5

Managing the Environmental Risks to Growth

The gains from growth and globalization could be undermined by their environmental side effects. Because increases in production magnify cross-border pollution, while improvements in technology make it possible to expand or intensify the exploitation of scarce global resources, decisions at the national level are having a growing impact on other countries. International institutions will thus be required to play a larger role in a wide spectrum of issues—all involving global public goods—where exclusive reliance on the decisions of individual governments or the private market can lead to adverse outcomes. Such goods include maintaining global security, keeping the trading system open and nondiscriminatory, and ensuring global financial stability. As developing countries enlarge their role on the global stage, their integration as full partners in multilateral solutions to global problems will be essential.

Mitigating climate change, containing infectious diseases, and preserving marine fisheries are three additional global public goods that demonstrate the need for—and benefits of—international policy cooperation. Rising industrial output means increasing concentrations of greenhouse gases in the atmosphere, which will have detrimental effects on future productivity and—more generally—on human welfare around the globe. Even in the next decade or two, scientists underscore the (unlikely) possibility that global warming could cause natural disruptions severe enough to depress growth rates below the low-growth scenario presented here. It is more likely that decades will pass before the most severe effects of climate change begin to be felt. Even so, the collective response of today's global leaders is almost certain to have far-reaching implications for the welfare of future generations.

Technological progress and rising demand have increased efforts to harvest fish from the open seas, degrading ocean environments and driving some valuable species to near-extinction. Longstanding efforts to limit marine catches to sustainable levels have met with only a few successes. Why? Because institutional weaknesses, technical difficulties, and fishing subsidies impede sustainable management.

The growing interaction of national economies through trade and movements of people, while broadly beneficial, has increased the risk of spreading contagious diseases. HIV/AIDS (human immunodeficiency virus/acquired immune deficiency syndrome) is one example. The severe acute respiratory syndrome (SARS) is another. The most prominent current threat is the avian influenza virus.

These examples of the side effects of globalization—one long-term, one medium-term, and one immediate—pose risks to the progressive expansion of the global economy, and to developing countries in particular. Some of the more catastrophic climate-change scenarios, if they materialize, could undermine

the development prospects of whole countries and even regions through their effects on agriculture, water, and ecosystems. Similarly, failure to contain an epidemic could bring global commerce to a sudden halt, isolate some populations, and impose huge losses on affected developing countries. Unrestrained marine fishing, while less potentially calamitous than climate change or a flu pandemic, could permanently exhaust a critical global food source and destroy irreplaceable deep-sea habitats and biodiversity.

Effective multilateral collaboration is needed to ensure that economic growth and poverty reduction will proceed without causing irreparable harm to future generations. Developing countries are central to the management of these risks. Although these countries are relatively small contributors to global warming today, the projections in chapter 2 imply that they will soon enough become large contributors to global warming. And if no action is taken, the standard of living that they could otherwise expect may well be put at risk. Given the limited supply of medical facilities and nursing care in the developing world, a flu pandemic could have horrific consequences. In many developing countries, people depend on fish for an important share of their diet, and the poor would suffer if the price of fish, as well as substitutes, were to skyrocket as supplies dwindled.

The degree of international coordination required varies greatly from issue to issue, depending on the nature of the issue and the geographical spread of its causes and effects (table 5.1). The need for international coordination falls with the degree to which an individual country can benefit from its own efforts to provide the good (or mitigate the evil), and rises with the number of countries involved (Barrett 2004). For example, the U.S.-Canadian agreement on reducing acid rain was facilitated in part because only two countries had to agree and because each country gained an important benefit from its own efforts to reduce pollution. By contrast—as shown below—negotiations over climate change are intractable in part because even though every country will be affected, there is little systematic relationship between the size of most countries' efforts to reduce carbon emissions and the damage these countries experience from climate change.

Ensuring that developing countries reap the benefits from global public goods is particularly difficult. Developing countries typically account for a small share of international transactions, so they often lack the clout to ensure that decisions made in international fora adequately reflect their interests. Many developing countries lack the financial and technical resources to participate effectively in international negotiations on many issues. For example, the simultaneous negotiations on a variety of critical environmental issues forces governments with inadequate resources to limit their participation (Esty and Ivanova 2002). Developing countries also lack the resources required to effectively address many common problems. For example, malaria kills millions in developing countries, but research on pertinent vaccines is limited, although some efforts are now under way.

While the three cases spotlighted here differ in the agreement on the extent of risks, there is a sufficient scientific consensus to move forward on all of them. The needs and the methods to protect against the spread of (selected) contagious diseases are well known, although the efficacy of particular strategies (quarantine, stockpiling of available vaccinations) in limiting the spread of avian flu is in dispute. The overexploitation of marine fish stocks is well understood, although disagreement remains on the amount of resources to commit, the limits on fishing to impose, and how to allocate access to fisheries. There is an international consensus that human activity is contributing to climate change, but the precise implications of different levels of greenhouse gas concentrations for climate change remain uncertain. While disagreements over the facts of each case have affected efforts at international cooperation, they have not been the major impediment to progress. In reviewing the state of knowledge in each area, this chapter

Table 5.1 Progress in providing many global public goods is limited

Examples of global public goods

Good	Role of developing countries	Progress of international efforts
Global commons		
Climate change	Limited current contributors, but major future source, of carbon emissions; potentially disastrous impact on many countries	Current mitigation efforts insufficient to stabilize global temperature
Biodiversity and ecosystems	Main reservoir of many species	Rate of species extinction rising; tropical forest cover declining
Water resources	Over 600 million people face acute freshwater shortage	Little international effort beyond increasing awareness; 2–3 billion people may face severe freshwater shortage by 2020
Fisheries	Many countries dependent on ocean fisheries for exports and domestic consumption	75 percent of commercial fish stocks exploited at or above sustainable levels
Human issues		
Infectious diseases	Developing countries could suffer severe losses in a global flu pandemic; already suffer millions of deaths from tropical diseases	Flu pandemic avoided (for now); limited progress in containing malaria, measles, AIDS in developing countries
Peacekeeping	Millions killed in civil wars and intercountry conflicts	Some interventions successful (Kosovo in the Republic of Serbia); others less so (Sierra Leone)
Poverty	1 billion people living on less than $1 a day	Asia expected to see continuing decline in people living in extreme poverty; Africa likely to see rise
Regulatory framework		
Trade	Developing countries account for 27 percent of global merchandise exports; goods and services exports represent 33 percent of developing countries' gross domestic product	Trade rules effective, but limited progress on removing trade barriers critical to developing countries
Financial architecture	Total fiscal costs of systemic crises in developing countries since 1975 exceeds $1 trillion	Crisis interventions have mixed success; little change in global rules that would dampen volatility

Sources: Rischard 2002; World Bank, World Development Indicators; Honohan and Laeven 2005.

discusses some of the key economic issues that constrain or support effective action to protect the environment and sustain growth.

The immediate risk of epidemics

Globalization has increased the volume and speed of cross-border transactions, thus increasing the potential for the transmission of contagious diseases. The international transmission of disease is nothing new.[1] But air travel and international contacts have greatly accelerated its potential speed. Over the next quarter-century the global economy will continue to be at risk of sharp downturns from disruptions caused by contagious diseases. For example, a human flu pandemic similar to the 1918 Spanish flu could reduce global GDP by 3 percent over a one-year period, with the more severe effects (in percentage terms) felt in developing countries (World Bank 2006).

The potential for a devastating global outbreak of contagious disease underscores the importance of international cooperation. Individuals benefit directly from access to vaccination, and individual countries benefit from

controlling disease within their borders—both benefits reduce the role that international institutions must play. Nevertheless, other countries do have a critical interest in containing disease, as containment reduces the probability of further transmission. Measures by individual countries to contain infectious disease may be insufficient from a global perspective, in part because individual countries may lack the resources to take all measures that the international community might consider prudent. And the supply of informational goods—for example, research on vaccines and knowledge of treatment and quarantine procedures—is likely to be impaired in the absence of effective international cooperation. This section discusses these issues in the context of the recent SARS epidemic and the potential for an avian flu pandemic.

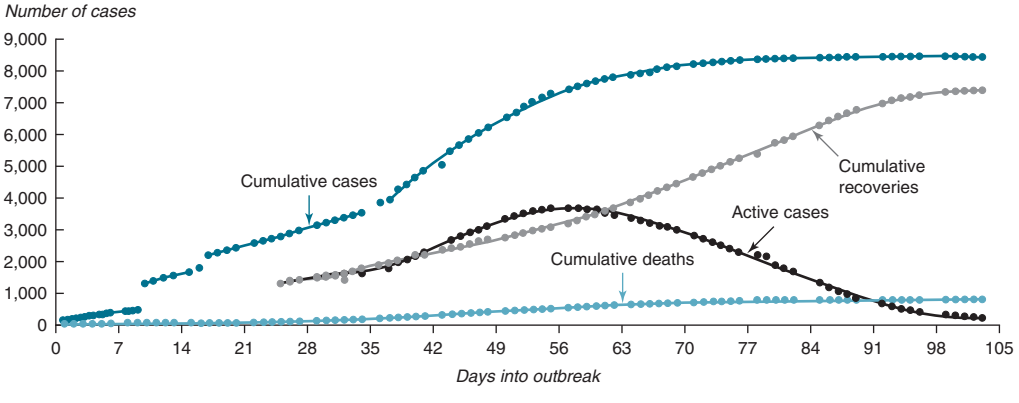
SARS was a case study in virus proliferation and containment

Five months after initial reports from East Asia (in February 2003) of an atypical respiratory disease, more than 8,000 cases had been reported in close to 30 countries.[2] The disease, labeled SARS, was highly contagious and life threatening: almost 10 percent of reported cases ended with the patient dying.

The global response to the rapidly spreading disease was swift and determined. Many countries—whether they had reported SARS cases or not—designated special treatment centers ("SARS hospitals") and put in place quarantine procedures. In some of the places most severely hit, the measures were very strict. Hong Kong (China) imposed restrictions on peoples' movement between city districts, and Singapore used TV surveillance and radio bracelets to monitor and control the movements of persons who had come in contact with SARS patients and of patients discharged from SARS hospitals. The World Health Organization (WHO) collected and disseminated up-to-date information on the development of the disease and how to respond, and coordinated scientific efforts to control and identify the virus causing the sickness. Given the crucial role of air traffic in the spread of SARS between countries and continents, WHO issued the first emergency travel advisory in its history. Travel bans were imposed for major affected areas in April 2003 (Bell and Lewis 2004).

The combined efforts by local, national, and international authorities to contain the threatening pandemic were successful: newly reported cases, which increased rapidly in March and April of 2003, peaked in early May and thereafter declined rapidly (figure 5.1). Although no cure has yet been found

Figure 5.1 The SARS epidemic was contained in a matter of months



Source: http://www.adrianboyko.com/SARS (WHO data).

for the disease, it was successfully contained by late 2004, and no new cases have been reported since 2005. The containment of SARS was facilitated by the fact that the disease is less transmissible than some influenzas experienced in the past. The SARS experience highlights the role of the technological developments and rapid communications that promote globalization both in speeding the spread of contagious diseases and in providing the tools to combat them.

Has the risk of avian flu been contained?

The virus causing avian flu (H5N1) affects primarily birds, although cases of human infection, recorded since 1997, have increased significantly since 2003, while remaining low. An outbreak of avian flu through human-to-human transmission could have catastrophic implications for welfare, particularly in developing countries where public health systems are weak, and could result in a sharp, short-term interruption in global growth.

Possible pandemic. The avian flu is a subject of great concern principally because more than half of all infected persons have died from the disease, and flu viruses have the potential to mutate into a form that is easily transmitted between humans (the "Spanish flu" pandemic of 1918–19 killed up to 50 million people). The rapid expansion of the poultry population, and in particular the close proximity between humans and animals in East Asia, has increased the likelihood that such a mutation may occur.[3] And if it does, the greatly increased speed and scope of human travel would facilitate a rapid spread of the disease worldwide. WHO projections reckon that the mutation of the avian flu virus permitting human-to-human transmission would, under best-case scenarios, entail the spread of the disease among humans across all continents (WHO 2005). Other estimates that assume a more virulent virus involve much higher numbers of deaths.

Prevention and countermeasures. Alternative measures of preventing or responding to an outbreak have been discussed widely at both the national and international level (WHO 2006; CDC 2004; Osterholm 2005; Sturm-Ramirez 2006). A large number of actions to address a potential avian flu pandemic can be envisaged:

- Reducing the incidence of avian flu in birds would reduce the probability of human infection. Effective systems to monitor flocks is required, coupled with compensation for damage if birds have to be slaughtered, and punishment for failure to report, as otherwise breeders are likely to conceal incidences of the disease in their flock. There also is a need to regulate bird breeding and marketing methods that facilitate the occurrence or spread of the disease.
- Developing a vaccine that is certain to be effective is impossible, given present knowledge, because the form of the future mutation of the virus is unknown. There is hope among researchers that it may be possible to develop flu vaccines that will be effective against whole classes of flu viruses, including future mutations. Many experts argue that the likely success rate from the use of existing vaccines is sufficiently high to make stockpiling vaccines a key ingredient in a comprehensive response strategy.
- An effective surveillance system will be essential to detect and report cases—even suspected cases—before they have a chance to spread. The SARS episode showed how important early detection can be for an effective containment strategy.
- Steps to treat victims and contain the disease may range from administering appropriate medicines to implementing quarantine procedures for contagious patients. It is uncertain whether current antiviral drugs would be effective against a future mutation of the avian flu virus. Even so, many experts argue that existing antiviral drugs are sufficiently likely

to be effective to justify stockpiling them as part of any response strategy.
- Should both prevention and containment in the early stage of the disease fail, trade and travel restrictions, quarantine procedures, the transformation of existing buildings into emergency hospitals, and general efforts to deal with the multitude of disruptions accompanying any such catastrophe would be required.

Avian flu threat receding. At this writing there are encouraging reports that the avian influenza is indeed in retreat. New cases are rarely reported, and the countries where the most human infections have occurred (Vietnam, Thailand, and China) report that cases observed in both poultry and humans have declined steeply.[4] Officials of WHO and the World Organisation for Animal Health (OIE) credit countries' aggressive countermeasures for the apparent success in getting the disease under control. Global communications and cooperation clarified the risks, publicized advanced methods to contain it, and induced valuable international cooperation at various levels. Virtual unanimity among national administrations on the need to act rapidly enabled WHO and OIE to implement appropriate supranational measures without delay. Nevertheless, these efforts have failed to prevent the disease from becoming fully endemic in several countries, and reducing the scope of the disease remains a high priority to limit the risk of another flu pandemic.

Global cooperation may prevent contagion

The success of international efforts to contain infectious disease is in part rooted in the nature of the problem. The threat of a global pandemic is immediate, well understood, and potentially catastrophic for the industrial countries that have the resources to act. In addition, while international cooperation has played a critical role in reacting to SARS and avian flu, individuals and individual governments have been willing to make major, independent efforts because they benefited directly, thus reducing the burden on international cooperation. Contrast this (so far) success story with the failure to eradicate other endemic diseases.[5] The burden of infectious diseases is greatest for developing countries, which often lack the resources to effectively distribute vaccines and treatments. Would these diseases still be so prevalent if industrial countries continued to be vulnerable to them?

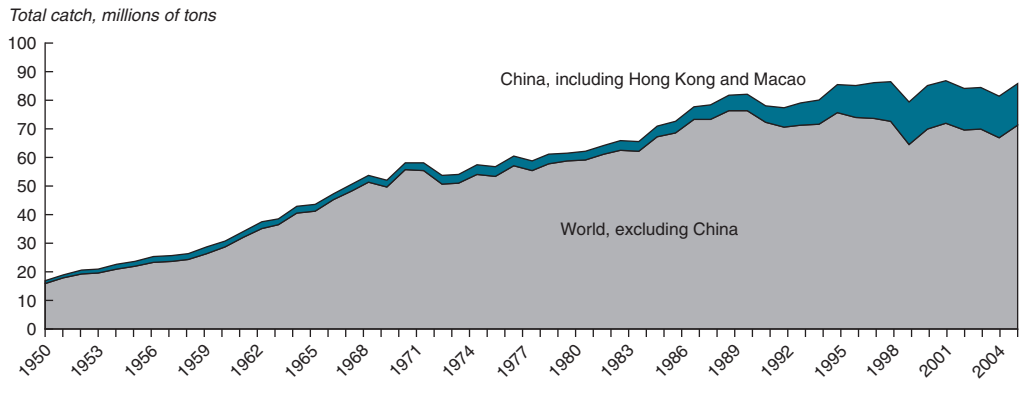
The medium-term risks to marine fisheries

Marine fishing, on the high seas and within many nations' 200-nautical-mile exclusive economic zone (EEZ), is reaching its limits. Increased demand and technological improvements have led to increasing pressures on marine fish, as well as on the fragile ecosystems in which they live.[6] Excluding data from China, the accuracy of which has been questioned, production has declined since about 1990 (FAO 2004 and figure 5.2). The acceleration of global growth envisioned in chapter 2 is likely to increase pressures on marine fisheries over the medium term. Without efforts at conservation, the global economy is likely to confront dwindling supplies of commercially exploited marine fish, coupled with rising demand for fish with growing incomes.

Marine fish are under increasing pressure

A significant number of the world's most valuable fish stocks have been depleted through overfishing, habitat degradation, pollution, or other causes (Bolton 2005). Fully 75 percent of the world's marine fish stocks are being exploited either at or above their maximum sustainable level (FAO 2004). While reductions in fish stocks from fishing are not new, they have accelerated over the past few decades owing to technological advances that have enabled large-scale commercial fishing fleets to increase their exploitation of traditional waters and expand to new areas

Figure 5.2 Total marine fish catch has leveled off



Source: FAO 2004.

in the Indian Ocean and the seas around Antarctica.[7] And improvements in fishing gear and onboard storage technology have made new species commercially viable (Kura and others 2005). Natural phenomena, for example the impact of El Niño on Chilean and Peruvian fisheries and of warmer water in the North Atlantic on North Sea cod, have contributed to the reduction in fish stocks (Schmidt 2002). Climate change (discussed below) will increase the acidity of the ocean as increasing amounts of carbon dioxide dissolve in sea water, with potentially serious implications for ocean environments and the sustainability of some fish species (U.K. Government 2006). And some deep-sea fish are particularly vulnerable to overfishing owing to their long lives and few offspring (Shotton 2006). Subsidies, estimated globally at between $12 and $20 billion a year, have also contributed to overexploitation of fish resources (Milazzo 1998; APEC 2000; WWF 2001).[8]

Managing high-seas fisheries is not easy

The UN Convention on the Law of the Seas (effective in 1994) helped define property rights by enabling coastal states to establish EEZs of up to 200 miles.[9] The UN Agreement for the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, called the UN Fish Stock Agreement (effective in 2001), established basic standards for fisheries management for highly migratory species, such as tuna, and for so-called straddling stocks—species that range between EEZs and the high seas (Lodge 2005). But high-seas bottom-dwelling species are in a jurisdictional vacuum. Few of the regional fisheries management organizations are mandated to manage bottom fishing on the high seas (Gianni 2004), and most of these fisheries should be considered unregulated (FAO 2004). Even when a mandate exists, the regional fisheries management organizations established for this purpose often suffer from inadequate resources or insufficient political support, and face several important obstacles:

- Data on catch volume and area, the number and size of fish, the number of juveniles that develop to maturity, interactions with other species, and the impact of environmental factors are often inadequate to define sustainable catches (Kura and others 2005). Overall, estimates of fish stocks may be off by as much as 30 percent (Berrill 1997), and single-species stock

assessments have failed to predict rapid stock declines in a number of cases (Pauly and others 2002).

- It can be difficult to set limits on fish catch that impose the right incentives. The allocation of licenses, the most common system for controlling fish effort (Cunningham and Greboval 2001), can be thwarted by expanding the capacity of individual boats or improving technology. Limits on the total catch (at which point a fishery is closed) can result in the harvest being caught more rapidly and using more resources than would be the case if quotas were allocated to individual fishers (difficult for regional fisheries management organizations, though it is done in areas controlled by single countries), and may encourage more dangerous fishing, such as during inclement weather (Kura and others 2005).[10]
- Monitoring and enforcing limits on fishing can be problematic, because fishers understandably are reluctant to provide information that can affect their competitiveness (Shotton 2006). Some fishers report data to national authorities under confidentiality agreements that prohibit release to international authorities.
- Fishers can attempt to evade enforcement of conservation measures by registering under a flag of convenience (with countries that exercise little control over their ships); at least 2,800 large fishing vessels either have a flag of convenience or no registry at all (WWF 2001).

Developing countries are particularly vulnerable

Developing countries, important participants in large-scale commercial fishing, confront particular weaknesses in managing fishery resources. In 2001, 6 of the top 10 marine fishing nations were from the developing world, with China and Peru (numbers 1 and 2) alone accounting for more than a quarter of total marine capture in metric tons. Developing countries also account for the vast majority of the increased trade in highly migratory species since the late 1970s (Webster 2006).[11] About 250 million people in developing countries depend directly on the fishing sector (including inland fishing) for food and income, and fish provide nearly 20 percent of animal protein consumed by people in developing countries (World Bank 2004).

Many developing countries lack the resources to police their own coastal waters and economic zone, much less establish effective regional institutions to manage nearby marine fisheries. The expansion of distant-water fishing fleets to new, mostly unregulated areas has spawned conflicts with traditional fishers in the poorer developing countries, while largely uncontrolled fishing has led to the depletion of valuable fishery resources in the southern seas—for example, the sharp decline in orange roughy and in Patagonian toothfish (Chilean sea bass), as worldwide demand for them increased. While some developing countries earn significant foreign exchange by selling fishing rights in their waters (several West African nations without significant industrial fleets have done so), this practice has intensified competition for small-scale fishers (Kura and others 2005).[12] Fish resources in the shallow waters off the west coast of Africa may have declined by half from 1985–90 because of distant-water fleets.

International cooperation aims to ensure sustainable fishing

There is a global consensus, expressed at the World Summit on Sustainable Development in Johannesburg in 2002, that depleted fish stocks should be restored to levels that can produce their maximum sustainable yield by 2015. Progress has been considerable in setting the institutional framework for conserving the ocean's fish, both through defining ownership rights (setting an EEZ of 200 miles) and in setting up multilateral institutions (regional fisheries management organizations). Effective management plans have been implemented for a few highly migratory fish stocks, for example the North Atlantic

swordfish and Atlantic bigeye tuna (Webster 2006). Still, most commercially exploited marine fish species face increasing pressures. Regional management is clearly inadequate in many fisheries. And further uncontrolled exploitation could lead to the irretrievable loss of valuable sources of the world's food. A further strengthening of domestic and multilateral institutions, particularly the regional fisheries management organizations, is a high priority for international action.

The long-term risk of climate change

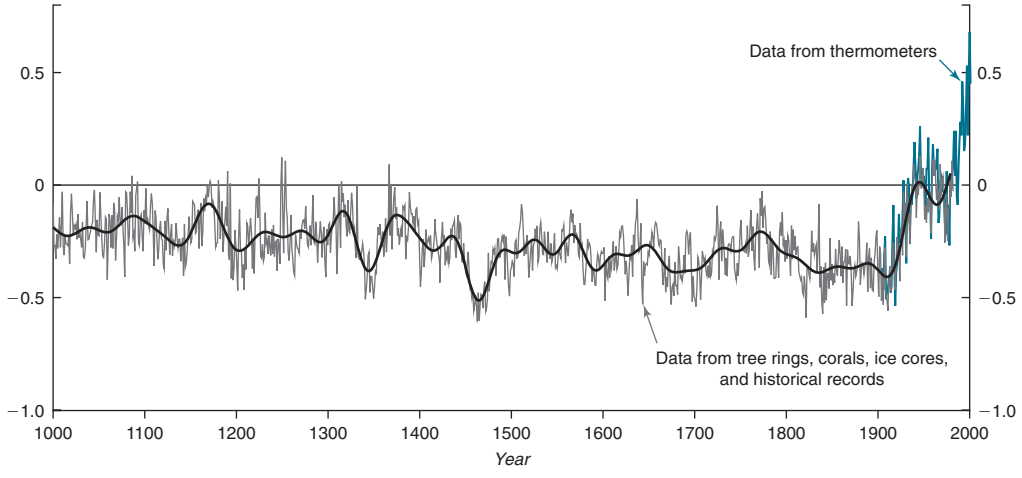
Climate change induced by carbon emissions already has had significant impacts on the global environment, and continuing emissions at current levels are likely to have severe implications for human welfare over the long term. The threat of climate change is inextricably linked with the scenario for global growth over the next 25 years, because there is a risk that climate change could accelerate, entailing greater-than-expected near-term consequences for growth. Moreover, the approach adopted to reducing carbon emissions could entail costs to growth, particularly if political constraints prevent the adoption of efficient policies. Developing countries, at the center of this issue, are likely to suffer the worst consequences of climate change and have the least ability to adapt. They also are the largest future source of additions to carbon emissions, and thus will have an important role in negotiations to limit emissions.

Global temperatures are rising

The burning of fossil fuels produces gases that trap incoming solar radiation, leading to a rise in global average surface temperature.[13] Measurements show that the average world temperature has increased since the start of the Industrial Revolution (figure 5.3). Models of the determinants of temperature change that take into account the addition of greenhouse gases (GHGs) into the atmosphere from human activities (second panel of figure 5.4) provide much more accurate explanations of historical trends in temperature than models

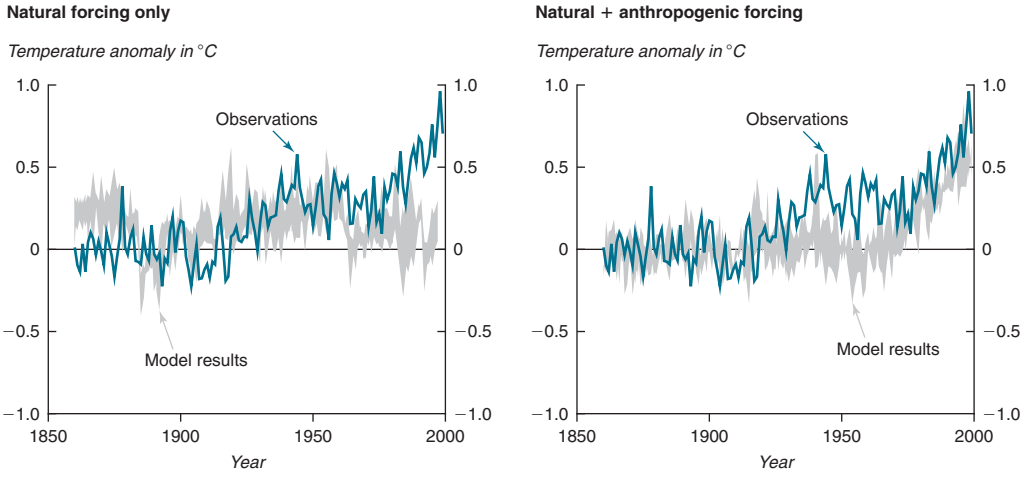
Figure 5.3 Temperatures have increased rapidly since the Industrial Revolution

Departure in temperature (°C) from the 1961–90 average, Northern Hemisphere



Source: Intergovernmental Panel on Climate Change (IPCC) 2001.

Figure 5.4 Temperatures and greenhouse gas emissions have risen



Source: IPCC 2001.

that ignore this addition (first panel of figure 5.4). There is general agreement that human activity has contributed to the rise in GHG concentrations and climate change since the start of the Industrial Revolution.

Climate change, while generally viewed as a long-term problem, has already had significant effects. Ice coverage has declined at the two poles (box 5.1), mountain glaciers are retreating worldwide, ocean temperatures are rising, the sea level is rising, the permafrost is thawing, growing seasons in mid- to high-latitude areas are lengthening, and the ranges of some animal and plant species are moving toward the poles and higher altitudes (IPCC 2001). Controversy remains about the precise quantitative impact of anthropogenic GHG emissions on the climate. Nevertheless there is widespread concern that a continuation of the rapid economic growth experienced since the beginning of the Industrial Revolution (and as a second industrial revolution unfolds in China and other major rapidly growing developing countries), supported by the continuing exploitation of fossil fuels, will induce significant changes in global and regional climates.[14]

Temperatures will continue to rise

The extent of climate change will depend on future GHG emissions (which will be determined largely by growth, technological developments, and policies that determine incentives for carbon efficiency) and on the ultimate effect of those emissions on climate. The Intergovernmental Panel on Climate Change (IPCC) has developed scenarios that relate forecasts of output, population, and technological developments to future CO_2 (the most important GHG) concentrations in the atmosphere, and thus to climate change. While the scope for limiting future GHG concentrations and the associated climate change remains great, past and current GHG emissions will continue to influence the global climate for some time. Even if emissions peak in the 21st century and then decline below current levels, global surface temperature will continue to rise for centuries, and sea levels will rise for several millennia (figure 5.5).

The IPCC scenarios cover a wide range of growth paths, with the four principal scenarios ranging from 1 percent to 3 percent growth in per capita income during 2000–30. Although these scenarios were developed in the

Box 5.1 The vanishing polar ice

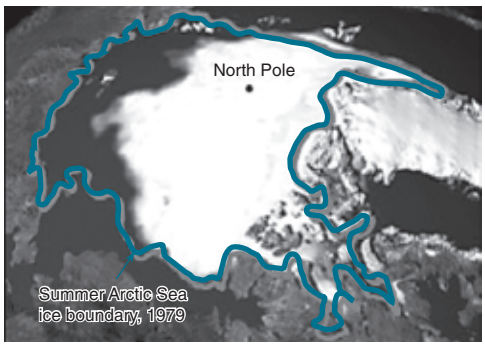
One effect of the rise in global temperatures has been the drastic reduction in large bodies of ice in the Arctic and in Antarctica, which appears to have accelerated recently. Average temperatures in the Arctic region are rising twice as fast as elsewhere in the world. Arctic ice is thinning, melting, and rupturing. The largest single block of ice in the Arctic, the Ward Hunt Ice Shelf, had been around for 3,000 years before it started cracking in 2000. Within two years it had split all the way through and is now breaking further into smaller pieces.

The polar ice cap as a whole is shrinking. Images from National Aeronautics and Space Administration (NASA) satellites show that the area of permanent ice cover is contracting at a rate of 9 percent each decade. If this trend continues, summers in the Arctic could become near ice-free by the end of the century.

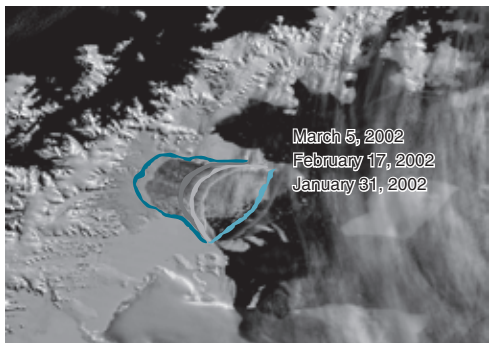
Consecutive satellite images also have revealed the collapse of the Larsen B ice shelf on the Antarctic Peninsula during the 2002 Antarctic summer, fulfilling predictions made by British Antarctic Survey (BAS) scientists. The collapse of the 3,250 km^2 ice shelf is part of the ongoing developments in a region of Antarctica that has experienced unprecedented warming over the last 50 years.

Continued melting of polar ice could induce significant rises in sea levels, with potentially catastrophic implications for many coastal areas, and raise the possibility of interrupting the Gulf Stream, which could drastically reduce European temperatures.

The summer arctic ice field is shrinking

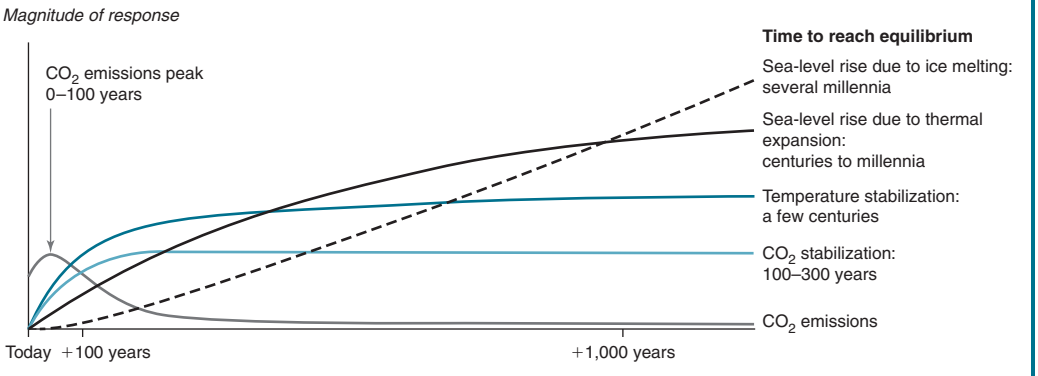


The Larsen B ice shelf collapsed



late 1990s, a recent review finds that they are roughly consistent with projections undertaken since then (Van Vuuren and O'Neill 2006). The scenario outlined in chapter 2 envisions global per capita growth of 2.2 percent. Thus, the path of carbon emissions implicit in this scenario is roughly similar to that envisioned in many of the IPCC scenarios. As discussed in chapter 2, this scenario assumes a steady improvement in the technical efficiency of energy use but no major policy initiatives that would raise the price of fossil fuels. Thus, the forecasts in this book would imply considerable potential for reining in carbon emissions over the medium term, given strong international efforts to slow climate change. While achieving reductions in emissions (as envisioned in figure 5.5) by improving efficiency holds considerable promise, the near-term prospects for reducing carbon emissions through alternative energy sources are limited (box 5.2). The world is not yet on a path toward the emissions reductions that will be essential even to stabilize global temperatures (at significantly higher levels than at present).

Figure 5.5 Greenhouse gas emissions have long-term effects



Source: IPCC 2001.

Box 5.2 Can efficiency and renewables be the answer?

Significant reductions in GHG emissions can be achieved through improvements in energy efficiency and increased use of renewable energy sources. Nevertheless, the share of renewables in energy use is not expected to increase much within the forecast period, and the demand for hydrocarbons is set to rise by more than 50 percent (IEA 2004, 2005). This underlines the need for policies to encourage energy savings and improve the profitability of alternative energy sources.

Developing countries have much greater potential than industrial countries for reducing emissions, in great part because they are moving toward the technological frontier in existing industry and infrastructure. For example, China could use some 20 percent less coal if its plants were as efficient as the average plant in Japan, and the potential for adopting proven energy savings in cement and pulp and paper is significant. Moreover, rapidly growing developing economies can invest directly in energy-efficient technologies, thereby leapfrogging earlier, inferior processes. For example, expansion of low-power, white-light-emitting diodes that run on batteries charged by solar panels could enable the rural poor in some countries to bypass the need for centralized electrical grids. Developing countries have the opportunity now to adopt more efficient choices for infrastructure and technology that could drastically reduce GHG emissions for decades to come.

Energy efficiency is often the most cost-effective and low-risk approach to reducing the need for energy, and can also generate significant environmental benefits. Considerable potential exists for adopting more efficient technologies in transport, industry, buildings, and power generation.

- In *transport*, new materials, compact engines, and advanced fuel systems can lead to lighter and more fuel-efficient vehicles, while hybrid vehicles can provide substantial fuel savings. If all technical means were implemented, the International Energy Agency estimates that a 40 percent improvement in fuel economy of gasoline engines is achievable in the coming decades. The prospects for hydrogen and fuel cell vehicles are less promising over the forecast period because they require significant cost reductions, performance improvements, and development of fuel cell vehicle markets and hydrogen infrastructure.
- Many new *buildings* could be 70 percent more energy efficient than the existing stock through the use of new technologies in windows,

Box 5.2 (*continued*)

insulation, furnaces, air conditioners, appliances, lighting, and standby power.
- In *industry* there is a large potential to improve the efficiency of motors, boilers, pumps, and heating and cooling systems. In addition, large amounts of energy can be saved through new processes in individual sectors, such as direct casting in iron and steel, and biofeedstocks in the production of petrochemicals.
- In the *electric power* sector, switching from coal to natural gas would reduce emissions, both because natural gas emits only about half as much CO_2 as coal per kilowatt hour and because the latest combined-cycle gas plants attain efficiencies of 60 percent, compared to 46–49 percent for the best available coal-fired plants. Nuclear energy offers emission-free technology but faces high capital costs, problems of waste storage, risks of accident, public opposition, and possible proliferation of nuclear weapons.

Renewable energy sources. Renewable energy now accounts for 14 percent of world energy demand, and while the authors of this chapter anticipate that its use may rise by 50 percent by 2030, its share of total energy is not expected to change greatly unless vigorous policies encourage switching from nonrenewable energy sources.

- Renewable electricity generation is dominated by *hydropower,* which accounts for 16 percent of global electricity production. Hydropower is the cheapest source of power in many areas. There is considerable potential for expansion, particularly in the form of small hydro plants, although concerns over undesirable environmental and social impact have been important barriers.
- *Biomass* generation can be highly economic, particularly for co-firing other hydrocarbon-based plants. New technologies are expected to reduce costs further, but the largest barrier to accelerated expansion is competition with other demands for biomass, particularly for use as food.
- *Wind* generation is expected to rise, buoyed by sharp declines in the cost from economies of scale with the use of larger turbines. Nevertheless, wind still has problems of intermittency, low reliability, problems connecting to the grid, and (more recently) difficulties in siting land-based turbines.
- Generation from *geothermal* sources is concentrated in a few countries. While geothermal is a very competitive and reliable source of power, and its potential is enormous, it is a site-specific resource that can only be accessed in certain parts of the world.
- *Solar* power is expected to account for less than 0.5 percent of total power supplies by 2030, as its investment and generating costs are the highest of all commercially deployed renewable energy sources, although the range of costs varies widely depending on the amount of sunshine available. There will also be some rise in solar thermal power, whose generation costs are typically double those of conventional energy sources.
- *Tide and wave* generation is still in its infancy. Projects need to be large-scale if they are to withstand offshore conditions, and these are very costly and carry high risks. Site-specific environmental effects also need careful assessment.

Biofuels may provide a significant alternative fuel option for transportation over the forecast period, with ethanol from sugarcane (from Brazil, for example) offering the best chance of commercial viability. Other feedstocks, such as corn, have much higher costs owing to lower yields and are unlikely to be financially viable without government support. If ethanol can be produced from cellulose using biomass as the fuel for the conversions process, net GHG emissions from well to wheel basis (that is, through the complete chain of fuel production and use) could be reduced to zero, according to the International Energy Agency.

Climate change could have a catastrophic impact on some countries

The effects of climate change on human welfare are uncertain, depending as they do on the magnitude and timing of increased temperatures, the precise climate changes involved, and the links between climate change and human activity. Available calculations indicate that the *aggregate* global economic impact of a small rise in temperatures would

be significant, but not enormous. Tol (2002) finds that the impact of a rise in the global mean surface air temperature of 1 degree Celsius (the temperature rise anticipated over the first half of the 21st century) could range anywhere from an annual increase of world GDP by 2.3 percent to a decrease of 2.7 percent, depending on assumptions made about the value of nonmarket goods and services. Examples include how to value human lives lost and gained, and the damage to ecosystems and biodiversity—a quarter of the world's known animals or plants, or more than a million species, are likely to die out because of the forecast warming over the next 50 years (Grubb 2006b).[15] A more recent analysis estimates that failing to address climate change could reduce welfare by an amount equal to a 5–20 percent fall in per capita consumption (box 5.3).

These estimates also do not capture low-probability risks that could imply severe consequences for the global economy over a relatively short timeframe. For example, if the Gulf Stream stalls as melting ice introduces more fresh water into the northern Atlantic, European temperatures could plummet. And there is potential for a rapid, almost self-perpetuating acceleration of climate change if the large methane deposits in arctic tundra are released as climate change proceeds.

Estimates of the aggregate economic impact of climate change mask extreme variations in costs and benefits for different countries. The brunt of the damage from climate change will be felt by low-latitude developing countries, with the extent of harm critically dependent on how much temperatures increase (so that damages are likely to rise as time goes on). Many developing countries are more vulnerable to climate change because they are already warmer than developed countries and suffer from high rainfall variability, they are heavily dependent on agriculture (the sector most vulnerable to climate change), poor public services increase the potential welfare loss, and low incomes impede adaptation (U.K. Government 2006). Countries near the poles could benefit from a modest rise in temperatures, while mid-latitude countries, many of them high-income, are likely to face small *net* effects from climate change through this century (the rise in the sea level may inundate some coastal areas and increasing severity of hurricanes and cyclones could increase coastal damages, while agricultural yields in other areas could improve). Over the long term, and in the absence of successful mitigation efforts, climate change is likely to be disastrous for all countries. Examples of the possible damage include the following:

- A rise of 1 degree Celsius could lead to an 80 percent loss of coral reefs; further increases in extreme precipitation causing drought and landslides; a 20 to 35 million ton loss in cereal production and an approximately 10 percent decline in yields of various African crops (such as barley and rice).
- A rise of 2 degrees Celsius could lead to large-scale displacement of people in the Mahgreb as rainfall declines by at least 40 percent; the total loss of summer Arctic sea ice; the likely extinction of the polar bear and walrus; millions more people at risk to malaria, particularly in Africa and Asia; and a 50 percent loss of the Chinese boreal forest.
- A rise of 3 degrees Celsius could lead to massive changes in habitats, such as the collapse of the Amazon rainforest and the Great Lakes wetland systems; the inundation of the Ganges delta region, undermining the agricultural system that feeds a quarter of a billion people; the spread of desert-like conditions in Africa as the Kalahari dunes become mobile; additional millions of people at risk of hunger; two to three hundred million more exposed to malaria; hundreds of millions more exposed to dengue; several tens of millions displaced from coastal areas because of rising sea levels; and billions more subject to increased water stress (Warren 2006).

Box 5.3 Stern Review: The Economics of Climate Change

The government of the United Kingdom recently issued a report on the economics of climate change prepared by Sir Nicholas Stern at Treasury. The report underlines the very serious global risks posed by climate change, and the urgency of steps to reduce carbon emissions. The principal finding is that the benefits of strong, early action on climate change exceed the costs involved, reflecting two insights.

First, the continued growth of carbon emissions at current rates raises the risk of serious, irreversible damage to global welfare. Absent changes in policies, carbon emissions could rise by the middle of this century to a level that would eventually commit the world to a rise in average temperatures of more than 5 degrees Celsius above preindustrial revolution levels, equal to the amount of global warming that occurred between the last ice age and today. The total cost of the climate change resulting from "business as usual" emissions over the next two centuries is estimated to equal a minimum reduction in global per capita consumption of 5 percent. Taking into account the nonmarket impacts (on the environment and human health) of these emissions, the potential for feedbacks that would amplify climate change, and an increase in the weight accorded to the poorer regions, and "business as usual" climate change results in a reduction of about 20 percent in global per capita consumption.

Second, atmospheric greenhouse gas concentrations could be stabilized at levels that greatly reduce the risk of climate change damages, at relatively low cost. Carbon emissions can be cut by reducing the demand for emissions-intensive goods and services, increasing energy efficiency, switching to low-carbon technologies, and reducing non–fossil fuel emissions (from deforestation and in agriculture). A series of model-generated estimates of the annual cost of cutting emissions to a level consistent with stabilizing atmospheric greenhouse gas concentrations at 550 parts per million average 1 percent of global GDP by 2050.[a]

Reducing emissions efficiently requires pricing carbon to reflect fully the risks of climate change. This can be done through *setting a tax on emissions* or through *establishing tradable quotas*, although regulation may also be used where market-based mechanisms are ineffective. However, setting an appropriate price for carbon may not lower emissions sufficiently, due to uncertainty on future pricing policies, barriers to technology development in key sectors related to climate change, and external benefits to technology development (for example, inspiring ideas for new technologies) that are not captured by investors. Thus, the public sector also should *promote low-carbon and high-efficiency technologies* through increasing support for research and development, demonstration projects, and early-stage commercialization investments in some sectors. Governments also should focus on *removing barriers to behavioral change*—such as transaction costs, organizational inertia, and a lack of reliable information—through regulation (for example, minimum standards for buildings and appliances), labeling, and sharing best practices, and financing the upfront costs of efficiency improvements.

Adaptation also will be essential to limiting the negative impact of inevitable climate change. While individuals will undertake adaptation in reaction to market or environmental changes, governments can provide policy guidelines as well as economic and institutional support.

The Stern report emphasizes the importance of *international collective action* to respond to climate change. Cooperation should cover all aspects of emissions reductions policies. It is necessary to create a broadly similar carbon price signal around the world, and to promote carbon finance to accelerate action in developing countries. An equitable distribution of effort that takes into account income, historic responsibility, and per capita emissions would have industrial countries undertaking emissions reductions of 60 to 80 percent (from 1990 levels) by 2050.

[a]Anything higher than 550 parts per million would substantially increase the risk of harmful impacts on global welfare while reducing the expected costs of mitigation by comparatively little.

These measurements generally consider the welfare impacts of a particular level of global average temperatures, and thus may exclude some significant risks. Climate change may increase the uncertainty surrounding, and variability of, weather, which could increase costs. For example, a higher mean sea level could make storm surges more devastating; and higher average temperatures may have a smaller impact on agricultural productivity than increases in long, hot, dry spells (Weyant 2000). The speed of climate change is also important, as many species may have trouble adapting to rapid increases in temperatures.

What can be done to reduce GHG emissions?

In the absence of intervention, global CO_2 emissions could reach between two and four times current levels by 2100, resulting in much greater GHG concentrations than envisioned in most models of climate change (Grubb 2006b). Thankfully, there is a wide variety of possible methods to reduce GHG emissions, for example improving energy efficiency and relying more on renewable energy sources (see box 5.2), switching to fuels with lower GHG emissions (from coal to natural gas, for example), capturing and storing carbon emissions, sequestering carbon through reforestation, changing lifestyles to reduce demand for energy, reducing growth in output, and geoengineering (to change the reflectivity of the atmosphere, oceans, and land).[16] Some measures, such as reducing subsidies that support high levels of energy intensity, may have low or even negative costs, while others involve very expensive regulatory intervention.

The costs of measures to achieve a given level of emissions reductions, and thus the consistency of mitigation efforts with an acceleration of global growth, will depend critically on technological developments and the policies adopted. Technological developments are uncertain, although the dangers posed by climate change encourage attention to subsidizing research. Policies that would induce polluters to seek the least costly method of reducing the risk of climate change are

- Setting a uniform price for the emission of GHG (a uniform global carbon tax, for example), and an equivalent subsidy for measures reducing atmospheric GHG concentrations and other conditions that can cause climate change.[17]
- Setting a global emissions target and establishing a market for emission permits. Industries and nations with high (or low) abatement costs would buy (sell) such permits, up to the point where abatement costs were equalized across industries and national economies, resulting in a uniform price of emissions permits.[18]

Location is important in determining costs because the marginal cost of combating climate change differs widely between countries and economic sectors. For example, the cost of a 100-million-ton reduction in carbon emissions by 2010 was estimated to be less than $5 per ton of carbon (in 1985 dollars) for the United States, about $40 for the European Union, and almost $400 for Japan (Ellerman, Jacoby, and Decaux 1998). Costs tend to be even lower for developing countries. The time span over which emissions are required to fall also affects the cost of abatement: longer time spans reduce costs because existing plants and equipment need not be retired before the end of their useful life, while shorter time spans improve the credibility of compliance targets. The future path of global growth may well be affected by efforts at mitigation, depending on their severity and the attention paid to ensuring that mitigation is achieved at least cost.

In addition to reducing carbon emissions, efforts to adapt to climate change will also be required. Even if the world succeeds in markedly reducing carbon emissions in the near future, the GHGs already in the atmosphere imply increases in global temperatures and rises in sea level for many years to come (see figure 5.5). The welfare impact of climate change on developing countries is likely to

be all the more devastating because developing countries bear the brunt of the anticipated damages and have less ability than industrial countries to adapt, and because the welfare impacts of income declines are greatest for the poor.

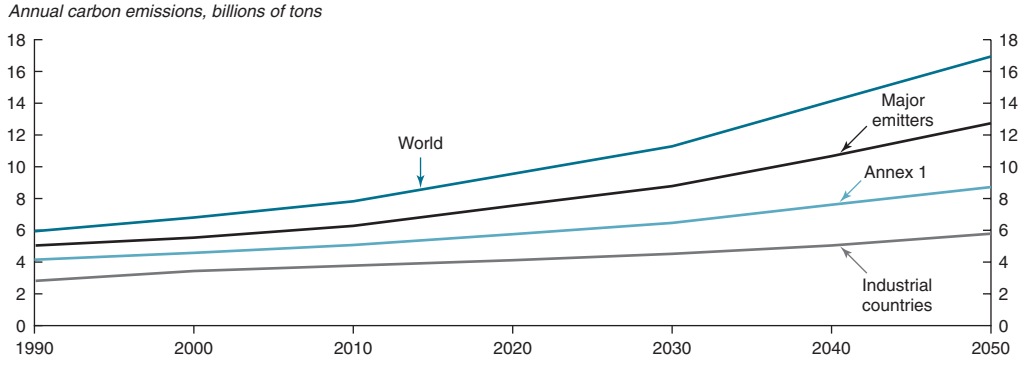
Given the critical nature of this issue for developing countries, the World Bank Group is rapidly expanding its activities to achieve a low-carbon economy. The Bank currently manages nine funds devoted to developing the carbon market, with a total investment of $2 billion. The Global Environment Facility is the largest source of multilateral grant financing for low-carbon technologies, with a total investment of $1 billion. The Bank is on track to meet its 2004 commitment to a 20 percent average annual growth in new renewable energy and energy-efficiency commitments between fiscal year 2005 and fiscal year 2009 (Sierra 2006).

Agreeing on policy is difficult

Model-based analyses suggest that the global net benefits of a coordinated international policy regime to reduce GHG emissions far exceed the benefits of individual countries acting on their own (Nordhaus and Yang 1996). However, as there is no systematic relationship between the locations where GHG emissions originate and where major damages induced by climate change are likely to occur, most countries gain very little direct benefit from their own mitigation efforts. Individual countries thus face a strong incentive not to make efforts to reduce emissions, and to minimize their own commitments to international efforts. The problem is exacerbated because likely damages are distributed unevenly around the globe. While the very existence of some island states may be threatened by rising ocean levels, countries with large Arctic areas may actually benefit from (modest) climate change.[19]

Developing countries can be major players in global efforts to reduce global climate change—they certainly will be greatly affected by success or failure. As discussed, developing countries are likely to bear the worst costs of climate change. At the same time, they bear little responsibility for the current stock of GHGs in the atmosphere and are understandably loath to impede their own growth to resolve a problem that is largely the creation of industrial countries. Still, future increases in GHG emissions will occur mainly in developing countries (figure 5.6), so that any policy strategy that excludes these major future emitters is unlikely to be effective. Moreover,

Figure 5.6 Carbon emissions from developing countries are set to rise



Source: OECD Green Model simulations.

Note: Annex 1 includes the industrial countries plus some countries in Eastern Europe and the former Soviet Union. Major emitters include Annex 1 countries plus large developing countries: China, India, Indonesia, Mexico, and South Africa.

agreements with limited geographic coverage may lead to the migration of key polluting industries to nonparticipating countries, thereby undermining success.[20]

Other aspects of climate change impede international agreement. With a few highly hypothetical exceptions, the most severe impacts of climate change are not expected for several decades, which raises uncertainty, leads to disagreement on how costs should be distributed over time and across generations, and discourages action by political leaders concerned with short time horizons (the next election). And as elaborated above, considerable uncertainty remains over the costs of mitigation and the precise impact of different levels of GHG concentrations on human welfare.

What has been done to reduce GHG emissions?

Despite the difficulties involved in reaching international agreements and the incentives for free riding, some progress has been made in reducing GHG emissions, both through international agreements and by individual countries and regions.

Kyoto Protocol. The Kyoto Protocol, which came into force in February 2005, committed most industrial countries and some of the transition economies (together referred to as the "Annex B countries") to targets that implied reductions by 2008–12 of some 5 percent of the GHG emissions recorded in these countries in 1990. Countries may either reduce actual GHG emissions or enhance the amount of carbon captured in "carbon sinks" (by sequestering GHG from the atmosphere), for example, through reforestation programs. The protocol also allows countries to achieve their emission-reduction obligations together, to buy emission rights from other Annex B countries whose emissions are below the limits, and to receive emission reduction credits for sponsoring GHG mitigation or sequestration projects in other Annex B countries (Joint Implementation Framework) or in developing countries (the Clean Development Mechanism). The provisions for carbon trading and the Clean Development Mechanism have provided useful practical experience on how to manage such mechanisms, which are likely to be part of future agreements on climate change.

The Kyoto Protocol represents a major attempt by the international community to come to grips with climate change, and by signaling future policy actions to reduce GHG emissions, it may encourage investors to adopt more efficient technologies. But it has been subject to many criticisms. The sharp cuts in emissions required of some participating countries restrained some countries from signing, particularly as no constraints were imposed on other countries where emissions will be growing fastest in the foreseeable future. The transaction costs involved in the Clean Development Mechanism and the Joint Implementation Framework make it difficult for countries to meet their obligations at the lowest global cost. It is too early to judge compliance (emission curtailment obligations are legally binding only for the 2008–2012 period). But emissions from transition economies are well below their Kyoto targets owing to the major decline in economic activity after 1990, while emissions from most industrial country signatories exceed their targets.[21] The penalties for noncompliance are not likely to change behavior. Countries that fail to meet their targets during 2008–12 must make up for this shortfall in the subsequent commitment period, plus a 30 percent penalty. A country liable for the penalty could fail to ratify the extension, or insist on raising its emissions limit as a condition of participation. Unlike the World Trade Organization (WTO) agreement, other countries are not provided with the means of enforcing compliance (Aldy, Barrett, and Stavins 2003).

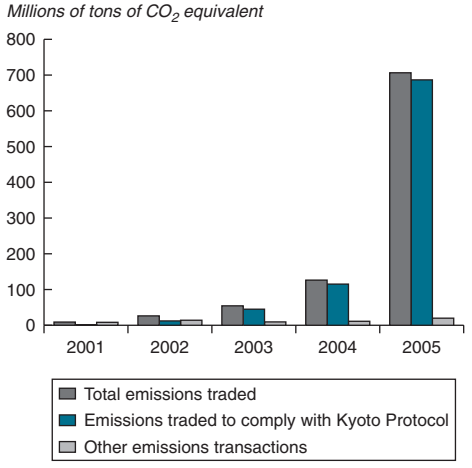
Country and local efforts. Individual countries, as well as some local governments, have taken steps to limit carbon emissions. While these have not yet had a major impact on the size of total emissions, they do help to

encourage similar initiatives, provide some momentum to efforts to limit climate change, and provide useful information on the feasibility of different approaches. Finland, the Netherlands, Norway, and Sweden adopted a carbon tax in the 1990s, and the United Kingdom has imposed a "climate change tax" on electricity generated by using fossil fuels since 2001.

In the United States, the California legislature recently passed a law that would cut carbon gas emissions 25 percent by 2020; Oregon has mandated cuts of 75 percent by 2050; 279 cities have signed a commitment to comply with the Kyoto targets; northeast states have set up the Regional Greenhouse Gas Initiative to control emissions; and 22 states have adopted so-called renewable portfolio standards to encourage renewable energy sources (Rabe 2006). Of course, a host of policies affect emissions, including many not designed to contain climate change. For example, high taxes on gasoline can help to reduce gasoline consumption and thus reduce emissions.

Carbon trading. The Kyoto Protocol and regional initiatives have created a carbon market that trades reductions in GHG emissions, supported by efforts from the government of the Netherlands and the World Bank (notably through the Prototype Carbon Fund, which began operations in April 2000). The overall market rose from about 13 million tons of CO_2-equivalent in 2001 to 704 million tons in 2005 (figure 5.7), when its value totaled $11 billion. The value of the market continues to rise—it was $7.5 billion in the first quarter of 2006 alone. The vast majority of transactions are aimed at complying with the Kyoto Protocol, and the market is dominated by the European Union's Emissions Trading Scheme. Developing countries accounted for almost half of global transactions in 2005 through the Clean Development Mechanism. Given the huge uncertainties about the post-2012 climate policy regime, the volume of project-based transactions may decline, as the window of opportunity to develop projects and validate their reduction credits under the Kyoto Protocol will soon start to close.

Figure 5.7 Global trading in carbon emissions has mushroomed



Source: Capoor and Ambrosi 2006.

The way forward

Because the establishment of institutions to address climate change requires considerable lead time, it would be desirable to start building such institutions immediately. And because lack of agreement on international cost distribution remains an important impediment to policy implementation, reaching a compromise on this question is a high priority. Progress in international negotiations concerning optimal climate policies would strengthen private incentives for energy efficiency and government incentives for appropriate policies. Progress would be encouraged by an agreement that the results of such efforts will be recognized in any future revisions of contractual obligations.

Proposals for a new agreement to succeed the Kyoto Protocol should be evaluated according to several criteria (Aldy, Barrett, and Stavins 2003). The emissions targets should reduce climate change to an acceptable

level. Participation should be as broad as possible. The policies should be efficient, either by maximizing the net benefits to society compared with alternatives, or at a minimum, by representing the least costly means of achieving an agreed-upon goal. The obligations and results of the policies should be viewed as equitable, both across countries and, given the long-term issues surrounding climate change, across generations. (A conflict currently exists between different notions of equity: the industrial countries are most responsible for climate change and have the greatest ability to pay, while developing countries are likely to be most affected.) Policies should be flexible enough to take account of new information; this is critical given the time scale involved and the potential impact of technological developments on emissions, mitigation efforts, and countries' ability to adapt. Finally, the design of the rules and the institutions established must effectively address the substantial difficulties involved in monitoring performance and ensuring compliance with treaty provisions.

Obviously there are important trade-offs among these goals. Targets that achieve large reductions in GHG emissions may not attract sufficient participation, and flexible arrangements may not reflect sufficient commitment to environmental targets. And the criteria for judging some targets are subjective. Individuals and governments may have different views of what level of climate change is acceptable, or how much future generations should pay for mitigation. So, designing an optimal agreement to limit climate change is ultimately a political, rather than a technical, exercise.

Negotiations for a successor to the Kyoto Protocol have already started within the framework of the United Nations Framework Convention on Climate Change. Failure to seize this opportunity to come up with an effective treaty curtailing the risk of climate change may seriously endanger not only the benefits of achieving the Millennium Development Goals, but also the welfare of entire future generations in industrial and developing countries alike.

Conclusions and policy recommendations

Avian flu, the depletion of marine fisheries, and climate change are very different issues representing different threats to global welfare. But in some respects, they are similar. All could involve substantial economic and human costs. In all cases, the risks posed have been intensified by globalization and the related acceleration in growth and technological progress. And in all cases, the necessary solutions will require a high degree of international policy coordination. No one country can, by itself, stem the rise of GHGs sufficiently to avoid a continued increase in global temperatures and potentially catastrophic effects. Similarly, cooperation by all countries is required to contain a potential flu pandemic that could result in millions of fatalities. And ensuring the sustainability of marine fisheries requires cooperation on sustainable management and observance by many countries of agreed-on fishing limits.

Institutional effectiveness varies from case to case

The effectiveness of the current institutional frameworks for addressing these issues varies. International efforts to contain the short-term threats of the SARS epidemic and avian flu virus have been swift and effective, although avian flu remains endemic in several countries and thus a continuing threat. The generally adequate legal framework governing the management of marine fish stocks is often rendered ineffective by inadequate enforcement and inappropriate incentive systems. The international institutions required to confront the longer-term threat posed by climate change have been generally ineffective. The Kyoto Protocol represents an initial effort to limit GHG emissions, and it has provided valuable experience in the implementation of controls. However, it lacks the participation of major current and future GHG emitters, enforcement of its provisions is problematic, and, in its present form, it is neither an effective nor an efficient response to the

climate change problem. There is at present no international institution able to coordinate an effective response to climate change.

Achieving strong international coordination to address threats to global welfare is easiest where there is a general consensus on the nature of the problem and what to do, where the threat is immediate, where individuals and countries have strong private incentives to address the problem in ways that have external benefits, and where the number of countries that must be involved in negotiations is limited (table 5.2).

The greatest difficulties in achieving effective international cooperation are presented by climate change. Although scientific understanding of the relationship between GHG emissions and global warming is sufficient to justify action, the implications for welfare of both problems and solutions are difficult to forecast. The most severe damages from climate change will likely take several decades to occur, leading to disagreements on the appropriate discount rate to apply to welfare calculations and the equitable division of costs among generations. No one country gains much relief from the threat of climate change through its own efforts to control emissions. And an effective response requires gaining agreement from all major polluters. It is no surprise that international institutions have made little headway, despite the potentially catastrophic costs of failure. By contrast, there is general agreement on the short-term threat posed by a flu pandemic, and individuals and individual countries gain substantial private benefits from prevention efforts, so international efforts to contain (some) infectious diseases have been relatively effective. The threat to the sustainability of marine fisheries occupies an intermediate position: there is little disagreement over the dangers of overexploitation of marine fish stocks, while the extent to which individual government efforts to manage fisheries generate private benefits varies depending on the species involved—and particularly on whether fish tend to migrate to the high seas or between exclusive economic zones.

Some policy priorities are clear

Climate change. Understanding how the lack of effective international institutions impedes an effective response to climate change focuses attention on policy priorities. Discussions are already under way under the aegis of the UN Framework Convention on Climate Change to replace the Kyoto Protocol, which expires in 2012, with a more comprehensive and ambitious agreement. Meanwhile, it may be useful for the global community to start putting in place the pertinent institutions, such as a global system for trading emission permits, as well as improved means of monitoring emissions (particularly in developing countries), which will allow a rapid implementation of effective policies once these are agreed upon.

Negotiations over the next agreement must take into account the position of developing countries. Since industrial countries are the major source of the current stock of GHGs in the atmosphere, there is a compelling

Table 5.2 Uncertainty and incentives affect international institutions

Threat	Time scale of threat	Degree of scientific consensus	Benefit of country's own mitigation efforts	Number of countries involved in solution	Effectiveness of institutions
Flu pandemic	Short-term	High	High	Many	High
Marine fisheries	Medium-term	High	High/moderate	Many or limited (depends on species)	Moderate
Climate change	Medium- to long-term	Moderate	Limited	Many	Low

Source: Authors.

argument that they should assume the lion's share of the costs. Nevertheless, future growth in emissions will occur mainly in developing countries. Industrial countries taking on a larger burden can be reconciled with achieving universal participation through a system of appropriate transfers, for example through the allocation of emission permits.

While international agreement is critical to limiting GHG emissions, individual countries need not delay action. A large number of measures could be adopted to limit atmospheric GHG concentrations while simultaneously raising current welfare. For example, eliminating subsidies on fossil fuels could reduce the energy intensity of production and thus unnecessarily high GHG emissions. These efforts could also have a substantial role in improving health by reducing local pollution. For industrial countries, the health benefits from reduced pollution may offset a large share of mitigation costs (see Burtraw and others 2003; Proost and Regemorter 2003; Aunan and others 2004; McKinley and others 2005). Choosing energy-efficient technology for the tens of trillions of dollars in global infrastructure investment will have irreversible impacts on GHG emission paths throughout the century (Grubb 2006a).

The focus on international coordination is essential, given the nature of the problem. But international negotiations typically proceed at the slow pace required to achieve consensus, while there is an urgent need for action *now* to slow the accumulation of GHGs. Further delays in addressing climate change would increase the costs of future, necessary mitigation efforts and greatly increase the risks of severe damage to global welfare. The scientific consensus is sufficient to demonstrate that prudence lies on the side of addressing climate change. Achieving policy consensus is more difficult, but it is now urgent.

Avian flu. Research remains a priority in combating future pandemics, particularly efforts to speed the development of vaccines in response to the next mutation of the flu virus, or—even better—to develop vaccines with broader application against groups of viruses. Because uncertainty concerning use, the large sunk costs involved, and lack of effective demand from many potential consumers in developing countries limit private investment in vaccines, this is an urgent area for public investment by the industrial countries.

Individual governments should focus on the distribution of vaccines, arrangements for quarantine, financial incentives for reporting disease, and sanctions for failure to report within their own jurisdictions. Industrial countries might consider it in their interest to subsidize such activities in developing countries, which may lack financial resources adequate to the task. And international discussions could be useful to provide for appropriate burden-sharing among the countries able to assume a portion of such costs.

Marine fisheries. Strengthening the system of regional fisheries management organizations, and establishing them where none exist, may merit further contributions by industrial countries. The UN General Assembly fund to aid developing countries in implementing the Fish Stocks Agreement appears to have gotten off to a slow start, with some developing countries calling for increased contributions and others noting that the fund is underused owing to a lack of knowledge by many potential recipients (Fiji UN Mission 2006). A reduction in fish subsidies, a redirection of subsidies toward assisting with exit from the industry, and the financing of general support to fishing through taxation of the fishing industry would help limit overcapacity and overfishing. Limits on the exploitation of the environment at the bottom of the sea are sensible until more knowledge has accumulated on how fishing and other activities affect that environment. Sustainability would be enhanced by implementing an ecosystem-based approach to fisheries management, which focuses on sustainable exploitation while safeguarding the ecosystem's structure, function, and productivity. The uncertainties involved in

determining sustainable levels of fish stocks argue for allowing a safe margin of error when setting management regimes and catch limits.

The need for international cooperation will grow

The scenario presented in chapter 2 envisions some acceleration in global growth and trade over the next quarter century. A deepening of globalization will lead to faster poverty reduction and a general improvement in global welfare. But continuing globalization will also increase the risks that countries face. This chapter has highlighted the short-term risks from infectious disease, the medium-term risk of depletion of marine fish resources, and the medium- to long-term risk posed by climate change. Of these, only climate change appears capable of seriously derailing global growth over the next quarter century. The strength of global institutions designed to meet these problems will have important implications for the likelihood of achieving this growth path.

Many other problems will, to differing degrees, require a global solution—among them preserving biodiversity, achieving an intellectual property regime that encourages innovation while limiting excessive monopoly rents, and reducing the transmission of macroeconomic instability. The countries involved in each case, the importance of the risks and benefits, and the scope for international action will vary considerably. But the interrelated phenomena of growth, technological progress, and globalization will intensify the need to find cooperative international solutions to all of these problems, while diminishing the ability of any single country to resolve critical issues on its own.

Notes

1. The Antonine Plague, either smallpox or measles, is estimated to have killed 5 million people in the second century A.D., and major episodes of bubonic plague occurred in the 6th and 14th centuries, the latter killing a quarter of Europe's population.

2. Subsequent investigations established that the disease originated in Guangdong province in China in late 2002, but news of the early cases of the sickness had not been made public by the Chinese government.

3. In China alone over the last 40 years the human population has increased by two-thirds, while the poultry population has expanded more than 10-fold. Similar increases in both human and animal populations have occurred in other Asian countries (Osterholm 2005). Additional concerns arise from the presence of the H5N1 virus in migratory birds (without showing clinical symptoms), which can lead to the transmission of the disease between continents, and the virus's ability to adapt to other species (including various mammals).

4. The disease outbreaks have been found to be strongly linked to the cold season, and the behavior of the disease over the coming months will be critical.

5. The one successful case of global eradication was smallpox, which succeeded in part because of the nature of the disease: no nonhuman host, potential for effective diagnosis and surveillance, ability to interrupt person-to-person transmission, and vaccination (Barrett 2004).

6. Bottom trawling, where the trawling rig is dragged along the sea floor, can damage vulnerable ecosystems on the sea bottom. Studies in Australia indicate that the sea floor ecosystem had not recovered from bottom trawling 15 years after an area is closed to fishing (FAO 2004). The use of explosives has damaged coral reefs, and poisons have killed nontarget species (Whole Systems 2006). The FAO estimates that marine fish discards (fish caught other than the target fish and thrown away) total about 10 million metric tons per year (Kura and others 2005), although discards declined since the early 1990s (FAO 2004).

7. For example, improved ships and freezer facilities enable ships to stay at sea for long periods. Sonar, satellite navigation systems, depth sensors, and air surveillance, combined with detailed maps of the ocean floor, help locate fish and improve the accuracy of net casting (Parsell 2002).

8. All subsidies do not threaten the sustainability of fish stocks, and few studies have attempted to link the value of subsidies quantitatively to their effect on fish stocks (FAO 2000). For example, subsidies to artisanal fishing may not raise catch levels enough to endanger sustainability, and some subsidies already are designed to facilitate exit from the industry. Quantitative modeling is extremely difficult owing to the lack of adequate data on subsidies and the multiple causes of changes in fisheries stocks (Tallontire 2004). The impact of subsidies will also depend on the effectiveness of management of fish stocks.

9. The Convention also provides that the freedom to fish on the high seas is subject to the general duty to cooperate in conservation and management and to

maintain or restore populations so as to obtain the maximum yield.

10. Examples of other approaches, rarely used in regional fisheries management organizations, are a total ban on fishing for several years to allow replenishment of fish stocks, restrictions on the capture of females or immature fish (to allow them reproduce), and closure of the fishery during spawning season.

11. Note that these data include China, which many believe has overstated fish captures (FAO 2004).

12. When industrial fishing fleets move close to shore they can damage the sea-bottom habitat, damage local fish nets, and drastically reduce fish species on which local craft fishers depend.

13. Climate change refers to the *incremental* effect of anthropogenic GHG emissions on the average global surface temperature and related changes in weather patterns. The natural greenhouse effect, caused by the pre–Industrial Revolution contents of GHGs in the atmosphere, is estimated to raise average global surface temperature by some 32 degrees Celsius from what it would be without natural radiative forcing, allowing human life to exist. So far anthropogenic emissions of CO_2, the most important GHG, have raised atmospheric concentration of CO_2 from 280 parts per million (ppm) at the start of the Industrial Revolution to 380 ppm, coinciding with an increase of average global surface temperature by about 0.6 degrees Celsius.

14. Given existing stocks of fossil fuels relative to current and projected economic growth, the past close link between output and fossil-fuel use could continue for a sufficiently long period to lead to a multiple increase in the atmospheric GHG concentrations that prevailed before the Industrial Revolution. The carbon contents of estimated fossil-fuel reserves are approximately five times the current atmospheric carbon content (in the form of CO_2) and more than 600 times current annual anthropogenic carbon emissions.

15. These estimates are clearly subject to multiple uncertainties (Grubb 2006b). In addition to the usual caveats for forecasts of growth and population, the economic and welfare impact of climate change is difficult to measure. Many market effects are not included owing to lack of data. The valuation of nonmarket effects is problematic and can raise ethical issues (life is typically valued in terms of the willingness to pay to preserve it, thus leading to high valuations in rich countries and low valuations in poor countries). Transition costs are typically not included, and the sensitivity of existing systems to transitional rises in temperature is largely unknown.

16. These may include, among other ideas, wind scrubbers to filter carbon dioxide from the air, "fertilization" of oceans with iron to encourage growth of plankton, petrification of carbon dioxide, and deflection of sunlight from the Earth through the use of a giant space mirror (Hall 2005). While considered of little practical relevance only a decade ago, geoengineering is gaining more serious consideration today (Broad 2006).

17. The existence of various GHGs requires that they be taxed in proportion to their contributions to climate change. Similarly, subsidies for alternative activities that reduce climate change potential (such as reforestation) should be proportional to their effect. While easy to formulate, the implementation of this principle is not a trivial task.

18. In a world without uncertainty, setting a price for emissions is equivalent to setting a quota. If the cost of reducing emissions is uncertain, the welfare effects of either setting prices or quantities of emission may differ (Weitzman 1974).

19. The present value of benefits from a coordinated solution may be negative for some countries (including the United States), thus further undermining incentives for participation (Nordhaus and Yang 1996). While side payments might be envisioned to encourage participation by those who suffer from a coordinated solution, the fairness involved in paying the world's largest GHG emitter to restrain emissions is problematic.

20. While the problem of carbon leakage is generally recognized, there remains disagreement concerning its quantitative importance: alternative model simulations come to different results as to the amount of carbon leakage likely to occur in response to a given policy for a given subregion (Burniaux and Oliveira Martins 2000).

21. Emissions from the European Union (EU15) countries are estimated at 0.8 percent below 1990 levels, compared with a target of −8 percent. Japan's emissions are estimated to be 7.4 percent, and Canada's 29 percent, above 1990 levels, compared to a target of −6 percent (UNFCCC 2006).

References

Aldy, Joseph E., Scott Barrett, and Robert N. Stavins. 2003. "Thirteen Plus One: A Comparison of Global Climate Policy Architectures." Available at www.nicholas.duke.edu/solutions/documents/.

APEC (Asia-Pacific Economic Cooperation). 2000. "Study into the Nature and Extent of Subsidies in the Fisheries Sector of APEC Member Economies." Available at www.APEC.org.

Aunan, K., J. Fang, H. Vennemo, K. Oye, and H. M. Seip. 2004. "Co-Benefits of Climate Policy: Lessons Learned from a Study in Shanxi, China." *Energy Policy* 32 (4): 567–81.

Barrett, Scott. 2004. "Critical Factors for the Successful Provision of Transnational Public Goods."

Background Study for the International Task Force on Global Public Goods. Available at www.gpgtaskforce.org.

Bell, Clive, and Maureen Lewis. 2004. "The Economic Implications of Epidemics Old and New." *World Economics* 5 (4): 137–74.

Berrill, M. 1997. *The Plundered Seas: Can the World's Fish be Saved?* Vancouver, BC: Greystone Books.

Bolton, D. A. 2005. "Managing Living Marine Resources Multilaterally: Some Threshold Questions." In *Deep Sea 2003: Conference on the Governance and Management of Deep-Sea Fisheries,* ed. Ross Shotton. Rome: Food and Agriculture Organization.

Broad, William J. 2006. "How to Cool a Planet (Maybe)." *New York Times,* June 27, F1.

Burniaux, Jean-Marc, and Joaquim Oliveira Martins. 2000. "Carbon Emission Leakages: A General Equilibrium View." OECD Economics Department Working Paper No. 242, Organisation for Economic Co-operation and Development, Paris.

Burtraw, D., A. Krupnick, K. Palmer, A. Paul, M. Toman, and C. Bloyd. 2003. "Ancillary Benefits of Reduced Air Pollution in the U.S. from Moderate Greenhouse Gas Mitigation Policies in the Electricity Sector." *Journal of Environmental Economics and Management* 45: 650–73.

Capoor, Karan, and Philippe Ambrosi. 2006. "State and Trends of the Carbon Market." Unpublished paper, World Bank, Washington, DC.

CDC (Centers for Disease Control). 2004. "Interim Recommendations for Infection Control in Health-Care Facilities Caring for Patients with Known or Suspected Avian Influenza." Available at www.cdc.gov/flu/avian/professional/infect-control.htm.

Cunningham, Steve, and Dominique Greboval. 2001. *Managing Fishing Capacity: A Review of Policy and Technical Issues.* FAO Fisheries Technical Paper No. 409, Food and Agriculture Organization, Rome.

Ellerman, A. Denny, Henry D. Jacoby, and Annelene Decaux. 1998. "The Effects on Developing Countries of the Kyoto Protocol and Carbon Dioxide Emissions Trading." World Bank Policy Research Working Paper No. No. 2019, Washington, DC.

Esty, Daniel H., and Maria H. Ivanova. 2002. "Revitalizing Global Environmental Governance: A Function Driven Approach." In *Global Environmental Governance: Options and Opportunities,* ed. Daniel H. Esty and Maria H. Ivanova. New Haven, CT: Yale School of Forestry and Environmental Studies.

FAO (Food and Agriculture Organization). 2000. "Report of the Expert Consultation on Economic Incentives and Responsible Fisheries." FAO, Rome.

_____. 2004. "The State of World Fisheries and Aquaculture." FAO, Rome.

Fiji UN Mission. 2006. "Report on the Review Conference on the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks." United Nations, New York. May.

Gianni, Matthew. 2004. "High Seas Bottom Trawl Fisheries and Their Impacts on the Biodiversity of Vulnerable Deep-Sea Ecosystems: Options for International Action." World Conservation Union, Gland, Switzerland.

Grubb, Michael. 2006a. "Framing the Economics of Climate Change: An International Perspective." Submission to the Stern Review on the Economics of Climate Change, HM Treasury and Cabinet Office, London.

_____. 2006b. "Climate Change Impacts, Energy and Development." Paper presented at the Annual World Bank Conference on Development Economics, Tokyo, May 30.

Hall, Wayne. 2005. "Climate Change and Geoengineering." Available at www.globalresearch.ca.

Honohan, Patrick, and Luc Laeven. 2005. *Systemic Financial Crises: Containment and Resolution.* Cambridge, U.K.: Cambridge University Press.

IEA. 2004. *World Energy Outlook.* Paris: International Energy Agency.

_____. 2005. *World Energy Outlook.* Paris: International Energy Agency.

IPCC (Intergovernmental Panel on Climate Change). 2001. *Third Assessment Report—Climate Change 2001.* Geneva. Available at www.ipcc.ch.

Kura, Yumiko, Carmen Revenge, Eriko Hoshino, and Greg Mock. 2005. "Fishing for Answers: Making Sense of the Global Fish Crisis." World Resources Institute Report, Washington, DC.

Lodge, Michael W. 2005. "Improving International Governance in the Deep Sea." In *Deep Sea 2003: Conference on the Governance and Management of Deep-Sea Fisheries,* ed. Ross Shotton. Rome: Food and Agriculture Organization.

Lomborg, Bjorn, ed. 2004. *Global Crises, Global Solutions.* Cambridge, U.K.: Cambridge University Press.

McKinley, G., M. Zuk, M. Hojer, M. Avalos, I. Gonzalez, R. Iniestra, I. Laguna, M. Martinez, P. Osnaya, L. M. Reynales, R. Valdes, and J. Martinez. 2005. "Quantification of Local and Global Benefits from Air Pollution Control in Mexico City." *Environmental Science and Technology* 39: 1954–61.

Milazzo, Matteo. 1998. "Subsidies in World Fisheries: A Reexamination." World Bank Technical Paper No. 406, Fisheries Series, Washington, DC.

Nordhaus, William D., and Zili Yang. 1996. "A Regional Dynamic General-Equilibrium Model of Alternative Climate-Change Strategies." *American Economic Review* 86 (4): 741–65.

OECD (Organisation for Economic Co-operation and Development). 2005. *Why Fish Piracy Persists: The Economics of Illegal, Unreported and Unregulated Fishing*. Paris: OECD.

Osterholm, Michael T. 2005. "Preparing for the Next Pandemic." *New England Journal of Medicine* 352 (18): 1839–42. Available at www.nejm.org.

Parsell, D. L. 2002. "High-Tech Fishing is Emptying Deep Seas, Scientists Warn." *National Geographic News,* February 26. Available at news.nationalgeographic.com/news/2002/02/0225_0226_fishcrisis.html.

Pauly, Daniel, Villy Christensesn, Sylvie Guenette, Tony J. Pitcher, U. Rashid Sumaila, Carl J. Walters, R. Watson, and Dirk Zeller. 2002. "Toward Sustainability in World Fisheries." *Nature* 418 (August 8): 689–95.

Proost, S., and D. V. Regemorter. 2003. "Interaction between Local Air Pollution and Global Warming and Its Policy Implications for Belgium." *International Journal of Global Environmental Issues* 3 (3): 266–86.

Rabe, Barry. 2006. "Race to the Top: The Expanding Role of U.S. State Renewable Portfolio Standards." Pew Center on Global Climate Change, Arlington, VA.

Rischard, Jean-François. 2002. *High Noon: Twenty Global Problems, Twenty Years to Solve Them*. New York: Basic Books.

Schmidt, Carl-Christian. 2002. "Fish Crisis: A Problem of Scale." *OECD Observer* 233 (August).

Sender, Elena. 2006. "Les retards du plan grippe aviare" (Bird flu plan delayed). *Science et Avenir* (March): 57–59.

Shotton, Ross. 2006. *Deep Sea 2003: Conference on the Governance and Management of Deep-Sea Fisheries*. FAO Fisheries Proceedings 3/2. Rome: Food and Agriculture Organization.

Sierra, Katherine. 2006. "An Investment Framework for Clean Energy and Development." Presentation at the Dialogue on Climate Change, Clean Energy, and Sustainable Development, October 3–4. Monterrey, Mexico.

Sturm-Ramirez, Katharine. 2006. Unpublished briefing memorandum, St. Jude's Children's Hospital, Memphis, TN.

Tallontire, Anne. 2004. "Trade Issues Background Paper: The Impact of Subsidies on Trade in Fisheries Products." Food and Agriculture Organization, Rome.

Tol, R. S. J. 2002. "New Estimates of the Damage Costs of Climate Change, Part I: Benchmark Estimates." *Environmental and Resource Economics* 21 (1): 47–73.

U.K. Government. 2006. "The Stern Review: The Economics of Climate Change." Available at www.hm-treasury.gov.uk/independent_reviews.

UNFCCC (United Nations Framework Convention on Climate Change). 2006. "National Inventory Submissions 2006" (data on emissions by country). Available at unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/3734.php.

Van Vuuren, Detlef P., and Brian C. O'Neill. 2006. "The Consistency of IPCC's SRES Scenarios to 1990–2000 Trends and Recent Projections." *Climatic Change* 75 (1–2): 9–46.

Warren, Rachel. 2006. "Impacts of Global Climate Change at Different Annual Mean Global Temperature Increases." In *Avoiding Dangerous Climate Change,* ed. J. Schellnhuber, W. Cramer, N. Nakicenovic, G. Yohe, and T. M. L. Wigley. New York: Cambridge University Press.

Webster, D. G. 2006. "Leveraging Competitive Advantages: The Role of Developing Countries in International Fisheries Management." Available at biology.usc.edu/PDF/WebsterDevcos.pdf.

Weitzman, Martin. 1974. "Prices vs. Quantities." *Review of Economic Studies* 61 (4): 477–91.

Weyant, John P. 2000."An Introduction to the Economics of Climate Change Policy." Pew Center on Global Climate Change, Arlington, VA.

WHO (World Health Organization). 2005. *Avian Influenza: Assessing the Pandemic Threat*. http://www.who.org.

———. 2006. "Avian Influenza, Including Influenza A (H5N1), in Humans: WHO Interim Infection Control Guideline for Health Care Facilities Alert." Available at www.who.int/csr/disease/avian_influenza/guidelines/infectioncontrol1/en.

Whole Systems. 2006. "Ocean Fish Production." Available at www.whole-systems.org/fisheries. html.

World Bank. 2004. "Saving Fish and Fishers: Toward Sustainable and Equitable Governance of the Global Fishing Sector." Agriculture and Rural Development Department, World Bank, Washington, DC.

_____. 2006. *Global Development Finance*. Washington, DC: World Bank.

WWF (World Wildlife Fund). 2001. "Hard Facts, Hidden Problems: A Review of Current Data on Fishing Subsidies." World Wildlife Fund Technical Paper. Washington, DC.