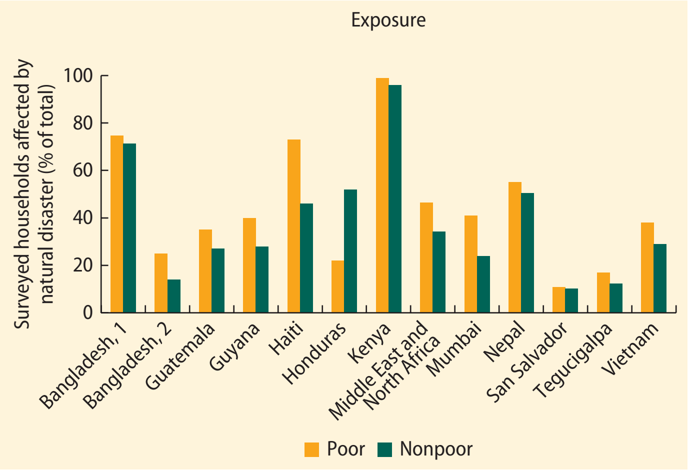
Poor people depend on fragile infrastructure and are not well protected

Besides private income and asset losses, natural disasters cause significant disruption to public infrastructure. While all people, to some extent, depend on electricity, working roads, and running water to earn a living, poor people tend to be less able to protect themselves from the consequences of disruptions in infrastructure services. And poor people often rely on more fragile or undermaintained infrastructure—such as unpaved roads that are impractical during the rainy season, or drainage systems that are insufficient or clogged by solid waste.

Another important issue is how infrastructure investments are distributed spatially (Fay 2005; Olsson et al. 2014; Tschakert 2007). Too often, investments are directed toward relatively wealthier places, at the expense of poorer neighborhoods. This effect can amplify the exposure gap between poor and nonpoor households and generate pockets of high risk. Progress along this dimension requires appropriate governance mechanisms, including giving poor people a voice in investment decision-making processes (chapter 5). Poor households

FIGURE 3.2 When disasters hit in the past, poor people were more likely to be affected

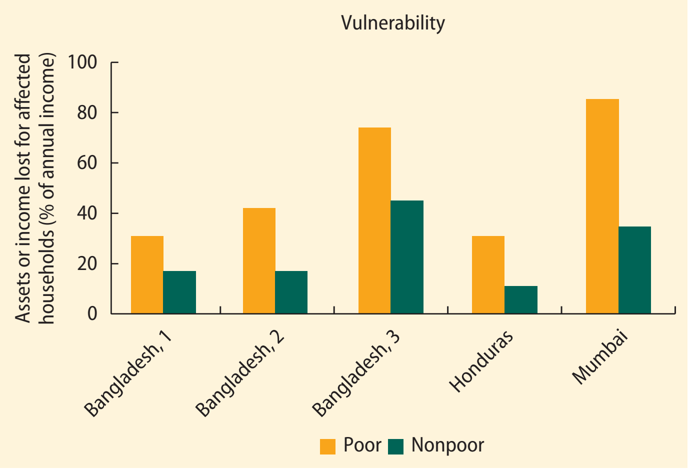
(Percentage of poor and nonpoor people affected by a disaster)



Source: Based on del Ninno et al. 2001 for Bangladesh (1) and Akter and Mallick 2013 for Bangladesh (2); Tesliuc and Lindert 2003 for Guatemala; Pelling 1997 for Guyana; Fuchs 2014 for Haiti; Carter et al. 2007 for Honduras; Opondo 2013 for Kenya; Wodon et al. 2014 for MENA; Baker et al. 2005 and Ranger et al. 2011 for Mumbai; Gentle et al. 2014 for Nepal; Fay 2005 for San Salvador and Tegucigalpa; and Nguyen 2011 for Vietnam.
Note: Each study has a different definition of "poor" and "nonpoor" people; further, exposure differs based on the type of hazard and context in which it occurs.

FIGURE 3.3 Poor people always lose relatively more than nonpoor people

(Percentage of assets or income lost for poor and nonpoor people after a disaster)



Sources: del Ninno et al. 2001 for Bangladesh (1); Brouwer et al. 2007 for Bangladesh (2); Rabbani, Rahman, and Mainuddin 2013 for Bangladesh (3); Carter et al. 2007 for Honduras; and Patankar and Patwardhan, forthcoming, for Mumbai.
Note: Each study has a different definition of "poor" and "nonpoor" in its sample. Vulnerability depends on the type of hazard and context in which it occurs; even within the same country (Bangladesh), vulnerability measures vary greatly based on location and severity of flooding. The first three studies use percent of income loss as a metric, while the Honduras case uses asset loss and the Mumbai case uses asset, income, and repair loss. For Honduras, the graph reflects asset losses relative to total assets.

TABLE 3.1 Poor people in Mumbai suffered higher relative losses from the 2005 floods

Average annual income (Rs.)	Number of households	Total loss (Rs.)	Income loss	Asset loss	Repair loss	Total loss
			as a % of yearly income			
< 60,000	192	51,000	16	29	40	85
120,000	806	62,000	10	20	22	52
270,000	124	83,000	6	13	12	31
450,000	15	143,000	3	7	21	32
> 540,000	10	104,000	8	4	8	19

Source: World Bank calculation based on Patankar and Patwardhan, forthcoming. Around the time of the flood, 50 Rupees was equivalent to about US$1. Numbers rounded for clarity.

sometimes spend a lot of time and effort lobbying local authorities to invest in their communities to provide basic infrastructure (such as roads, piped water, and sanitation) (Moser 2007, 85). Nevertheless, households with little social capital will be unable to "invest" in public goods and improve their quality of life.

In Mumbai, impacts from a lack of appropriate infrastructure can be pervasive (Patankar, forthcoming) (box 3.4). Many low-lying and reclaimed areas across the city get flooded, especially when heavy rains combine with high tide or storm surges, with the added difficulties due to unsanitary methods of solid waste and sewage disposal and problems with the drainage systems. After flooding, more than 75 percent of surveyed households report electrical disruptions, a lack of local transport and clean drinking water, and sewage and garbage in their homes—all of which magnified the impacts of floods (Patankar and Patwardhan, forthcoming). Although many people were affected, poor people were the ones with fewer options to cope with infrastructure damage.

Many poor people depend on agricultural and ecosystem incomes that are particularly vulnerable to hazards

Another source of vulnerability is the reliance on agricultural and ecosystem incomes. Chapter 2 discussed the fact that poor people, especially in rural areas without functioning markets, are highly dependent on agricultural income and ecosystems, and are therefore vulnerable to the impacts of climate change on yields and ecosystems' health and functioning. Here we focus on how this dependency translates into a higher vulnerability to natural hazards.

Large-scale events can wreak havoc on natural capital. In 2008, Cyclone Nargis hit southwest Myanmar, killing an estimated 140,000 people, and recovery is still far from complete (World Bank 2015c). A major reason is the damage to embankments and streams from the cyclone, which resulted in a reinforcing chain of events for affected farmers. Erosion and destroyed embankments made fields more prone to flooding. Further, the duration of daily and monthly tides became longer after Nargis, making fields more saline and prone to pest infestation. Without funds for repair, affected farming villages became more prone to these external events—flooding, saline intrusion, and pest infestation. As a result, yields decreased, as did income. Households have attempted to borrow money but this has led only to more indebtedness.

Furthermore, natural capital often serves as a safety net after a disaster, when not depleted (Barbier 2010). In Bangladesh after Cyclone Aila hit in 2009, households living closest to the coast, while more exposed and vulnerable to the storm (and poorer), had a

BOX 3.4 Hidden costs of recurrent hazards for poor people in Mumbai and Ho Chi Minh City

Large-scale events make the news, but repeated small adverse events such as regular floods often have serious implications for poor people, affecting their livelihoods and their ability to accumulate assets. To get a better sense of the "hidden costs" of such events, take the following two cases.

Recurrent floods in Mumbai. Mumbai is prone to recurrent floods during the monsoon season, with significant impacts on poor people (see a background paper for this report, Patankar, forthcoming). Based on the experience of recurrent floods, the authorities have identified 40 chronic flood spots (low-lying areas) and 200 localized flood spots (where waterlogging is due to inadequate drainage and poor land use planning). When we combined this spatial data with land use maps (Planning Department 2015), we found that land use in the flood-prone wards suggests an unplanned mix of residential, commercial, and industrial activities coexisting without clear zoning. As a result, recurrent floods expose a large number of residents, including those in the many low-income slum settlements, who report floodwaters entering their houses many times during the monsoon season.

A survey of 200 households yields two key insights. First, households regularly report problems with transport, drinking water, power supply, and food and fuel availability because of the floods. One implication is that households lose workdays: on average 2.5 per year because of poor infrastructure (more than 50 percent cite unavailability of transport or flooded roads)—implying a loss of income and productivity and sometimes jobs. Second, almost 40 percent of households report someone in the family experienced health impacts from diarrhea yearly due to floods, with this figure rising to 64 percent for malaria and 86 percent for viral fever. Between 2001 and 2011, the number of reported cases of malaria has increased by 217 percent, mainly due to lack of sanitation in slums and water accumulation during the monsoon season (Public Health Department 2015).

Recurrent floods in Ho Chi Minh City. A survey of three flood-prone districts in Ho Chi Minh City finds health impacts to be pervasive (World Bank and Australian AID 2014). Regular floods in a heavily polluted environment have led to many ailments—including skin and intestinal diseases, rheumatism, bronchitis, and chronic coughing, especially among children under five. Every year, more than two-thirds report that they are suffering from health issues, with more than half suffering from a water-borne (55 percent) or respiratory disease (52 percent) directly related to local flood conditions. These impacts also take a significant toll on employment and income, especially for poor people (table B3.4.1).

TABLE B3.4.1 The health of Ho Chi Minh City's poor is especially vulnerable to flood impacts

Indicator	Total	Poor (n = 36)	Nonpoor (n = 210)
% households whose health was affected	68	86	64
% households whose employment was affected	58	69	56
% households whose income was affected	44	67	40

Source: Based on World Bank and Australian Agency for International Development 2014.

more resilient income because the proximity to mangrove reserves offered higher income-generation opportunities than for inland inhabitants (Akter and Mallick 2013). As stressed in chapter 2 and in a background paper for this report (Noack et al., forthcoming), climate change impacts on these ecosystems may impair their ability to serve as a safety net and to smooth consumption in the face of shocks.

Poor people are more vulnerable to rising food prices after a disaster

Another point that was made in chapter 2 is that poor people in developing countries spend on average between 40 and 60 percent of their household budget on food—far more than the 25 percent spent by nonpoor people. This makes them more vulnerable than the rest of the population to increases in food prices (although net food producers could gain, if they can maintain their production level). Here, we show that this vulnerability matters in postdisaster situations.

After tropical Storm Agatha struck Guatemala in 2010, per capita consumption fell 13 percent, raising poverty by 18 percent; in particular, food expenditures fell 10 percent, accounting for 40 percent of the total consumption drop (Baez et al. 2014). This stemmed from a major loss in food infrastructure and transport, resulting in a 17 percent increase in food prices 10 months after the storm. Agatha thus caused a logistical problem rather than a decline in domestic production, since it occurred in the middle of the first planting season, at a benign time with respect to local agricultural cycles.

Natural disasters can also result in food price spikes as a result of supply shocks. Disasters can destroy crops and seed reserves, destroying productive assets in agricultural communities and sparking food price shocks, as occurred after the unprecedented 2010 floods in Pakistan (Cheema et al. 2015). The floods destroyed 2.1 million hectares of agricultural land, decimating production and sending prices of wheat upward of 50 percent above the preflood level.

How does poverty fit into the picture? In Bangladesh, after the 1998 Great Flood, a study shows that consumption levels differed based on exposure *and* poverty status (del Ninno et al. 2001). There was no difference in calorie consumption between exposed and nonexposed households in the top quintile, but in the bottom quintile the difference was 11 percent. For those exposed, bottom-quintile households on average consumed 1,400 calories per capita, and 80 percent fell below the minimum daily caloric requirement of 1,800; however, the average calories consumed for exposed top-quintile households remained above 3,000. In addition, two-thirds of bottom-quintile households spent more than 70 percent of their budget on food. As a result, 48 percent of the households in the poorest quintile were deemed food insecure after the flood, compared to an average of 16 percent across all quintiles (table 3.2).

Children are particularly vulnerable to indirect impacts through health and education

Building human capital through better health and education is a vital component of escaping poverty, but natural disasters can worsen health and education outcomes, especially for children (chapter 1).

TABLE 3.2 Bangladesh's poor became food-insecure after the 1998 Great Flood
(Percentage of affected households reporting food security impacts by expenditure quintile)

	Quintiles					
	Poorest	Q2	Q3	Q4	Richest	All
Spending more than 70% on food	66	59	66	51	0.4	49
Below minimum caloric requirement	80	50	25	13	0.1	35
Food insecure	48	17	9	0	0.9	16

Source: del Ninno et al. 2001.
Note: Numbers rounded for clarity.

There are acute health effects on children from the direct impact of disasters and lower postdisaster consumption, especially after droughts. In Ho Chi Minh City, in the Thanh Xuan Ward of District 12, a majority of children experience fevers, coughing, and flu during a high-tide period (World Bank and Australian AID 2014; and box 3.4). Following weather shocks in Sub-Saharan Africa, asset-poor households provide children with lower-quality nutrition and are less likely to take sick children for medical consultations, with long-term impacts on child development and prospects (Alderman, Hoddinott, and Kinsey 2006; Dercon and Porter 2014; Jensen 2000; Yamano, Alderman, and Christiaensen 2005).

Impacts on education are also prevalent. In Africa, children affected by droughts are less likely to complete primary school (Alderman, Hoddinott, and Kinsey 2006; Dercon and Porter 2014), and similar impacts have been found in Asia, Latin America, and elsewhere (Baez, de la Fuente, and Santos 2010; Maccini and Yang 2009).

Moreover, women are particularly vulnerable as they often take greater responsibility for household chores, increasing their hardships during floods. This is in addition to time taken off work (sometimes for a couple of months) to care for children who become sick because of living in flood conditions, which can be especially punitive for factory workers. Women also spend more time at home to clean after a flood, making them more likely to contract waterborne diseases.

The reasons why poor people are more at risk point to possible policy solutions

So, if poor people are disproportionately affected by disasters—and here the evidence is compelling—what can be done to make them less exposed or vulnerable? This section builds on the insights of the previous one to identify six examples of policies that could improve the resilience of poor people. The benefits of these actions could be significant, even without man-made climate change. An increase in the frequency or intensity of natural hazards due to climate change would make these benefits even larger, provided that policies and measures are designed to account for climate change and the uncertainty it creates.

Risk-sensitive land use regulations: Critical but challenging to implement

A major reason why poor people often live in riskier areas is cheaper housing. In Ho Chi Minh City, qualitative surveys suggest flooded areas can be much cheaper than nonflooded areas for the same quality of accommodation (World Bank and Australian AID 2014). In addition, recent experience of a flood can reduce housing prices by around 9 percent (Husby and Hofkes 2015).[1]

In developing countries with informal markets, land scarcity can be particularly acute and land markets function poorly (Durand-Lasserve, Selod, and Durand-Lasserve 2013). In these places, it may not be the prices that push poor people into risky places, but simply the availability of land with appropriate access to jobs and services. Informal settlements are often located in hazard-prone locations, such as on hill slopes, close to riverbanks, or near open drains and sewers, as in Pune, Dhaka, Caracas, Rio de Janeiro, and Mumbai (Lall and Deichmann 2012; Lall, Lundberg, and Shalizi 2008; World Bank 2007).

Land use regulations can help by ensuring that new development occurs in places that are safe or easy and cheap to protect. They can also avoid unchecked urban development that leaves too little porous green space and further increases runoff and flood risk (Lall and Deichmann 2012). But doing so remains challenging for a number of reasons.

First, countries need appropriate data on risk and hazard to identify places that are too risky to develop, or where development is possible provided that buildings and infrastructure are built following strict rules. Unfortunately, access to risk information still varies greatly and is quite limited in low-income environments. To address this issue, the World Bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) are investing in risk information. The GFDRR's *Open Data for Resilience Initiative* supports the creation of GeoNode, a web-based open source platform that makes it easier to develop, share, manage, and publish geospatial data (www.geonode.org). Such initiatives can make a difference locally, by making risk information freely available not only to professionals but also to the public.

Second, countries need strong institutions that can ensure that land use plans are actually enforced. In most of the world today, risk-sensitive land use plans face strong political economy obstacles, and are only rarely enforced (World Bank 2013, chapter 2). One of the main obstacles is the asymmetry between the costs and benefits of risk-sensitive land use planning. The costs of flood zoning are immediate, visible, and concentrated, in the form of reduced land values for landowners and higher housing costs for tenants (Viguie and Hallegatte 2012). In contrast, the benefits occur through avoided losses—which nobody can see—sometimes in the future, and go to unknown people. In such a context, the opponents to flood zoning are usually vocal and well organized while beneficiaries are absent, making the policies difficult to pass and enforce.

Third, countries need to design land use plans in a way that accounts for the reasons why people decide to live in risky places—primarily, access to jobs and services. When asked what it would take to consider relocating to a safer, less flood-prone area, 44 percent of households in Mumbai cited transport, along with the availability of health services, schools, and social networks (Patankar, forthcoming). In Ho Chi Minh City, local and migrant households do not have any plans to move despite high flood risk and health impacts (World Bank and Australian AID 2014). The reasons, according to most of the 246 survey respondents, are the considerably cheaper rents in risky areas and proximity to work (usually in factories) for late return at night. Thus, to be effective, flood zoning should be accompanied by investment in transport infrastructure to make it possible for people to settle in safe places while maintaining access to the same (or comparable) jobs and services.

Fourth, countries need to remember that land use regulations can have unintended consequences, particularly for poor people. Restrictive flood zoning policies can increase housing costs, making it more difficult for rural poor people to move to cities and capture the opportunities of an urban life (like better-paying jobs and better health care and education). Restrictive policies can also worsen risks. In Mumbai, because of strict regulations, buildings have been held to between a fifth and a tenth of the number of floors allowed in other major cities (Lall and Deichmann 2012). The resulting low-rise topography contributes to land scarcity, higher housing prices, and slum formation, including in flood zones.

More resilient infrastructure and protection systems that serve poor people

Poor people suffer from frequent disasters because they lack the type of protective infrastructure that is common in wealthier countries. As described in box 3.2, lower protection levels are the main reason why flood risks are higher in relative terms in poor than in rich coastal cities (Hallegatte et al. 2013). And the difference is even more obvious within cities: for instance, poor households are often exposed to recurrent floods because of the lack of infrastructure, or its poor condition, especially drainage systems (box 3.4). Solving this problem requires investing more and investing better.

Investing more. Governments in both developed and developing countries already struggle to finance infrastructure. Millions of people in developing countries still lack access to safe water, improved sanitation, electricity, and transport. Even disregarding climate concerns, developing countries need substantially more infrastructure to grow and address poverty, inequality, and unemployment concerns.

Little data exist on how much is being spent on infrastructure, but the World Bank Group estimates that at least $1 trillion per year would be needed in developing countries to close the infrastructure gap, with about $100 billion for Africa alone.

This lack of infrastructure is an obvious multiplier of natural hazard consequences, and one that could be closed through increased investments. But infrastructure does not attract enough capital, especially in developing countries: long-term, largely illiquid investments are not perceived as attractive destinations for global capital. Many countries are simply too poor to generate domestically the needed pool of savings. Many others lack local capital markets that are sufficiently developed to transform local liquidity into the patient capital that is needed for longer-term investments. Further, public spending is limited by a low tax base (10–20 percent of GDP in many countries) and low debt ceilings.

Recommendations typically include leveraging private resources to make the most of available capital, which involves well-known steps like improving the investment climate (making sure regulations are clear and predictable and the rule of law and property rights are enforced), developing local capital markets, and providing a pipeline of "bankable" projects (Fay et al. 2015). Official development assistance (ODA) can play a catalytic role in mobilizing additional resources, but it is constrained by donors' fiscal constraints and remains limited relative to overall needs—at its highest around 2011, it reached about $90 billion.

Investing better. New and additional investments will reduce the long-term vulnerability of the population—and especially the poorest—only if new infrastructure is designed so that it can absorb climate change and remain efficient in spite of changes in climate and environmental conditions.

The challenge of addressing the long-term risks from climate change in development projects is multifaceted. First, there is high uncertainty as to how global climate change will translate into local changes in environmental conditions, especially for extreme events. Second, climate change is often an exacerbating factor of other development stressors (such as poverty, urbanization, water degradation, increasing population, resource use, and existing natural hazards). Third, if investment in disaster risk reduction or climate adaptation is designed to maximize economic returns, it will be concentrated toward areas with highest asset values—that is, toward wealthier groups (Füssel 2012; Tschakert, forthcoming).

Fortunately, there are innovative ways to manage the long-term, uncertain risks of climate. These approaches seek to identify robust decisions (those that satisfy decision makers' multiple objectives in many plausible futures and over multiple time frames) rather than being optimal in any single best estimate of the future (Bonzanigo and Kalra 2014; Kalra et al. 2014; Lempert et al. 2013). Decision making under uncertainty starts with the options available—from infrastructure to early warning systems—and does not attempt to predict the most likely future(s). The performance of each option is then tested against many different possible future conditions to identify its vulnerabilities. Those future conditions include climate, political, and socioeconomic risks.

At that point, it becomes possible to evaluate the trade-offs among the different options (using different measures of success, like economic return, number of people benefiting, whether poor or nonpoor people are the main beneficiaries) and to identify policies that reduce the vulnerability of future investments. Often, these methods favor soft and flexible options over hard ones—including monitoring systems to make sure risks are systematically assessed throughout the life of the project, so that solutions can be adjusted over time. They also encourage decision makers to look beyond within-sector interventions, and combine prevention and reactive actions

BOX 3.5 In an uncertain future, developing into the wetlands of Colombo is dangerous

Colombo faces recurrent floods that largely affect low-income populations and threaten the city's long-term development. Its urban wetlands have been identified by local agencies as a critical component of its flood protection, but wetlands have declined rapidly in recent years because of continuous infilling, unmanaged development, and land dredging for lakes. In collaboration with government agencies, NGOs, and local universities, a World Bank analysis was conducted to examine the value of Colombo's urban wetlands in the short term and long term and to identify the most viable strategies available to increase the city's flood resilience in an uncertain future (in terms of climate change, urban development patterns, and the resilience of poor communities). This involved the use of numerous hydrological and socioeconomic scenarios as well as the evaluation of some wetlands benefits (such as ecosystem services for the populations who fish in the wetlands, wastewater treatment, or recreational services).

The analysis determined that, if all urban wetlands across the Colombo catchment were lost, in some scenarios the metropolitan area would have to cope with annual average flood losses of about 1 percent of Colombo's GDP in the near future, with significant impacts on the poorest populations—a level of risk considered unacceptable by local decision makers and stakeholders.

For long-term strategies, trade-offs between urban development, lake creation, and wetland conservation were weighed, with active management of urban wetlands emerging as the lowest regret option. The analysis also found that, faced with climate change and fast urban development, wetlands would not be sufficient to protect Colombo against severe floods. This means that proactive urban planning and land use management are essential to protect existing wetlands, provide incentives for vulnerable populations to move to safe areas, and reduce future exposure of people and assets.

within a consistent strategy. Projects following these methodologies that are being piloted by the World Bank include water supply in Lima, flood risk management in Ho Chi Minh City and Colombo (box 3.5), hydropower investment in Nepal, and road network resilience in Peru and across Africa.

Finally, better-designed infrastructure and public investment will translate into reduced vulnerability only if infrastructure designs are respected during the construction phase. Studies show that most of the deaths after earthquakes occur in countries with a high level of public sector corruption, where building norms are not enforced, and where public buildings are often not built according to the designed standards (Ambraseys and Bilhan 2011; Escaleras, Anbarci, and Register 2007). The same is likely true for climate-related disasters such as floods and storms, although data are not available.

The Global Program for Safer Schools, created by the World Bank and the GFDRR, aims at making school facilities and the communities they serve more resilient to natural hazards, with a strong focus on the enforcement of building norms. It supports a safety diagnostic of schools in Lima, Peru, and provides technical assistance in Mozambique to optimize the delivery of resilient schools at the local level—targeting both government and community construction. Similar actions exist in other sectors. For example, the World Health Organization, the International Strategy for Disaster Reduction, and the World Bank partnered in 2008 in the "Safe Hospitals" initiative to help health facilities withstand natural shocks.

Improved property rights to incentivize resilience investments

One reason why poor people lose a larger share of their assets and income is that they live in buildings with low resistance to natural hazards. In Latin America, a 1993 inventory found 37 percent of its housing stock

TABLE 3.3 Mumbai's poor spend a lot to regularly repair their dwelling

(Share of households undertaking recurrent measures to protect against flooding, by income group)

	Very poor (%)	Poor (%)	Nonpoor (%)
Repairing roof (Rs. 1,300)	50	35	25
Repairs inside house (Rs. 800)	35	22	14
Overhauling vehicle (Rs. 600)	5	6	5
Cleaning house surroundings (Rs. 200)	70	56	68
Cleaning nullah (Rs. 200)	50	48	57

Source: Patankar, forthcoming.
Note: Average cost, in Rs. (rupees), of each measure is shown. Very Poor: Rs. 5,000 and less in monthly income; Poor: between Rs. 5,000 and Rs. 10,000; Nonpoor: above Rs. 10,000. Numbers rounded for clarity. A nullah is a stream or waterway.

provided inadequate protection against disaster and illness (Fay 2005). Since then, rising trends in urbanization, settlements in risky areas, and the low quality of those settlements have likely increased this share (Lall and Deichmann 2012).

In Mumbai, both poor and nonpoor households undertake short-term and recurrent measures to reduce the intensity of flooding in their premises (Patankar, forthcoming). This includes cleaning surroundings and gutters choked with garbage, repairing leaking roofs, overhauling vehicles, and house repairs. But the difference between poor and nonpoor is visible in the type of action undertaken (table 3.3). Poor people undertake repairs for roofs and houses in larger numbers than the nonpoor, because their houses are made of more vulnerable material. Such repairs have to be undertaken annually, are financed without much support from the government, and end up being more costly than building high-quality roofs in the first place. These expenses place another financial burden on poor households.

The lack of clear and effectively enforced land and property rights discourages poor households from making more robust and durable—but also costlier—investments. Facing the permanent risk of eviction, they are unlikely to invest in the physical resilience of their homes (like retrofitting to strengthen homes against disasters) (Rentschler 2013). In Buenos Aires, the fear of eviction, along with low levels of household income, is the main reason for underinvestment in housing infrastructure, according to a survey of two informal settlements without tenure security (van Gelder 2010). In contrast, in Tanzania, as figure 3.4 shows, households with home ownership (and especially those holding some form of documentation) invest significantly more in their dwelling (Rentschler 2013).

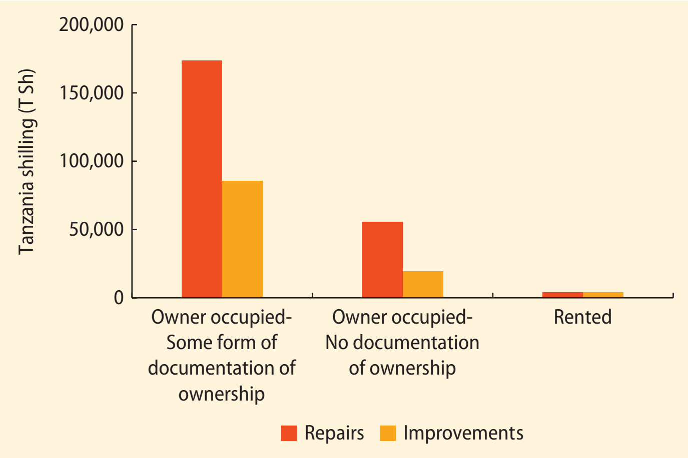
The lesson here is that better tenure security encourages investment in housing, including risk reduction. In Peru, starting in 1996, the government issued property titles to over 1.2 million urban households, which at the time was the largest titling program targeted at urban squatters in low-income countries. A study on the impact of this program on housing renovations found that households in program neighborhoods invested significantly more than those in nonprogram ones (Field 2007). In addition to better housing, access to services (water) rose, and crowding was reduced as households enlarged their homes and increased the number of rooms—thereby stimulating the rental market (Mosqueira 2003).

Efficient and sustainable air-conditioning to reduce vulnerability to extreme heat

In May 2015, a major heat wave swept across India, with temperatures hitting highs of 118°F (48°C) in some parts. Official statistics

FIGURE 3.4 Home ownership in Tanzania encourages home investment

(Average annual expenditure on repairs and improvement of dwelling by ownership category)



Source: Rentschler 2013.
Note: Based on household survey data (Living Standards Measurement Surveys). US$1 is equal to about 20,000 T Sh.

reported more than 1,100 deaths (Al Jazeera 2015). Elderly people, as in most heat waves, were among the most vulnerable, along with low-income workers, employed outdoors, in jobs from rubbish collection to farming and construction. In the state of Andhra Pradesh, which experienced the greatest impacts from the heat wave, a majority of the 900 reported victims were elderly or low-income workers (Al Jazeera 2015; Vice News 2015). Homeless people, who are unable to find shelter, are also among the most vulnerable: according to a Delhi-based nongovernmental organization (NGO), of the 186 people who died in the capital, 80 percent were homeless (Vice News 2015). But these figures may underestimate the death toll, since reliable statistics are difficult to find (*The Economist* 2015).

In Chicago, a lack of air-conditioning was a critical risk factor for death after the 1995 heat wave, which resulted in over 700 deaths, concentrated among the poor and elderly populations (Whitman et al. 1997). People who did not have a working air conditioner, access to an air-conditioned lobby, or visited an air-conditioned place were 20–30 percent more likely to die compared to people with access to air-conditioning (Semenza et al. 1996). In fact, the strongest protective factor found was air-conditioning: more than 50 percent of the deaths related to the heat wave could have been prevented if each home had a working air conditioner. And a meta-analysis of heat wave studies finds working home air-conditioning reduces the odds of death by 23 to 34 percent (Bouchama et al. 2007).

Thus, access to air-conditioning, which implies reliable electricity production and distribution, could be a critical tool to reduce health impacts from heat waves—but only if it reaches the most vulnerable segments of the population. In France, programs like the National Heat Wave Plan set up after the 2003 heat wave are designed to provide air-conditioning shelters in community centers and in senior citizen homes to reach these populations. For those working outdoors, air-conditioning is unlikely to help much. Thus, adaptations such as flexible work hours (like not working during direct sunlight) and shorter shifts may become necessary in more places.

One caveat is that increasing air-conditioning is likely to have a significant environmental cost. First, air-conditioning in buildings increases street temperatures, increasing the potential impact on homeless persons or those working outside. Second, air-conditioning consumes energy: stabilizing climate change will thus require that air-conditioning equipment be extremely efficient and electricity low carbon (zero carbon in the longer term). A recent study for Mexico tried to quantify the potential climate impacts from air-conditioning, drawing on household-level data (Davis and Gertler 2015). It finds that on hot days there is a large increase in electricity consumption: above temperatures of 21°C, usage increases nonlinearly; and, for every additional day above 32°C, usage rises by 3.2 percent.

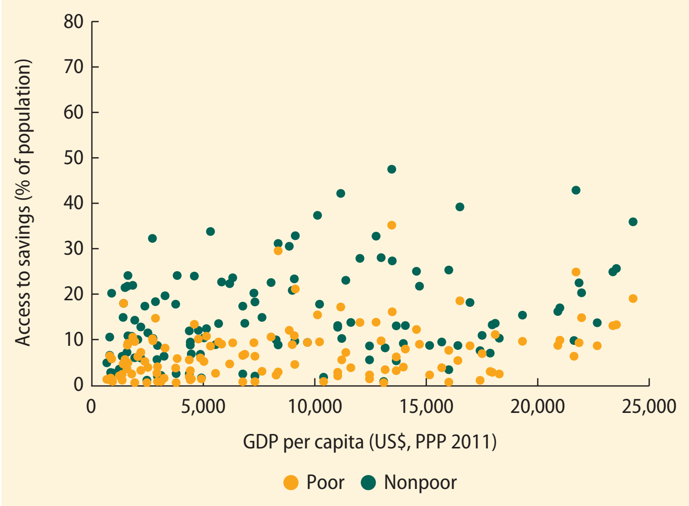
The negative impacts of air-conditioning can be mitigated by additional measures. For instance, urban planning, improved housing quality, highly reflective materials for roads and buildings, and irrigated parks can minimize heat waves and reduce energy demand for air-conditioning (Chapman et al. 2009; Masson et al. 2013 and 2014).

Improved financial inclusion and savings options

In most countries, poor people suffer from lower access to finance than nonpoor people (figure 3.5), often forcing them to save "in kind." Fortunately, in the past decade, an alternative method of extending banking services has developed: mobile money. Most adults in the world today—poor people included—have access to mobile phones: the United Nations estimates that out of 7.3 billion people, 6 billion have access to these devices. Mobile money accounts, by providing more convenient and affordable financial services, offer promise for reaching unbanked adults traditionally excluded from the formal financial system—such as women, poor people, young people, and those living in rural areas (Demirguc-Kunt et al. 2015). As such, the expansion of mobile money has the potential to improve parity in financial inclusion and to make the savings and asset portfolio of poor people less vulnerable to natural hazards. (For a fuller discussion on financial inclusion, see chapter 5).

FIGURE 3.5 Poorer people lack sufficient access to financial instruments

(Fraction of poor and nonpoor people with savings at a financial institution)



Source: Data from FINDEX.
Note: Each dot represents poor people or nonpoor people in one country. PPP = purchasing power parity.

Better observation systems, early warning, and evacuation planning

Early warning and disaster preparedness can save lives and reduce economic losses. Weather forecasts enable the anticipation of, and preparation for, extreme events.

The value of preparedness was illustrated when Cyclone Phailin made landfall in the State of Odisha, India, on October 12, 2013, around 9:15 pm with wind speeds of around 200 km/hour.[2] The storm that hit the same coastline 14 years before, in 1999, Cyclone 05B, caused massive devastation, killing more than 10,000 people and destroying housing and public infrastructure in coastal Odisha. This time around, however, the story unfolded differently. After 72 hours, the official death toll was 38 people, less than 0.4 percent the death toll from the 1999 cyclone. Close to a million people were evacuated to cyclone shelters, safe houses, and locations inland in Odisha (around 850,000) and in Andhra Pradesh (around 150,000). This success was made possible by years of effort from the Odisha State Disaster Management Authority (OSDMA) and the government of Odisha—thanks to planning, construction of disaster risk mitigation infrastructure, setting up of evacuation protocols, identification of potential safe buildings to house communities, and, most important, working with communities and local organizations to set up volunteer teams and local champions who knew what needed to be done when the time came to act.

Preparing a house before a hurricane (by shuttering windows, for example) can reduce damage by up to 50 percent (Williams 2002). After the Elbe and Danube floods in 2002, studies show that 31 percent of the population in flooded areas implemented preventive measures (Thieken et al. 2007; Kreibich et al. 2005). These measures included moving goods to the second floor of buildings, moving vehicles outside the flood zone, protecting important documents and valuables, disconnecting electricity and gas supplies and unplugging electric appliances, and installing water pumps. Warning timing was critical: businesses that protected their equipment or inventories were those that received the warning early enough. One study estimates that a warning emitted 48 hours before a flood enables the overall damage to be reduced by more than 50 percent (Carsell, Pingel, and Ford 2004).

Yet, in spite of these large benefits (Hallegatte 2012b), early warning and evacuation systems are still underdeveloped. In the subdistrict of Shyamnagar in Bangladesh, only 15 percent of nonpoor people and 6 percent of poor people attend cyclone preparedness training (Akter and Mallick 2013). In the Lamjung district of Nepal, the penetration of early warning in flood and landslide-prone communities is lower than 1 percent (Gentle et al. 2014). In Mumbai, levels of early warning are also paltry, with only 10 percent of the surveyed households reporting receiving some form of early flood warning. These shortfalls highlight the challenges and the opportunities associated with building hydrometeorological institutions and systems that could produce actionable warnings (box 3.6) (Rogers and Tsirkunov 2013).

BOX 3.6 Reversing the degradation of hydrometeorological services

Over the past 15–20 years, the situation of many hydrometeorological services in developing countries has worsened, primarily because of underfunding, low visibility, economic reforms, and in some instances military conflict. As a result, many hydrometeorological services do not function well, with some lacking the capacity to provide even a basic level of service. Observation networks have deteriorated, technology is outdated, modern equipment and forecasting methods are lacking, the quality of services is poor, support for research and development is insufficient, and the workforce has been eroded.

In Central Asia, for example, observation systems deteriorated dramatically after 1985. In the Kyrgyz Republic, the number of meteorological stations has been cut by 62 percent, and in Tajikistan the number of hydrological stations and posts has been cut by 41 percent. In both of these countries and Turkmenistan, upper-air observations—which are very important for forecasting but are expensive—have been completely abandoned. These trends are also observed in the rest of the world.

As a result, substantial human and financial losses have occurred, which could have been prevented if hydromet agencies were more developed. And the ability to monitor local climate and increases in natural risk has eroded, making developing countries less able to anticipate and adapt to climate change.

Globally, more than 100 countries—over half of which are in Africa—need to modernize their hydrometeorological services. How much will modernization cost? A conservative estimate of high-priority investment needs in developing countries exceeds $1.5–$2.0 billion. In addition, a minimum of $400–500 million per year will be needed to support operations of the modernized systems (staff costs plus operating and maintenance costs). National governments should cover these recurrent costs, but few are ready to do so. Moreover, the amount of international support for the national hydrometeorological services is significantly below what is needed just for the high-priority items.

It has been estimated that upgrading all hydrometeorological information and early-warning capacity in developing countries would save an average of 23,000 lives annually and would provide between $3 billion and $30 billion per year in additional economic benefits related to disaster risk reduction.

Source: Rogers and Tsirkunov 2013.

In conclusion

The fact that disasters are often followed by a measurable increase in poverty is not a surprise, considering the findings of this chapter:

- Poor people are often highly exposed to natural hazards, and at the local level they are often more exposed than their wealthier neighbors.
- Poor people lose relatively more from disasters because their livelihood and asset portfolio is more vulnerable.
- The measures and policies that could be mobilized to help poor people manage natural risks in a changing climate amount to "good development," with the important caveat that the design of such measures and policies needs to take into account climate change and the uncertainty it creates. All of these measures also face significant implementation challenges—but with climate change expected to increase risk in many places, it will become even more urgent to make meaningful progress with these measures.

One important implication of these findings is that the differential in risk levels between poor and nonpoor people may create a decoupling between aggregate growth and poverty reduction, meaning that the poverty reduction impacts of growth may decrease. Indeed, where the wealthier can protect themselves against disasters, natural hazards are unlikely to lead to a visible shock on GDP. However, the impact on poorer households, which does not appear in aggregate statistics, may nonetheless lock them into poverty traps, creating or magnifying regional pockets of poverty.

One of the most striking results is the vulnerability of children to natural disasters. This calls for targeted efforts to protect children in poor families from disasters and avoid irreversible consequences for their lifelong prospects. The next chapter expands this discussion to look at health shocks that poor people, and especially children, are exposed to, along with measures that could play a big role in mitigating the consequences of natural disasters—namely the provision of better health services and care, and universal health coverage.

Notes

1. A review of empirical studies finds that the range of prices between flood-exposed and non-flood-exposed houses varies widely; a meta-analysis of 37 studies mostly in rich countries finds a spread of −7 percent to +1 percent (Beltran, Maddison, and Elliott 2015).
2. This illustration is from Saurabh Dani and http://www.worldbank.org/en/news/feature/2013/10/17/india-cyclone-phailin-destruction-preparation.

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Under the Weather: Climate Change, Health, and the Intergenerational Transmission of Poverty

4

Main Messages

- Climate change will magnify some threats to health, especially for poor and vulnerable people such as children and the elderly, but large uncertainties remain in what is still an emerging research field.
- Health shocks and poor health contribute to poverty through loss of income, health expenses, and caring responsibilities, so that climate change impacts on health will represent an additional obstacle to poverty reduction and will increase inequality.
- Development—notably better access to health care and to services such as water and sanitation infrastructure—has the potential to reduce, but not eliminate, the risks climate change poses for health.
- Universal health coverage would contribute greatly to climate change adaptation—and monitoring and surveillance systems (both in the health and environmental sectors) will be critical to deal with emerging health issues.

Introduction

One reason why people fall into poverty, or cannot leave it permanently, is that they are sometimes affected by health shocks and diseases, or by a death in their household. Illness can reduce human capital through permanent health consequences and disability, which makes it difficult or impossible to work and reduces productivity. It can also diminish financial assets through medical expenditures, especially in the presence of high borrowing costs (Krishna 2006).

Poor people are more vulnerable to health shocks because they have fewer resources with which to maintain good health, have less access to improved water and health care, and are more likely to depend on labor-intensive livelihoods that require good health such as agriculture or construction. As a result, they incur a more severe burden of disease than nonpoor people, and this burden hampers their ability to accumulate and retain assets and improve living conditions.

Chapters 2 and 3 explored two key channels of poverty—agriculture and ecosystems, and natural disasters—noting that climate change impacts on agriculture and ecosystems and that natural disasters affect health in many different direct and indirect ways, such as through undernutrition due to lower crop productivity, or via the spread of diseases after a disaster.

This chapter explores how health, the third key channel of poverty in this report, will be affected by climate change. A changing climate can reduce the quantity and quality of water resources, along with altering the susceptibility to, and spatial distribution of, climate-sensitive diseases. And climate change is likely to amplify many of the diseases that already threaten poor households—for instance, by allowing malaria-bearing mosquitoes to spread in new places, or accelerating the replication of pathogens in water. Even climate change adaptation measures can contribute to worsening health conditions. Irrigation dams, water storage receptacles, and other land use and water management practices can create suitable conditions for vectors and pathogens to reproduce, thereby worsening the incidence of disease (Asenso-Okyere et al. 2011; Keiser et al. 2005; Medlock and Vaux 2011).

These potential impacts of climate change on health are important in and of themselves, as they could directly cause a massive reduction in well-being. But they could also affect households in economic terms, magnifying the initial impact on welfare. This chapter begins by reviewing the evidence on the impact of health shocks and poor health on poverty. It then summarizes what we know about the health impacts of climate change and concludes with options to minimize these impacts, including better health infrastructure and universal health coverage.

Our main message is that economic development—notably better access to health care and to services such as water and sanitation infrastructure—has the potential to reduce, but not eliminate, the enhanced risks that climate change poses for health.

Disease and poor health contribute to poverty

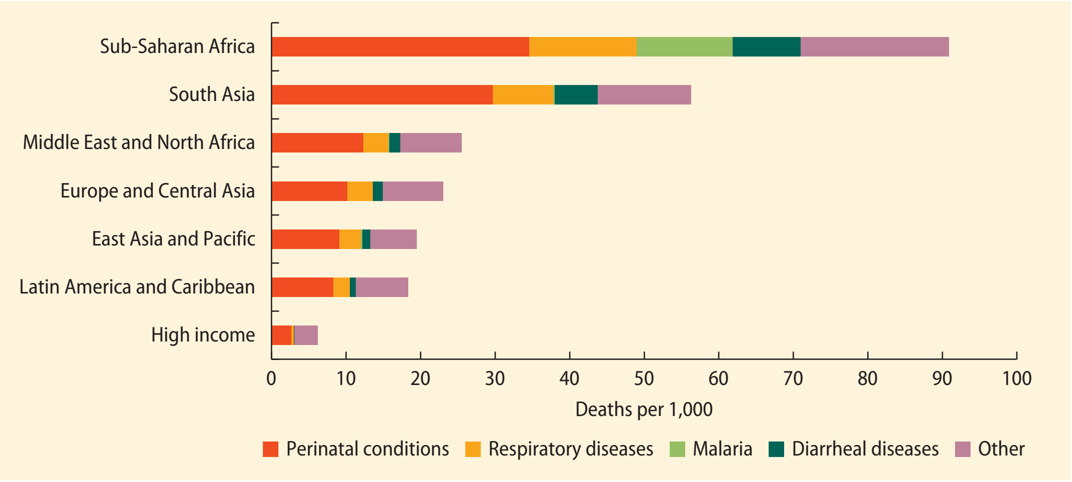
The impact of poor health on low-income households is already large. In Sub-Saharan Africa and South Asia, the number of deaths in children under five is much higher than in other regions, as shown in figure 4.1. Diarrheal and respiratory diseases, and malaria in Sub-Saharan Africa, contribute significantly to this gap. For adults, there is a striking difference in the diseases that affect rich and poor countries. In particular, communicable diseases—including HIV—represent almost half of the cause of mortality for adults in Sub-Saharan Africa, while in richer regions non-communicable diseases, including cancer and cardiovascular diseases, dominate (WHO 2015).

Over 40 percent of the global burden of disease attributed to environmental factors falls on children under five years of age, most of them living in developing countries. An estimated 800,000 out of the annual 2 million deaths among children under the age of five caused by respiratory infections is due to indoor air pollution; another 760,000 children die as a result of diarrhea (WHO 2013a). These deaths could be prevented with minimal health care and better hygiene, shifting toward cleaner fuels, and by better access to safe water and improved sanitation.

Diseases—and more generally poor health—increase poverty for several reasons. Health expenditures can absorb a large share of a household's income. Diseases reduce productivity because of missed work and school days, caregiving responsibilities, or reduced productivity. And in the long term, they can impair children's development and reduce their ability to learn, which can affect earnings.

FIGURE 4.1 Diarrheal diseases, respiratory diseases, and malaria contribute to record child mortality rates in Sub-Saharan Africa and South Asia

(Mortality rates by cause and region for children under 5)



Source: Based on WHO 2015 (data from 2013).

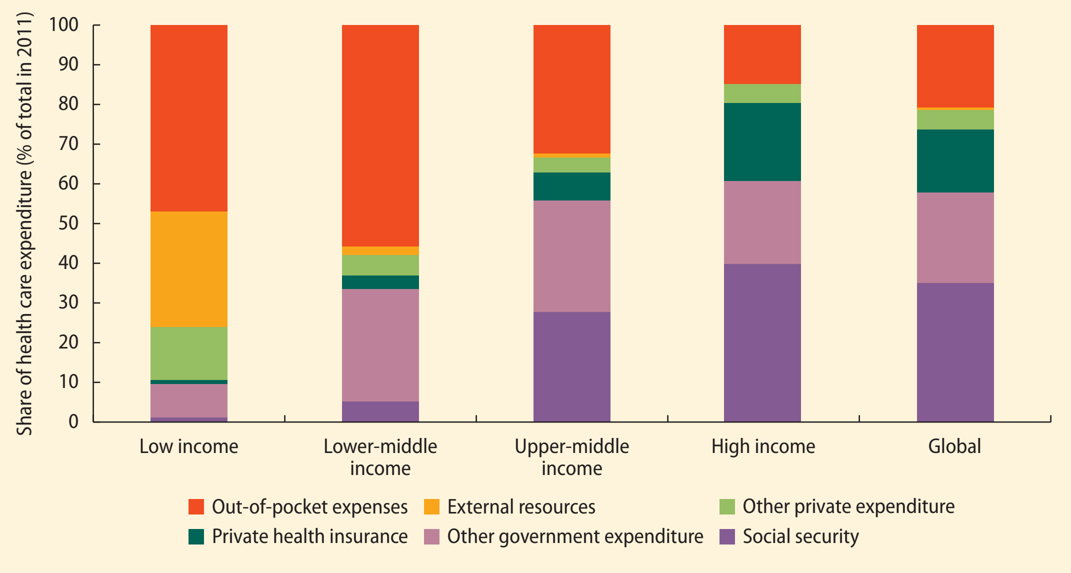
Health care costs are regressive and have large impacts on poor households

Health expenditures absorb a large share of poor households' budget, especially in developing countries. Whereas higher-income countries tend to have more sophisticated social insurance systems to support access to health care, financial risk protection is largely absent in lower-income countries, where about half of health costs borne by households are out of pocket (figure 4.2). These poorer households typically rely on their own funds, remittances, private health insurance, or external resources (such as development assistance or support from nongovernmental organizations [NGOs]). Public funds for health care are rarely available to those who need them the most, and in most low-income countries the bottom quintile receives less than its share of public outlays for health.

Catastrophic health expenditures often drag people into poverty. In western Kenya, nearly 73 percent of households mention health expenses as a principal reason for their decline into poverty, and 32 percent mention the death of a major earner as a result of illness as a contributing factor to their poverty (Krishna et al. 2004). Similar results are found in several countries (Krishna 2007) (figure 4.3). And even when households have the means to cover health care costs, illness has a regressive cost burden on poorer patients and households (Asenso-Okyere et al. 2011).

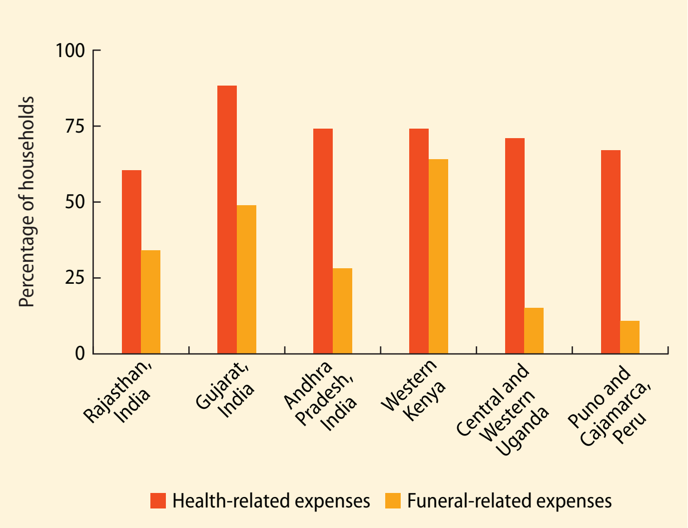
Looking at malaria, a review of multiple studies in Burkina Faso, Cameroon, Ghana, Malawi, Nigeria, and Sri Lanka finds the cost of treatment ranging from \$0.41 to \$5.98 per month, per person,[1] which can be a significant burden for poor people relative to their monthly income or expenditure. In Malawi, malaria treatment represents 2 percent of monthly income for the average household, but 28 percent for the poor (Ettling et al. 1994). In Kenya, malaria accounts for 7.2 percent of household expenditure on average in wet seasons and 5.9 percent in dry seasons—but for the bottom quintile the ratios increase to 11 percent in wet seasons and 16.1 percent in dry seasons (Chuma, Thiede, and Molyneux 2006). For diarrhea, the cost of treatment can also be significant for poor households, especially if the cost of transport to health care facilities is included (Hutton and Haller 2004).

FIGURE 4.2 In poorer countries, half of all health expenditures are paid out of pocket, unlike in richer ones



Source: Watts et al. 2015.
Note: Data show the global health care expenditure profile from 2011. PPP = purchasing power parity.

FIGURE 4.3 Health and funeral expenses are a major reason why households fall into poverty
(Percentage of households citing health and funeral expenditures as a principal reason for their descent into poverty)



Source: Based on Krishna 2007.

In the extreme case where one household member dies, the economic impact on the other members can be large, not only through the loss of income but also through funeral expenses. Household surveys in India, Kenya, Peru, and Uganda find that in some places funeral expenses represent a significant cause of poverty, sometimes comparable to health expenditures (figure 4.3) (Krishna 2007).

Forgone wages, reduced productivity, and caregiving responsibilities increase poverty

Missed days of work as a result of illness—and resulting wage forgone—can also have a significant impact on income. Table 4.1 reviews studies on the number of days lost because of malaria episodes in various countries, for the sick and for the caregiver (which is an important component because it is often children who are affected). Because people can go through many episodes per year, the total number of days lost to malaria can be large. In Oyo State in Nigeria, adults lost on

TABLE 4.1 Many days of work are lost because of malaria episodes

Country	Number of missed days of work per episode
Burkina Faso	4 days for sick adult and 1.2 days for caregiver for child
Ethiopia	18 days for sick adult and 2 days for caregiver for child
Ghana	5 days
Kenya	2–4 days for sick adult, 2 days of lower productivity for sick adult, and 2–4 days for caregiver
Malawi	2.7 days for sick adult and 1.2 days for caregiver for child
Nigeria	1–3 days for sick adult, 3 days of lower productivity for sick adult, and 1–3 days for caregiver
Sri Lanka	4 complete days and 5.3 days partially lost

Source: Based on Guiguemde et al. 1994 for Burkina Faso; Cropper et al. 2000 for Ethiopia; Asenso-Okyere and Dzator 1997 for Ghana; Leighton and Foster 1993 for Kenya and Nigeria; Ettling et al. 1994 for Malawi; and Attanayake, Fox-Rushby, and Mills 2000 for Sri Lanka.

average 22 working days per year to the disease (Ajani and Ashagidigbi 2008). For diarrhea, which can reach 3 to 7 days per episode, it is usually the caregiver who is missing work, since it mostly affects children (Hutton and Haller 2004). And missed days of work can be even more detrimental if people are fined or even fired when they miss work (World Bank and Australian AID 2014).

Disease can also lower productivity or result in the complete inability to work. In agrarian households in Africa, repeated malaria illness has led to a decline in farm output and income and contributed to greater incidence of poverty (ESPD 2005). In Ho Chi Minh City, frequent floods were found to be a cause of chronic respiratory disease, rheumatism, and skin and intestinal diseases, especially for children under five, rendering affected people and caregivers unable to work (World Bank and Australian AID 2014; this report, chapter 3).

Impacts on child development result in the intergenerational transmission of poverty

Children, with less mature immune systems, are more susceptible to illness—and tend to have less access to health care when they most need it after a shock. In Côte d'Ivoire, the share of children taken to a health practitioner fell from 50 percent to around 33 percent in areas of extreme rainfall (Jensen 2000). In Nicaragua, after Hurricane Mitch, children in affected communities were 30 percent less likely to be taken to health care facilities when ill (Baez and Santos 2007).

This lack of access to health care for children matters greatly because illness has particularly severe impacts on children. Children—particularly those under the age of five—are in critical periods of their development so that illness and malnutrition can affect lifelong health, educational attainment, and labor market outcomes. And when poor families cannot protect their children from these effects, poverty can be transmitted from one generation to the next, depriving children of a fair chance to escape poverty.

Illness can lead to irreversible effects on cognitive function, either because it affects the supply of nutrients to the brain or because of responses in the immune system that damage the structure of the brain (Jukes 2005). This is particularly true of illnesses that affect the central nervous system (such as severe cerebral malaria), which lead to lifelong cognitive impairment in survivors. In Kenya, children aged six to seven who had suffered cerebral malaria were found to be 4.5 times more likely than their peers to suffer cognitive impairments (ranging from mild challenges to severe learning difficulties) (Holding et al. 1999). Similar results were found in Senegal among children between the ages of 5 and 12 who had suffered cerebral malaria with coma before the age of 5 (Boivin 2002).

Chronic undernutrition is associated with impairment in the development of cognitive functions in young children, with subsequent effects on sociability and educational attainment (Grantham-McGregor 1995; Whaley et al. 1998). In Jamaica, children who suffered from severe undernutrition between 6 and 24 months of age lagged behind their adequately nourished peers in overall IQ, vocabulary, and education tests, even when accounting for differences in backgrounds (Grantham-McGregor et al. 1994).

More generally, reduced access to education associated with health shocks and disasters impact lifelong prospects. Children who are withdrawn from school to earn income and support their households are particularly at risk for long-term effects on their earning potential (Asenso-Okyere et al. 2011). Children exposed to extreme natural disasters tend to spend fewer years in school and have lower educational achievement, delayed development, behavioral issues, and lower IQ (Caruso 2015; Currie 2009; del Ninno and Lundberg 2005; Victora et al. 2008).

But these impacts are not unavoidable—as evidenced by the fact that long-lasting impacts on children's health are only observed in a small share of the population and chronic impacts are not manifest in more than 30 percent of those affected by a disaster (Bonanno et al. 2010). Many of these impacts can be avoided or managed by strategic prioritization, sufficient allocation of resources, and political will to manage transient shocks and increase the resilience of individuals and households. Policies that reduce the exposure and vulnerability of children to risks and facilitate recovery after shocks will be essential to manage the impacts of climate change, particularly in poor communities (see chapter 5).

Climate change magnifies threats to health, especially for poor people

So health matters for poverty, and the evidence is growing that climate change matters for health. We know that higher temperatures, varied rainfall patterns, and more frequent droughts and floods will affect health in many ways—through heat exposure, undernutrition, natural disasters, and increased proliferation and transmission of illnesses that affect poor households (such as malaria and diarrhea). Hales et al. (2014) estimate that by the year 2030, climate change could be responsible for an additional 38,000 annual deaths due to heat exposure among elderly people, 48,000 due to diarrhea, 60,000 due to malaria, and about 95,000 due to childhood undernutrition. Morbidity (incidence or prevalence of a disease) would also increase, with the consequences for poverty we described above (Hales et al. 2014). These estimates assume that socioeconomic development will reduce mortality rates, so numbers may be higher if development is slower or adaptation is less efficient than expected.

This section explores five health issues—(i) vectorborne diseases (malaria); (ii) waterborne diseases (diarrhea); (iii) stunting; (iv) mental disorders; and (v) productivity loss due to high temperatures—that are likely to be sensitive to climate effects and to lead to large impacts on the well-being of the poor. Other issues, like diseases related to air pollution, are also likely to worsen with climate change (box 4.1).

Climate change threatens to reverse progress made on vectorborne diseases such as malaria

The first major health issue is vectorborne diseases, accounting for over 17 percent of all infectious diseases and causing more than 1 million deaths annually. Vectorborne diseases are caused by an infectious microbe transmitted to people mainly by bloodsucking insects. Their spread is determined by a combination of environmental and social factors. In recent years, globalization of travel and trade, urbanization, and environmental challenges have had a significant impact on transmission. Climate change also partly explains changes in the spatial distribution of these diseases (Beugnet and Chalvet-Monfray 2013).

Malaria is the most prevalent vectorborne disease in the tropics and subtropics and probably the most important for developing countries where insufficient health infrastructure, favorable climate, drug resistance, and poverty have made it difficult to control. It occurs all

BOX 4.1 Getting harder to breathe

Air pollution is already a challenge for human health—exposure to pollution can lead to heart and lung disease as well as increased hospital visits and mortality (Peel et al. 2005; Peel et al. 2007; Hoyt and Gerhart 2004; Moore et al. 2006). Globally, about 3.3 million premature deaths occur every year because of outdoor air pollution, predominantly in Asia (Lelieveld et al. 2015). Those who spend a lot of time outdoors and engage in physical activities (like outdoor workers, children, and athletes) and those who already suffer from respiratory diseases are the most vulnerable.

Will climate change make the situation worse? We know that higher temperatures and lower rainfall are likely to lead to a worsening of air quality in some areas. It may increase exposure to ground level ozone, small particulate matter, and air contaminants such as allergens and spores (Hogrefe et al. 2004).

Model projections indicate that, without greenhouse gas (GHG) emissions-reduction policies, the contribution of outdoor air pollution to premature mortality could double by 2050 (Lelieveld et al. 2015). One study that looks at the impact of climate change–induced changes on premature mortality estimates that there could be an increase of 100,000 premature deaths associated with small particulate matter exposure and 6,300 premature deaths associated with ozone exposure annually (Fang et al. 2013). The incidence of cardiovascular and respiratory illnesses is also expected to increase as a result of climate change (Takaro, Knowlton, and Balmes 2013; D'Amato et al. 2014).

Possible solutions lie in air surveillance systems and information campaigns to encourage adaptive behavior. In addition, certain technologies can be used to reduce emissions of many pollutants at the combustion source (like air filters or fuel switching). Some health cobenefits can also be expected from emissions-reduction policies (see chapter 6).

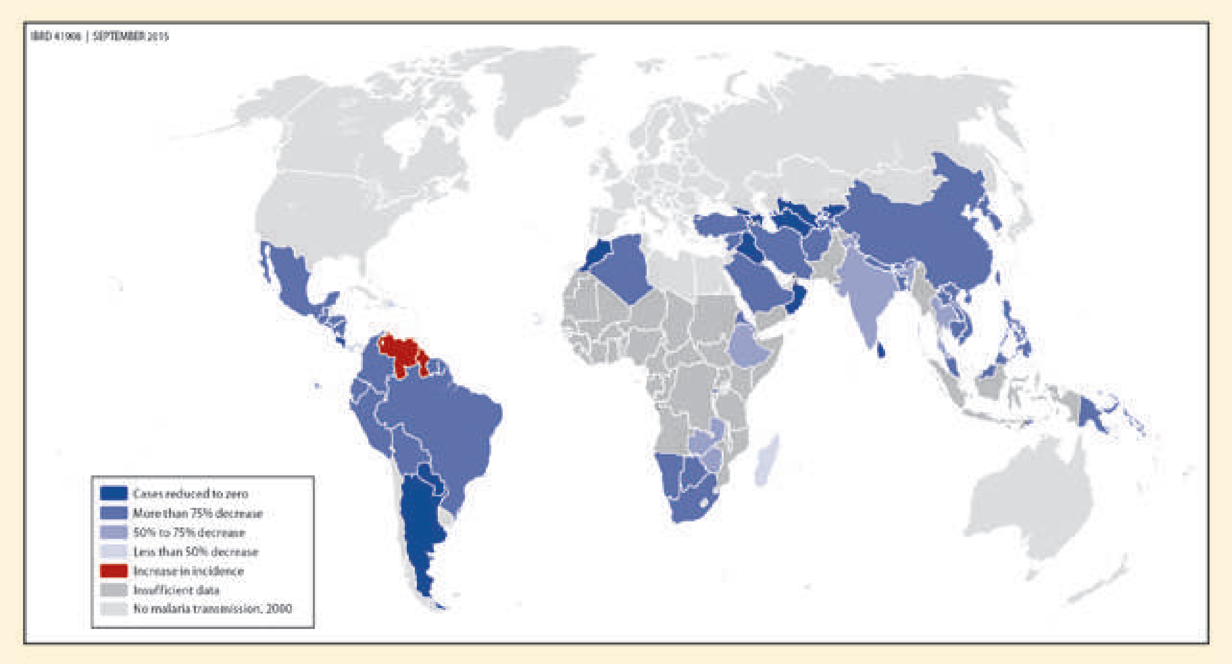
Source: Based on Kinney 2008; Ebi and McGregor 2008; Tibbetts 2015.

over the world, with an estimated 3.3 billion people exposed to the risk of infection. In 2013 alone, around 198 million cases occurred, leading to 584,000 deaths, mostly among children. The challenge is greatest in Sub-Saharan Africa, which accounts for over 90 percent of malaria-related deaths—78 percent of which occur in children under the age of five (WHO 2014). Four out of every ten people who die of malaria live in the Democratic Republic of Congo and Nigeria (WHO 2014). A large share of the deaths occurs among poor and vulnerable communities living in rural areas, with limited access to health facilities.

At the household level, malaria is a burden on incomes, especially because of health care costs. These household-level impacts add up to a significant impact on the growth and development of countries—with particularly dire effects on low-income countries. At the country level, a 10 percent reduction in malaria could be associated with a 0.3 percent increase in annual growth (Gallup and Sachs 2001). Conversely, a study in Africa found that a 1 percent increase in malaria morbidity leads to a reduction in real GDP growth of 0.4 percent in Ghana (Okorosobo et al. 2011). In Kenya, 2–6 percent of production loss could be attributed to malaria incidence (Leighton and Foster 1993).

Fortunately, since 2000, there has been strong progress in reducing the incidence of malaria (map 4.1). Moreover, since the launch of the World Health Organization's (WHO's) global malaria eradication program in the 1950s, 79 countries have eliminated malaria, although mostly in temperate climates. With the shift in focus to malaria control (as opposed to eradication) in the tropics, the incidence has decreased by 33 percent in Africa and 17 percent globally (Caminade et al. 2014).

MAP 4.1 Most countries on track for significant declines in the incidence of malaria
(Projected change in malaria incidence in 2015 compared to 2000)



Source: Based on WHO 2014.

Climate change can favor vectorborne diseases such as malaria. Climate variability and change influence the epidemiology and geography of vectorborne diseases for several reasons. Rising temperatures boost the odds that climate-sensitive infectious diseases will emerge in new areas—as is already being observed in the densely populated highlands of Colombia and Ethiopia (Siraj et al. 2014). And they increase the likelihood of longer seasonal transmission and higher incidence in areas with high current burdens. Variability in temperature and precipitation affects the survival and reproduction of vectors that carry disease pathogens, their biting rate, and the incubation rate of pathogens within the vectors—either raising or lowering transmission. Changing precipitation patterns also affect the quantity and quality of breeding sites for vectors like mosquitoes, and shelter and food availability for disease-spreading rodents, affecting the odds of outbreaks (WHO 2003).

Higher temperatures could have a major effect on malaria transmission. At the global level, increases of 2°C or 3°C could raise the number of people at risk for malaria by up to 5 percent—affecting more than 150 million people (WHO 2003). In Africa, malaria could increase by 5 to 7 percent among populations at risk in higher altitudes due to rising temperature, possibly increasing the number of cases by up to 28 percent (Small, Goetz, and Hay 2003).

Moreover, if adaptation measures to cope with other consequences of climate change are not designed carefully, they can also increase malaria prevalence. In Kumasi, Ghana, a study found that irrigated urban agriculture led to higher densities of anopheline mosquitoes (those responsible for transmitting malaria) in peri-urban and urban locations and a subsequent higher reported incidence of malaria than in nonagricultural parts of the city (Afrane et al. 2004).

On the positive side, malaria is likely to decrease in areas where warming brings very high temperatures and less precipitation—the expected case for Central America and the Amazon. Above 34°C, transmission is reduced because it becomes more difficult for vectors and parasites to survive (Smith et al. 2014; WHO 2003). Already in Senegal, less precipitation and drought have led to the virtual disappearance of some mosquito species and reduced malaria prevalence by over 60 percent (Githeko et al. 2000).

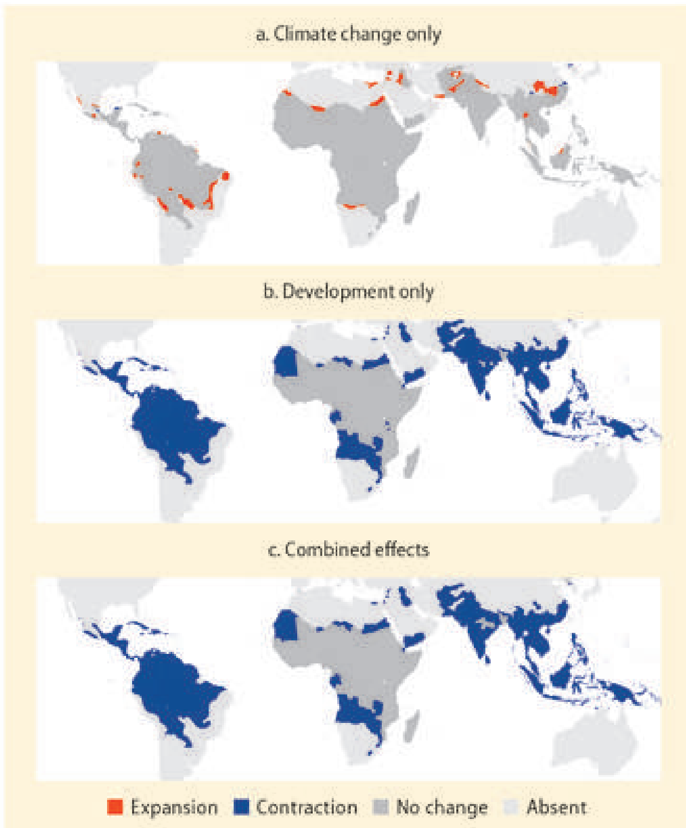
Development and specific policies can eradicate—or at least control—malaria. Despite the expected change in climate conditions, the future of malaria will be largely determined by socioeconomic conditions, such as access to resources and the efficient use of existing prevention and treatment mechanisms (Gething et al. 2010; Hales et al. 2014).

One way to sort out the different influences is to examine the separate impacts of climate change and economic growth on malaria, and their combined impacts by 2050 (Béguin et al. 2011). As shown in map 4.2, panel a, an expansion of malaria is expected globally when only considering climate change impacts. When only considering economic growth, as map 4.2, panel b, shows, malaria is expected to contract in most places with the notable exception of large areas of Sub-Saharan Africa. And what would happen if we combined the two factors? We still expect to see a contraction of malaria by 2050, as map 4.2, panel c, shows. But climate change—even if it does not reverse the positive impacts of development—could still significantly slow down the contraction of malaria, especially in Sub-Saharan Africa and India. By 2030, the same study finds that if both economic growth and climate change are present, an estimated 3.6 billion people could be at risk of malaria, including 100 million because of climate change. This number is about 30 percent lower than the estimate for the population at risk if economic growth were absent, which is around 5.2 billion.

The highland of east Africa is particularly likely to experience significant impacts with an increase in population at risk projected by all models and a potential reach of over 200 million additional people at risk of malaria by 2080 (Caminade et al. 2014).

Thus, greater efforts will still be needed if current gains in the malaria fight are to be maintained in spite of climate change. Increased transmission is most alarming in areas of unstable or seasonal transmission, as these populations have no immunity and health systems are less equipped, leading to much higher mortality rates (Chima, Goodman, and Mills 2003).

MAP 4.2 By 2050, socioeconomic development should reduce malaria incidence, even with climate change



Source: Based on Béguin et al. 2011.
Note: Map of projected areas of malaria presence for 2050. Areas where the malaria status changes between the baseline and the scenario period are shown in color. Absent means the model predicts no malaria transmission by 2050 in any scenario.

BOX 4.2 Dengue's future hinges on whether development or climate change prevails

Over the past 50 years, there has been a 30-fold increase in global cases of dengue fever, with an annual incidence of 390 million infections, mostly manifested in the Asia-Pacific region (Smith et al. 2014). Economic development and better infrastructure are expected to reduce dengue in the future. But will climate change undercut some of that progress? And will it affect dengue's spread to other regions?

At this point, there is still a lot of uncertainty about how climate change will affect the distribution of dengue. This uncertainty is related partly to the fact that there are other important factors—notably urbanization and migration—besides climate change (Hales et al. 2002; Wilder-Smith and Gubler 2008). However, several studies show that its incidence is correlated with the weather, even though the effects are delayed for weeks or months (Hii et al. 2009; Johansson et al. 2009). Dengue fever seems to proliferate under both heavy precipitation and drought conditions when households store water in containers suitable for mosquito breeding. This means that if these extreme events occur more often, it may extend the suitability of the areas for dengue. As a result, the dengue risk is likely to become more significant in parts of Europe (Bouzid et al. 2014) and Africa.

Predominantly an urban disease, dengue will be a greater risk in urbanized areas with poorly managed water and solid waste systems. Though climate change may extend the suitability of areas for dengue, economic development—including better access to piped water, strong vector control programs, and air-conditioning—can counter this effect. But in Africa, climate change could undermine the progress that has been made thanks to higher economic growth, making it more challenging to eradicate dengue and reduce its impacts on welfare and poverty (Åström et al. 2012).

Malaria prevalence can be reduced by measures such as mosquito control, improved access to bed nets and malaria treatments, and better buildings with air-conditioning. In Oman, in 2000, malaria was pervasive except for high-altitude and desert areas (Gallup and Sachs 2001), but in 2014, thanks to strategic intervention and significant resources, there are no indigenous cases of malaria (WHO 2014).

Successful elimination requires organization, resources, and strategies. Exposure is usually highest in remote and rural areas where vector control (removal of larvae breeding sites and residual indoor spraying) is difficult or impossible, making developing countries—like those in Africa where urbanization and connectivity are quite low—more vulnerable (WHO 2003). Also, medicine (such as chloroquine) has become ineffective in many areas, and new drugs are often unaffordable for poor populations.

Climate change is also expected to impact other vectorborne diseases—like dengue (box 4.2), encephalitis, Lyme disease, Rift Valley fever, the plague, and chikungunya fever (Bouley and Planté 2014; Smith et al. 2014). Less is known about the relationship between climate change and these diseases, even though they could have significant and increasing impacts on well-being and poverty.

Diarrhea and other waterborne diseases are also expected to increase because of climate change

Poor water and food quality continue to pose a major threat to human health, especially for the poor. Soil-transmitted helminthes and schistosomes (parasitic worms) are some of the most prevalent chronic diseases in poor regions, with serious and insidious effects on health and nutrition (Stephenson, Latham, and Ottesen 2000). Diarrhea alone is responsible for 1.5 million deaths every year (WHO 2013a).

Diarrheal outbreaks can occur after drinking water becomes contaminated and are often reported after flooding and related displacement (Watson, Gayer, and Connolly 2007). In Bangladesh, after the 2004 floods, more than 17,000 cases of diarrhea were registered (Qadri et al. 2005), and the cholera epidemic in West Bengal, India in 1998 was attributed to preceding floods (Sur et al. 2000). In Pakistan, incidence of infectious disease and diarrhea increased as a result of the impact of the 2010 floods on the quality of water. Ongoing efforts to eradicate polio were also interrupted, further setting back this agenda (Warraich, Zaidi, and Patel 2011).

Diarrhea and other waterborne diseases affect households' well-being and prospects because they are so widespread. The cost of one episode of diarrhea is important for poor households, with treatment costs of $2–4 and the loss of a few days of work. But diarrhea can have even larger impacts, because it can provoke undernutrition by making children unable to absorb nutrients, even if they consume enough food. The total number of deaths caused directly or indirectly by undernutrition induced by unsafe water, inadequate sanitation, and insufficient hygiene is estimated at 860,000 per year among children under five (Vir 2011; this report, chapter 1).

Climate change can increase the risk of diarrhea through its impacts on temperature and water scarcity. Diarrhea is highly seasonal and higher rates of diarrhea have been associated with higher temperatures, although which specific pathogens are responsible for the association is unclear (Kolstad and Johansson 2010; Paz 2009). In Lima, Peru, a 4 percent increase in hospital admissions for diarrhea occurred for each °C increase in temperature during warmer months and a 12 percent increase for every degree centigrade increase in cooler months over six years of observation (Checkley et al. 2000).

Greater water stress will further challenge countries' ability to provide access to high-quality water and push people to use lower-quality sources, increasing the risk from contaminated water. Lower water quantity also reduces dilution, degrades water quality, and can change how people use water, in ways that can increase infectious disease transmission. In 18 Pacific islands, diarrhea cases increased with reduced water availability (Singh et al. 2001). Globally, low rainfall locations are strongly associated with higher diarrhea disease prevalence among children (Lloyd, Kovats, and Armstrong 2007). Hygiene is the main protection against diarrhea, but studies suggest that water scarcity makes it difficult for households to pursue it. In Peru, it was a lack of water that prevented a high awareness of the benefits from handwashing being translated into changed practices (Gilman et al. 1993).

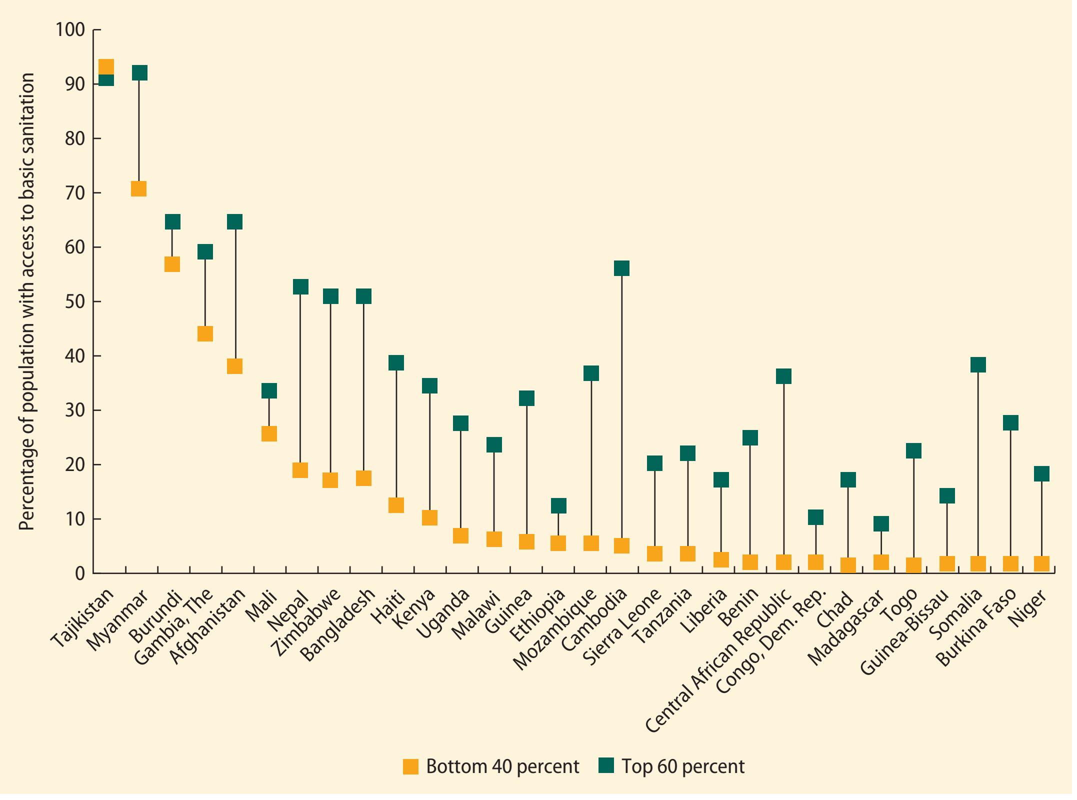
Overall, climate impacts could increase the burden of diarrhea by up to 10 percent by 2030 in some regions (Kolstad and Johansson 2010; WHO 2003, 2002). An estimated 48,000 additional deaths annually among children under the age of 15 resulting from diarrhea illness are projected by then (Hales et al. 2014).

The combined effects of temperature fluctuation, coastal salinity, humidity, heavy rainfall, flooding, and drought are likely to contribute to outbreaks of other waterborne diseases such as cholera and schistosomiasis (Bandyopadhyay, Kanji, and Wang 2012; Cann et al. 2013; Delpla et al. 2009; Stephenson, Lathan, and Ottesen 2000). Schistosomiasis is second to malaria as the most devastating illness in the tropics, causing a debilitating illness that not only damages the internal organs of its patients but also has lasting impact on the growth and cognitive development of children (Asenso-Okyere et al. 2011).

The risk of diarrhea and other waterborne diseases is reduced by better infrastructure, education, and hygiene. To eradicate diarrhea, both infrastructure improvement and education are needed. The risk for diarrheal disease outbreaks is higher in developing countries than in industrialized countries (Ahern et al. 2005; Noji 2000)—and a significant number of these diseases could be prevented in developing countries through better access to safe water supply, adequate sanitation facilities, and better hygiene practices (Bartram and Cairncross 2010). Indeed, diarrhea is an important risk for poor households because of unsatisfactory hygiene conditions that are related to a lack of infrastructure (WHO 2008). *The Global Monitoring Report 2014* (World Bank 2015a) shows large differences in access across groups even within low-income countries, with access to improved sanitation for the poorest 40 percent of the population everywhere much worse than for the richer 60 percent (figure 4.4).

The prevalence of diarrhea decreases with income, across and within countries, but there is a large variance at low-income levels (figure 4.5), suggesting that even poor countries can do much to reduce the prevalence of the disease among poor people. In rural India, access to piped water can significantly reduce the frequency and duration of diarrhea episodes among children under five, but only if combined with other behavioral interventions to promote good hygiene (Jalan and Ravallion 2003). Similar results are found elsewhere with an emphasis on the importance of systemic effects: for a family, gains from access to sanitation are relatively small; most of the benefits arise when the entire community gains access. Within poor communities, children living in a household with access to improved sanitation in a village with complete coverage manifest 47 percent fewer cases of diarrhea than children living in a household without access to improved sanitation in a village without sanitation coverage. One-fourth of this benefit can be attributed to household effects and the rest is due to community gains (Andres et al. 2014).

FIGURE 4.4 For poorer countries, access to better sanitation for the bottom 40 percent is much worse than for the top 60 percent



Source: World Bank 2015a.
Note: Most recent data between 2005 and 2012 are used.

Climate change can exacerbate stunting

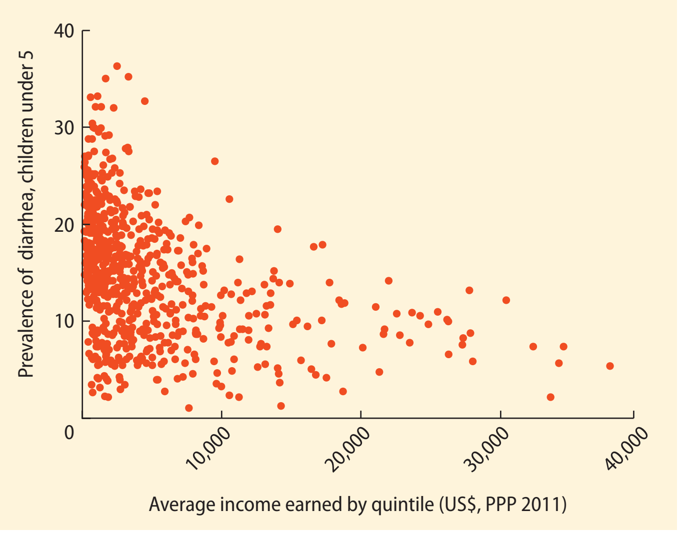
Despite international efforts in the last 15 years—and large progress in Latin America, some parts of Asia, and northern Africa—severe undernutrition remains a problem in Sub-Saharan Africa and Southern Asia. Chronic undernutrition, or stunting, is defined as a very low weight for height (below −3z scores of the median WHO growth standards), whereby children are smaller and shorter but appear normal.

Stunting can start before birth and is caused by poor maternal nutrition, poor feeding practices, poor food or water quality, and frequent infections. Around 25 percent of stunting among young children can be linked to having had five or more episodes of diarrhea before the age of two (Checkley et al. 2008). The consensus among scientists is that the damage to physical growth, brain development, and human capital formation that occurs in the period before pregnancy to 24 months of age is largely irreversible (World Bank 2006; Black et al. 2008).

Stunting in childhood has been associated with a greater risk of noncommunicable diseases and lower economic productivity in adulthood. The medium- and long-term effects of an increase in stunting among children could significantly reduce their ability to cope with shocks. Moderate stunting increases the risk of death by 1.6 times and severe stunting by a staggering 4.1 times (Black et al. 2008). Even when not mortal, severe stunting brings a higher risk of morbidity and significantly reduces future education and earning potential (Victora et al. 2008; Maccini and Yang 2009; Maluccio et al. 2009). Stunting therefore contributes to poverty and its intergenerational transmission.

Over 800 million people are currently undernourished, according to the Food and Agriculture Organization (FAO 2015). Children are highly represented in these numbers, with over a third of the burden of disease in undernutrition attributable to children under five (Black et al. 2008). In 2011, around 45 percent of deaths among children (3.1 million deaths) could be attributed to undernutrition (Black et al. 2013). And 165 million children under five years of age are stunted, 85 percent of whom live in 20 countries, mainly in South Asia and Sub-Saharan Africa (UNICEF 2013).

FIGURE 4.5 As incomes rise, the prevalence of diarrhea for children under five falls



Source: Based on data from World Bank 2014, 2015b.
Note: Each dot represents one income quintile in one country; the figure therefore shows differences across and within countries. PPP = purchasing power parity.

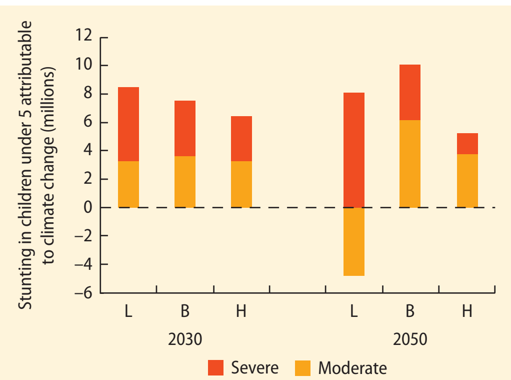
Climate change will likely be a strong obstacle to the eradication of stunting. Its impacts on food production and ecosystems, and natural disasters (like droughts or floods) force poor and uninsured households to reduce their food intake and quality—which in turn can lead to more frequent manifestations of undernutrition and stunting, particularly among children. Modeling studies suggest that unabated climate change could significantly challenge the increase in available calories per capita in Sub-Saharan Africa and South Asia. Such an impact would directly affect food intake and health. Poorly designed land-based mitigation policies could magnify these issues by increasing competition for land, and thus reducing food availability and contributing to undernutrition and stunting (see chapter 2).

Regardless of socioeconomic development, climate change will largely increase severe stunting among children (figure 4.6). An additional 7.5 million children are expected to be stunted by 2030, of whom 3.9 million would be affected by severe stunting (a 4 percent increase). A WHO report estimates this number will rise in 2050 to about 10 million additional children stunted, with an increase of moderate stunting to about 6 million children (Hales et al. 2014). These estimates include assumptions on improved public health due to technology and economic development, but they do not include nonagricultural interventions, like water and sanitation provision. Climate change could lead to an increase in severe stunting of up to 23 percent in Sub-Saharan Africa and up to 62 percent in South Asia, compared to scenarios without climate change (Lloyd et al. 2011). These increases correspond to an absolute increase in the number of stunted children in some parts of Sub-Saharan Africa, with the negative effect of climate change outweighing the positive effect of economic growth.

The quality of the diet is also essential. At least half of children worldwide aged six months to five years suffer from one or more micronutrient deficiencies (iron, iodine, vitamin A, folate, and zinc), and globally more than 2 billion people are affected.[2] Climate change could reduce the nutritional quality of food and worsen this issue (Myers et al. 2014), but no quantified estimate of the impact is available.

In Sub-Saharan Africa, there is evidence that households provide lower-quality nutrition to children in response to weather shocks (Alderman, Hoddinott, and Kinsey 2006; Dercon and Porter 2014; Hoddinott 2006; Yamano, Alderman, and Christiaensen 2005), which in turn increases the likelihood that they will suffer illness (Dercon and Porter 2014). These household behaviors and trends have significant and long-lived impacts on physical health, particularly for younger children and women. In Ethiopia, as early as six months following a disaster, households that reduced the nutritional quality of their food intake displayed lowered growth among children under two years by 0.9 cm (Yamano, Alderman, and Christiaensen 2005).

FIGURE 4.6 Stunting projections for 2030 and 2050 suggest that regardless of the socioeconomic scenario, climate change will increase severe stunting among children under 5



Source: Hales et al. 2014.
Note: The bars show the additional number of children under 5 stunted because of climate change in 2030 and 2050 under low-growth (L), base-case (B), and high-growth (H) socioeconomic scenarios. Moderate stunting decreases in 2050 in the low-growth scenario mostly because stunting becomes more severe, not because fewer children are stunted.

Climate-related shocks and disruptions can increase mental disorders and may exacerbate the "cognitive tax"

The evidence is growing that poverty is associated with mental disorders, even though the causality is unclear (Patel and Kleinman 2003). In developed countries, rates of mental disorders are much higher among low-income and homeless people than the rest of the population (Bassuk et al. 1998; Fazel et al. 2008). In low- and middle-income countries, a review of 115 studies reports a positive association between a range of poverty indicators and mental disorders (Lund et al. 2010).

We know that natural disasters can cause high levels of stress and mental disorders. Anxiety, depression, and post-traumatic stress disorder (PTSD) have been reported in populations affected by flooding and during slow-onset events such as droughts (Ahern et al. 2005; Paranjothy et al. 2011). In Nicaragua, a study of adolescents half a year after Hurricane Mitch found instances of PTSD, stress, and depression, particularly among those in most affected communities who suffered the highest impact and those who experienced a death in the household (Goenjian et al. 2001). In Sri Lanka, children between the ages of 8 and 14 in areas affected by the 2004 tsunami had rates of PTSD ranging from 14 to 39 percent within a month of the event (Neuner et al. 2006). These trends can lead to chronic distress and increased incidence of suicide (Berry, Bowen, and Kjellstrom 2010; Hanigan et al. 2012; Keshavarz et al. 2013). To mitigate impacts, psychosocial and psychological interventions must be incorporated into disaster response and recovery management interventions.

The worry is that climate change may exacerbate mental disorders and stress. It could do so directly through greater exposure to trauma (from floods and other disasters) but also indirectly through impacts on physical health, household dynamics, and community well-being. Poor households, already strained by the pressures of poor living conditions and scarce resources, could be more prone to larger mental health effects after exposure to extreme weather events. After Hurricane Katrina in the United States, those with anxiety prior to the storm were more likely to experience PTSD symptoms afterward, and younger children had more symptoms (Kronenberg et al. 2010; Weems et al. 2007). In the longer term, flooding affects perceptions of security and safety and can lead to depression, anxiety, PTSD, and other chronic and severe mental health disorders (Ahern et al. 2005; Berry, Bowen, and Kjellstrom 2010; Fritze et al. 2008; Paranjothy et al. 2011). Higher temperatures and extreme rainfall also raise concerns about more frequent conflicts, which tend to impede poverty reduction (box 4.3).

Risks and stresses also affect cognitive performance and decision making. Planning for contingencies (for example, because of a shock), unpredictable income, and constant worry about the financial situation create stress and depression for the poor, which

BOX 4.3 The uncertain triangle of climate change, conflict, and poverty

Conflict, fragility, and lack of security and stability are fundamental barriers to poverty reduction and the well-being of the poor (World Bank 2011). This is illustrated by the increasing share of poor people living in conflict environments. In the 33 countries (representing half a billion people) classified by the World Bank as fragile and conflict-affected states, the poverty headcount is 51 percent. Similarly, within countries, poor people are also more exposed to crime: in Cape Town, South Africa, 44 percent of all homicides occur in three neighborhoods that are among the city's poorest (World Bank 2013, chapter 4).

What type of impact does the environment—and potentially climate change—have on conflicts? This is an area of active research (Burke, Hsiang, and Miguel 2014), which can be split into studies covering conflicts from either the interpersonal level (like assaults and rape) or the intergroup (national) level (like civil conflicts, wars, and riots).

Interpersonal conflicts: There is a strong correlation in the United States between crime and violence and temperature, raising the question of whether climate change will increase murders, assaults, rape, and other violence (Ranson 2014). In developed countries, studies typically cite psychological factors for this correlation (such as people become more aggressive during heat waves). In less developed countries, like India, the trigger may be lower income from higher temperatures, which in turn can raise crime rates (Iyer and Topalova 2014).

Intergroup conflict: A large body of literature suggests a link between weather or climate and conflict, especially in low-income areas. A meta-analysis suggests that intergroup conflicts increase by 11 percent when temperatures increase one standard deviation and by 3.5 percent when rainfall deviates one standard deviation (Hsiang, Burke, and Miguel 2013; Burke, Hsiang, and Miguel 2014). However, a vigorous debate has emerged around the robustness of these results (Buhaug et al. 2014; Hsiang, Burke, and Miguel 2014), with the IPCC noting that "*collectively the research does not conclude that there is a strong positive relationship between warming and armed conflict*" (Adger et al. 2014).

reduces focus, lowers productivity, and interferes with making long-term decisions (Banerjee and Duflo 2012). Poor people may have little time or energy to think about the future, as their day-to-day economic lives are more consuming of cognitive control than for the rich (Banerjee and Duflo 2012). This effect has been referred to as the "cognitive tax": the high level of stress of poor people acts like a tax that reduces their productivity and earnings, contributing to their poverty.

Already today, natural risks are a major source of stress. In flood-prone wards of Mumbai, 71 percent of the households surveyed cited flooding as a critical stressor, second only to "hectic life," and more important than stress from transportation or congestion (figure 4.7) (Patankar, forthcoming). Against the background of anticipated more frequent natural hazards due to climate change, this cognitive tax for poor people may increase.

High temperatures are a health hazard and affect labor productivity

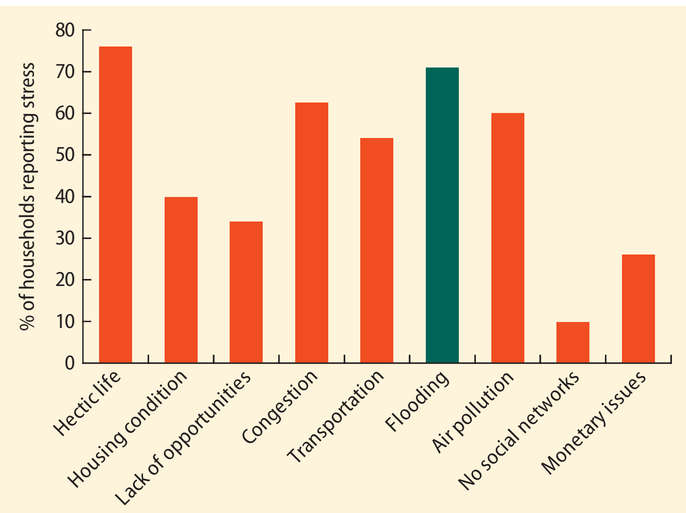
Though extreme cold-related deaths will decrease in temperate regions, the negative effects of heat waves will likely outweigh these benefits. Health effects from extreme heat exposure are expected to result from both higher average seasonal temperature and more frequent and intense extreme heat wave events (Huang et al. 2011; IPCC 2014). Chapter 3 discussed exposure to heat waves, showing that poor individuals are more likely to be exposed to higher temperature, especially in hot countries. It also showed that poor people are particularly vulnerable to high temperatures, because of their living conditions, the poor quality of their housing, and a lack of access to air-conditioning. Here, we explore the consequences of this exposure to high temperature, looking at direct health consequences and their impacts on performance and productivity.

Heat-related problems will not be limited to developing regions. It is projected that, globally, by 2030, without accounting for adaptation, there could about 100,000 additional deaths annually in 2030—and 250,000 annual deaths in 2050—among those aged 65 and over (Hales et al. 2014). Of course, humans adapt, so adaptation may lower these estimates. But these estimates do not include morbidity and mortality in other age groups and among vulnerable people, nor do they factor in extreme heat wave events.

Most heat wave–related deaths occur among poor elderly people and people who have existing illnesses (such as cardiovascular or chronic respiratory diseases and mental illness) (WHO 2003). Urban dwellers are particularly at risk because of inefficient housing and the heat island effect—where urban environments with high thermal mass and low ventilation retain heat, thereby amplifying the rise in temperature, especially at night. Air-conditioning practices in urban areas further amplify this effect as indoor heat is transferred outdoors, which hurts the destitute and homeless. In Taiwan, China air-conditioning was found to have added 0.7°C to the outdoor temperature (Liu, Ma, and Li 2011). And as a greater portion of the population becomes elderly and urbanization increases, a bigger share of the population will be vulnerable to heat stress.

One possible solution is climate-smart urban design and innovative architecture,

FIGURE 4.7 Poor households in Mumbai face multiple stresses, with a key one the risk from floods



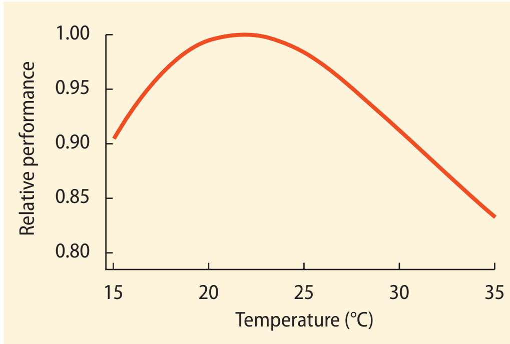
Source: Patankar, forthcoming.
Note: Y-axis shows the percent of respondents who cited each stress as being important. Multiple stresses could be reported.

which can reduce this effect while taking advantage of shade provision, solar heat management, and other measures that use thermal insulation to minimize energy consumption (Masson et al. 2013; Masson et al. 2014; Stone, Hess, and Frumkin 2010). Additionally, well-designed early warning and surveillance systems can help detect and respond to heat waves. These must be adapted to the levels of risk so as to have a significant impact on reducing mortality (Ebi et al. 2004; Schmier and Ebi 2009).

High temperatures reduce labor productivity and can thus increase poverty. A well-established medical and task productivity literature has uncovered a systematic relationship between temperature stress of the human body and reduced performance (Seppänen, Fisk, and Lei 2006). Lab experiments have quantified this relationship by randomly assigning subjects to rooms of varying temperatures and asking them to perform cognitive and physical tasks. They find that extreme temperature reduces human performance on a wide range of tasks, including time estimation, vigilance, and higher cognitive functions (like mental arithmetic and simulated flight) (Grether 1973). A review of the experimental literature finds that in laboratory settings task productivity improves up to a temperature threshold of around 20°C to 25°C, but after that it declines significantly—with the average productivity loss on the order of 2 percent per °C for the various tasks surveyed (figure 4.8). Similarly, a review of historical fluctuations in temperature within countries identifies that higher temperatures reduce economic growth in poor countries (Dell, Jones, and Olken 2012).

Responses by workers to temperature shocks may take many forms (Heal and Park 2013; Zivin and Neidell 2014). There may be declines in task productivity, labor supply (hours worked), labor effort, or all three. The emerging microeconometric literature finds evidence for at least the first two in particular, and likely reflects a combination of all three—the specific breakdown of which will depend on labor market institutions and specific

FIGURE 4.8 If it gets too hot, productivity falls significantly



Source: Seppänen, Fisk, and Lei 2006.

incentives faced by workers. And even though these studies focus on the developed world, a similar impact in developing countries can be expected.

In developing countries, temperatures above 24–25°C are associated with poorer performance (Federspiel et al. 2004). Indian manufacturing worker efficiency at the plant level declines substantially on hotter days, with a magnitude of roughly minus 2.8 percent per °C, an effect that is driven primarily by on-the-job task productivity decline as opposed to increased missed days of work or absenteeism (Adhvaryu, Chari, and Sharma 2013; Sudarshan et al. 2015). Granted, air-conditioning is typically a scarce commodity in the developing world, but there does seem to be evidence that the same phenomena occur even in developed economies such as the United States (Deryugina and Hsiang 2014; Park, forthcoming). This result suggests that air-conditioning, while useful, may not be able to cancel out all of the impacts from higher temperature.

There is also evidence of a drop in labor supply in response to heat stress (Zivin and Neidell 2014). In U.S. industries with a high exposure to climate, workers report less time spent at work and less time spent on outdoor leisure activities, on hot and cold days. At temperatures over 38°C, labor supply in outdoor industries drops by as much as one hour per day compared to those in the 24–27°C range. Using U.S. plant-level output data from

1994–2004 for the automobile sector, a study found that hot days are associated with lower output across the board. At the extreme, a week with six or more days above 32°C reduces that week's production by about 8 percent (Cachon, Gallino, and Olivares 2012).

Poorer households are more likely to be affected by the downsides of higher temperatures because they are less likely to benefit from air conditioning and more likely to work in sectors that are more sensitive to temperature stress: namely, manual labor–intensive industries, and outdoor work–intensive sectors (like agriculture and construction). It is also likely the case that manual labor and outdoor work occupations pay lower wages on average. The U.S. Bureau of Labor Statistics reports that the average construction laborer earns 25 percent less than the median U.S. worker, and laborers in the farming, fishing, and forestry sector earn 48 percent less (BLS 2015).

It remains unclear how much can be expected from adaptation and how large the expected social costs of adaptation will be—whether in the form of physical capital investments, relocation costs, or the nonpecuniary costs of changing habit patterns and social norms. Also, the role of technological change is unclear; the same goes for possible public investment in research and development on these issues.

Climate change impacts on individual productivity could have an effect at the macroeconomic level. As to the toll climate change might take on economic growth at the global and national levels, researchers have long noted a relationship between temperature and macroeconomic variables (namely income and growth). As far back as Montesquieu in the 18th century (Huntington 1922; Montesquieu 1758), there has been a suggestion that extreme climate may reduce economic growth. Using data from agricultural and manufacturing occupations in North Carolina, a study showed that aggregate productivity was highest in moderate temperatures (fall and spring), and lower in more extreme temperatures (summer, winter) (Huntington 1922).

Since then, numerous cross-country analyses have suggested that hotter countries have tended to grow more slowly on average. Many have noted that hotter countries tend to have lower income levels generally—with a gradient of roughly minus 8.5 percent per capita income per °C hotter average temperatures (Dell, Jones, and Olken 2009; Horowitz 2009). However, it is likely that unobservable effects play an important role (like institutions, levels of human capital, and agricultural productivity) (Acemoglu, Johnson, and Robinson 2000).

This negative relationship between temperature and income seems to hold within countries, albeit to a milder extent. This suggests that institutional factors are not wholly responsible for the temperature-productivity relationship and there are limits to adaptation through better buildings and air-conditioning. An assessment of incomes at the municipality level for 12 U.S. counties finds that a 1°C rise in temperature is associated with 1.2–1.9 percent lower per capita income (Acemoglu and Dell 2009). Similar results are found analyzing a larger set of counties, using U.S. income and payroll data from 1986–2012 (Deryugina and Hsiang 2014; Park, forthcoming).

Health care systems and development pathways play a critical role

The outcome of climate-induced health effects will be determined by institutional structures and the combined effects of parallel global changes—such as urbanization, population growth, and demographic shifts. Also relevant are social norms and behavior, along with differences in the vulnerability of populations due to nonclimatic factors (Ebi and Semenza 2008; Patz et al. 2005; Sutherst 2004). For instance, in developing countries, around 43 percent of the reduction in the number of children underweight between 1970 and 1995 can be attributed to greater access to education for women, 26 percent to greater access to food, and 19 percent to improved water and sanitation (Smith and Haddad 2000).

Health infrastructure, access, and quality of care need to be improved

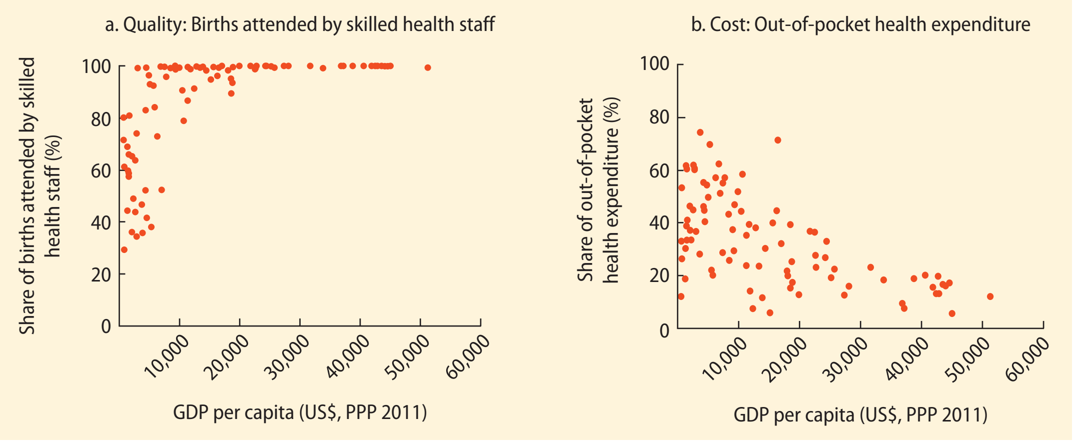
Given that low-income countries will be the most vulnerable because of limited public health infrastructure, a top priority should be improving health care. Often, treatable illnesses are not addressed because of lack of access to adequate health care services. In rural areas, transportation may not be available to transfer the ill to clinics. Further, many of these rural clinics do not have adequate equipment or trained health personnel, and require payment up front.

Today, the share of births attended by skilled health staff is close to 100 percent for countries above GDP per capita of $20,000 but varies widely below this level, suggesting progress can be made even at low-income levels (figure 4.9, panel a). If skilled health staff are not available—for birth, injuries, or diseases—people are more likely to suffer from permanent consequences on health, income, and well-being. Improving health care systems (staff training, vaccination programs, information campaigns, and access to rapid diagnostic kits and drugs for treatment) is therefore essential. With significant investments over the next 20 years, it is possible to improve the level of health care supply in low-income countries to the level of the best middle-income countries today (Jamison et al. 2013).

Although beyond the scope of this report, the health sector can also play a role in emissions reductions. In the United Kingdom, this sector is responsible for about 25 percent of all public sector emissions and, in the United States, about 8 percent of total emissions. It is thus crucial that investments contribute to greening the health infrastructure.

The risk from emerging diseases or unexpected crises also increases the urgency to put in place effective risk monitoring systems (Wesolowski et al. 2015; Semenza and Menne 2009) and to share experience and information (Ebi and Burton 2008)—as illustrated by the emergence of chikungunya in France, Italy, and the Caribbean. This means an urgent need for surveillance systems that rely on all participants in the health care system (especially private practice physicians), effective communication of good behaviors through general media, and international cooperation and exchange of information. Such efforts pay off. Following the 2003 heat wave in France, the government introduced a heat wave warning system and national action plan. Health worker training and new infrastructure helped avoid an estimated

FIGURE 4.9 A lot of room to improve the quality and cost of health care in poor countries



Source: Based on data from World Bank 2015b.
Note: PPP = purchasing power parity.

BOX 4.4 Universal health coverage: Kenya's bottom-up strategy

Launched in 2010, Kenya's Health Sector Services Fund (HSSF) aims to expand the supply of health care and strengthen primary care by providing direct cash transfers to public health facilities—particularly in rural areas where health centers and dispensaries are a primary source of care and over 80 percent of the population resides. Jointly supported by the government of Kenya, the Danish International Development Agency (DANIDA), and the World Bank, this initiative complements better access and transparency of resources with sector reforms to improve the availability of human resources and essential medicine for service delivery. The HSSF encourages transparency, community participation in decision making, and accountability for resource allocation and results. Local communities are tasked with managing the funds through representative management committees and work with the staff of health facilities to improve delivery of services.

So far, this initiative has reached 3,000 public primary health facilities and boosted the use of health facilities. Preliminary observations show better reporting and accounting for user fees collected and stronger information and governance systems. In some facilities, these funds were used effectively to upgrade service delivery (such as providing electricity in maternity wards for 24-hour services) and better maintain facilities by hiring more local staff. A successful pilot exploring the incorporation of performance-based financing in this program shows further potential for improving service quality (for example, with better prenatal care and more child immunization).

The direct funding provided by HSSF has helped ensure that resources reach the periphery of the health system at low levels of bureaucratic interference without compromising transparency. A demand-based "pull system" approach that requires facilities to order supplies and commodities based on need, as opposed to centrally determined allocation, has significantly reduced wastage and expiry of drugs while increasing the reliable availability of health commodities.

Source: Ramana, Chepkoech, and Workie 2013.

4,400 deaths in a subsequent 2006 heat wave (Fouillet et al. 2008; Pascal et al. 2006).

And research and development efforts in the health sector should be intensified to better prevent, diagnose, and treat diseases that affect poor people, especially those that are expected to increase over time, including because of climate change. This is especially true for the so-called "neglected tropical diseases"—those diseases that thrive mainly among the world's poorest populations.[3] Of these, several, such as dengue, leishmaniasis, and chikungunya are sensitive to climate and likely to change in spatial distribution with climate change. Private research and development (R&D) alone is unlikely to develop the needed solutions without public intervention (Trouiller et al. 2001). Today, annual R&D spending on "infectious diseases of particular concern to low-income and middle-income countries" amounts only to $3 billion—out of the nearly $250 billion spent annually on health-related R&D (Jamison et al. 2013).

Social protection systems can also play a significant role, especially in helping avoid irreversible losses from undernutrition—but only if they can be scaled up quickly after shocks and targeted to reach the poorest and most vulnerable (Alderman 2010; Clarke and Hill 2013; this report, chapter 5).

Universal health care coverage is an adaptation priority

Even if skilled health care is available, its affordability is not a given. Health shocks tend to bring households into poverty even more where people have to borrow, often at high interest rates, creating debts that they may never be able to repay (Krishna 2006). The WHO estimates that about 100 million people fall into poverty each year just to pay for health care (WHO 2013b). A big problem is that financial risk protection varies widely, with people in low-income countries having to bear very high and variable fractions of out-of-pocket health expenditure (figure 4.9, panel b).

Thus, better health care coverage and lower out-of-pocket expenses would be efficient ways to reduce the health impacts of climate change vulnerability and reduce poverty, especially by helping the poor to manage catastrophic health expenditures (Jamison et al. 2013). Providing health coverage is possible at all income levels, but context and implementation challenges will determine the optimal path for countries, as the case in Kenya illustrates (box 4.4). Rwanda invested in a universal health coverage system in 1994, and today over 80 percent of its population is insured.

Employment-based social insurance is limited to the formal sector. But strategic policies that promote equitable and propoor financing mechanisms can accelerate the process toward universal health coverage. In Thailand, the government has expanded coverage to the informal sector with a minimal charge of $0.70 per visit, drawing on general tax revenues. In Colombia, through a multilevel government scheme and cross-subsidization from contributory schemes, the poor are covered against primary care and catastrophic event costs—with coverage among the poorest quintile rising from 3 to 8 percent in 1993 to 47 percent by 1997. In parts of Africa and Asia, an efficient tool is community-financed coverage schemes that pool expenditure risks at lower administrative levels. Strong community solidarity and administrative capacity is important for these interventions (O'Donnell 2007).

What can we learn from past efforts to expand health coverage? Four insights stand out: (i) affordability is important but not sufficient to achieve universal access, and measures to ensure affordability should be included within a broader strategy; (ii) targeting the poor is necessary, but it is also important to assess the consequences of reforms on the nonpoor; (iii) solutions are best designed starting from population needs—including the local epidemiological profile, major barriers to access to care, unsatisfied demand, and major sources of financial hardship; and (iv) highly focused interventions (such as on one barrier to access or one disease) can be a useful initial step toward universal coverage (Giedion, Andrés Alfonso, and Díaz 2013).

In conclusion

Health shocks and poor health bring and keep people in poverty, and can reduce lifelong earning prospects when children are affected. Climate change is expected to worsen many of these issues—although big uncertainties remain, such as the extent to which climate change will affect the nutritional quality of food. Moreover, the combined effects of multiple health stressors are largely unknown, in spite of the importance of interactions among diseases. For instance, undernourished children are known to be more vulnerable to malaria and other vectorborne or waterborne diseases, but these interactions have not been investigated yet in the context of climate change.

The encouraging news is that economic development, poverty reduction, and better infrastructure and access to health care could compensate for many of the negative projected climate-related trends. Indeed, if developing countries could achieve the present level of health care access in industrialized countries by 2030, they could avoid many of the impacts that would worsen health conditions. Child mortality could fall by an estimated 63 percent globally if coverage rates of effective prevention and treatment mechanisms rose to 99 percent (Jones et al. 2003).

A recent Lancet Commission on Investing in Health concludes that by 2035, a "grand convergence" in mortality and morbidity rates across the world is achievable, as is the global provision of universal health care

(Jamison et al. 2013). The report contends that enhanced investments to scale up health technologies and systems in developing countries could bring down mortality rates in most low-income and middle-income countries to those presently seen in the best-performing middle-income countries. This would mean the prevention of about 10 million deaths in 2035 in these poorer countries relative to a scenario of stagnant investments and no improvements in health technology. The benefit-cost ratio of these investments is estimated between 9 and 20, without accounting for climate change. And, as this chapter has shown, climate change only amplifies the benefits of acting now to improve health services.

Of course, a "grand convergence" would significantly reduce the impact of climate change on poor people through the health channel. But even with prevention and hygiene, and even if health care and health coverage are available, diseases and accidents cannot be fully prevented—and they will continue to lead to reduced income, lost days of work, and higher expenses. To help poor households cope with these shocks and avoid the irreversible impacts on children's development and education, other tools can be mobilized and developed, such as financial products to save and borrow, social safety nets (such as cash transfers and social insurance), and remittances and support from family and friends. The next chapter explores how these instruments can help, and whether they need to be designed differently, in a context of climate change.

Notes

1. Asenso-Okyere and Dzator 1997; Attanayake, Fox-Rushby, and Mills 2000; Desfontaine et al. 1989; Ettling et al. 1994; Guiguemde et al. 1994; Konradsen et al. 1997; Louis et al. 1992; Onwujekwe, Chima, and Okonkwo 2000
2. http://www.cdc.gov/immpact/micronutrients/
3. http://www.who.int/neglected_diseases/diseases/en/

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Lend a Hand: Poor People, Support Systems, Safety Nets, and Inclusion | 5

Main Messages

- Poor people struggle more than others to cope with and adapt to climate change and natural hazards: not only are they more exposed and vulnerable to shocks but the support they receive from families, communities, financial system, and government is also weaker, and they are often not granted a voice in decision-making processes.
- Financial inclusion, insurance, social safety nets, and remittances complement each other in protecting different populations against different types of shocks.
- Given the limits to how much protection the financial system can offer, especially to the poorest, social safety nets are needed to provide effective protection to poor households. To be effective, safety nets must be rapidly scalable, even if speed of delivery may come at the cost of targeting.
- An adaptive social protection system creates a formal liability for the government, which may need to draw on instruments such as reserve funds, contingent finance, reinsurance products, or even international aid.

Introduction

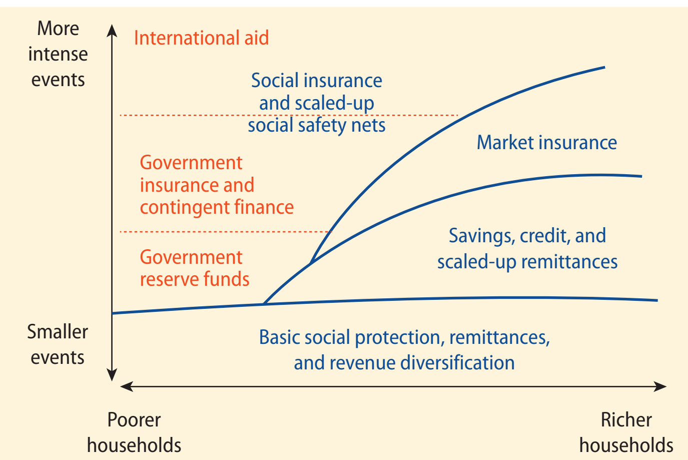
Poor people are particularly exposed and vulnerable to the physical impacts of climate change, such as reduced crop yields, more intense floods, or lower productivity due to extreme temperature, making climate change and disasters a magnifier of existing inequalities. However, these direct impacts tell only part of the story. When people are affected by a shock or a change in economic conditions (like higher food or energy prices), they may adapt to reduce the losses or even benefit from the changes. Hence, the overall impact on welfare and quality of life also depends on how well people cope and adapt.

One reason why poor people struggle to adapt to changes in environmental and economic conditions is limited resources—for instance, limited financial resources can push poor people to live in the most flood-prone areas of cities, even if they are aware of the risk (chapter 3). In addition, as discussed in the World Bank's *World Development Report 2014: Risk and Opportunity*, the ability to manage risk also depends on the "support systems" available to them: the household, the community, the enterprise and financial sectors, and the state. These support systems are also critical to help individuals and firms adapt to the effects of climate change, cope with the impacts that cannot be avoided, and deal with the potential adverse side effects from emissions-reduction policies.

This chapter investigates how these systems support people in the face of natural hazards, environmental changes, and economic and policy transitions. It assesses the obstacles that prevent effective risk management and adaptation to environmental and economic changes—and then suggests available policies to help poor people adapt to climate change and cope with its consequences. It follows by reviewing the role of financial instruments, social protection systems and safety nets, and migrations and remittances, closing with thoughts on governance and the poor.

The chapter finds that poor people's disproportionate suffering from climate change and shocks arises not just from the fact that they are more exposed and vulnerable but also because they receive less support from financial instruments, social protection schemes, and private remittances. For instance, in response to flooding and landslides in communities in Nepal in 2011, only 6 percent of the very poor sought government support, compared to almost 90 percent of the well-off (Gentle et al. 2014). Besides suffering from larger immediate shocks than the wealthier, poor people also tend to be more alone in the struggle to cope and recover.

FIGURE 5.1 Poorer households need different types of solutions



The key message of this chapter is the need for a holistic and flexible risk management strategy—with a range of policy instruments appropriate for different disasters and affected populations (figure 5.1). Revenue diversification and basic social protection, where it exists, can help households at all income levels cope with small shocks. But, when a shock is larger, these instruments will not be sufficient, and additional tools are needed. For relatively wealthier households, savings will help; and market insurance can provide them with efficient protection for larger losses. However, for the poorest households, savings are often not an option; and high transaction costs make private insurance unattainable.

For the poorest households—and to cover the largest shocks—well-targeted and easily scalable social safety nets are needed. These systems need to be designed so as to maintain incentives to invest in long-term adaptation to economic and environmental changes. Such an adaptive social protection system creates a liability for the government, which may need to rely on financial instruments such as reserve funds (for small-scale events), contingent finance, reinsurance products, or even international aid if its capacity is exhausted. Social protection systems and financial protection have always been needed to help people cope with individual and systemic shocks, including disease and natural disasters, but this need has been intensified and made more urgent by climate change.

Saving, borrowing, and insurance help people adapt to changes and cope with shocks, but are not always accessible for poor people

People use financial instruments—notably their savings and assets—to smooth consumption and limit the effects of income shocks. While evidence suggests that this smoothing is significant, it is also far from complete (Kinnan and Townsend 2012; Morduch 1995). In extreme cases, households have even been found to reduce consumption to protect their assets, thus exacerbating consumption shocks (Zimmerman and Carter 2003). In general however, financial instruments (such as bank accounts and insurance contracts) can complement informal risk-sharing mechanisms and play a critical role in helping households and firms adapt to climate change, prepare for natural shocks, and recover when affected (World Bank 2013a, chapters 4 and 6).

We know that savings at financial institutions tend to be less vulnerable to natural disasters than in-kind savings (chapter 3). Livestock and housing can be washed away by a flood, while savings accounts are far less likely to be affected. Financial inclusion makes it possible for households to protect their savings and lower the vulnerability of their asset portfolio, so they can cope with income losses while maintaining consumption and avoiding radical coping measures, such as reduced food intake.

Financial inclusion also enables people and firms to reduce risk in the first place. For instance, if changes in rainfall patterns call for adapting farming activities, farmers will need to invest in new machines and seeds, or possibly learn new techniques. Without access to credit, these measures may be unaffordable, thus locking them into activities with declining productivity and income.

Poor people lack access to savings and credit, but policies can enhance financial inclusion

Unfortunately poor people often lack access to formal financial instruments—possibly because of the cost of bank accounts, large distance and time to access a financial agent, or lack of documentation and mistrust in banks. Some people also prefer to stay in the informal sector, or are not fully aware of the benefits of using financial tools for risk management (Allen et al. 2012). For instance, in Indonesia, more than 20 percent of households in the top 60 percent of the income distribution saved at a financial institution in 2011, compared to less than 8 percent from the bottom 40 percent. Poor people also have less access to credit when affected by a shock or worsening environmental conditions.

What can governments do? The *2014 World Development Report* (World Bank 2013a, chapter 6) discusses the actions that governments can take to help households at all income levels gain access to financial instruments for risk management. Two categories emerge.

Financial infrastructure. To reduce costs and improve trust in the banking system, governments can strengthen the financial infrastructure (including payment and security settlement systems and public credit registries). Physical access to financial instruments can be improved by using the postal network, and improving infrastructure for hosting financial agents and facilitating transport (roads and public transit). Wide coverage by mobile phone networks can make financial instruments accessible virtually, by using cellular banking and electronic payment technologies (Gupta 2013).

Competition, protection, and flexibility. Governments can help keep service costs low by ensuring fair competition and consumer protection, or by requiring the introduction of low-cost bank accounts for vulnerable populations. Moreover, ensuring convenience and flexibility is critical for accommodating the relatively high frequency at which poor people tend to make deposits and withdrawals, or take out and repay loans. For instance, poor households benefit greatly from flexible loan schedules that can be readily renegotiated or forborne in "hungry months," or paid in advance when the household enjoys extra liquidity. Experience from microcredit also demonstrates the benefits from schemes that create self-discipline—like using planned saving schedules (Banerjee and Duflo 2012). Poor people are also less able to protect themselves against fraud and abuse, underscoring the need for adequate and accessible consumer protection schemes. In Mexico and South Africa, the government has established financial ombudsmen to resolve disputes in consumer finance (Brix and McKee 2010).

While borrowing can help maintain consumption in the short term, it can also create a debt trap from which poor households have trouble escaping. For instance, health shocks are more likely to push people into poverty in the presence of high borrowing costs, precisely because of such trap effects (Krishna 2006). Stringent borrowing conditions paired with postdisaster destitution mean that poor households affected by disasters are likely to quickly incur high levels of debt.

In Bangladesh after the 1998 floods, borrowing was by far the most common coping mechanism chosen by a sample of 757 households in a postdisaster survey (del Ninno et al. 2001). Almost 60 percent of these households were in debt in the months immediately following the floods, with average debt rising to almost 1.5 months of average consumption. Furthermore, 57 percent of flood-affected households in the bottom three quintiles resorted to purchasing food on credit. This borrowing mitigated the shock, but higher prices meant that poor flood-affected households consumed less. The financial cost of borrowing was found to vary widely, with interest rates from zero (for many loans from family and neighbors) to an average of 50 percent for loans from banks and cooperatives. Better access to finance ex ante and lower interest rates could have reduced the debt trap and improved recovery.

The development of insurance markets in low-income economies faces many obstacles

To cope with large shocks that affect many people, savings or borrowing may not be adequate. Instead, insurance products can provide protection at a lower cost. However, insurance markets are complex, and behaviors often deviate from what theory suggests, making it challenging to provide appropriate insurance products to poor households or small firms in developing countries, which are often exposed to many risks (Kunreuther, Pauly, and McMorrow 2013).

The classical indemnity insurance products are commonplace in high-income countries and are based on the observation of losses, with insurance payments triggered once losses occur. Classical indemnity insurance requires that robust data be available for the insurer to assess risks ex ante—something that is often lacking in developing countries (Rogers and Tsirkunov 2013). And loss assessment may be costly if it requires that an expert visit every victim.

One problem with indemnity insurance is that asymmetric information results in *adverse selection* and *moral hazard*. Adverse selection refers to the fact that if the price of insurance cannot be adjusted to the level of risk that clients face—because the information is unavailable or too costly to collect—then those clients facing more risk will demand more insurance, threatening the sustainability of the insurance scheme. But this problem can be solved by making insurance mandatory, although it will be tough to do in countries with little capacity or where premiums would be particularly high.

Moral hazard refers to the fact that people protected against the negative impact of a shock could choose to do less to prevent the shock or reduce associated losses. In the case of insurance against natural hazards, moral hazard is mitigated by the fact that households suffer from significant nonmonetary uninsured losses (such as the hassle of relocation and loss of personal property if one's house is flooded). In most contracts, it is mitigated further by deductibles, which ensure that the insured face a portion of the losses in case of a shock.

Even in developed countries, penetration of indemnity insurance against natural hazards remains low, albeit with some exceptions: (i) when insurance is subsidized, as with floods in the United States with the National Flood Insurance Program; (ii) when insurance is mandatory and backed by the government—such as the Turkish insurance against earthquakes and fires, which is an excellent example of how insurance access can be increased in middle-income countries (box 5.1); or (iii) when insurance is mandatory, cross-subsidized, and backed by the government, the case of France's Cat-Nat storm and drought insurance (Paudel 2012). However, subsidizing insurance can be prohibitively expensive, and the penetration of indemnity insurance is very low in developing countries.

These problems have led to the development of index-based insurance products, in which insurance payments are not made based on observed losses, but when a physical variable—such as a rainfall deficit or wind speed—exceeds a predetermined threshold (regardless of the existence of losses). For instance, a farmer will receive a predefined insurance payment if rainfall is below a minimum threshold over a one-month period. Index-based insurance

BOX 5.1 Developing catastrophe insurance in Turkey through public-private partnerships

Few countries in the world are more exposed to earthquakes than Turkey. Around 70 percent of its population and 75 percent of its industrial facilities are exposed to large-scale earthquakes. Since 1984, direct property and infrastructure losses due to earthquake episodes in Turkey have frequently exceeded $5 billion (in current US$ terms). The last major earthquake in the Marmara region in 1999 resulted in the loss of 15,000 lives and placed an enormous financial burden on the economy and the government.

Before 1999, earthquake insurance uptake had traditionally been low in Turkey (at around 3 percent of residential buildings) because households traditionally relied on the government to finance the reconstruction of private property after major natural disasters. This presented massive challenges to government budgets. But, in the aftermath of the Marmara earthquake, the government decided to develop a catastrophe risk insurance mechanism to reduce its fiscal exposure to natural hazards—arising from publicly funded reconstruction of private property. In 2000, it created a compulsory earthquake insurance system for all residential buildings on registered land in urban areas.

The World Bank provided financial and technical assistance for creating the Turkish Catastrophe Insurance Pool (TCIP)—the first national catastrophe insurance pool in World Bank partner countries that provides a stand-alone earthquake insurance coverage to homeowners and small and medium enterprises. The TCIP provides mandatory property earthquake insurance for owners of private dwellings built legally on registered land. Premium rates are actuarially sound, not subsidized, and vary with construction type and property location. Covered risks include earthquakes and fire.

The catastrophe risk financing strategy of the TCIP relies on both risk retention and reinsurance. The TCIP absorbs the first $80 million of losses through its reserves (initially complemented by a $100 million World Bank contingent loan facility) and transfers excess losses to the international reinsurance markets. The government covers losses that would exceed the overall claims-paying capacity of the TCIP, which is estimated to be able to withstand a 1-in-350 year earthquake. Economies of scale are obtained through countrywide pooling of the risk and transaction costs, which results in more affordable premium rates.

Source: Global Facility for Disaster Reduction and Recovery (GFDRR) policy note on the TCIP. More information can be found in Gurenko 2006.

schemes have major advantages compared with traditional contracts: (i) transaction costs are reduced because losses do not need to be measured; (ii) individuals are still encouraged to take preventive measures since the payout does not depend on the losses or the actions taken to reduce risks (in other words, there is no moral hazard with index-based insurance); and (iii) the payment decision is simple and objective, making it easier to enforce contracts.

However, index-based insurance suffers from *basis risk* (that is, the difference between the payment received by contract holders and the actual losses they suffer). If the index is well correlated with actual losses, contract holders will receive an adequate insurance payment when (and only when) they have losses. But, in practice, the correlation between losses and payout can be low, because of wide variations in impacts from natural hazards and limitations of hydrometeorological observation systems. This means that people may receive a payment in the absence of losses, or receive nothing even in the presence of large losses—which would be catastrophic for those close to the subsistence level.

Despite its advantages, the take-up of index-based insurance is low, with several reasons being proffered (Brown, Zelenska, and Mobarak 2013; Cole et al. 2012; Cole et al. 2013). One is that basis risk plays a key role, because a low correlation between losses and payout undercuts the product's benefits (Karlan et al. 2012; Mobarak and Rosenzweig 2013). Another is that index insurance typically covers only one type of risk, while producers may be exposed to many (like price risk or supply chain risk). Other reasons include a general distrust in the insurance policy, limited financial literacy, and insufficient understanding of the product. The decision to purchase an insurance contract may hinge on whether the individual has had prior experience with it (especially having received a payout) (Karlan et al. 2012). Overall, evidence suggests that the take-up of index-based insurance requires large subsidies, although, as with indemnity insurance, subsidies can make the schemes unsustainable (Brown, Zelenska, and Mobarak 2013; Cole et al. 2012; Cole et al. 2013).

Some of these obstacles can be removed by improving technology, policy design, and adopting best practices—for example, modernizing observation systems and improving index designs may reduce the basis risk and strengthen index-based instruments (Barnett, Barrett, and Skees 2008; Rogers and Tsirkunov 2013).

Social protection schemes are critical for helping people adapt and cope with shocks, but must be flexible and easily scalable

Against this backdrop of the poor being at a major disadvantage in terms of financial resources, it is critical that governments also provide *social protection*—that is any government program concerned with preventing, managing, and overcoming situations that adversely affect people's well-being. Social protection schemes can act as a crucial complement to formal risk management tools provided by markets. They also complement informal support from communities and informal insurance, which tend to be insufficient in the face of large or systemic shocks, and too often exclude the most vulnerable (World Bank 2013a).

The three main types of social protection are (i) *social safety nets* (also known as *social assistance*), which include conditional and unconditional cash transfers, public work programs, subsidies, and food stamps; (ii) *social insurance*, which consists of contributory pensions and contributory health insurance; and (iii) *labor market measures*, which include instruments such as unemployment compensation (table 5.1) (World Bank 2012, 2015a).[1]

TABLE 5.1 Social protection includes safety nets, social insurance, and labor market policies

Category	Examples
Social safety nets (or social assistance)	Conditional and unconditional cash transfers, including noncontributory pensions and disability, birth and death allowances Food stamps, rations, emergency food distribution, school feeding and food subsidies Cash or food-for-work programs Free or subsidized health services Housing and utility subsidies Scholarships and fee waivers
Social insurance	Old age, survivor, and disability contributory pensions Occupational injury benefits, sick or maternity leave Health insurance
Labor market policies	Unemployment, severance, and early retirement compensation Training, job sharing, and labor market services Wage subsidies and other employment incentives, including for disabled people

Source: ASPIRE documentation, World Bank 2015a.

Social safety nets can reduce the poverty impact of disasters and economic shocks

A growing body of evidence shows that social insurance and social safety nets are efficient tools to support poor people affected by disasters or environmental and economic shocks. In Kenya, the *Hunger Safety Net Program* prevented a 5 percent increase in poverty among beneficiaries following the 2011 drought (Merttens et al. 2013). In Bangladesh, the *Chars Livelihood Program* protected 95 percent of recipients from losing their assets after the 2012 floods (Kenward, Cordier, and Islam 2012). In Mexico, beneficiaries of *Prospera*, the national cash transfer program (previously known as *Oportunitades* or *Progresa*), are less likely to withdraw their children from the classrooms following a shock (de Janvry et al. 2006; Fiszbein, Schady, and Ferreira 2009; Gertler 2004).

In the short term, social protection helps mitigate adverse effects on livelihoods during economic crises (Akresh, De Walque, and Kazianga 2013; Handa et al. 2015) and disaster shocks (World Bank 2012). In Latin America, social safety nets played a critical role in helping poor people cope with the food, fuel, and financial crisis in 2008. In Mexico, the expansion of the *Progresa* program significantly mitigated the impacts of the crisis for the poor: without the policy response, the incomes of those in the bottom 20th percentile of the distribution would have fallen by over 8 percent; by expanding the cash transfer program this fall was reduced to 5 percent (Grosh, Bussolo, and Freije 2014). Similar instruments can help poor people cope with increases in food or energy prices (due to droughts or ambitious climate policies).

But social protection may be less effective at protecting against prolonged adverse trends, such as sea level rise. A background paper for this report explores how including nonpoor but vulnerable households in social protection can prevent them from falling into poverty. In the long term, this reduces the number of people in poverty, and thus allows spending more to support each poor person. (Carter and Janzen, forthcoming). The same paper suggests that there is a limit: if shocks become too frequent and intense, social safety nets become inefficient and livelihood changes are needed.

Social protection can support long-term transformations toward more adaptive and resilient societies if it does not lock people into unsustainable locations or activities

Poor people, with fewer resources, tend to invest less in preventing and mitigating adverse effects of natural hazards and environmental changes. In China, Indonesia, the Philippines, Thailand, and Vietnam, wealthier households are more likely to take proactive ex ante adaptation measures, while poorer households mostly react to shocks ex post (Francisco et al. 2011). In addition, poorer individuals, lacking resources for long-term investments and proactive risk management, often rely on short planning horizons (Lawrance 1991). However, wealth is not the only determinant: policies favoring training in disaster preparedness and higher education can help both rich and poor households (Francisco et al. 2011).

Social protection and safety nets can support long-term adaptation to changing risks or environmental and economic situations. In Nicaragua, the *Red de Protección Social* cash transfer scheme greatly helped beneficiary households cope in the aftermath of the "coffee crisis" (coffee price decline); it also helped coffee laborers intensify alternative agricultural activities even before the crisis (Maluccio 2005). In the Philippines (see annex 5A for case study) and many other cases (Arnold et al. 2014), community-driven development projects can align the response to a shock, building longer-term resilience and empowering the poorest.

Further, countries with strong social protection can provide better support for workers transitioning from declining to growing sectors. The United States has done this with trade liberalization—typically through unemployment insurance for laid-off workers and wage subsidies in sectors that benefit to help them absorb workers from declining sectors. Studies show that these measures can mitigate most of the losses at a very small overall cost (Porto and Lederman 2014; Trebilcock 2014).

Social protection can also be used directly to facilitate long-term economic transformation. In Ethiopia, the *Productive Safety Net Program* (PSNP) contributes to increased resilience and climate change adaptation by investing in the creation of community assets to reverse the severe degradation of watersheds and by providing a more reliable water supply under different climatic conditions.

Social protection can also improve education and health levels, improving poor people's ability to escape poverty and adapt to environmental and economic changes (Adger et al. 2014).

- In Burkina Faso, cash transfers (conditional and unconditional) helped increase enrollment rates of primary and secondary children by 18 percent compared to a control group (families not receiving a transfer) and, in Chile, by 8 percent (Akresh, De Walque, and Kazianga 2013; Martorano and Sanfilippo 2012). Similar positive outcomes are consistently found for health, nutrition, and food security status of participants (FAO 2015).
- In Peru, women of childbearing age enrolled in the *Juntos* cash transfer program were 91 percent more likely to have a doctor-assisted delivery compared to those not participating in the program (Perova and Vakis 2012).
- In Ecuador, a supplementary feeding program more than halved child mortality in households exposed to the program for at least 8 months (Meller and Litschig 2014).

One potential drawback of strong social safety nets is that they can lower incentives for people to adapt and change occupation or activity as early as possible, when the first effects of climate change appear (Chambwera et al. 2014). If poorly designed, safety nets can even lock them into locations or activities that will become more dangerous or less productive. But then this challenge is not new or specific to climate change. We discuss in the next section the role of migration in poverty reduction, and the efforts made to make social protection a facilitator of—and not an obstacle to—long-term change and adaptation (Brown, Zelenska, and Mobarak 2013; Bryan, Chowdhury, and Mobarak 2014). In terms of design, the need to support long-term change favors the portability of benefits if the recipient decides to move to capture better opportunities (Gentilini, forthcoming).

Poor people often lack coverage, or amounts are too small to make a difference

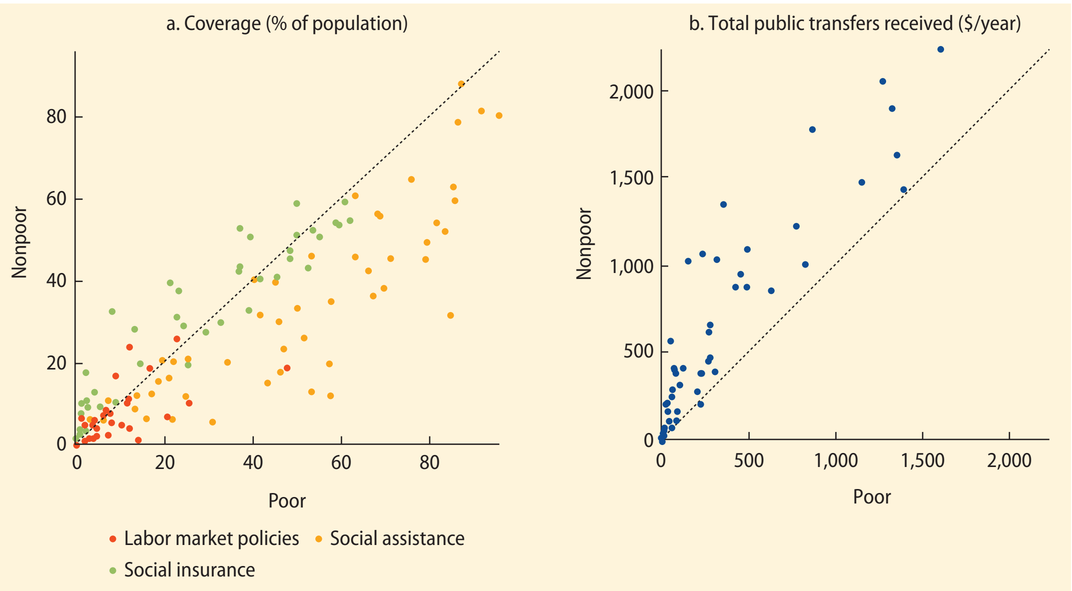
Unfortunately, poorer households often have limited access to social protection and safety nets. One reason is limited coverage. Social assistance consistently reaches more poor than nonpoor people (figure 5.2, left panel)—conditional and unconditional cash transfers specifically target poor households and are increasingly associated with good coverage among households in the bottom quintile (World Bank 2015b). But the two other types of transfers (social insurance and labor market policies) reach poor and nonpoor households in about the same proportion. This does not necessarily mean that those schemes are poorly designed; some programs, such as contributory pensions, are designed for those who can afford to contribute.

However, poor people are often excluded from programs they should benefit from. Some programs are tied to formal employment, whereas most poor people work in the informal economy. Also, poor people in remote rural areas can be difficult to reach. And conditional and unconditional cash transfer programs that have revolutionized social protection over the last decade are much easier to deploy in rural than in urban areas, given the challenge of targeting the poor in cities, where they often live next door to the wealthier (Gentilini, forthcoming). As a result, even social assistance shows a large range of coverage for poor people: in many countries, coverage does not exceed 50 percent, meaning that half of poor people within a country do not receive any social assistance, and even below 10 percent in many low-income countries (figure 5.3).

Even when poor households are covered by social protection schemes, amounts received are often too small to enable better coping strategies. According to the World Bank's ASPIRE database (World Bank 2015a), within countries the average per capita transfer received by households in the bottom

FIGURE 5.2 Coverage of poor people is often under 50 percent, and they often receive lower transfer amounts

(Coverage and average transfer received, by household income category)



Source: ASPIRE database, World Bank 2015a.
Note: Each dot represents a country and shows the coverage of poor people (horizontal axis) and nonpoor people (vertical axis) in panel a, and the average transfer toward poor and nonpoor people in panel b.

FIGURE 5.3 Poor people in the poorest countries barely covered by social safety nets

(Coverage of the poorest quintile, by social safety net program and country income group)

Source: World Bank 2015b.

Note: Coverage rates refer to the percent of poor receiving any social safety net transfer. The number of countries with available survey data for at least one program category in each income group is indicated in parentheses. CCT = conditional cash transfer; SSN = social safety net; UCT = unconditional cash transfer.

quintile from social protection is lower than the transfer received by the four other quintiles (right panel of figure 5.2). In Malawi, the poorest quintile receives on average 0.5 cents per day, while the richest 20 percent receives more than 17 cents. In Vietnam, transfers are respectively 9 cents and $1.6; in Colombia, the poorest receive 23 cents per day and the richest more than $4.6.

After a disaster, amounts can also be insufficient when examining ad hoc schemes to support affected people. In Bangladesh following the 1998 Great Flood, 66 percent of households in the bottom quintile received transfers, compared with 33 percent in the top quintile; and 53 percent of the flood-exposed households received transfers, compared with 34 percent of non-flood-exposed households (del Ninno et al. 2001). While targeting was relatively good, however, transfer amounts were small: they represented only 4 percent of total household monthly expenditure for poor households, and 2 percent for all households. Household borrowing highlights this limit: poor households affected by the flood borrowed about six to eight times more compared to the level of government transfers.

Social protection schemes can be made more responsive

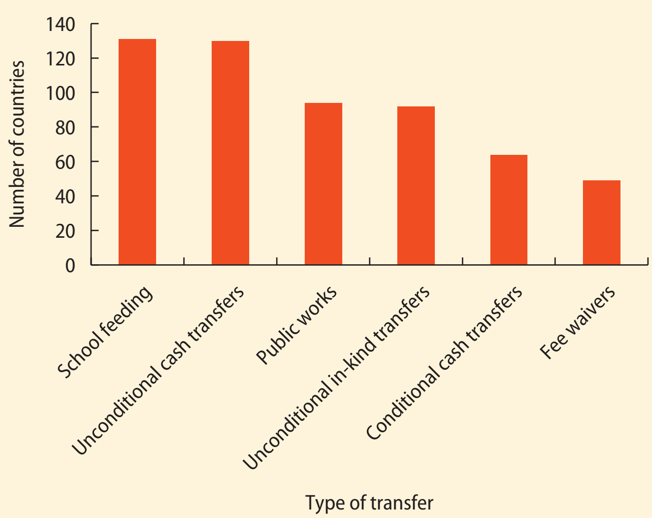
To help the population cope with shocks, disasters, and environmental and economic change, social protection programs must be designed for scalability and flexibility, especially for coverage. Moreover, they need to do so while encouraging adaptation and asset accumulation, without locking beneficiaries into unsustainable activities and locations. Thus, the choice of the right instrument is context specific. Cash transfers cannot ensure short-term food security if food supply is limited, making the case for dedicated measures for food provision in some emergencies (box 5.2). Similarly, it is futile to attempt to implement theoretically optimal policies if institutional capacity is weak in practice—using simpler policy tools may be more realistic, even if they are less

BOX 5.2 Food provision and school feeding schemes are commonplace and effective

The distribution of food is a common measure in situations of humanitarian emergency, following disasters, severe economic crises, or conflicts, even if it can distort local markets and reduce local production. During the food, fuel, and financial crisis of 2007–2008, Benin, Burkina Faso, Mali, and Niger introduced emergency food distribution and used cereal banks to sell food at reduced prices (World Bank 2015b).

Food distribution is also widely used beyond crisis situations. School feeding programs remain the most common social protection and safety net system in the world (figure B5.2.1), even though they reach less than 15 percent of the poor, on average, in each country (World Bank 2015b). School feeding programs are efficient in times of crisis because they rely on existing infrastructure and human resources—schools themselves, as well as the teachers and parents who are part of school systems (Bundy et al. 2009). Moreover, they have the advantage of discouraging parents from taking children out of school in times of crises (FAO 2013).

FIGURE B5.2.1 School feeding programs are the most prevalent type of social safety net



Source: World Bank 2015b.

efficient or less well targeted (World Bank 2013a).

While designing effective social protection can be a challenge, recent experience from social protection systems globally offers encouraging and valuable lessons. It suggests that countries at all income levels can set up systems that increase resilience to natural hazards. But, to do so, the systems need to be rapidly scalable in case of crisis and feature targeting mechanisms flexible enough to adjust quickly to new situations. Three key approaches stand out: (i) increasing the amount transferred by an existing program to its beneficiaries or relaxing rules and conditionality such that the transfers increase; (ii) extending the coverage of an existing program to include new beneficiaries; and (iii) introducing extraordinary payments or creating an entirely new program (Bastagli 2014).

Increasing the amount or value of transfer. This works best when beneficiaries of existing social protection programs are those who are affected the most by the crisis, the shock affects primarily the poorest, and there is already at least one large-scale social protection program in place with efficient delivery systems for disaster response. An example of such a program with built-in mechanisms for rapid scale-up in response to a shock is Mexico's *Temporary Employment Public Works Program* (PET). Similarly, after Typhoon Yolanda hit the Philippines in 2013, external actors such as the World Food Program and the United Nations Children's Fund (UNICEF) used the preexisting *Pantawid Pamilyang Pilipino Program* (4Ps) conditional cash transfer program to deliver their support to affected 4Ps beneficiaries—in effect, increasing the value of the transfer (see annex 5A). For some shocks, such as changes in food prices, indexing of social transfers provides a method for automatically adjusting the amount of transfers to a changing situation, without a discretionary decision (box 5.3).

It is also possible to increase transfers by relaxing program rules and conditionality. Disasters may make existing program rules unpractical or inappropriate: if a disaster destroys schools in a region, attendance is no longer an applicable condition for disbursing conditional cash transfers. In Colombia, the cash transfer scheme *Familias en Acción* suspended conditionality temporarily in 2008 to accommodate the shortfalls in service provision as a result of damaged infrastructure. In the Philippines, all conditionality linked to the 4Ps cash transfers was relaxed in response to Typhoon Yolanda, allowing the government to quickly release a total of P550.5 million (US$12.5 million) between November 2013 and February 2014 in temporarily unconditional transfers (see annex 5A).

Expanding the coverage. In case of severe shocks and those with heterogeneous impacts (such as a flood), even relatively well-off households may lose enough to be pushed into poverty—possibly becoming poorer than existing beneficiaries. To provide adequate support to such at-risk households, the program must be expanded to include the people affected by the shock. In 2008, the Mexican government expanded the coverage of the national *Oportunidades* cash transfer scheme by 1 million recipients to mitigate the food and fuel crisis. The total number of Mexicans assisted by the program reached 5 million households (one out of four families) (Demeke, Pangrazio, and Maetz 2009). In Ethiopia, the *Productive Safety Net Program* incorporates innovative features to scale up automatically and enroll additional beneficiaries when there is poor rainfall (see annex 5A).

Creating a new program. In the absence of an appropriate program that can be used or extended to respond to the crisis, it is possible to introduce new programs or initiatives—sometimes, a disaster or a crisis even creates the opportunity to strengthen or reform the social protection systems. In certain cases,

BOX 5.3 Indexing as an automatic scale-up mechanism

Price changes pose a major threat to the smooth working of social protection schemes. Take, for instance, what happened in Kenya when food prices rose in 2007–2008: the *Hunger Safety Net Programme's* cash transfer scheme lost more than half of its value over 18 months (Devereux 2015).

To avoid such risks, many countries index the benefits in their social protection systems by using inflation data or the price of a basket of goods and services. In Malawi, two schemes—the *Food and Cash Transfers* and *Dowa Emergency Cash Transfers*—adjust the transfers before each monthly disbursement based on observed prices (Sabates-Wheeler and Devereux 2010). Experience has shown that indexing works best when there is a contingency fund to absorb changes in the program's cost.

Source: Based on Bastagli (2014).

countries have used extraordinary payments. In Chile, the government paid a one-time bonus (Ch$40,000 or about US$66) in March 2009 to 1.7 million poor families to cope with the effects of the ongoing financial crisis.[2] A similar measure was introduced in March 2010 following a major earthquake. In other cases, new durable programs have been introduced. The 1990 Honduran *Programa de Asignación Familiar* and the 2001 Colombian cash transfer scheme *Familias en Acción* were launched during recessions and macroeconomic adjustment periods—and transformed into permanent programs, part of the national safety net system. In Guatemala, the food and fuel crisis in 2008 prompted the introduction of a new program, *Mi Familia Progresa*.

But the challenge is larger when responding to a disaster or a crisis with immediate and urgent needs. Creating and rolling out a new program takes time—this is why countries with existing scalable programs are more resilient and better placed to respond to crises and disasters.

To extend support to new beneficiaries—whether through an existing or a new program—it is necessary to be able to identify them rapidly. A challenge is to strike a balance between providing rapid support when needed and targeting precisely the most in need. Case studies suggest that the cost of a drought to households can increase from zero to about $50 per household if support is delayed by four months, and to about $1,300 if support is delayed by six to nine months (Clarke and Hill 2013). This rapid increase is due to irreversible impacts on children and distress sales of assets (especially livestock).

Thus, most postdisaster responses have multiple stages, with initial (survival-related) support delivered quickly even at the expense of targeting and accuracy, and reconstruction support provided later with more effort to target support appropriately (de Nicola 2015). In Pakistan after the 2010 floods, the government implemented the *Citizen's Damage Compensation Program* (CDCP), a rapid response cash grant program that included two phases to better balance the urgency of postdisaster support and the need to carefully target the larger transfers supporting reconstruction (see annex 5A).

Postcrisis responses need to balance timeliness with targeting accuracy

In the aftermath of a crisis or a disaster, it can be tough to identify those affected and at risk of being pushed into poverty. There are several approaches to targeting beneficiaries, all of which face challenges (table 5.2). Economic shocks or disaster consequences are often heterogeneous, making geographic or demographic targeting approaches difficult (Alderman and Haque 2006; Grosh et al. 2008). Registries with socioeconomic information and precise location are seldom available—and, as in Nepal, there may not even be a reliable street address system. Usual targeting methods (like proxy-mean testing) are based on slowly changing household characteristics (like assets) and are slow and expensive to implement—meaning that they cannot capture sudden changes in income and consumption. And affected populations are often displaced in camps or with family or friends, and thus hard to reach.

Because these approaches will always have inclusion and exclusion errors, grievance appeal mechanisms are critical. In Pakistan, the grievance redress system in the second phase of the *Citizen's Damage Compensation Program* cut exclusion errors from an initial 61 percent to 32 percent (see annex 5A).

Options to manage this challenge include developing—before a crisis occurs—large and flexible social registries that include both potential and existing beneficiaries, the use of self-targeting methods, and the use of subsidies.

Social registries. These are crucial because they facilitate quickly identifying households that are vulnerable to being pushed into poverty by a disaster. Social registries should include demographic, socioeconomic, and location information on households that can potentially be supported by a social program.

TABLE 5.2 Methods for targeting beneficiaries with social safety nets are more or less appropriate during a crisis or after a disaster

	Principle	Advantage	Limitation
Means testing and damage assessments	Benefits are allocated conditional on income and the presence or magnitude of losses	High level of accuracy and therefore appropriate in heterogeneous situations Can be adjusted after a shock, taking into account the specificity of the shock and the varying impacts at the household level	Costly (thus only appropriate for large benefits) and requires high administrative capacity It takes a long time to collect the data, so it cannot be applied for rapid response
Proxy-mean testing and damage assessments	Income and losses from the shock are proxied by quantifiable and easily measurable characteristics, such as ownership of a house made of bricks, or visible damages	Verifiable and objective, cheap because based on available data Able to capture heterogeneous situations, if proxies are well selected Captures asset losses from disasters	Focuses on slow-changing household characteristics (for example, assets) that may ignore income shocks Ignores large shocks that may change the statistical relationship between poverty and the selected proxies It takes a long time to collect the data, so data cannot be applied for rapid response
Community targeting	Communities eligible for support are selected, and distribution of benefits is then delegated to the head of a formal or informal community	Can be quickly adjusted in response to a shock or disaster, based on low-resolution estimates of the impact (leaving local decision makers to identify small-scale needs) Makes best use of local knowledge on needs and priorities Can include nonmonetary dimensions of poverty and nonmonetary impacts of the shock	Works only in sufficiently cohesive communities, and may exacerbate social exclusion and affect authority of local actors Requires an estimate of community-level needs, often based on proxy-mean testing at the community level (leading to the same issues as above)
Demographic targeting	Benefits are given based on characteristics such as age or gender	Simple and cheap to administer, and usually popular Appropriate for supporting highly vulnerable groups such as children	Requires good demographic data Inaccurate when impacts are imperfectly correlated with demographics
Geographical targeting	The program covers only inhabitants of specific regions	Simple and cheap to administer Can be quickly adjusted in response to a shock or disaster, based on low-resolution estimates of the impact	Appropriate only for large-scale shocks with relatively homogeneous impacts Unable to account for household-level vulnerability and heterogeneous impacts Performs poorly where poverty is not concentrated (for example, in urban areas) Can be politically controversial and limit migration and its benefits
Self-targeting	Mainly cash and food-for-work programs	Simple and cheap to administer, as no registry of beneficiaries is needed Can be quickly adjusted in response to a shock or disaster Can be used to reduce risks (for example, public work programs that improve drainage) or to reconstruct after a disaster	Cannot be used to deliver large benefits and may stigmatize the affected population Inaccurate or inadequate if the demand for work exceeds supply, as the poorest and most in need are typically excluded Requires the availability of good projects, appropriate for the beneficiaries' skill set

Source: Based on Gentilini, forthcoming.

In Brazil, the *Cadastro Unico* registry includes households with a per capita income below half the national minimum wage, a threshold that is higher than the income eligibility threshold of existing social programs. As a result, the registry includes households that are not currently beneficiaries of social protection but are considered to be vulnerable to economic shocks or disasters. Moreover, individuals can register at any time based on self-reported income, thereby reducing transaction costs (Bastagli 2009). Such a design ensures that the *Bolsa Familia* cash transfer scheme can be rapidly adjusted when shocks occur, thus acting as an insurance facility for vulnerable households.

Large social registries make it possible to introduce *dynamic targeting*, in which potential beneficiaries are segmented—before a disaster or a crisis—into multiple categories, based on their income, assets, location, or occupation (like farmers and fishermen). Then, the different categories receive a varying level of support depending on the situation. For instance, potential beneficiaries can be ranked starting from the poorest, and the number of people provided with support ("how far you go down the list") can depend on the situation, for instance to provide more people with support during a drought. The level of support in each category can even be based on an objective rule or a weather index (like using cumulative rainfall or a trigger based on wind speed).

When social registries are not available, an alternative is combining geographical targeting (to concentrate resources in the most affected municipalities or communities) with community targeting (to use local knowledge to concentrate resources on the most affected households). Pakistan used this approach in the first phase of the CDCP after the 2010 floods, when timeliness was a priority and there was no reliable data on the distribution of losses. The second phase—less urgent but with larger transfers—put a stronger emphasis on targeting, using housing damages as a proxy for livelihood losses (see annex 5A).

Self-targeting. This approach, which does not necessitate much institutional capacity, can be done via work programs—which provide jobs and income by putting in place public projects (like road construction, maintenance, irrigation infrastructure, reforestation, soil conservation) or, especially in postdisaster situations, reconstruction tasks. It usually works by offering a below-market wage; people join only if alternative income sources are lacking (Cazes, Verick, and Heuer 2009). In Côte d'Ivoire, the *Highly Labour Intensive Works Program* was created to support and rehabilitate 35,000 former combatants via road building and reconstruction work. The key drawback is that works programs fail to reach those who face constraints that prevent them from working (like those facing disabilities, sickness, and exclusion) and who are often the poorest (McCord 2013).

The use of works programs as a social protection measure in postdisaster situations requires that cost-effective and socially beneficial projects be readily identified before a crisis strikes. In practice, however, extreme natural events, such as storms or floods, are typically associated with obvious and significant labor needs. Reconstruction of public infrastructure and buildings and the clearing of rubble are examples of needs that can be met by works programs, which can benefit affected poor and vulnerable people (even those with low skills), as well as the wider community.

Subsidies. These are widely used to help poor people, especially in the absence of other social protection programs, and not least because they can be simple and quick to implement. The Egyptian food subsidy program was expanded in 2008 to include 15 million additional beneficiaries (Jones et al. 2009)—thereby avoiding an increase in the poverty rate from 22 percent to 31 percent due to food price increases. Indonesia used a system of generalized subsidies as a safety net during the 1997 financial crisis.

But the drawbacks of subsidies are many. They can lead to waste and corruption. For instance, analyses of India's *Public Food*

Distribution Program, which provides subsidized food and fuel, found a number of operational challenges—including underprovided entitlements as a result of "leakages" of food through the supply chain, commodities being diverted, food getting underweighted, beneficiaries being overcharged, shops being closed, and food falsely being declared out of stock (Drèze and Khera 2015; Government of India 2011; World Bank 2011).

In addition, subsidies are often difficult to remove when the crisis is over, and they are an expensive and inefficient tool for supporting poor people because in many cases a large fraction of the funds go to those who do not need them the most. Fossil fuel subsidies, for instance, are typically implemented and publicly justified with the rationale of helping poor people gain access to energy and energy services. But while low energy prices indeed reduce poverty by reducing the cost of energy services, they do so in an extremely inefficient way, since energy is overwhelmingly consumed by the wealthier.

Thus, it is strongly in the poor's interest to reallocate resources used to subsidize basic goods in order to implement better-targeted and more efficient support measures instead. Ghana's 2005 fossil fuel subsidy reform increased the price of transport fuels by 50 percent, but also included in-kind benefits for the poor—an expansion of primary health care and electrification in poor and rural areas, large-scale distribution of efficient light bulbs, public transport improvements, and immediate elimination of school fees at government-run primary and secondary schools (IMF 2013; Vagliasindi 2012). Indonesia has introduced programs to mitigate the effects of higher energy prices through subsidized rice, free health care, cash assistance to poor students, and a one-year conditional cash transfer scheme targeting poor households with pregnant women or school-age children (Perdana 2014). Iran implemented a quasi-universal cash transfer (about $45 per month per capita) when it reformed its energy subsidies (IMF 2013).

Building solid social protection systems requires resources but is affordable even for the poorest countries

Governments in poor countries face many competing needs and have limited resources, so the development of social protection and safety net programs needs to be justified carefully. Overall, however, costs are moderate, even in low-income countries—and instruments are available to help governments face the liability created by social protection programs.

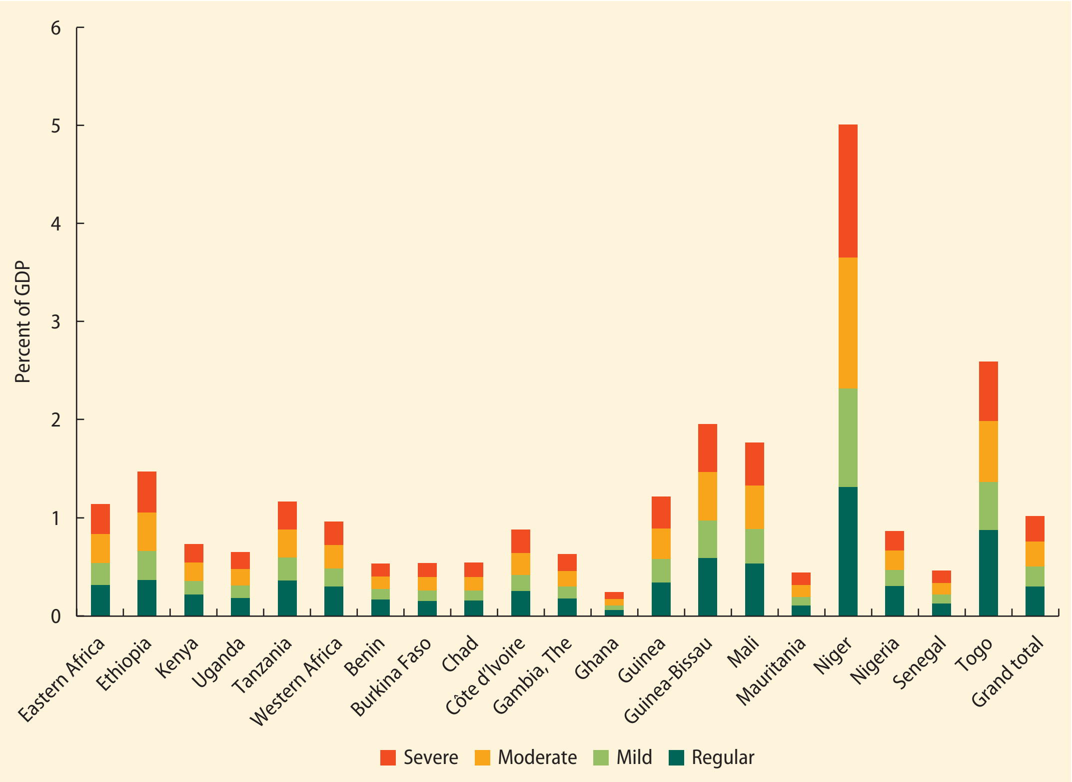
Experience suggests the cost of social protection can be managed. For instance, a recent study assesses how much social protection would be needed to support vulnerable people in the Horn of Africa and the Sahel in 2030 (accounting for population growth and socioeconomic and climatic change) (del Ninno and Coll-Black 2015). It finds that—assuming that vulnerable people can be protected against the worst effects of droughts with an annual social protection package of $300 per capita (the typical size of such support systems in the region)—1 percent of the region's GDP would be sufficient to cover this population, although more is needed in some countries (figure 5.4).

This would be a moderate cost compared with the cost of some short-term coping strategies, such as reduced food intake or suspension of schooling, which can have irreversible, life-long effects, especially on children. While such a social protection package can by no means prevent all negative impacts of droughts, it reduces the need for expensive humanitarian relief. In fact, the total cost of providing this protection to disaster victims in Africa during the period from 2010 to 2013 is lower than what was spent on humanitarian relief measures (del Ninno and Coll-Black 2015).

The government's ability to provide social protection to poor households will be greater if the middle class has access to instruments to manage risks, such as private insurance (box 5.4). Otherwise, the middle class is often better able to demand and obtain support from governments, at the expense of the

FIGURE 5.4 **Providing safety nets in the Horn of Africa and Sahel is affordable, but the cost is very volatile**

(Cost of providing safety net coverage)



Source: del Ninno and Coll-Black 2015.

Note: Cost of providing safety net coverage to the fraction of Sahel's population affected by drought in a regular year (25 percent of vulnerable population is affected), and in years characterized by mild, moderate, and severe drought (with 35, 50, and 65 percent of the vulnerable population affected, respectively). For the entire region, the cost would increase from 0.3 percent to 0.5 percent, 0.76 percent, and 1 percent of GDP, respectively.

BOX 5.4 Private insurance and social protection schemes are complements, not substitutes

The different instruments for managing risk and coping with crises—from private insurance to unconditional cash transfers—are not substitutes: they are part of the toolbox available to governments, individuals, and firms, and can be used together, depending on the context and the considered risks. For instance, some tools can be more appropriate and efficient than others, depending on the probability with which a natural hazard turns into disaster. It is widely accepted that risk-reduction investments—such as physical protection against floods—are more efficient at dealing with frequent events than risk-sharing mechanisms: one cannot insure against regularly recurring events. Similarly, self-insurance and risk retention will be preferred for some risks, while contingent finance, private insurance, and risk sharing will be preferred for rarer events. As a result, the optimal risk management strategy for a government or an individual typically consists of a series of tools, combined within a consistent and holistic strategy.

Moreover, the adequacy of different tools depends not only on the risk itself but also the varying characteristics of individuals and firms. While the middle class and formal firms can have access to private

box continues next page

BOX 5.4 (continued)

insurance markets, providing insurance products adapted to poor people's needs can prove extremely challenging—for them, social protection schemes may be a more effective alternative to private insurance. Thus, protecting a population against shocks may require both developing a stable and competitive insurance market and providing social safety nets.

Well-established private insurance markets can be beneficial for poor populations, even if they lack direct access: if higher-income households are covered by private insurance schemes, public funds for postdisaster relief can be better focused on supporting poorer households. In Turkey, the fact that all dwellers in urban areas are covered by an insurance product (the TCIP) makes it easier for the government to focus public resources on rural areas, which are poorer and where market insurance would be challenging to introduce.

poorer if resources are scarce. In two case studies on Thailand, it was found that the majority of post-flooding government support was benefiting the well off, with 500 Bahts per capita (about US$14) going to the richest quartile, compared to 200 Bahts for the poorest quartile (Noy and Patel 2014).

Scalable social protection creates a formal liability for the government, but contingent finance and insurance are available to manage it

Just how costly is social protection? Certainly, the cost of providing coverage to vulnerable people affected by natural hazards changes from year to year. In the case of the Horn of Africa and Sahel regions, protection costs can increase by a factor of four in a year of severe drought, compared to an average year (figure 5.4). For other (rarer) disasters or shocks, the impact on social protection costs can be even larger. In Bangladesh in 1998, households had to borrow at high costs to cope with floods, with long-term impacts on welfare and poverty (del Ninno et al. 2001). Avoiding such emergency borrowing would have required a transfer of approximately Tk 5,000 (approximately US$90 at the time) for each of the indebted households. For the government, total costs would have amounted to more than $1.5 billion (3.5 percent of GDP), a significant impact on public finances and social program budgets.

Managing such increases in social expenditures can be a challenge for governments who often face reduced tax revenues following a disaster (Noy and Nualsri 2011; Ouattara and Strobl 2013). To cover these liabilities created by natural hazards and other environmental risks, different instruments have been developed and implemented (Mahul and Ghesquiere 2007; Ghesquiere and Mahul 2010; Hochrainer-Stigler et al. 2014; Cardenas et al. 2007). The optimal choice of instruments is country specific and depends on both costs and timeliness (Clarke and Poulter 2014). These instruments include:

Reserve funds. The *Risk Financing Mechanism* in Ethiopia is a fund dedicated to scaling up social protection, which allows the PSNP to disperse additional transfers to existing recipients or temporarily expand its coverage to reach beneficiaries not enrolled in the regular PSNP program, but who are affected by a shock (see annex 5A). In the Philippines, the *National Disaster Risk Reduction and Management Fund* finances a range of disaster-related expenditures but is not able to disburse rapidly in the case of crisis; this is why the government created the *Quick Response Fund*, which focuses on emergency response (see annex 5A). Mexico's *Natural Disasters Fund* (FONDEN) was created as a budgetary tool to rapidly allocate federal funds for rehabilitation of public infrastructure affected by disasters.

However, reserve funds have limited capacities and cannot be designed to cope with the more rare and extreme events. In the Philippines, Typhoon Yolanda raised questions as to the adequacy of the *Quick Response Fund* volume and the process to replenish it if it gets emptied by a major event (or a series of smaller disasters). Thus, additional instruments have been developed to protect public finances.

Insurance and catastrophe bonds. The contingent fund FONDEN in Mexico now leverages private sector financing as part of a strategy combining risk retention and risk transfers. In 2006, FONDEN issued a $160 million catastrophe bond to transfer Mexico's earthquake risk to the international capital markets—the first parametric catastrophe bond issued by a national government. However, studies suggest that using reinsurance or international capital markets for financial protection can be more expensive than building additional reserves (that is, the opportunity cost of public funds) (Cardenas et al. 2007). Nevertheless, insurance products offer benefits in the form of fiscal discipline and timeliness of budget allocation. In emergency situations, these financial schemes are able to disburse funds rapidly—more rapidly than would be possible with public budgets. And by predefining payout rules for allocating postdisaster support, formal insurance and financial products can reduce political economy biases (Clarke and Poulter 2014).

Regional risk-sharing facilities. Regional mechanisms are also popular solutions. The *Caribbean Catastrophic Risk Insurance Facility* (CCRIF) currently pools disaster risk across 16 countries. It was the world's first regional catastrophe insurance facility, using parametric insurance to provide participating governments quick, short-term liquidity for financing responses and early recovery from major earthquakes or hurricanes. The *Pacific Catastrophe Risk Assessment and Financing Initiative* (PCRAFI) and *African Risk Capacity* are other, more recent examples of donor-supported regional mechanisms that offer quick-disbursing index-based coverage against tropical cyclones, earthquakes, or droughts. In response to Cyclone Pam in March 2015, the PCRAFI provided Vanuatu with a rapid $1.9 million payment to support immediate postdisaster needs. This payout is limited compared with total losses and reconstruction needs—estimated at $184 million—but was still 8 times the annual emergency relief provision held by the government, and 7 times higher than the annual insurance premium paid by the government of Vanuatu.

Contingent credit: The Cat-DDO. In 2007, the World Bank introduced *Catastrophe Deferred Drawdown Options* (Cat-DDOs), a new financing instrument allowing countries to access budget support in the immediate aftermath of a disaster. A contingent loan can be rapidly disbursed if a state of emergency is declared, and thus help governments finance the upscaling of social protection (see annex 5A). Cat-DDOs can also be used to back up an existing insurance pool, as is the case in Turkey (box 5.1).

Further, Cat-DDOs do not only aim to provide immediate liquidity. They also function as a mechanism to incentivize proactive actions toward risk reduction. To be eligible for a Cat-DDO, governments are required to develop ex ante capacity to manage natural risks. As such, it is the first instrument linking immediate disaster response funding with proactive engagement in risk reduction. Other institutions, such as the Inter-American Development Bank and the Japan International Cooperation Agency have since introduced similar instruments.

Cat-DDOs have proven to be an effective instrument for implementing disaster risk management strategies. However, experience shows that, facing a finite financing envelope, governments tend to favor cash in hand at the expense of contingent instruments. As a result—and despite strong interest from client countries—the uptake of Cat-DDOs has been limited. One option to improve access to contingent finance and build the resilience of developing countries would be to remove this trade-off between cash in hand and contingent finance by separating the budget allocated to contingent instruments from the budget allocated to traditional lending.

International aid. When a country's capacity to cope with a disaster is exceeded, international aid and humanitarian emergency measures can be critical. Foreign aid includes essential in-kind support (including emergency equipment such as emergency water treatment stations, reconstruction material, equipment and machinery, and emergency relief goods like food, blankets, and clothes), as well as financial aid for social protection and reconstruction costs.

However, in the past, increases in foreign aid have been low, averaging only a small percent of total economic losses stemming from the disaster (Becerra, Cavallo, and Noy 2013). Generally, studies have found that increases in financial aid are larger for more severe disasters and for particularly poor countries with limited disaster management capacities. This suggests that these resources are relatively well targeted and not politically biased (Becerra, Cavallo, and Noy 2013). Nevertheless, increases in foreign aid in response to disasters remain sensitive to media coverage, are hardly predictable, and can be slow to arrive—all of which make it ever more difficult to prepare contingency plans based on available resources. Foreign aid should thus be regarded as a resource of last resort.

To improve the timeliness, transparency, and predictability of postdisaster or crisis international aid, and provide additional financing, a special *Crisis Response Window* (CRW) was created as part of the International Development Association, the World Bank Group's fund for the poorest countries, in 2011. Its primary objective is to (i) provide poor countries with extra resources in a timely manner; (ii) help them respond to severe economic crises, price shocks, and major natural disasters; and (iii) return to their long-term development paths. In Malawi, the CRW provided $40 million of postdisaster support after the large floods that affected the country in January 2015.

Migration and remittances play an increasingly important role and need to be supported by policies

Migration plays a key role in the ability of poor households to escape poverty by opening opportunities for better jobs, higher pay, and better access to services and education. Migrants typically benefit from relocating, as do their families and areas of origin, through remittances, enhanced social networks, and access to information (Adger et al. 2002; Bryan, Chowdhury, and Mobarak 2014; Moser and Felton 2007).

Migrations help households adapt to and cope with shocks

Migration can be an important way of adapting to extreme weather events and climate change impacts, and thus of reducing impacts that lower welfare (Adger et al. 2014; Black et al. 2011b; Jülich 2011). Particularly in areas where in situ adaptation is difficult or extremely costly (such as in low-density coastal areas or remote areas with low productivity), migration can be critical. By migrating, individuals and households can reduce their exposure to natural hazards and increase the set of available opportunities, thus improving well-being and livelihood prospects. However, the poorest households have a lower capacity to migrate and may therefore be unable to use this option (Black et al. 2011a). This can also be the case for households in conflict and fragile areas, or those being socially excluded or marginalized.

Climate change can affect migration decisions, but migration is usually driven by a variety of pull and push drivers, both environmental and socioeconomic (Adger et al. 2014; Black et al. 2011a). In the past, direct environmental factors have generally played a minor role (Black et al. 2011b), except in extreme circumstances such as large disasters. The most important factor remains the socioeconomic context in the origin and destination areas (Wodon et al. 2014). In the future, as the effects of climate change intensify, environmentally induced migration is expected to increase although no robust global estimates are available (Adger et al. 2014). A study investigating this question in five countries in the Middle East and North Africa region concludes that a significant deterioration of climatic conditions would lead to an increase of about one-tenth to one-fifth of current migration levels (Wodon et al. 2014).

Climate change and climate policies can also impede migration—whether through constraints on urban development and higher housing costs linked to natural risks (higher construction costs due to stricter building norms or restrictive flood zoning) or through increased conflict and exclusion (crime and violence or civil unrest). In that case, climate change would diminish the opportunities that individuals and households can capture. In addition, the ability to migrate depends on household assets (including land tenure), the ability to sell assets, information and social capital, financial resources, and human capital.

Given the importance of mobility as an instrument for poverty reduction, climate change adds to the rationale for portable social protection benefits (Holzmann, Koettl, and Chernetsky 2005; Kuriakose et al. 2013): safety nets that are linked to specific locations could tie poor people to places that may no longer support livelihoods. Safety net programs must thus consider the portability of benefits—that is, help households or individuals to remain engaged in programs and to maintain their benefits even as they move (Gentilini, forthcoming).

For portability of participation, in the absence of a central registry, programs require systematic tracking of beneficiaries. Some programs place the responsibility on beneficiaries to inform programs of their migration. In the Philippines, beneficiaries must declare a change in residency and notify the program six months in advance of a move. Alternatively, many countries have program offices in major urban centers where migrants can register upon arrival. Whichever strategy is adopted, the provision of information is critical—both on the procedure of how to remain in the program and on the location of registration offices.

Modern technologies can help simplify access to benefits, at least when the program involves cash transfers rather than vouchers and in-kind transfers. The *Bolsa Familia* program in Brazil provides beneficiary cards that can be redeemed at outlets across many urban centers. A similar system exists in Ecuador, but with mobile vendors that visit beneficiaries. While effective and secure, such systems can be costly to implement at a large scale. Mobile money programs can be an efficient alternative, as they are typically low-cost and have a wide reach (Aker et al. 2014; Vincent and Cull 2011).

Domestic and global remittances are key to increase recipients' resilience

Remittances—that is, the private transfer of money by a foreign worker to individuals in his or her home country—are estimated at \$584 billion in 2014. They are a vital resource for developing countries and significantly exceed official development assistance and foreign direct investment everywhere except China (Ratha et al. 2015). Fragile and conflict-affected countries, in particular, have large diaspora savings as a share of GDP: some 81 percent in Somalia, and 53 percent in Haiti (Ratha et al. 2015). In addition, domestic remittances can play an important role, especially in rural areas. In India, the domestic remittance market was estimated to be \$10 billion in 2007–08, with 80 percent of that being directed toward rural households for whom this represents a large fraction of total consumption (Tumbe 2011).

International remittance flows are a stable source of finance that are generally not correlated with capital flows and that can help hedge against shocks (Bugamelli and Paterno 2009; Chami, Hakura, and Montiel 2009; World Bank 2006, 2015c). After natural, economic, financial, and political shocks, these flows have been found to either remain stable or even increase (Clarke and Wallsten 2004; Fagen 2006; World Bank 2006). Unsurprisingly, countries with a larger stock of emigrants as a share of the home population tend to experience a greater surge in remittances following natural disasters (Mohapatra, Joseph, and Ratha 2009).

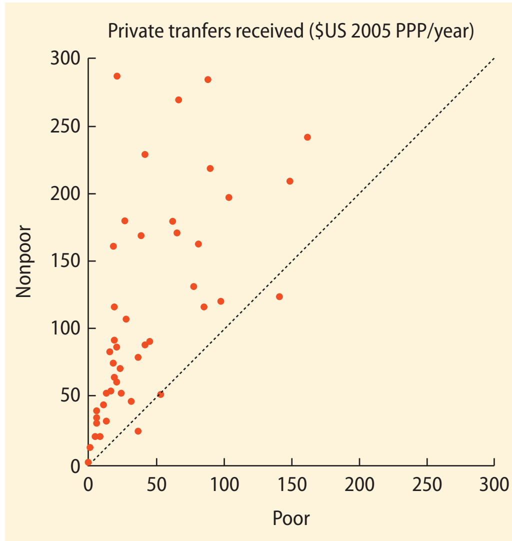
Remittances can help smooth consumption and finance recovery and reconstruction. After the 1998 flood in Bangladesh, consumption was higher in remittance-receiving households (Mohapatra, Joseph, and Ratha 2009). In the Philippines, it was estimated that remittances compensated for nearly 65 percent of lost income after rainfall shocks (Yang and Choi 2007). Despite disruptions in transfer channels and financial services, remittances remained relatively stable after disasters hit Pakistan and Indonesia, and they were an important factor in recovery and reconstruction (Suleri and Savage 2006; Wu 2006). In Indonesia, households that received remittances in the Aceh region recovered faster from the 2004 tsunami, despite disruptions in financial services and informal transfer channels (Wu 2006).

However, international and domestic remittances tend to benefit the wealthier within a country (figure 5.5). They also have sometimes been shown to lower government spending through a substitution effect between private insurance provided by remittances and public insurance provided through government expenditures (Kapur and Singer 2006). But policies that encourage and facilitate the use of remittances for investments can also promote microsaving and microinsurance, and lead to cobenefits such as enhanced financial integration.

To support the positive impacts of remittances, adequate financial and banking infrastructure and frameworks are essential. Globally, the burden of transfer costs stood at 7.7 percent of overall transfers in 2014—and they tend to be the highest in Sub-Saharan Africa, where they average 11.5 percent (Ratha et al. 2015), partly reflecting limited competition among service providers. The UN Open Working Group on Sustainable Development has proposed reducing remittance costs to 3 percent, which would translate into savings of over $20 billion annually for migrants. Commonly available technologies (like instant money transfers through cell phones) could play a key role in streamlining processes and reducing transaction costs.

FIGURE 5.5 Within a country, remittances tend to be higher for the wealthier

(Remittance transfers for poor and nonpoor people)



Source: ASPIRE database, World Bank 2015a.
Note: Each dot represents a country for which adequate data exist.

Voice and governance

When it comes to adaptation and coping, the affected populations must have access to and some control over the country's economic, social, and institutional resources. Because poor communities lack human and social capital (like social networks and influence on policies and strategies that impact well-being), they are typically excluded from accessing such resources. A background paper for this report argues that only with inclusive and participatory decision-making processes can policies be designed to protect the poor and vulnerable effectively (Tschakert, forthcoming). When such processes fail, as in conflict-affected states, governments may be unwilling or unable to support those affected, with poor people being the first to suffer.

Vulnerability to climate change interplays with many other vulnerabilities

Efforts to improve the ability of poor people to cope with climate shocks can be more effective if they address the broader issues related to power relations within societies, instead of narrowly focusing on one particular shock (such as disasters or changes in agricultural yields). It may be more effective to boost income-generating activities for the poor to enable them to afford living in safe areas, rather than to implement strict land use regulations that prevent destitute people from settling in flood-prone areas. Assessments of vulnerability need to go beyond analyzing physical assets and location, and on to exploring the structural drivers of poverty (like social capital, institutional arrangements, and governance).

Poor people are often confronted with multiple dimensions of inequality (including gender, age, race, caste, ethnicity, and disability), with implications for their capacities and opportunities to cope and participate in adaptive decision making (Tschakert, forthcoming). These inequalities can marginalize specific groups and further aggravate their vulnerability. In Benin, while progress in the multidimensional poverty index can be observed for most ethnic groups, no reduction in poverty was observed among the Peul, the poorest ethnic group (Alkire, Roche, and Vaz 2014). These types of inequalities not only reinforce systematic constraints to marginalized groups' access to opportunities, but they can also be a source of conflict that further amplifies the stress caused by climate impacts (Stewart 2010).

A narrow focus on poor people's vulnerabilities to climate change can lead to the justification of top-down interventions that undermine the role of communities (Tschakert, forthcoming). Adaptation strategies that fail to account for the needs and circumstance of marginalized groups (including women or ethnic minorities) can exacerbate risk dynamics (Vincent et al. 2014). In contrast, well-designed adaptation projects can promote equity, as in India's Karnataka watershed project—which increased income, employment, and agricultural productivity among the poorest participants (Olsson et al. 2014).

When social dimensions are disregarded, climate change and climate policies can systematically reinforce and exacerbate inequalities along with other drivers that amplify vulnerability. Gender impacts can be reinforced leading to differential access to social and environmental adaptation resources and exclusion from decision making and planning (Vincent et al. 2014). In Ghana, observations show that some husbands seek to maintain their power positions by preventing women from cultivating their own plots, even though it could compensate for yield losses due to shifting precipitation patterns (Carr 2008).

Overlooking local marginalized groups has major implications for the efficacy of climate policies and the ability of these communities to cope and adapt. Natural resource-dependent communities—including indigenous groups—often have extensive knowledge and long-lasting traditions for adapting to changes in the climate and environment, but are overlooked in policy-making and planning processes. These cultural practices are at risk of disappearing because of the effects of climate change on the livelihoods and identities of these communities. Other factors exacerbate this risk further, sometimes because of the dependencies created by policies, inadequate entitlements and rights, obstacles for intergenerational knowledge transmission, and the lack of inclusion in formal decision-making processes (Adger et al. 2014; Tschakert, forthcoming).

Poor people need a voice in decision-making processes—community-based development and strong institutions can help

When poor people are excluded from governance and have no say in the decision-making process, the policy options discussed in previous sections are unlikely to be implemented in a timely and adequate manner. This issue is closely linked to the values and criteria that determine which segment of the poor population is considered "deserving" of support and the openness, inclusiveness, and fairness of the decision-making processes.

Decision-making processes matter. A cost-benefit analysis of adaptation investments would favor policies that protect higher-income assets rather than less-productive assets. Without an explicit focus on the poor and vulnerable, such an efficiency criterion may fail to help poor communities and instead concentrate support and resources on the wealthier. A recent study assessing impacts of sea level rise on U.S. coastal communities found that 99 percent of the most vulnerable populations in the gulf region of the United States live in areas where protection from inundation (such as sea wall construction) is not cost-effective, compared to only 8 percent of the most resilient segments of the population (Martinich et al. 2013). Protecting only areas where the benefits from avoided property loss exceed the costs of protective measures is a sure way of directing protective investments toward rich areas. Explicit choices to support or compensate poor communities are thus necessary to ensure that adaptation policies support communities with the least adaptive capacities.

And yet for poor people the ability to influence such decisions is often limited, thus contributing to their vulnerability to climate change and climate mitigation policies—which, in turn, aggravates preexisting poverty (Lawson and Elwood 2014). That is why participatory decision-making processes can improve the diversification of coping strategies for disasters and help address the causes of different vulnerabilities, rather than just their consequences.

One study, which analyzes how governance structures affect the variety of coping strategies for hurricanes in the Mexican Caribbean, finds that regions with less hegemonic political structures have developed more diversified coping strategies, compared to regions with strong top-down management that discourages participation (Manuel-Navarrete, Pelling, and Redclift 2011). Another study shows that community-driven development projects have in various cases succeeded in helping communities deal with disaster and climate risks (Arnold et al. 2014).

In conclusion

This chapter provides evidence that poor people suffer more from economic and environmental shocks than does the rest of the population—and not only because they are more exposed or vulnerable to the impacts discussed in chapters 2 (agriculture and ecosystems), 3 (natural disasters), and 4 (health).

Another crucial difference between poor and nonpoor people is the strength and scope of "support systems" available to them: family, friends, communities, financial institutions, and the government. These systems provide tools for people to manage risks or cope with disasters and shocks (such as social safety nets, market insurance, savings, access to credit, and remittances). They are crucial for reducing vulnerability and adapting to changing environmental and economic conditions (World Bank 2013a). And they are critical for complementing other climate change adaptation measures—and preventing (at least partially) the associated harmful impacts on poverty.

The chapter calls for a comprehensive strategy, combining multiple tools that can protect against a variety of events (like small and frequent shocks, rare extreme disasters, and adverse long-term trends in precipitation)—and remain suitable and accessible for various income and demographic groups. For instance, developing market insurance for the middle class to protect against relatively frequent events helps governments concentrate resources on the poorest and vulnerable people and on hedging against exceptional shocks that exceed the capacity of private insurers. While the private provision of insurance for the very poor is associated with large challenges, governments can provide quasi-insurance via tax-financed social protection schemes, and in turn reinsure against the resulting liability. But, for such protection strategies to be effective, they must rely on a good understanding of the benefits of different tools for the poor and facilitate participation in the decision-making process.

Now that this report has underscored the vulnerability and exposure of poor people to the adverse effects of climate change—and the various channels through which this can occur—we can ask what the overall impact on poverty will be by 2030. The next chapter tackles this question, along with weighing the implications of these results for climate change mitigation and its role in contributing to poverty reduction.

Annex 5A. Case studies of social protection and risk management in Ethiopia, the Philippines, and Pakistan

Ethiopia: Moving from crisis and humanitarian response to resilience building and proactive risk management[3]

Given the persistence of food insecurity in Ethiopia, the government of Ethiopia launched the *Food Security Program* (FSP) in 2005. The FSP was designed to institute a movement away from ad hoc responses to food insecurity—as characterized by a major drought in 2002—to a planned and systematic approach. It includes two programs:

- *Productive Safety Net Program (PSNP)*: This is the primary program, which includes a Public Works component (builds community infrastructure and agricultural assets) and a Direct Support component (provides social assistance to the poorest).
- *Household Asset Building Program (HABP)*: This is designed to empower rural households to increase their incomes, food production, and assets, by supporting livelihood activities, extension services, and access to financial services.

Households that receive support from these programs are expected to "graduate" from chronic food insecurity to food self-reliance. The FSP is implemented by the Ministry of Agriculture (MoA) and is largely funded by international donors and financial institutions.

PSNP targets the poorest and fights chronic food insecurity. The PSNP uses a mix of geographic and community-based targeting to identify chronically food-insecure households in chronically food-insecure woredas (or districts) in rural areas. The greater use of community-based targeting has led to more participatory and accountable targeting processes. As a result, there is a general consensus among the highlands communities that the PSNP targets the poorest households. In fact, it is considered better targeted than any other African safety net program (Coady, Grosh, and Hoddinott 2004; Coll-Black et al. 2013).

The PSNP provides cash or food transfers, typically for six months each year, coinciding with the lean season (between June and August). The transfer value from the program launch in 2005 to June 2015 equaled 15 kg of cereals per household member per month, or its cash equivalent. Households with able-bodied adults contribute to developing their communities through public works activities (such as soil and water conservation measures, school room construction or rehabilitation, water point development, and road rehabilitation). Households with no able-bodied adults are considered "permanent direct support" households and are not required to undertake public works activities. The PSNP can also scale up in a crisis, by drawing on contingency budgets.

Scaling up to ensure prompt, proactive response to crisis and humanitarian needs. The PSNP has various components that can scale up in response to shocks to support transitory needs. A key one is the *Risk Financing Mechanism* (RFM), which facilitates additional transfers to existing recipients or a temporary expansion of coverage to reach nonrecipients who are affected by a shock. The RFM acts as an intermediate policy response between the PSNP (addressing chronic food insecurity) and emergency operations. The process of scaling up has three stages:

1. *Early warning triggered:* The early warning system routinely collects and analyzes early warning data. When the early warning system triggers a response, a request for the release of funds is prepared and the RFM Management Committee determines the number of beneficiaries and length of support required. Through contingency plans developed at the woreda level, bottom-up needs are reconciled with available resources and funds are released for distribution.
2. *Resource transfer:* Funds are released by the RFM Management Committee either for transfer to the regions and onward to woredas or for food to be purchased, which is then dispatched directly to the woredas.
3. *Implementing contingency plans:* Although the contingency plans are woreda plans, implementation of most activities such as public works will be carried out at the ward level with technical support from woreda and sectoral experts. Normal public works procedures will be used. Notably, however, the RFM Guidelines provide an option to waive the public works requirements in severe situations.

The advantage of this approach is that it is early and preventive, rather than late and reactive (IDL Group 2009). The newest phase of the program, PSNP 4, involves measures that support a better emergency response by integrating with the humanitarian system more directly.

PSNP smooths consumption and protects assets in times of crisis. How is the PSNP faring? Biannual PSNP Impact Evaluations have concluded that the program is succeeding in smoothing consumption and protecting assets—even during times of crisis (see Box 5A.1). The transfers provided to PSNP households are the equivalent of 45 percent of annual food needs for public work beneficiaries, and 90 percent for "permanent direct support" beneficiaries. Moreover, while much of the cash transfer is spent on consumption, around 25 percent of funds are invested in productive assets. Further evidence suggests that the PSNP helps beneficiaries boost agricultural investments, leading to higher rates of agricultural productivity.

Although emergency operations are not necessarily less efficient than PSNP risk-financed transfers at delivering food, the potential for greater cost-effectiveness lies in (i) the typically lower cost (though not always greater cost-efficiency) of cash as opposed to food delivery, alongside a range of other less quantifiable benefits of cash; (ii) the use of existing capacity to deliver; and (iii) the prevention of asset erosion and weakening of future household livelihoods with timely risk-financed transfers, rather than lengthy humanitarian appeals.

PSNP explicitly supports long-term adaptation and resilience. As for concerns that safety net programs such as the PSNP can, to varying extents, be "maladaptive" in the face of climate change, the public works component of the PSNP and the HABP/livelihoods component are designed to explicitly encourage adaptation. Factors like soil erosion and water scarcity are being actively countered to make locales and livelihoods sustainable through regeneration. In fact, 60 percent of the PSNP's public works subprojects target soil and water conservation, strengthening both livelihoods and resilience to the impacts of variable rainfall. Together, soil erosion– and water conservation–focused PSNP projects have led to significant and visible increases in wood and herbaceous vegetation cover and a broader diversity of plant species.

BOX 5A.1 How the PSNP helped households cope with Ethiopia's 2011 food crisis

The risk financing procedure was set in motion following several successive inadequate seasonal rains and local crop failures—made worse by a sharp rise in food prices during the main PSNP transfer period. Initially, the cash value of the transfer was raised from 10 to 15 birr (US$0.50 to $0.75) for a wage day doing public works (and the same increase for direct support beneficiaries). Next, a detailed assessment was done for the size and distribution of a contingent risk financing operation (GFDRE 2011). It found that 9.26 million PSNP and nonPSNP clients in hotspot woredas would require risk financing support to meet consumption needs for up to three months between September and November 2011. It also found that risk finance payments should be provided as unconditional transfers to avoid payment intervals built into public works transfers and to prevent households from neglecting agricultural activities during this period.

Over 80 percent of 11.1 million people identified as experiencing transitory food insecurity in 2011 were brought into the PSNP, leaving only 20 percent to be covered by emergency operations. Of the total 9.26 million people to be assisted from contingency funds, 6.5 million (70 percent) were PSNP clients and 2.8 million (30 percent) were humanitarian recipients. Since a total of 11.1 million people were determined to need transitory assistance in Ethiopia as a whole, this highlights the size of the potential humanitarian caseload shifted from emergency operations to contingency funding thanks to risk financing.

Philippines: A postdisaster response to Typhoon Yolanda based on existing social protection institutions and instruments[4]

Typhoon Yolanda (internationally referred to as Typhoon Haiyan) struck the Philippines on November 8, 2013, costing the country an estimated P571.2 billion (US$12.9 billion) in damages, with over a million homes damaged or destroyed. Nearly 6,300 people died. A further 4.1 million people were displaced. It affected some of the country's poorest regions and was estimated to increase national poverty incidence by 1.9 percent, with estimates of up to an additional 1 million people falling into poverty. Given such immense human and economic consequences, Typhoon Yolanda provides an interesting case study on how existing social protection (SP) systems can be used to coordinate and implement postdisaster support.

The Philippines has one of the most advanced SP systems—backed with advanced information and delivery systems—in the East Asia Pacific region, designed to help poor households manage risk and shocks. The Department of Social Welfare and Development (DSWD) is the lead agency for "disaster response" within the government's National Disaster Risk Reduction and Management Plan (NDRRMP). It also has responsibilities across the national prevention and mitigation, preparedness, recovery, and rehabilitation pillars of the NDRRMP. And it is the lead agency of four coordinating clusters of the UN cluster system—food security, shelter, camp coordination and camp management, and protection. As a result of this linkage of social protection and disaster risk management, SP programs are well positioned to respond to disasters.

From the emergency to long-term reconstruction. In response to Yolanda, DSWD implemented a variety of SP and social welfare programs: distribution of in-kind relief items, cash transfers (unconditional and conditional), shelter, and community-driven development. These programs are mapped out in figure 5A.1, illustrating the postdisaster phases in which each program was implemented.

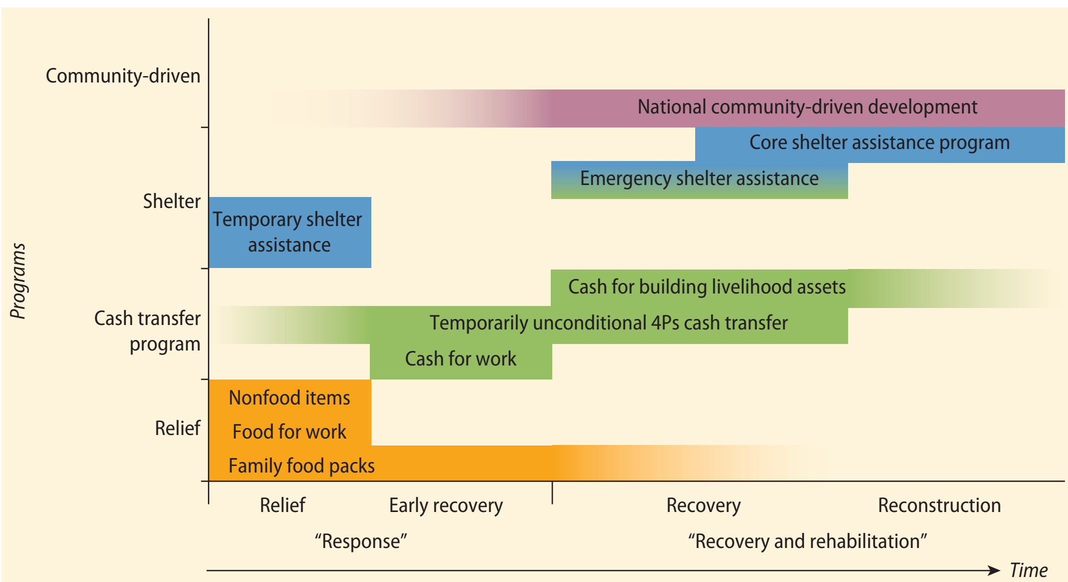
Initially, the emphasis was on food and nonfood items (like mats, blankets, tarpaulins, hygiene kits, and clothing) to meet the immediate and urgent survival needs, plus temporary shelter assistance for displaced households. By end-November 2013, 375,000 food packs had been distributed, rising to 5.1 million by end-December.

After immediate survival needs were addressed, DSWD delivered a number of cash-based response programs, such as *Cash for Work*, *Cash for Building Livelihood Assets*, and cash for shelter ("*Emergency Shelter Assistance*")—then transformed into the *Core Shelter Assistance Program* to rebuild permanent housing. DSWD also temporarily removed all conditionality of *Pantawid Pamiliya Pilipino Program* (4Ps), a usually conditional cash transfer program. In addition, at least 45 international humanitarian agencies implemented cash transfers (unconditional and conditional), partly delivered through the 4Ps infrastructure. Four agencies alone distributed around $34 million, benefiting 1.4 million disaster-affected people.

Over the longer term, the Yolanda experience has demonstrated the important role that community-driven development programs can play in the recovery of poor and vulnerable people from disasters. The *National Community-Driven Development* (NCDD) program of DSWD was set up in 2002 to alleviate rural poverty. A contingent component of the NCDD was designed to adjust and simplify procedures in the case of disasters, triggered by the declaration of a state of calamity. Under this program, infrastructure selected by communities is being constructed (or reconstructed) in Yolanda-affected areas.

Integration of postdisaster support with existing social protection systems. In the event of a disaster, the 4Ps regular conditional cash transfer can be leveraged to deliver its cash transfers unconditionally, through the removal of grant conditions for beneficiaries in affected areas for a defined period of time. After a natural disaster, it is unrealistic to assume that beneficiaries can meet the conditions of the conditional cash transfer, especially in instances where the supply side may be down, with schools and health centers destroyed or being used for relief operations. In such cases, the DSWD Regional Director of an affected area submits a request to deem all beneficiaries in the

FIGURE 5A.1 Multiple programs answer different needs in postdisaster contexts in the Philippines



Source: Bowen, forthcoming.

affected area as compliant to the 4Ps' National Project Management Office. If approved at the level of the Secretary, beneficiaries will be deemed compliant for a maximum of three consecutive compliance verification periods (three months). This is not an unprecedented procedure, with the *Bolsa Familia* program in Brazil having undertaken similar steps to deliver unconditional payments to beneficiaries affected by flooding in 2011. Using the preexisting 4Ps system in this way, DSWD was able to quickly release a total of P550.5 million (US$12.5 million) in unconditional cash transfers to Yolanda-affected 4Ps beneficiaries between November 2013 and February 2014 (DSWD 2014).

Considerable effort was also made to coordinate the large number of cash transfer providers with the government cash-based response programs—with some positive results. In the case of Yolanda, both the World Food Program (WFP) and UNICEF used the 4Ps system to deliver additional cash transfers to affected households. The WFP and UNICEF "topped up" the amount delivered by DSWD to households in affected areas, effectively scaling up the conditional cash transfer grant amount during a time of increased need for affected beneficiaries. This was an innovative and replicable practice illustrating the potential efficiency gains of delivering post-disaster grants through a national cash transfer program to pretargeted poor and vulnerable households. Finally, DSWD and the UN Office for the Coordination of Humanitarian Affairs (UNOCHA) also encouraged the humanitarian cash transfers to leverage existing social protection and other systems to increase coordination in their delivery, including:

- *Disaster Affected Family Assistance Card (DAFAC)* is the primary tool for monitoring the receipt of all benefits by affected households, including cash. It records basic information pertaining to whether the beneficiaries' houses were damaged (partially or totally), whether they are 4Ps beneficiaries, whether they are vulnerable (like older persons or lactating mothers), and their estimated monthly income. Humanitarian agencies were encouraged by the government to adopt the DAFAC as their primary tool for monitoring their programs to increase coordination between the government agencies and humanitarian programs.
- *The Listahanan* is a national registry used to target beneficiaries of the national conditional cash transfer program and other government social programs. In 2011, it contained information on 11 million households, but it is only updated every four years. A process was created for humanitarian agencies to coordinate with the *Listahanan*, thereby helping the DSWD to meet its mandate to increase the 4Ps coverage by 20,000 poor households affected by Typhoon Yolanda.
- *The 4Ps Beneficiary Update List (BUL)* is a subset of the *Listahanan*. Updated every two months, it contains information on poor households (as identified using the *Listahanan* and a Proxy Means Test targeting method) that are also beneficiaries of the national 4Ps program. A number of humanitarian cash transfer programs directed assistance directly to 4Ps households using this up-to-date beneficiary information.
- *The 4Ps Grievance Redress System (GRS)* is a component of the 4Ps that allows anyone to direct queries, clarifications, complaints, grievances, and appeals to the appropriate 4Ps committees at the community, provincial, regional, and national levels (UNOCHA 2014).

The extent to which these recommendations were adopted by the interagency humanitarian response remains unclear, and details on lessons learned are yet to emerge. Nevertheless, the potential value of a more unified overall response facilitated by preexisting SP information systems is clear, and further research into the streamlining of these information systems into future interagency response would add much value. Ultimately, however, post-Yolanda response documentation and reviews reveal that (i) there has been no rigorous evaluation of the impact of the overall response and (ii) there nevertheless appear to have been issues in coordinating cash transfer programs, leading to coverage gaps and duplication.

As currently designed, the postdisaster cash transfers are only provided to 4Ps beneficiaries and not to other affected households that may be equally or more poor and as or more affected by the disaster. A solution could be to implement a complementary but separate emergency cash transfer program, based on the 4Ps information and payment systems, that would be able to reach these households. This would create a more equitable and efficient postdisaster cash-based intervention while preserving the integrity of the existing 4P conditional cash transfer and its long-term human capital accumulation objectives.

Scaling up of social protection requires funding—while reserve funds were available, contingent finance mechanisms could also help. Accessing finance to fund relief programs through preestablished budget lines in a timely fashion is a necessity postdisaster, when the affected may be slipping into destitution by the hour. The Philippines recognized that response activities of the sort carried out by DSWD require immediate liquidity to be delivered rapidly, and that this could not be achieved quickly enough through the regular calamity fund—the *National Disaster Risk Reduction and Management Fund* (NDRRMF). *The Quick Response Fund* (QRF) was created to address this issue, with dedicated reserves for response activities. Nevertheless, the specific case of Yolanda highlights problems in sourcing financing from even the QRF in a timely fashion. It also raises questions about the adequacy of the QRF amount for a fiscal year's worth of disasters because, although the QRF may be replenished once emptied, that is a lengthy process.

There are a number of risk financing mechanisms that could allow DSWD to fund the grant top-ups in times of disaster, including specific contingent financing or linking to the broader government risk financing strategy (like a *Catastrophe Deferred Drawdown Option* (CAT-DDO)). In this way, the Department of Finance would be able to utilize a proven delivery mechanism to better cover household level risk, delivering additional assistance directly to those most in need.

Pakistan: A two-phase window to balance urgency with targeting[5]

In July and August 2010, during the monsoon season, Pakistan experienced the worst floods in its history. The floods covered all four provinces of the country (Sindh, Punjab, Khyber Pakhtunkwa, and Baluchistan), as well as the autonomous territories of Gilgit-Baltistan and Azad Jammu and Kashmir (AJK). More than 20 million people were affected, with over 1,980 reported deaths. About 1.6 million homes were destroyed, 2.4 million hectares of crops damaged, and both farm and nonfarm livelihoods were severely affected (United Nations 2010).

Pakistan's main response was the creation of the federal government's *Citizen's Damage Compensation Program* (CDCP), a rapid-response cash grant program—rather than using an existing social safety net mechanism. Drawing on positive prior experience from the 2009 civil crisis, it decided to deliver the cash transfers through commercial banks, working closely with provincial governments and the National Database Registration Authority (NADRA). Selected program beneficiaries were issued Visa direct debit cards, called *Watan* cards, for collecting grants from ATM machines or designated points of sale.

Phase I of the CDCP focused on immediate support. In Phase I (September 2010 to June 2011), the goal was to provide quick assistance to families who lost their homes or faced a serious threat to their well-being. The program was funded by the government, which provided almost $400 million in cash grants to more than 1.62 million families

(World Bank 2013b). Eligible households were given a one-off cash grant in the amount of PRs 20,000 (about US$213), based on funds available to cope with the urgent needs of a very large flood-affected target population.

The provincial and regional governments identified CDCP beneficiaries in two ways. A geographical targeting system was used in Punjab, Sindh, and Balochistan. Entire communities were identified as calamity affected through notification by each province of the flood-affected areas (determined by visually calculating that at least 50 percent of houses or crops were lost). A Rapid Housing Survey was used in Khyber Pakhtunkwa (KP) province and the autonomous territories of Gilgit Baltistan and AJK, with families living in flood-affected housing units, rather than communities, being identified as flood affected.

The findings from the Phase I evaluation showed that the funds helped households cover their needs at a crucial time (World Bank 2013b), with the grants mostly used for food, health needs, housing repair, and debt repayment (Hunt et al. 2011). However, the amount was insufficient for the flood-affected households to recapitalize their damaged or lost assets. The evaluation also suggested that for every 100 potentially eligible family heads, only 43 had received the *Watan* card. Inclusion and exclusion errors explain these results. Geographical targeting missed households that suffered from damages but lived in a weakly affected community; and the Rapid Household Surveys missed some damages and were conducted by local notables, not by experts able to detect all damages. Finally, the beneficiary selection and verification process proved to be lengthy and cumbersome, particularly for those who had lost the documentation necessary for verification either prior to, or during, the floods.

Phase II of the CDCP distributed larger amounts and was better targeted. In Phase II (June 2011 to June 2013), with total resources of around $600 million, flood-affected households, including many of those from Phase I, were provided with cash payments that could be used to meet any recovery needs (like reconstructing houses, restoring livelihoods, or repaying accumulated debt). The size of the grant to eligible households was doubled to PRs 40,000 (around US$426), a more suitable amount to support recovery, provided in two installments of PRs 20,000 each.

Measures were taken from the outset to address the targeting issues found in Phase I. These changes meant that not all Phase I beneficiaries were eligible for Phase II support, and some people excluded from Phase I were included in Phase II. Housing damage was adopted as a proxy indicator for livelihood losses nationwide, rather than the geographic targeting method previously used in Balochistan, Punjab, and Sindh. This meant that the existing Rapid Housing Surveys could be used for targeting in KP and the autonomous regions, whereas new surveys needed to be conducted in the other three provinces.

The eligibility criteria were further refined to filter out the wealthier and to include particularly vulnerable households by adding two new eligibility criteria:

- Well-off households are excluded from receiving the Phase II transfer. Wealth is measured by a combination of proxies—such as those having bank accounts in international banks, frequent international travel activities, and executive jobs.
- All legitimate vulnerable beneficiaries (defined as female- and disabled-headed families in the NADRA's database) included in Phase I but not captured as head of household through the housing damage survey will, de facto, become Phase II beneficiaries.

The vulnerability characteristics of flood-affected families or households were profiled by analyzing a random sample from NADRA's flood registration database and linking this with information on gender, disability, and educational levels in the civil registration database (World Bank 2013b). Additionally, the outstanding legitimate grievance claims from Phase I were settled and considerable resources used to strengthen the government's communications, grievance redress, and policy and implementation capacities at different levels.

The new targeting mechanism was cumbersome for good reason—with fairly large transfers, the focus had to be on reducing inclusion errors and then addressing the exclusion challenge through a rigorously applied grievance appeals system that came to play a critical role in determining legitimate beneficiaries and drawing up beneficiary lists. Data suggest that Phase II has been reasonably successful in targeting the most severely affected and the most vulnerable households (like the poorest and least educated) in the four provinces (except Balochistan). However, beneficiaries experienced payment delays, with just 63 percent of households having receiving both tranches and 13 percent having received neither tranche—more than a year after the inauguration of Phase II and almost three years after the 2010 flooding.

Grievance appeals are standard features in safety net systems, and can be particularly important in emergency-type interventions, where often simple and straightforward selection procedures are applied within relatively short periods of time. They made for substantially improved targeting. Whereas initial beneficiary identification (the baseline) had resulted in the estimated exclusion of 61 percent of potentially eligible flood-affected households, with modified processes, and especially a fully operational grievance-redress system, errors of exclusion were reduced to 32 percent. Where exclusion did occur, it was driven by difficulties in capturing people without identity cards (who would be automatically excluded), those without a permanent address, very isolated households, and those living in insecure areas. Enrollment difficulties were encountered in particular in Balochistan and Gilgit-Balistan, where low administrative capacity in both areas, and stone-built, less flood-sensitive houses in the latter, resulted in few households being verified. Still, improved processes reduced exclusion errors in Balochistan to 30 percent, compared to a baseline of 73 percent.

A model of beneficiary registration and payment. The CDCP offers a model of how to establish an efficient decentralized beneficiary registration system for a very large number of clients over a widespread geographic area. By the end of Phase I, more than 1.6 million families had been enrolled, and RPs 33 billion (US$374 million) was distributed (World Bank 2013b). A further 874,000 *Watan* cards have been issued since then and nearly RPs 31.9 billion (US$337.6 million) disbursed during Phase II up to June 2012 (World Bank 2013b). This is an impressive logistical and administrative achievement.

Over the course of Phases I and II, NADRA established 101 CDCP local offices, named *Watan* Card Facilitation Centers (WCFCs), covering all of the flood-affected districts. The WCFCs serve as a "one-stop shop," where the beneficiaries are enrolled, register complaints or grievances, and often receive payments via a Point of Sale machine. Biometric screening is used to verify the beneficiary identities to prevent fraudulent claims. Beneficiaries are then registered and issued a *Watan* card, which can be used at the Point Of Sale desk or any ATM. In certain districts, the placement of a cash desk at the WCFC (like on-site cash storage) was deemed a security risk and payments have been processed at a local bank branch, usually one or two kilometers away from the WCFC.

Notes

1. Grosh et al. (2008) provide an extensive review of existing social protection schemes.
2. http://www.bcn.cl/de-que-se-habla/bono-solidario-marzo-2009.
3. Source: Background paper for this report by Johnson and Bowen (forthcoming).
4. Source: Background paper for this report by Bowen (forthcoming).
5. Source: GFDRR case study on Pakistan (World Bank 2013b) and Implementation completion and results report ICR00003119 (World Bank 2014).

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A Window of Opportunity: Climate-Informed Development and Pro-Poor Climate Policies

6

Main Messages

- In a pessimistic development scenario, climate change could drag more than 100 million people into poverty by 2030. This number can be reduced to fewer than 20 million, if rapid, inclusive, and climate-informed development is combined with targeted adaptation actions.
- The impacts of climate change on poverty by 2030 mostly depend on development policy choices.
- Immediate emissions-reduction policies are needed to reduce the longer-term threat of climate change to poverty and avoid the post-2030 impacts on poverty that development policy alone cannot manage.
- To ensure that emissions-reduction policies do not slow down poverty reduction, countries need to focus on options that yield local (health or economic) cobenefits and protect poor people from the negative consequences of mitigation policies.
- In poor countries where domestic resources are insufficient to protect poor people, support from the international community is essential. This is particularly true for investments with high upfront costs that are critical to prevent lock-ins into carbon-intensive patterns (such as for urban transport, energy infrastructure, or deforestation).

Introduction

So far, this report has presented plenty of evidence that unmitigated climate change could become a significant obstacle to development and poverty eradication and—maybe even more important in a risk-based framework—that the uncertainty around the potential impacts on poverty, development, and welfare are extremely large.

Our analysis has been centered on the three channels through which climate-related events already affect the ability of poor people to escape poverty: (i) agricultural production, ecosystems, and food security; (ii) natural disasters; and (iii) health.

- Chapter 2 shows that losses in the agricultural sector and spikes in food prices pushed people into poverty in the past, as exemplified by the 2010–2011 episode that increased poverty by 44 million people—and that climate change will likely magnify this threat.
- Chapter 3 discusses how natural disasters are already preventing many households from escaping poverty, with the poor more vulnerable to these events—and how climate change is likely to worsen the situation.
- Chapter 4 shows that climate change will magnify the type of health shocks that are already a serious burden for poor people and poor countries—such as malaria, diarrhea, and stunting.

These chapters also identify many options to reduce the impact of climate change, especially on the poor and vulnerable—from dikes and irrigation systems to early warning systems, better connection to markets, and universal health coverage. In addition, chapter 5 presents instruments to make the population more resilient to shocks at an affordable cost for public finances—for example, financial inclusion and social safety nets that are scalable and can target people hit by a health shock or a flood.

The message that emerges from these sectoral and thematic chapters is that poverty is one of the key markers of vulnerability and that much of what is recommended as measures to make people and societies more resilient is simply good development policy. And, given that greenhouse gas (GHG) emissions-reduction policies have limited impacts on climate change between now and 2030, it is development progress that will be the key determinant of the impacts of climate change on poverty in the short to medium term.

How much of a difference could good development make to the resilience of individuals and societies? This chapter tries to answer this question—and for the first time, to give a sense of the magnitude of the impact of development on the vulnerability to climate change impacts. But this report has also shown that there are limits to adaptation. The evidence is strong that climate change mitigation action is needed now to prevent much more severe impacts later this century (Fay et al. 2015; IPCC 2014; NCE 2014; OECD 2015). This chapter provides thoughts on how mitigation policies can stabilize the climate and the risks it creates, and do so without slowing down poverty reduction.

By 2030, climate change will increase; but rapid, inclusive, and climate-informed development can minimize its impact on poverty

Between now and 2030, climate policies can do little to reduce the amount of global warming already under way because of the long lag between the introduction of mitigation policies, their impact on emissions, and the effect of emissions reductions on the climate system. Only changes in short-lived climate pollutants (like black carbon and methane) could have a rapid impact, especially at local scale, but their potential at global scale remains relatively limited (Rogelj et al. 2014). This scientific certainty means that the only way to reduce climate change impacts by 2030 is by lowering socioeconomic vulnerability to climate change—through both climate-informed development and targeted adaptation efforts.

We investigate here the potential efficacy of these development policies to reduce the poverty consequences of climate change (full results and technical details of the analysis presented below can be found in a background paper for this report, Rozenberg and Hallegatte, forthcoming). To do so, we first look at what the future could look like without climate change. We then use the likely impacts of climate change on the poor identified in chapters 2–4 to examine how the aggregate impact of climate change on poverty is affected by overall development progress.

The results are unequivocal: the impact of climate change on poverty is conditioned by overall development progress.

Even without climate change, very different futures can be imagined for poverty and development

It is impossible to forecast future socioeconomic development. Experience suggests we are simply not able to anticipate structural shifts, technical breakthroughs, and geopolitical changes (Kalra et al. 2014). Here, we do not predict future socioeconomic change and we do not predict the impact of climate change on poverty.

Instead, we follow a scenario-based approach that is the basis of all Intergovernmental Panel on Climate Change (IPCC) reports. It consists of analyzing a set of *socioeconomic scenarios* and exploring how climate change would affect development in *each* of these scenarios. These scenarios do not correspond to particularly likely futures (box 6.1). Rather, they are possible and internally consistent futures, chosen to cover a broad range of possible futures to facilitate assessing possible orders of magnitude of future climate change impacts. People sometimes refer to these scenarios as "what-if" scenarios because they can help answer questions such as: "*What* would the climate change impact be *if* socioeconomic development followed a given trend?" Our goal is to better understand how the impact of climate change on poverty depends on socioeconomic development, estimate the potential impacts in "bad" scenarios, and explore possible policy options to minimize the risk that such a bad scenario occurs.

BOX 6.1 It is possible to inform decision making, even in a context of deep uncertainty

We do not attribute probabilities or likelihood to our scenarios. These scenarios thus cannot be used as forecasts or predictions of the future of poverty or as inputs into a probabilistic cost-benefit analysis. That said, they can still be an important input into decision making. Indeed, decisions often are not based on average or expected values or on the most likely outputs, but instead on the consequences of relatively low-probability outcomes. For instance, insurers and reinsurers are often regulated on the basis of the 200-year losses (that is, the losses that have a 0.5 percent chance of occurring every year). And we buy insurance to protect ourselves against low-probability events that could have a large impact on our well-being.

Moreover, in a situation of deep uncertainty, it is often impossible to attribute probabilities to possible outcomes (Kalra et al. 2014). For example, we know that conflicts, such as those in North Africa and the Middle East, could continue over decades, slowing down growth and poverty reduction. But they also could subside, allowing for rapid progress. While these two scenarios are obviously possible, it is impossible to attribute probabilities to them in any reliable way. The same deep uncertainty surrounds the future of technologies and most political and socioeconomic trends. In such a context, exploring scenarios without attributing probabilities to them is commonplace. Since the 1990s, the IPCC and climate community have used such long-term socioeconomic scenarios—the Special Report on Emissions Scenarios (SRES) and now the Shared Socioeconomic Pathways (SSPs)—to link policy decisions to their possible outcomes (Edenhofer and Minx 2014). Similarly, the U.K. government performs national risk assessments using "reasonable worst case scenarios" (for example, regarding pandemics, natural disasters, technological accidents, or terrorism), which are considered plausible enough to deserve attention, even though their probability is unknown (World Bank 2013, chapter 2).

While these scenarios cannot be used to perform a full cost-benefit analysis, they make it possible to elicit trade-offs and to support decision making. For instance, they help identify dangerous vulnerabilities that can be removed through short-term interventions (Kalra et al. 2014). In our case here, our two scenarios help us explore and quantify how poverty reduction can reduce the vulnerability to climate change.

To explore how climate change could affect poverty reduction, we create two scenarios for the future of poverty by 2030, in the absence of climate change (figure 6.1; box 6.2).

Prosperity scenario. This scenario is optimistic in that it assumes that the World Bank's twin goals of extreme poverty eradication and shared prosperity are met by 2030—with less than 3 percent of the world

BOX 6.2 Building two scenarios to explore the large uncertainty on the future of poverty

To build representative scenarios that are sufficiently differentiated, we first identify the potential drivers of future poverty—like demography, structural change, technological change and productivity, and redistribution—and explore the range of uncertainty for each of these drivers. We combine them to create hundreds of socioeconomic scenarios for 92 countries. This analysis combines homogenized household surveys (from the I2D2 database) and microsimulation techniques (Bourguignon, Ferreira, and Lustig 2005; Bussolo, De Hoyos, and Medvedev 2008; Olivieri et al. 2014).

We start from a database of 1.4 million households (representing 1.2 billion households and 4.4 billion people in 92 countries). We transform the population structure to account for demographic changes, and we modify the income of each household to account for socioeconomic changes, by 2030. We factor in assumptions on future demographic changes (How will fertility or education change over time?); structural changes (How fast will developing countries grow their manufacturing sector or shift to services?); technology, productivity, and economic growth (How fast will productivity grow in each economic sector? What is the future of technologies and their productivity?); and policies (How much redistribution will occur?).

Since evolutions are uncertain, we use a framework inspired by robust decision-making techniques (Groves and Lempert 2007; Kalra et al. 2014; Lempert et al. 2006; Rozenberg et al. 2014), in which all uncertain parameters are varied systematically across the full range of possible values. This enables us to generate hundreds of scenarios for the future socioeconomic development of each of the 92 countries. Then, we select two representative scenarios per country—one optimistic and one pessimistic in terms of poverty reduction and changes in inequality—and we aggregate them into two global scenarios labeled "prosperity" and "poverty" (table B6.2.1).

To guide the selection of the "prosperity" and "poverty" scenarios in our large set of possible futures, we use socioeconomic scenarios developed by the scientific community to support climate change research, the Shared SocioEconomic Pathways (SSPs). Our prosperity scenario is chosen such that it is consistent with the 5th SSP (or SSP5; see O'Neill et al. 2013) for population and GDP. SSP5 is the scenario with the largest economic growth and a small population. We also ensure that in this scenario, extreme poverty is below 3 percent of the global population in 2030. Similarly, we select the "poverty scenario" using the population and GDP pathways of the SSP4, the most pessimistic in terms of poverty and inequalities, and we minimize structural change, so that 11 percent of the world population lives in extreme poverty in 2030. Because of constraints on microsimulations, our scenarios have a 2030 time horizon, and we cannot use this tool to explore the future after that point.

TABLE B6.2.1 Our optimistic and pessimistic scenarios

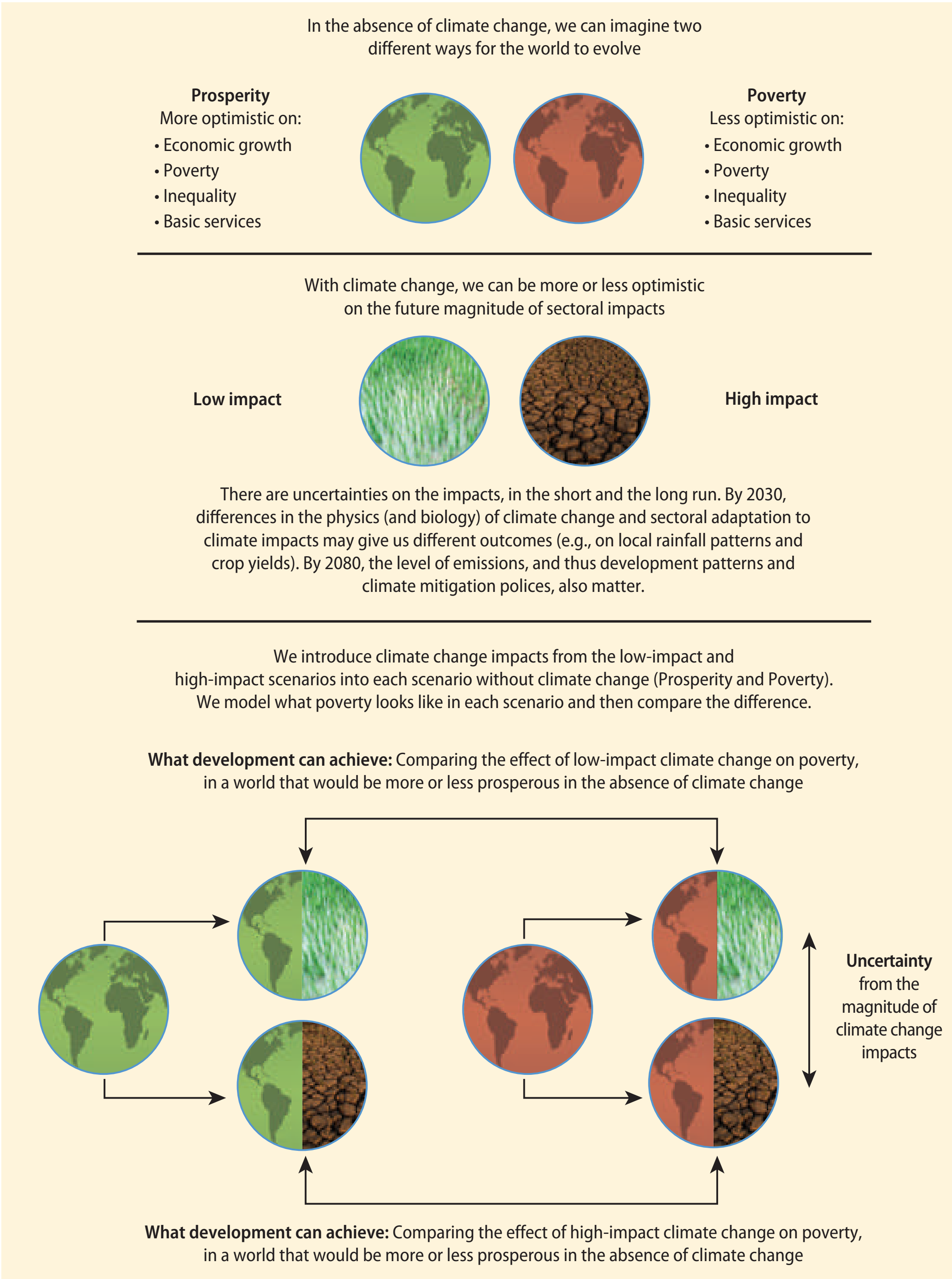
(Population, GDP, and extreme poverty in the 92 modeled countries, in 2030 and in the absence of climate change)

	Population (billions)	Average income per capita (US$ 2005 PPP)	Number of people below poverty line in 2030 in the absence of climate change (million people)
Prosperity scenario	5.9	4,100	142 (2% of global population)
Poverty scenario	6.2	3,700	900 (11% of global population)

Source: Rozenberg and Hallegatte, forthcoming.
Note: PPP = purchasing power parity.

FIGURE 6.1 **Our model for estimating the number of people in poverty because of climate change**

(A schematic to represent the modeling undertaken to estimate the impact of climate change on extreme poverty in 2030 under different scenarios of future development, and thus in worlds with different levels of exposure and vulnerability)



population living in extreme poverty;[1] that population growth is slow in developing countries; that education levels and labor productivity increase rapidly; and that the productivity gap between developing and developed countries decreases quickly. It also assumes fast globalization and technology transfers between countries, allowing rapid structural changes in developing countries and the reduction of the share of unskilled jobs in agriculture in favor of the industry and service sectors. Governance is good, and fiscal systems are efficient, allowing for high levels of redistribution. Even the most vulnerable populations have access to universal health coverage, water and sanitation, and efficient safety nets. And agricultural workers have enough market power to receive a large share of agricultural price increases if price shocks occur.

Poverty scenario. This scenario is pessimistic in that it assumes high population growth in developing countries and more particularly in Africa, low economic growth, and greater inequalities between and within countries—with 11 percent of the world population living in extreme poverty. The world is assumed to be fragmented, with few technology transfers, low structural change, and in 2030 a significant share of the global population still unskilled and working in agriculture. Many near-poor people remain vulnerable and risk falling back into poverty if a shock occurs because of low redistribution levels and inexistent or inefficient safety nets. Health care and water and sanitation are not accessible to all, making the eradication of vectorborne diseases more difficult.

These two scenarios are counterfactual *reference* scenarios, which do not include climate change. In a second stage, we add climate change impacts into each of these scenarios. We do not attribute probabilities or likelihood to our scenarios because we are not interested in forecasting the future of poverty. Instead, we want to explore how the impacts of climate change on poverty are different in different development scenarios, with and without climate change, to inform decision making on poverty reduction and climate policies (box 6.1).

The effect of climate change on poverty is a combination of many sectoral impacts

In each country and for each of the two selected socioeconomic scenarios (*prosperity* and *poverty*) we introduce climate change impacts on food prices and production, natural disasters, and health, drawing on the results from chapters 2–4 (figure 6.1). In the projections of the 1.4 million households modeled in our scenarios, we adjust the income and prices to reflect the impact of climate change on their ability to consume, and thus derive the impact on poverty (box 6.2). The impacts are estimated using sectoral models (such as crops and agricultural trade models) and include adaptive behaviors (such as changing agricultural practices or trade patterns).

With a 2030 horizon, impacts barely depend on emissions between 2015 and 2030 because these affect the magnitude of climate change only over the longer term, beyond 2050. Regardless of socioeconomic trends and climate policies, the mean temperature increase between 2015 and 2035 is between 0.5 and 1.2°C—depending on the response of the climate system (IPCC 2013). The impacts of such a change in climate are highly uncertain and depend on how global climate change translates into local changes, on the ability of ecosystems to adapt, on the responsiveness of physical systems such as glaciers and coastal zones, and on spontaneous adaptation in various sectors (such as adoption of new agricultural practices or improved hygiene habits).

To account for this uncertainty, we define a *low-impact* and a *high-impact* scenario that represent the uncertainty on the magnitude of the physical and biological impacts of climate change. For agriculture, for instance, the difference between the low-impact and the high-impact scenario comes from the uncertainty in the global climate system, crop responses, and trade models that are used. For health, one difference across low-impact and high-impact scenarios comes from the uncertainty on the additional number of cases of dengue and malaria due to climate change and on the cost of treatment.

There are several limits to our approach. First, we follow a bottom-up approach and sum the sectoral impacts, assuming they do not interact. We do not focus on the macroeconomic impact of climate change and its effects on overall economic growth—and thus on the secondary impact on poverty reduction, a limitation considering the evidence that overall growth is a major driver of poverty reduction (Dollar, Kleineberg, and Kraay 2013; Dollar and Kraay 2002). We do so because previous research suggests that the macroeconomic impact of climate change is likely to remain limited by 2030, and because we hypothesize that the main channel from climate change impacts to poverty is through the direct impacts, which are largely invisible in macroeconomic models (chapter 1). Second, we consider only a subset of impacts, even within our three sectors—for instance, we do not include the loss of ecosystem services and the nutritional quality of food. Third, we cannot assess the poverty impact everywhere. Our household database represents only 83 percent of the population in the developing world. Some highly vulnerable countries (such as small islands) cannot be included in the analysis because of data limitations, in spite of the large effects that climate change could have on their poverty rates.

Food prices and food production. Impacts of climate change on agriculture affect poverty in two ways, first through prices and consumption, and second through farmers' incomes (chapter 2). Higher food prices reduce households' available income—especially for the poor, who spend a large share of their income on food products. In our scenarios, the impact depends on the fraction of food expenditure in total expenditure, and this fraction decreases as households get richer. Food price changes also affect farmers' incomes. However, this channel is complex since lower yields (which are expected in many areas because of climate change) mean that higher food prices do not necessarily translate into higher farmer revenues: the net effect depends on the balance between changes in prices and quantities produced.

Using the data from our analysis of food prices and production, we change the income of all workers in the agricultural sector, according to the combination of changes in prices and in the quantities that are produced in a region (see Rozenberg and Hallegatte, forthcoming, for details). We also rescale the (real) income of all households, accounting for the change in food prices and the share of food in households' budget. The impact of the agriculture channel on poverty depends on the number of farmers in each country, the income of these farmers, and the income of the entire population (which affects the share of food in consumption).

Our results show that in the high-impact scenario, the number of people living below the extreme poverty line in 2030 increases by 67 million people in the *poverty* scenario because of climate change impacts on agriculture, and by 6.3 million people in the *prosperity* scenario. Thus, on average, the negative impact of climate change on yields and prices outweighs the potential positive impacts on income that will come from higher food prices. Those numbers are possibly an underestimation of actual impacts because both climate scenarios (low and high impact) assume that there is CO_2 fertilization. The removal of the CO_2 fertilization assumption could bring 3 million additional people into poverty in the *prosperity* scenario and 12 million in the *poverty* scenario.

Note that we did not model the impact of climate change on ecosystem services—even though those will likely have a strong impact on poverty—partly because the income derived from ecosystems represents a small part of the ecosystem's role, but mostly because ecosystem impacts remain impossible to anticipate.

Natural disasters. We estimate that the number of people who lose income as a result of a natural disaster is on average 100 million people per year (or 1.4 percent of the world population).[2] To account for climate change by 2030, we assume that the fraction of the world population that will be annually affected by a disaster rises from an average today of around 1.4 percent to 2 percent in the low-impact case and 3 percent in the high-impact case. This is an increase of 40 to 120 percent, which is in the range reported by Bouwer (2013) and the IPCC (2012 and 2014) for the expected rise in economic losses. It means that between 0.6 percent and 1.6 percent of the world population would be affected by natural disasters because of climate change, on top of the reference risk without climate change. Ultimately, these numbers will depend on the effectiveness and timeliness of adaptation to new climate conditions.

In the low-impact case, we assume that affected people lose 20 percent of their annual income if they are poor and 10 percent if they are nonpoor; in the high-impact case, the losses would be 30 percent for the poor and 15 percent for the nonpoor.[3] These numbers are in line with postdisaster household surveys, even though much higher values are often observed (Patankar, forthcoming; Patankar and Patwardhan, forthcoming; Noy and Patel 2014; Carter et al. 2007). We also assume that natural disasters affect income only during one year, which is a conservative estimate that is valid for small disasters, but not for large-scale events like Typhoon Yolanda in the Philippines or Hurricane Katrina in the United States.[4]

Our results show that for natural disasters, in the high-impact scenario, the number of poor people rises by 5.6 million people in the *poverty* scenario and by 1.5 million in the *prosperity* scenario.

Health and high temperatures. We now include a set of additional impacts of climate change on health (malaria, diarrhea, and stunting), based on the literature reviewed in chapter 4.

For *stunting*, we include the additional share of children estimated to be stunted because of climate change in 2030. To factor in development, we use data from the Demographic and Health Surveys (DHS) by wealth quintile to explore the relationship between household income and stunting. We find that the prevalence of stunting drops for families whose income is above $8,000 per year. We calculate the fraction of the stunted individuals in the families with income below $8,000, so that stunting prevalence is consistent with data for the current situation. Then, we increase this fraction using projections from Hales et al. (2014) to account for climate change. We assume that stunted individuals have lifelong earnings reduced by 5 percent (low-impact scenario) and 15 percent (high-impact scenario), regardless of employment sector and skill level.

For *malaria*, we increase the number of malaria cases in 2030 in each country following Caminade et al. (2014). As with stunting, we calculate the fraction of people who are affected by malaria, based on current prevalence, and we vary this fraction using estimates of future change due to climate change in various regions. Then, based on the literature reviewed in chapter 4, we assume that these people are affected between 0.1 and 2 times per year and lose income through the cost of treatment (between $0.7 and $6 per occurrence) and lost days of work (by the sick or caregivers, between 1 and 5 days per occurrence). Note that we consider only the monetary expenses due to the disease and do not model nonmonetary effects (like the cost of life or loss in well-being from being sick), which would be important in a multidimensional analysis of poverty.

For *diarrhea*, we start from data on the number of cases per country today, the cost of treatment (between $2 and $4 per episode), and the number of days out of work (between 3 and 7 days for the sick and caregivers) (Hutton and Haller 2004). We assume that the prevalence of diarrhea will increase by 10 percent by 2030 because of climate change (in all regions), using results from Kolstad and Johansson (2010). To account for development, we use DHS data to explore the relationship between household income and exposure to diarrhea. We find a threshold at $15,600 per year, and we assume that only households with income below this level are affected by impact of climate change on diarrhea.

Further, we assume that fast progress in access to water and sanitation in the *prosperity* scenario would halve the number of cases, which is consistent with a recent assessment in India (Andres et al. 2014). Of course, this assumes that the new water and sanitation infrastructure can continue to perform well in 2030 and beyond—in other words, that development has been climate informed. For that to occur, the uncertainty in climate projections would need to be accounted for in the design phase, as would the extra funds needed to invest in more resilient infrastructure (possibly factoring in safety margins and retrofit options) (Kalra et al. 2014).

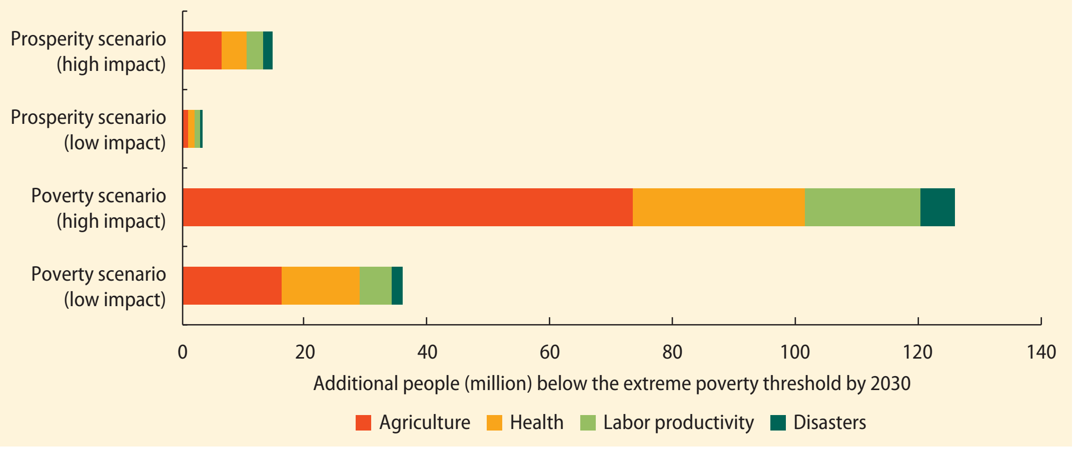
Our results show that the health impacts of climate change are severe: in the high-impact case, 28 million people would be pushed into poverty in 2030 in the *poverty* scenario and 4.1 million people in the *prosperity* scenario. The impact is smaller than that of agriculture for both scenarios but remains significant.

As for the impact of high temperatures on labor productivity (also based on results presented in chapter 4), we assume that, in hot countries, people working outside or without air-conditioning will lose between 1 and 3 percent in labor productivity because of this change of climate, compared with a baseline with no climate change. To assess the number of people affected, we estimate the shares of people working outside or without air-conditioning in the two socioeconomic scenarios. We find that with high climate change impacts, 19 million people would be pushed into poverty in 2030 in the *poverty* scenario, and 2.7 million people in the *prosperity* scenario because of the impact of temperature.

Comparing sectoral influences. Which of these sectors has the greatest impact on poverty in our simulations? As figure 6.2 illustrates, agricultural impacts are the chief culprit in all four scenarios (*prosperity* and *poverty*, combined with high and low impacts). Next come health impacts (diarrhea, malaria, and stunting), and the labor productivity effects of high temperature with a second-order but significant role. Disasters play a limited role, but we have to be careful because only the direct impact of income losses was accounted for.

FIGURE 6.2 Agriculture is the main sectoral factor explaining higher poverty due to climate change

(Summary of climate change impacts on the number of people living below the extreme poverty threshold, by source)



Source: Rozenberg and Hallegatte, forthcoming.

By 2030, climate change is not the dominant driver of global poverty but can have a large impact if development is not rapid, inclusive, and climate informed

So how do these sectoral results add up in terms of climate change's effect on future poverty trends? We definitely find that a large effect on poverty is possible, even though our analysis is partial and does not include many other possible impacts (for example through tourism, energy prices, foreign direct investment, or remittances) and looks only at the short term (during which there will be small changes in climate conditions compared with what unabated climate change could bring over the long term). Indeed, our overall results show that between 3 million (in the *prosperity* scenario with low impact) and 122 million (in the *poverty* scenario with high impact) additional people would be in poverty because of climate change (Table 6.1).

- In the *poverty* scenario, the total number of people living below the extreme poverty line in 2030 is 1.02 billion people in the high-impact climate change scenario; this represents an increase of 122 million people compared to a scenario with no climate change. For the low-impact scenario, the increase is 35 million people.
- In the *prosperity* scenario, the increase in poverty due to a high-impact climate change scenario is "only" 16 million people, suggesting that development and access to basic services (like water and sanitation) are effective in reducing poor people's vulnerability to climate change. For the low-impact scenario, the increase is 3 million people.

Note that the large range of estimates in our results—3 to 122 million—may incorrectly suggest that we cannot say anything about the future impact of climate change on poverty. The reason for this rather wide range is not just scientific uncertainty on climate change and its impacts. Instead, it is predominantly policy choices—particularly those concerning development patterns and poverty reduction policies between now and 2030. While emissions-reduction policies cannot do much regarding the climate change that will happen between now and 2030 (since that is mostly the result of past emissions), development choices can affect what the impact of that climate change will be.

In the *prosperity* scenario, the lower impact of climate change on poverty comes from a reduced vulnerability of the developing world to climate change compared to the *poverty* scenario. This reduced vulnerability, in turn, stems from several channels.

TABLE 6.1 Climate change can have a large impact on extreme poverty, especially if socioeconomic trends and policies do not support poverty eradication

(Poverty headcount in the four scenario types)

	Climate change scenario				
	No climate change	Low-impact scenario		High-impact scenario	
Policy choices	Number of people in extreme poverty	Additional number of people in extreme poverty because of climate change			
Prosperity scenario	142 million	+3 million		+16 million	
		Minimum +3 million	Maximum +6 million	Minimum +16 million	Maximum +25 million
Poverty scenario	900 million	+35 million		+122 million	
		Minimum –25 million	Maximum +97 million	Minimum +33 million	Maximum +165 million

Source: Rozenberg and Hallegatte, forthcoming.
Note: The main results use the two representative scenarios for prosperity and poverty. The ranges are based on 60 alternative poverty scenarios and 60 alternative prosperity scenarios. For full details, see Rozenberg and Hallegatte, forthcoming.

- People are richer and fewer households live with a daily income close to the poverty line. Wealthier people are less exposed to health shocks (such as stunting and diarrhea) and are less likely to be pushed into poverty when hit by a shock.
- The global population is smaller in the *prosperity* scenario in 2030, by 2 percent globally, 4 percent in the developing world, and 10 to 20 percent in most African countries. This difference in population makes it easier for global food production to meet demand, thereby mitigating the impact of climate change on global food prices. The *prosperity* scenario also assumes more technology transfers to developing countries, which further mitigates agricultural losses.
- There is more structural change (involving shifts from unskilled agricultural jobs to skilled manufacturing and service jobs), so fewer workers are vulnerable to the negative impacts of climate change on yields. In the *prosperity* scenario, a more balanced economy and better governance mean that farmers capture a larger share of the income benefits from higher food prices.

Up to 2030, climate change remains a secondary driver of global poverty compared to development: the difference across reference scenarios due to socioeconomic trends and policies (that is, the difference between the *poverty* and *prosperity* scenarios in the absence of climate change) is almost 800 million people. This does not mean that climate change impacts are secondary at the local scale: in some particularly vulnerable places (like small islands or in unlucky locations affected by large disasters), the local impact could be massive.

Note that although climate change impacts are secondary in our scenarios, they are also highly uncertain. There is a big difference in poverty outcomes when we consider climate change in the *low-impact* or *high-impact* scenario. This occurs because of the large uncertainty surrounding the future magnitude of physical impacts, largely in agriculture. In fact, a systematic sensitivity analysis based on our model shows that almost 90 percent of the uncertainty on poverty impacts arises from the uncertainty on the local agriculture impacts (like how crops respond to higher temperatures and resulting impact on yields), which is due to the different climate models used in the agricultural analysis (chapter 2).

This uncertainty prevents us from providing a precise estimate of the future impacts of climate change on poverty, even for a given socioeconomic development trend. And the present analysis underestimates this uncertainty since many of the least-known impacts have been disregarded—such as recent findings of the impact of climate change on the nutritional quality of food (Myers et al. 2014), or the possibility of a more rapid rise in sea level than expected.

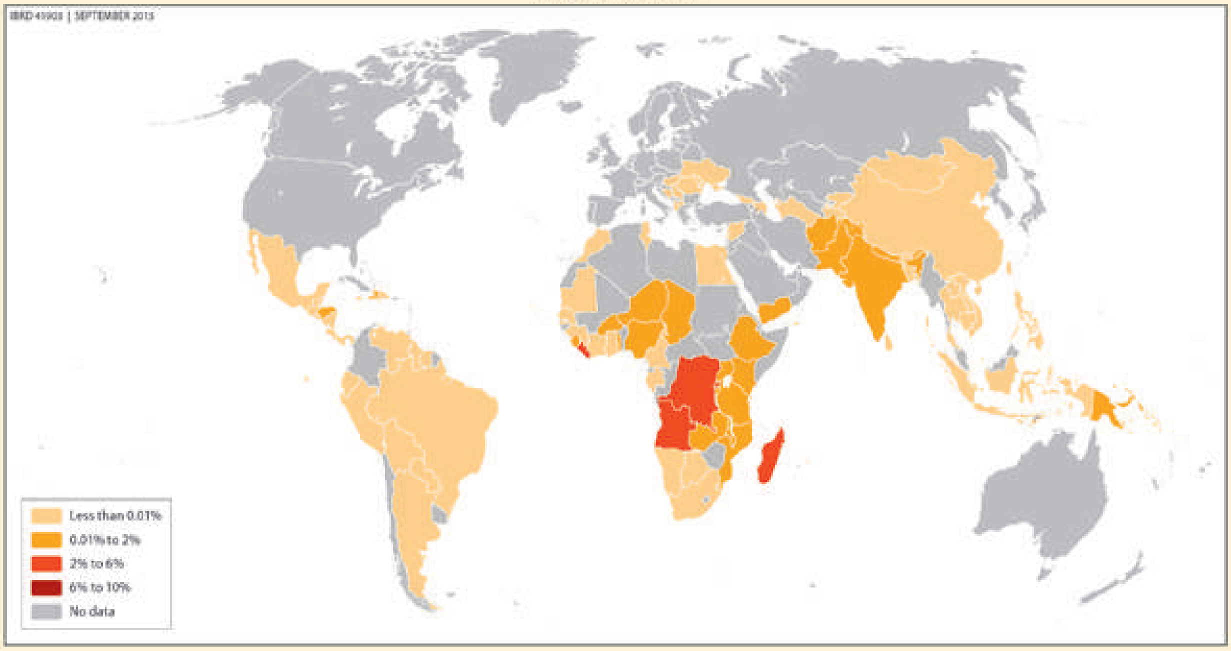
Since most of the variation in our estimate of the climate change impact on poverty arises from the socioeconomic trends and policies, we explore this variation further and use 60 alternative *prosperity* and 60 alternative *poverty* scenarios. These scenarios represent different world evolutions that achieve similar progress to the two reference scenarios in terms of economic growth and poverty reduction. We assess the poverty impacts of climate change on all 120 scenarios. We find that the range of possible impacts is extremely large, especially in the *poverty* scenario (table 6.1)—which also features more uncertainty. In the *poverty* scenario, some scenarios (12 out of 60) show a *decrease* in global poverty numbers. These are scenarios where climate change impacts remain moderate (low-impact), where a large share of the population still works in the agricultural sector, and where farmers benefit the most from higher food prices (assuming a proportional pass-through of higher revenues to their incomes).

Our global results in the representative *prosperity* and *poverty* scenarios also hide higher impacts at a finer scale. At the country and regional level, the hotspots for increased poverty because of climate change are Sub-Saharan Africa and—to a lesser extent—India and the rest of South Asia, especially in the *poverty* scenario (map 6.1). Those countries, in Africa in particular, bear a higher burden

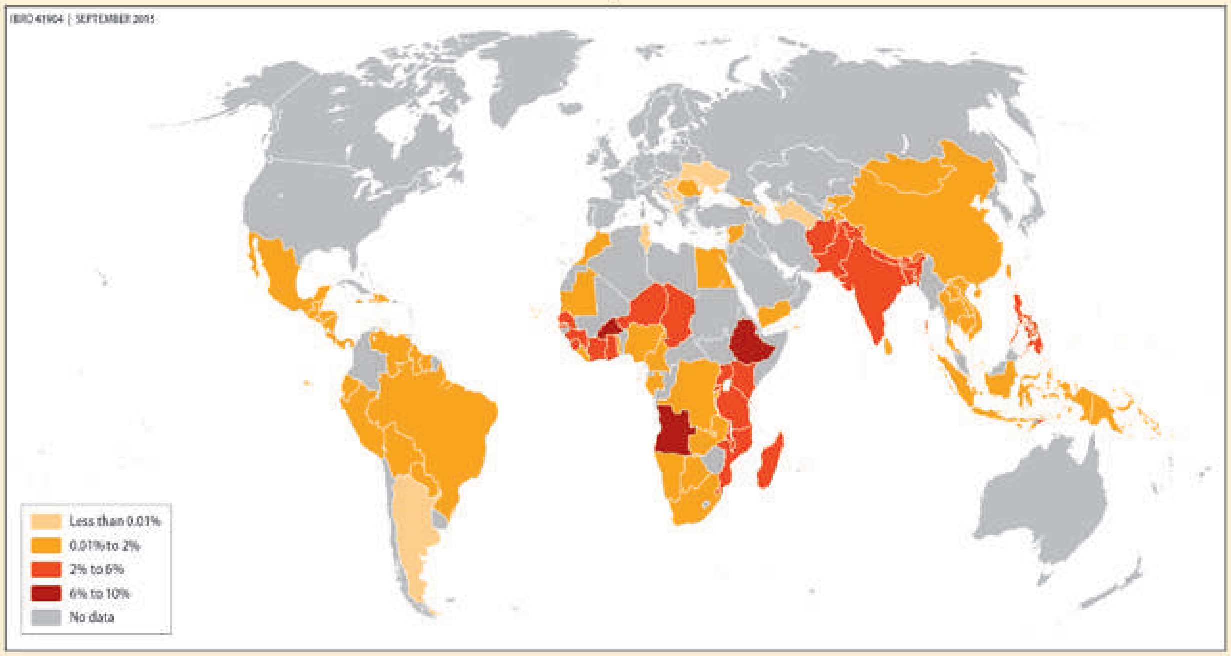
MAP 6.1 Sub-Saharan Africa and—to a lesser extent—India and the rest of South Asia are the most vulnerable

(Increase in poverty rate due to climate change in the high-impact scenario)

a. Prosperity scenario



b. Poverty scenario



Source: Rozenberg and Hallegatte, forthcoming.

because they have the highest initial number of poor people and the steepest projected food price increases.

In almost all countries, the additional number of poor people due to climate change is higher in the *poverty* scenario than in the *prosperity* scenario. Two exceptions are Liberia and the Democratic Republic of Congo, for which the number of poor people pushed into poverty because of climate change is higher in the *prosperity* scenario than in the *poverty* scenario. This is because, in the *poverty* scenario, 70 percent of the population still lives below the extreme poverty threshold in 2030 even without climate change. There are fewer people at risk of falling into poverty because most of the population is already poor—a reminder that the depth of poverty (not just the poverty headcount) also matters.

Moreover, our results show that it is not just the extreme poor who are affected. By 2030, the income of the bottom 40 percent is reduced compared to the scenarios without climate change by more than 4 percent in many countries in the *high-impact* climate change scenario. In most Sub-Saharan African countries and Pakistan, the income of the bottom 40 percent decreases by more than 8 percent in the *high-impact* climate change scenario.

What messages should we take away from all of these results?

First, the quantitative impacts of climate change on poverty are uncertain, but could be significant, even over the relatively short term. It is true that our analysis does not cover all climate change impacts (like those on ecosystem services) or the entire developing country population (17 percent is left out), yet we still find that more than 100 million people may be pushed into poverty because of climate change impacts.

Second, most of the uncertainty surrounding these impacts comes from development choices made between now and 2030, and can therefore be actively reduced by implementing the right policies. The quantitative impacts of climate change on poverty are much smaller in a world where socioeconomic trends and policies ensure that development is rapid, inclusive, and climate informed, than in a world where extreme poverty would persist without climate change. Development policies thus appear to be good adaptation policies, in addition to the more targeted sectoral interventions described in previous chapters.

Pro-poor mitigation policies are needed to reduce the long-term threat of climate change

So far, we have looked only at what occurs by 2030—a period during which emissions-reduction policies have almost no impact on the magnitude of climate change (IPCC 2013). By this time, climate change impacts also remain moderate compared with what is expected in 2050 and beyond. Indeed, the impacts of climate change will grow with its magnitude, which will continue increasing as long as net emissions of carbon dioxide (CO_2) are not reduced to zero.

While chapters 2 to 5 propose options to reduce these impacts, they also point to the limits of these options. Land use planning faces difficult political economy obstacles, financial constraints make it tough to invest in protection infrastructure, the provision of health care in rural areas remains challenging, and targeting social assistance after a disaster and in emergency conditions will always be difficult. There are clear limits to what adaptation can achieve, and these limits will be tested by climate change. As summarized in IPCC (2014), "*without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread and irreversible impacts globally*."

Moreover, the long-term impacts of climate change are highly uncertain. How will ecosystems react to rapid changes in temperature, rainfall, and ocean acidity? How fast will icecaps disappear, raising global sea levels and threatening coastal settlements? Could more pressure on natural resources trigger more conflicts? Importantly, this uncertainty is skewed toward catastrophic outcomes: while climate change impacts might turn out to be moderate, they could escalate to extremely high levels and in that case—again—poor people would be the most affected (Pindyck 2013; Stern 2013; Weitzman 2014).

Thus, uncertainty is not a reason to delay climate change mitigation action. On the contrary, the need for climate stabilization arises from a risk management approach that takes into account threats created by long-term impacts and the fact that GHG emissions lock us into irreversible warming. These risks—that remain impossible to quantify in terms of consequences or probability—largely explain why the international community has committed to the goal of stabilizing global temperature (16th Conference of the Parties of the United Nations Framework Convention on Climate Change, UNFCCC 2010), and thus to the full decarbonization of the global economy (Fay et al. 2015; G7 2015).

Climate stabilization requires immediate departure from current development trends

What might a mitigation game plan look like? To begin with, there is agreement that current development trends are incompatible with the internationally agreed climate targets (IPCC 2014). Energy consumption, the main driver of GHG emissions worldwide, is expected to increase over time in a development-as-usual scenario—reflecting the huge income gaps among regions and countries.

Typically, very poor, agriculture-focused countries do not consume a lot of energy. In 2011, the 900 million persons (13 percent of the population) living in the 50 poorest countries emitted only 0.8 percent of global CO_2 emissions (figure 6.3). Indeed, below about $5,000 GDP per capita, increases in income tend to result in only modest increases in energy consumption (figure 6.4). But, beyond this threshold, a major factor in development has been industrialization, which comes with a tighter link between GDP growth and energy consumption growth. And energy is required to fuel hospitals, schools, transportation, and other productive activities that support development. At high-income levels (above about $10,000 per capita), economies and growth diversify away from manufacturing, and energy consumption increases more slowly with income (Medlock III and Soligo 2001; van Benthem 2015).

Looking ahead, can this relationship change through *energy leapfrogging*? Thanks to technological progress, the energy efficiency of lighting, vehicles, appliances, and industrial processes has improved considerably in the past decades. This means that, when countries that are currently less developed reach the income per capita levels that today's developed countries had, say in the 1960s, they will have access to more energy-efficient technology than was available for developed countries at that time. Will this reduce energy consumption associated with future development? So far, there is no evidence of leapfrogging: economic development has not been less energy intensive in follower, developing countries than past growth in leader, now-developed countries. Three factors can explain this result (van Benthem 2015).

First, developing countries may not fully adopt available efficient technology because their regulations are less stringent, access to technologies remains limited by trade barriers and skill mismatch, and governments investing in infrastructure and firms investing in productive capital face strong constraints in terms of access to capital and financial markets (Fay et al. 2015; World Bank 2012). As a result, they typically favor technologies with lower upfront capital costs, in effect, favoring less energy-efficient technology.

Second, globalization and outsourcing mean that developing countries today are manufacturing not just for themselves, as developed countries did during their development, but also for the developed world. Their economy thus relies relatively more on manufacturing for exports, which tends to increase energy consumption.

Third, more efficient technology is offset by increased use of such technology (Gertler et al. 2013; Gillingham et al. 2013). Developing countries may use more (or larger) cars and refrigerators than developed countries in the past at similar income levels—this earlier access of poor people to energy services is one of the positive impacts of higher energy efficiency, but it results in more energy consumption.

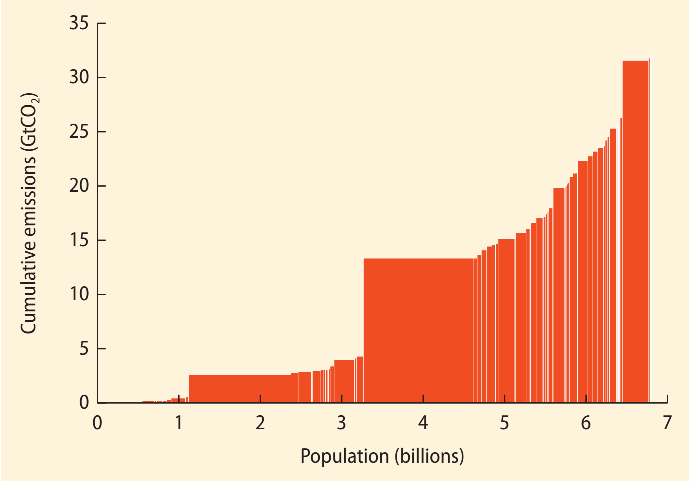
Energy leapfrogging could occur in the future if (i) developing countries enact policies that favor the adoption of cleaner technologies (like performance standards on light bulbs, appliances, buildings, or private vehicles); (ii) they correct other market or government failures that prevent technology adoption (like mandating labels that inform on energy consumption, or removing energy subsidies); (iii) manufacturing patterns become more balanced (for instance if developed countries increasingly use robots to manufacture locally); or (iv) technology adoption in developing countries saturates at lower levels than in developed countries (car ownership may end up being lower in developing countries than in already developed countries if developing countries build mass transit–oriented cities). But the evidence suggests that energy consumption and related emissions are unlikely to decrease by themselves.

Policies are thus needed to make development and climate change stabilization compatible. Energy consumption and related emissions are unlikely to decrease by themselves, and maintaining global warming below 2°C, or even below 3°C, will require reducing emissions to zero by 2100 (figure 6.5). Modern living standards will thus need to be supported in a more efficient and radically less carbon-intensive way, and residual emissions offset though natural carbon sinks like forests (Fay et al. 2015).

With this goal in mind, it makes economic sense for all countries to account for the carbon constraint, especially in decisions with long-term consequences, and to drive their development toward efficient patterns (Fay et al. 2015; Vogt-Schilb and Hallegatte 2014; World Bank 2012). If the carbon constraint is not accounted for now, development will create lock-ins into energy- and carbon-intensive patterns—such as inefficient urban forms (Avner, Hallegatte, and Rentschler 2014), insufficient investment in public transport (Vogt-Schilb, Hallegatte, and de Gouvello 2014), or insufficient investment in zero-carbon electricity (Lecuyer and Vogt-Schilb 2014). Without early retirement, the lifetime of energy infrastructure that is built now ranges

FIGURE 6.3 One billion people living in the poorest countries emit less than 1 percent of global emissions

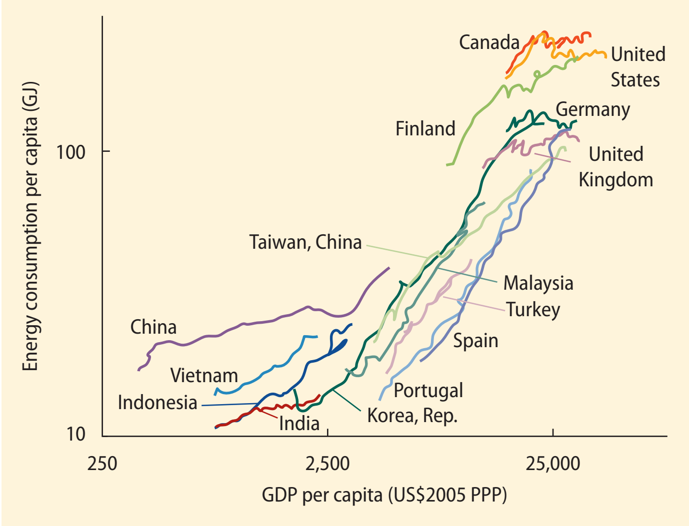
(Carbon emissions and population by country)



Source: World Bank calculation based on World Development Indicators data for 2011.
Note: This *emission Lorenz curve* shows cumulative population ranked by income (horizontal axis) and cumulative carbon emissions (vertical axis). Each rectangle represents a country. $GtCO_2$ = gigatons of carbon dioxide.

FIGURE 6.4 Energy consumption is low when GDP per capita is below $5,000, but then increases fast until $10,000

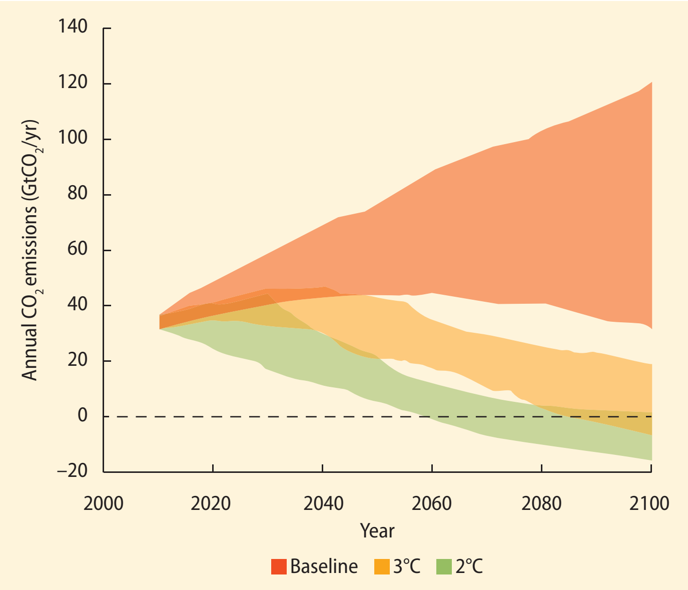
(Per capita final energy consumption and GDP, 1960–2006)



Source: van Benthem 2015.
Note: Both axes have a logarithmic scale. GDP = gross domestic product; GJ = gigajoule; PPP = purchasing power parity.

FIGURE 6.5 Carbon neutrality is needed by 2100 to achieve climate goals

(Global CO_2 emissions in the scenarios analyzed by IPCC 2014)



Source: Adapted from IPCC 2014.
Note: $GtCO_2$ = gigatons of carbon dioxide.

from 20 to 60 years, in effect creating an "emission commitment" (Davis, Caldeira, and Matthews 2010; Davis and Socolow 2014; Guivarch and Hallegatte 2011). This commitment is rapidly increasing today, especially because much coal-related infrastructure continues to be built across the world (figure 6.6) (Steckel, Edenhofer, and Jakob 2015).

These carbon-intensive patterns would be costly—or sometimes impossible—to reverse later on, which would impair an efficient transition toward a zero-carbon economy and make it much more expensive and politically difficult (Rozenberg, Vogt-Schilb, and Hallegatte 2014). Thus, it is urgent that all countries—especially developing ones that are building their infrastructure stocks at present—take steps to redirect investment in long-lived capital and infrastructure toward low- or zero-emission alternatives.

To achieve an efficient decarbonization of the world economy, all countries must work on enacting comprehensive packages of mitigation policies (IPCC 2014)—ranging from carbon pricing and innovation support to environmental performance standards, information labels, financing facilities, and land use and urban planning (Fay et al. 2015; NCE 2014; OECD 2015). These packages must be designed in a way that does not threaten the objective of eradicating poverty by 2030.

Climate change mitigation need not slow down poverty alleviation, as long as climate mitigation policies are done right

What would such ambitious mitigation policies portend for poverty reduction? They could reduce GDP growth, in turn slowing down poverty reduction. Higher energy prices (due to more expensive low-carbon energy technologies) could reduce poor people's consumption, as would higher food prices (due to land use for bioenergy or carbon sequestration).

However, reviews of modeling exercises suggest that mitigation policies would not lead to large losses in this area, even without considering benefits from lower climate change impacts and cobenefits. The IPCC (2014) estimates that mitigation policies would reduce global consumption by 1–4 percent in 2030 and 3–11 percent in 2100 relative to an expected consumption growth of more than 300 percent in all scenarios. But these limited costs at the global scale remain uncertain and heatedly debated; models still neglect many mechanisms that could magnify these losses, such as imperfections in labor markets. More important, global estimates hide large impacts on certain countries or sectors.

Even so, policy makers can design climate-mitigation policies that do not threaten poverty eradication. This can be done in three ways: (i) building on no-regret options and focusing on local and immediate cobenefits; (ii) protecting the poor and vulnerable populations against adverse consequences of costly emissions reduction options; and (iii) in the poorest countries, using support from the international community to offset potential trade-offs between poverty reduction and climate change mitigation—especially for the options that involve immediate costs but are urgently needed to prevent irreversibility and lock-ins into carbon-intensive patterns (like those regarding deforestation or urban transport).

Climate change mitigation offers cost-effective opportunities and cobenefits, especially for poor people. Many climate mitigation policies are consistent with development objectives and contribute to higher productivity and efficiency (Fay et al. 2015; World Bank 2012, 2014a). In other words, sometimes the most effective development options also reduce GHGs emissions (or increase them in a negligible manner; see box 6.3).

For instance, using modern, energy-efficient technologies for lightning and transportation can help provide cheap energy services at a low environmental and economic cost. The Global Fuel Economy Initiative's (GFEI) goal of doubling the efficiency of the global fleet of cars (from 8 to 4 liters per 100 km) would result in savings in annual oil import bills alone worth over $300 billion in 2025 and $600 billion in 2050 (based on an oil price of $100/barrel). According to the United Nations Environment Programme (UNEP)/Global Environment Facility (GEF) *en.lighten* initiative, eliminating inefficient lighting by 2030 would save about 1,000 terawatt-hour (TWh)/year in electricity consumption and more than $100 billion in electricity bills.

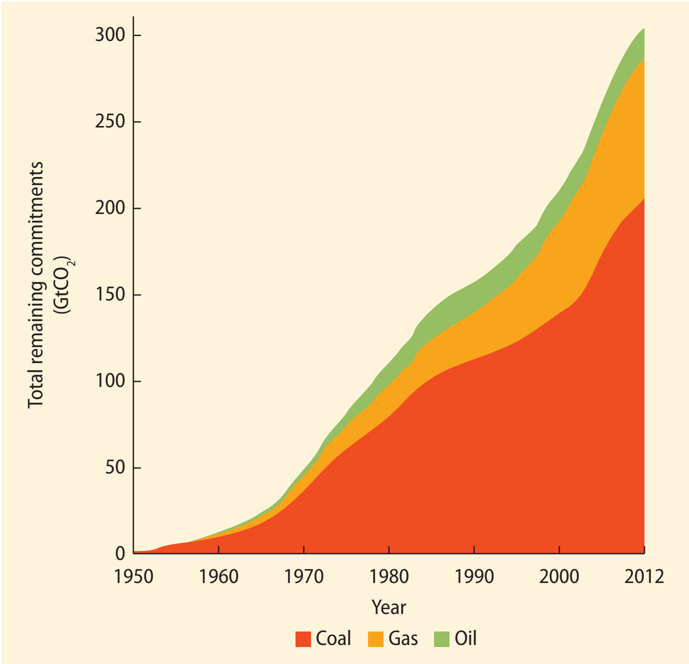
Also, renewable energy can meet the needs of poor households at competitive prices, especially in remote rural areas where grid development and centralized production would be expensive (Deichmann et al. 2011). Under the World Bank–managed Community Development Carbon Fund Nepal Micro-Hydro Promotion project, 426 community-run micro-hydropower plants were installed, benefitting 625,000 people and avoiding the emissions of about 66,000 tons of CO_2 per year.

In addition, climate mitigation efforts can lower local air pollution, thereby providing massive health benefits and higher agricultural yields. Recent studies have found that the benefits from lower air pollution alone could more than offset the cost of mitigation in many regions, especially before 2030 (Shindell et al. 2012; Shindell 2015; Thompson et al. 2014; West et al. 2013). A pathway leading to a reduction in CO_2 concentrations from 720 to 525 parts per million (ppm) in 2100 would avoid 0.5 million premature deaths annually in 2030, 1.3 million in 2050, and 2.2 million in 2100, compared to a scenario with only the progress that can be expected from the historically observed uptake of pollution-control technologies (figure 6.7a).

In places where air pollution has reached alarming levels in the past decade, health cobenefits can be particularly large (Matus et al. 2012). In China, air pollution is estimated to result in 7.4 times more premature deaths than in the European Union (EU) (Watts et al. 2015), and the estimated cost of ambient air pollution in terms of morbidity and mortality is around $1.9 trillion annually in China and India alone (OECD 2014a). In East Asia, about 500,000 premature deaths would be avoided annually in 2050 under

FIGURE 6.6 Investments in coal-related infrastructure have created large emission commitments

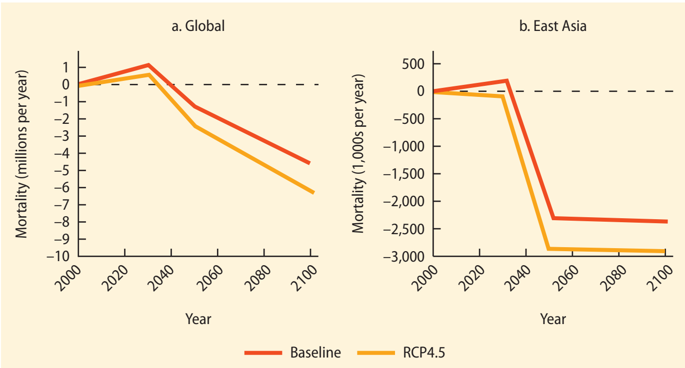
(Total emissions committed by existing infrastructure, for oil, gas, and coal)



Source: Davis and Socolow 2014.
Note: $GtCO_2$ = gigatons of carbon dioxide.

FIGURE 6.7 **Lower air pollution means lower mortality rates**

(Changes in mortality in baseline and mitigation scenarios, from small particulate matter (PM2.5) at the global scale and in East Asia)



Source: Adapted from West et al. 2013.
Note: Baseline is a reference scenario leading to CO_2 concentration around 720 parts per million (ppm) in 2100, which assumes an uptake of pollution control technology consistent with historical experience (Smith, West, and Kyle 2011). RCP4.5 is a scenario with mitigation policies that would lead to 525 ppm in 2100. (More ambitious decarbonization would tend to increase cobenefits). The difference between *Baseline* and *RCP4.5* can be attributed uniquely to GHG emissions reductions.

climate mitigation (figure 6.7b). In India, if health benefits from lower PM2.5 emissions (a decrease of 50 percent by 2050 in tiny particulate matter) were valued similarly to the approach used in the EU for air pollution, they would offset the cost of emission reductions in full (Markandya et al. 2009; Watts et al. 2015). Public transportation is an example of a measure that can reduce local pollutants—in addition to transport costs, congestion, and GHG emissions.

Another area where cobenefits can be generated using mitigation policies is land-based mitigation and policies and payment for ecosystem services. These schemes require developing effective institutions (like land tenure) and enforcement capacity, and they need to be designed explicitly to support poverty reduction. If carbon-related payments were fully developed and pro-poor participation conditions secured, an estimated 25–50 million low-income households could benefit from them by 2030 (Milder, Scherr, and Bracer 2010). And climate-friendly landscape management can be more productive and more resilient to climate shocks (chapter 2).

In most cases, governments need to enact policies to actively promote the adoption of such no-regret options. A recent World Bank report reviews market and government failures that hamper their adoption—including incorrect pricing, split incentives, poor enforcement of existing regulations, lack of information, behavioral failures, and limits to the financing capacity of stakeholders. It also proposes available solutions to overcome them, like information labels or performance standards (Fay et al. 2015).

Capturing these opportunities should be a priority for all countries at all income levels. The international community can help, by providing a combination of technical assistance and better access to green technologies. For instance, the UNEP/GEF *en.lighten* initiative supports countries to implement measures to reduce inefficient lighting. The GFEI builds administrative and technical capacity in developing countries, with the final objective of helping them implement the policies that will double the energy efficiency of the global private car fleet.

The international community—and high-income countries—can also help fund innovation to come up with the solutions that developing countries need (like improved building design and materials for tropical climates).

Multilateral or bilateral development banks (MDBs) can provide advisory services to help countries develop strong capital markets and channel official development assistance. This is particularly important for infrastructure: although MDBs' financial resources are small relative to the need—MDB lending for infrastructure were about $90 billion in 2011, whereas $1 trillion per year would be needed to close the infrastructure gap in developing countries—they often fund a substantial share of infrastructure investments in the poorest countries. MDBs can have a significant impact if they are leveraged to make emissions-reduction investments more attractive to the private sector (for instance, by derisking projects with guarantees and blended financial instruments).

Financial tools for the private sector are also important. The International Finance Corporation recently provided a $30 million loan to the responsAbility Energy Access

Fund, which finances manufacturers and distributors of affordable solar-powered devices. These devices give underserved people access to LED-based lighting and power for charging cell phones or small appliances, thereby supporting economic activity and better livelihoods.

To protect poor and vulnerable people, climate mitigation policies can be combined with complementary policies, including social protection. To stay on a pathway compatible with zero net emissions before 2100, countries will have to do more than implement win-win options, potentially creating costs and trade-offs with poverty reduction. For instance, a key concern is that carbon taxes or fossil fuel subsidy removals can jeopardize the switch from traditional biomass (which would not be impacted by higher energy or carbon prices) to modern cooking fuels, such as electricity or liquefied petroleum gas (LPG) (which would become more expensive). This matters greatly because traditional cooking fuels are unhealthy and worsen gender imbalances and educational opportunities, given the time women and children must spend to collect them (WHO 2006).

Fortunately, studies suggest that countries can reduce their GHG emissions while ensuring universal access to modern cooking (for example, Pachauri et al. 2013). One approach is to sequence fossil fuel subsidy removal, removing subsidies on LPG later on. Similarly, carbon taxes can be combined with policies that help the shift to modern energy, such as low-cost financing for clean cookstove purchase or temporary subsidies for modern energy. If well targeted, policies that support LPG use would have a negligible impact on GHG emissions (Pachauri et al. 2013). More generally, providing universal access to basic services would have no significant impact on global emissions—even using current technologies (box 6.3).

In Peru, the *Fondo de Inclusion Social Energetico* mails LPG vouchers to poor households with their electricity bill (targeting households who own an LPG cookstove and consume less than a given threshold of electricity per month). Under India's Direct Benefits Transfer for LPG program, cash transfers are credited directly to the bank accounts of LPG consumers (this is done instead of reducing the market price of LPG

BOX 6.3 Is there a trade-off between climate mitigation and reducing extreme poverty?

Many recent studies support the idea that providing those who are currently extremely poor with access to basic services would not jeopardize climate mitigation.

- Above a human development index (HDI) of 0.8 (the UN threshold to be considered a developed country), carbon emissions and the HDI are decoupled (Steinberger and Roberts 2010).
- The International Energy Agency (IEA) estimates that universal access to basic energy services by 2030 could be achieved by increasing electricity consumption by 2.5 percent, and fossil fuel consumption by only 0.8 percent (IEA 2011).
- The World Development Report 2010 estimates that the additional emissions needed to provide universal access to electricity in 2010 could be offset by a switch of the U.S. vehicle fleet to European standards (World Bank 2010).

However, these studies rely on a very restrictive definition of access to basic services—one that remains far below what is considered acceptable in developed countries. For instance, for access to electricity, the IEA uses two threshold levels of consumption: 250 kilowatt-hours (kWh) per year for rural households and 500 kWh per year for urban households. In rural areas, this is sufficient to use a floor fan, a mobile telephone, and two compact fluorescent light bulbs for about five hours per day. In urban areas, it can include an efficient refrigerator, a second mobile telephone per household, and another appliance (such as a small television or a computer). Even middle-class living conditions imply a much higher level of consumption

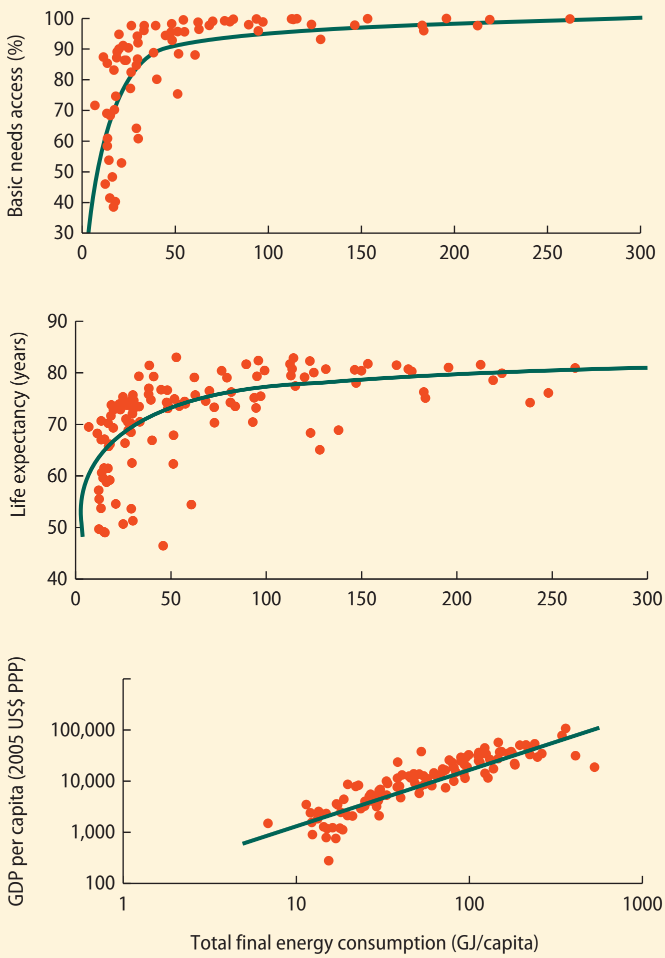
box continues next page

BOX 6.3 (continued)

(ESMAP and SE4ALL 2015). And, historically, there has been a strong relationship between energy consumption and GDP—even though there are decreasing returns on how much energy consumption helps increase life expectancy and basic needs (Figure B6.3.1).

So eradicating extreme poverty can be done at low energy consumption levels, but generalizing affluence and modern living standards with current development patterns and technologies would result in much higher energy consumption and GHG emissions (Rao, Riahi, and Grubler 2014). This is why immediate action is needed in all countries to achieve affluence and shared prosperity while decarbonizing the global economy by the end of the century.

FIGURE B6.3.1 Energy use keeps rising with GDP even though less energy might be enough for basic human needs



Source: Lamb and Rao 2015.
Note: GDP = gross domestic product; GJ = gigajoule; PPP = purchasing power parity.

cylinders, to reduce fraud). Sometimes the modern cook fuel is electricity, and governments want to phase out LPG (this will likely be increasingly important as governments engage on the path to zero net GHG emissions). Ecuador is considering how to remove LPG subsidies to reduce LPG imports and GHG emissions without hurting poor households. The idea is to facilitate the switch to electric cookstoves before LPG subsidies are removed by providing financing options when buying the stoves and temporarily subsidizing electricity (which comes mainly from local hydropower).

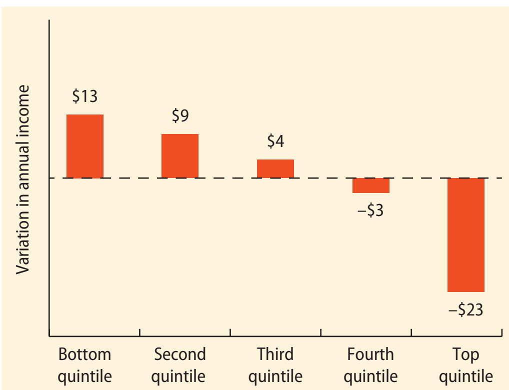
However, fuel subsidies introduce risks of subsidy diversion, smuggling, and fraud (Barnwal 2014; Cunha, Trezzi, and Calvo-Gonzalez 2015). In Ghana, illegal diversion of a heavily subsidized fuel for fishing, “premix,” has been problematic for decades. For many years, the price of gasoline has been double—and between 2011 and 2013 even triple or quadruple—the price of premix fuel, creating enormous scope for commercial malpractice and illegal gains (Kojima 2013). This is why more countries are now turning toward cash transfers to compensate poor people and protect them against higher energy prices.

Indeed, the best strategy may be to implement carbon prices or remove fossil fuel subsidies, while recycling revenues through cash transfers or programs that help the poor (OECD 2014b; Vagliasindi 2012). When carbon revenues or savings from fossil fuel subsidy removal are recycled in lump-sum cash transfers to the population, the overall impact is to improve equity (Bento et al. 2009; Callan et al. 2009; Cohen, Fullerton, and Topel 2013). That result directly follows from the fact that poor households consume less energy, in absolute amounts, than nonpoor households. Data from developing countries suggest that taking \$100 away from fossil fuel subsidies and redistributing the money equally throughout the population would on average transfer \$13 to the bottom quintile and take \$23 away from the top quintile (Arze del Granado, Coady, and Gillinghan 2012) (figure 6.8). In other words, a carbon tax (or fossil fuel subsidy removal) coupled with targeted or untargeted cash transfers, achieves two different objectives: reducing GHGs and improving income distribution (Klenert et al. 2015).

All the revenues from carbon prices or fossil fuel subsidy reform cannot always be used for direct redistribution to households, but that does not necessarily threaten the positive distributive impact. In British Columbia, revenues from the carbon tax are used to cut taxes on both labor and capital, and the scheme is still progressive overall (Beck et al. 2015).

Poverty benefits can be further increased if revenues are used for more targeted instruments that help poor people (like targeted cash transfers), or for better social safety nets (like school feeding). Based on current CO_2 emissions and without any international transfer, a \$30/tCO_2 (ton of carbon dioxide) domestic carbon tax would raise resources amounting to more than 1.5 percent of local GDP in half of the 87 countries (both developed and developing) where data are available (figure 6.9, panel a). Remember from chapter 5 that, in Sahel countries, 1.5 percent of GDP is more than the amount needed to protect households affected by severe droughts. And in 60 out of the 87 countries, a \$30/tCO_2 domestic tax would provide the resources to more than double current levels

FIGURE 6.8 Recycling \$100 from the global fossil fuel subsidy budget as a universal cash transfer would benefit poor people



Source: Based on Arze del Granado, Coady, and Gillingham 2012.

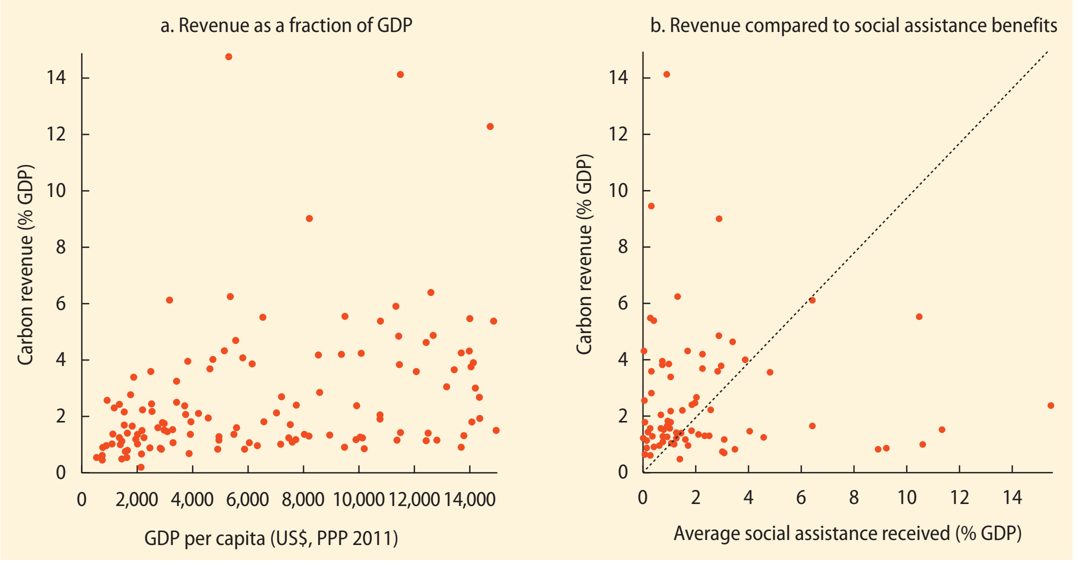
of social assistance in the country (figure 6.9, panel b). Even a low carbon tax at \$10/tCO2 would make it possible to significantly scale up social assistance, or other investments that benefit poor people, such as connection to sanitation and improved drinking water or access to modern energy. Brazil, the Dominican Republic, Indonesia, and Mexico provide examples where well-functioning cash-transfer programs have been used to protect basic consumption by the poor from price increases resulting from subsidy removals (Beaton and Lonton 2010; Di Bella et al. 2015; Vagliasindi 2012).

Other emissions-reduction policies can also have significant distributional impacts that need to be explored before policies are implemented (Fay et al. 2015). For instance, it has been shown that feed-in tariffs for renewable energy in the United Kingdom and Germany are slightly regressive (Grösche and Schröder 2014; Grover 2013). Wealthy households benefit from the scheme, because they tend to own more houses or land where photovoltaic panels can be installed, and can better afford the high upfront cost of installing panels. In contrast, everyone pays higher electricity tariffs to finance the scheme. This problem applies to other subsidies to encourage low-carbon investment—such as hybrid or electric vehicles, residential heating, or air-conditioning—that are more likely to be undertaken by wealthy households (Borenstein and Davis 2015). But solutions have been proposed, such as financing subsidies with progressive income taxes or specifically encouraging poor households to participate (CPUC 2013; Granqvist and Grover 2015; Macintosh and Wilkinson 2010).

More generally, the distributional impacts of climate mitigation policies can in principle be corrected using independent policies specifically designed to redistribute income in the economy, such as using income or consumption taxes to fund cash transfers or social

FIGURE 6.9 Using the revenue from a carbon tax could boost social assistance

(Potential carbon revenue as a fraction of GDP and compared to current social assistance benefits)



Source: World Bank calculations, using data from *World Development Indicators* and ASPIRE.

Note: Panel a: revenue of a \$30/tCO2 carbon price expressed as a fraction of GDP. Each dot represents a country. Panel b: How this revenue compares to current social assistance benefits in the countries. In 60 out of 87 countries for which data are available, a \$30/tCO_2 tax would provide the resources to more than double current social assistance transfers (dots above the diagonal line on the right panel). Calculations assume unchanged energy consumption. GDP = gross domestic product; tCO_2 = tons of carbon dioxide. PPP = purchasing power parity.

safety net programs (Borenstein and Davis 2015; Gahvari and Mattos 2007; Lindert, Skoufias, and Shapiro 2006). A study based on World Bank household surveys reveals that most countries where the GDP per capita is above $4,000 (in purchasing power parity) can reliably redistribute poverty away using their own internal resources (Ravallion 2010), and thus can protect poor people against the potential negative effects of climate mitigation policies. This is important because around 70 percent of people in extreme poverty live in countries with a GDP per capita above $4,000, where they could be protected by redistribution from possible negative effects of climate mitigation.

The international community has a critical role to play in helping reconcile immediate poverty-reduction objectives and climate stabilization. In very poor countries, however, it may be difficult for economic, political, or institutional reasons to protect poor people against possible negative side effects of climate policies. In particular, countries with a GDP per capita below $4,000 per capita (in purchasing power parity) cannot always rely on internal redistribution (Ravallion 2010). In the poorest countries, even the "middle class" is poor, and there are simply not enough resources for redistribution: even taxing 100 percent of the income of the "rich" would not suffice to lift the poorest out of poverty. In these very poor countries, even if most of the cost of climate mitigation is paid by the upper quintiles of the population, climate mitigation could still aggravate poverty, because the top quintiles are still in or close to poverty.

In countries where poor people cannot easily be protected by domestic resources and policies, support from the international community is needed to offset potential trade-offs between poverty reduction and climate change mitigation. This is especially the case for investments that involve high immediate costs—and therefore large trade-offs with other investments—but are urgently needed to prevent irreversibility and lock-ins into carbon-intensive patterns (like those regarding urban transport, energy infrastructure, or deforestation).

The typical example is urban transit. While transit-oriented development may require higher upfront costs and investments than road-based low-density urbanization, the high urbanization rate in many developing countries and the lifetime of urban forms and transit infrastructure means that there is a window of opportunity now to build efficient transit-oriented cities. After a city is developed, it is practically impossible to modify its urban form. This makes it essential to provide developing countries with the resources and financial instruments that make it possible for them to drive urban development toward the efficient patterns that are needed to decarbonize the economy before the end of the century.

One source of international funding is private climate finance, for instance through interconnected carbon markets (World Bank 2014b). But these flows are likely to focus on the cheapest emissions-reduction options available in developing countries (Narain and Veld 2008; Rose, Bulte, and Folmer 1999). Indeed, carbon markets are designed to help economic actors capture the lowest cost options to meet a short-term emissions-reduction target, not necessarily to trigger investment in long-lived low-carbon equipment that avoid lock-ins into carbon intensive patterns (Vogt-Schilb and Hallegatte 2014). For example, these flows alone are unlikely to finance the upfront cost of more efficient cities and land use planning, or any other measure that generates benefits only over the very long term.

Thus, additional resources are needed that focus on these long-term challenges. In particular, they can substantially increase the efficiency of the global decarbonization by financing urgent measures that avoid carbon-intensive lock-ins in low-income countries (like public transportation infrastructure)—even if these measures are more expensive (per abated ton of carbon) than alternative short-term emissions reductions (Vogt-Schilb, Hallegatte, and de Gouvello 2014).

In conclusion

This report provides new quantification of how climate change will affect poor people and poverty through agricultural impacts (chapter 2), natural disasters (chapter 3), and health shocks (chapter 4). In each of these chapters, it also identifies opportunities for better policies or specific interventions that can reduce these impacts, sometimes even below their current levels in spite of climate change. Chapter 5 builds on these sectoral solutions by exploring cross-cutting options to enhance resilience (like financial inclusion and social safety nets). It also identifies options to adapt to a context of changing climate with more frequent and intense shocks and changing environmental conditions, like permanently reduced rainfall. And it stresses the need for a governance system that gives a voice to poor people.

This report suggests that developing countries have a window of opportunity to build resilience and reduce short-term climate change impacts on poverty through development policies that are inclusive and climate informed. For governments, two implications emerge:

- Greater urgency in reducing poverty and providing poor people with opportunities, basic services, and well-designed social safety nets to reduce their vulnerability before climate change impacts become much larger.
- The critical importance of ensuring that investments and development patterns are not creating future vulnerabilities as environmental and climate conditions change.

In parallel, the international community can do much to ensure that development is rapid, inclusive, and climate informed. It can offer resources for climate risk analysis and project preparation; and it can ensure that financing instruments and support are available to cover higher upfront costs.

However, in the absence of mitigation policies, risks for development and poverty eradication will only grow over time. This means that countries need to act now to reduce their emissions, using two approaches:

- Focus on emissions-reduction options that create synergies with development or yield health or economic cobenefits—like using renewable power and minigrids in remote rural areas, or switching to energy-efficient light bulbs and appliances.
- Protect poor people—for instance by strengthening social protection and cash transfers, possibly financed with energy taxes or fossil fuel subsidy removal.

But the second approach will be particularly challenging for low-income countries, because they sometimes lack the capacity or simply the resources to implement substantial redistribution policies. The international community should support costly emissions reduction in these countries, especially investing in long-lived low-carbon infrastructure (like urban public transit in cities), because waiting will only make low-carbon development more expensive over the long term.

Bringing together the short- and long-run view, this report overall emphasizes the negative impact of climate change on poverty eradication, and the risk that unabated climate change creates for the objective of eradicating extreme poverty. In parallel, it also identifies many policy options that can be implemented and would make it possible to achieve our poverty objectives in spite of climate change. Doing so implies a combination of (i) rapid, inclusive, and climate-informed development and targeted adaptation interventions to cope with the short-term impacts of climate change; and (ii) pro-poor mitigation policies to limit long-term impacts and create an environment that allows for global prosperity and the sustainable eradication of poverty.

Notes

1. These simulations are performed using 2005 PPP exchange rate and the $1.25 extreme poverty line, but results are not expected to change significantly under the $1.90 poverty line and using 2011 PPP.

2. We cannot use data on the number of "affected persons" because the usual definition of *affected* is much broader and includes people who do not lose income because of the disasters.
3. Because the analysis proposed in chapter 3 does not include all countries, we assume that poor and nonpoor people are equally exposed to natural disasters.
4. Note that the impact of droughts on children through stunting is accounted for in the health impact category.

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Climate change threatens the objective of eradicating poverty. Poor people and poor countries are already vulnerable to all types of climate-related shocks—natural disasters that destroy assets and livelihoods; waterborne diseases and pests that become more prevalent during heat waves, floods, or droughts; crop failure from reduced rainfall; and spikes in food prices that follow extreme weather events. Such shocks can erase decades of hard work and leave people with irreversible human and physical losses. Changes in climate conditions caused by increasing concentrations of greenhouse gases in the atmosphere will worsen these shocks and slow down poverty reduction.

The good news is that, at least until 2030, "good development" can prevent most of these impacts. By "good development," we mean development that is rapid, inclusive, and climate informed; includes strong social safety nets and universal health coverage; and is complemented with targeted adaptation interventions such as heat-tolerant crops and early warning systems. Absent such good development, many people will still be living in or close to extreme poverty in 2030, with few resources to cope with climate shocks and adapt to long-term trends, and climate change could increase extreme poverty by more than 100 million people by 2030.

In the longer run, beyond 2030, our ability to adapt to unabated climate change is limited. To keep the longer-term impacts on poverty in check, immediate emissions-reduction policies are needed that bring emissions to zero by the end of the 21st century. These policies need not threaten short-term progress on poverty reduction—provided they are well designed and international support is available for poor countries.

Ending poverty and stabilizing climate change will be unprecedented global achievements. But neither can be attained without the other: they need to be designed and implemented as an integrated strategy. *Shock Waves: Managing the Impacts of Climate Change on Poverty* brings together those two objectives and explores how they can more easily be achieved if considered together. The book provides guidance on how to design climate policies so they contribute to poverty reduction, and on how to design poverty reduction policies so they contribute to climate change mitigation and resilience building.

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