Four Economic Questions About Climate Change

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1.1 Introduction

One of the authors of this book recently had some surprise visitors to his environmental and natural resource economics class. It was alumni week at the college, and four members of the class of 1955, *back for their 60th reunion*, joined our discussion. We were talking about sustainability, and suddenly the day's lecture became very real. How has life really changed since these visitors left college in 1955? Have seven decades of intervening economic growth—with per capita gross domestic product (GDP) more than tripling—made life better? Or have the costs of growth made things worse? Is economic growth sustainable? And in the coming decades, will your generation's quality of life rise or fall?

So imagine now: You are that older person, heading to the classroom this week for your 60th class reunion. You are 80-something, and for you, it will be sometime in the 2080s. As you listen to the young professor at the head of the class talking about the latest theories, you sit back and reflect on the changes that you have witnessed in your lifetime. Maybe your story will go something like this:

> *Over the twenty-first century, you lived through both deep recessions and economic booms, through wars and political upheavals. You experienced staggering technological breakthroughs, unprecedented droughts, sea-level rise that forced millions from their homes, large-scale extinctions, and the outbreak of new diseases. Against this background, you and your classmates from around the world maintained a relentless focus: redesigning every city on the earth, reengineering production processes, reimagining the global food system, and reinventing transportation.*
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> *World population increased from 8 to eventually 10 billion people in 2060 when it stabilized, and recently, it has actually started to decline. And through a heroic effort, ramping up in the 2020s, your generation managed to completely phase out fossil fuels, rewiring the entire planet with a new generation of renewable energy technologies and stabilizing the global climate.*
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> *At the end of the day, you shepherded both the human race and the remaining species on the planet through a critical bottleneck in human history, in which rising populations, aspiring to ever-higher levels of consumption, ran up against critical global resource shortages. Above all, you managed, by 2050, to roll back emissions of global warming pollutants by 80 percent and stabilize the climate. In doing all this, you created tens of millions of jobs, helped lift billions of people out of poverty, and built a global economy that is well on the road to becoming truly sustainable.*

Will this be your story?

We hope it will. And if so, you have a lot of work to do! Yours will be the "greatest generation" because you must guide the earth through this extraordinary half century. Your decisions will have profound consequences not only for you and your children but indeed for a thousand human generations to follow.

This book introduces you to economic concepts and tools that you will need to make the journey. We begin by framing economics in terms of four basic questions as they apply to the defining environmental—indeed, civilizational—challenge of your lifetime: climate change.

1.2 Four Questions

Did you drive to school today? Or to work? Every mile you drove, you pumped around a pound of carbon dioxide (CO_2) into the air. This is a part of your small daily share of more than 35 billion pounds of carbon dioxide people around the world contribute annually from the burning of carbon fuels such as coal, oil, natural gas, and wood. **CO_2** is a **greenhouse gas**—a compound that traps reflected heat from the earth's surface and contributes to **global warming**. Other greenhouse gases include nitrous oxide from natural and human-made fertilizers; methane emitted from oil and gas production and transport, as well as from rice production and the digestive processes of cows and sheep; and chlorofluorocarbons (CFCs), once widely used for air-conditioning, refrigeration, and other industrial applications.[1]

As a result of industrialization and the ensuing rapid increase in greenhouse gases in our atmosphere, the earth's surface temperature has been steadily increasing and will continue to rise over the next few decades. The extent of warming is uncertain: the lowest-end estimates suggest an overall increase in the earth's average surface temperature over pre-industrial levels of 3 degrees F by the year 2100. The official high-end prediction from the UN's International Panel on Climate Change is 11 degrees over this time period. To put that number in perspective, during the last ice age, the earth's average surface temperature was only 9 degrees F colder than it is today.

The consequences of this warming range from manageable to catastrophic. Global warming impacts people and natural ecosystems through factors including intensified heat, drought, flooding, fire, extreme storms (including hurricanes), sea-level rise, and ocean acidification. Question: How can warming cause both droughts and floods? As the planet heats up, it "forces" the hydrologic cycle by adding more and more moisture to the air. This water has to come back down and leads to both more extreme precipitation and flooding. At the same time, more heat means increased drought, and changed patterns of drought.

Both people and **natural ecosystems** are suffering directly from climate change. Record-breaking heat is already rendering outside work difficult for people in many cities during longer-lasting heat waves, and particularly in countries without universal air-conditioning, death rates from heat are rising as well. Wildfire seasons also extend longer and intensify, large-scale forest dieback is occurring in, among other places, the western United States and the Amazon Basin. Human and animal diseases and agricultural pests are also thriving in a warmer climate.

In the oceans, major ecosystem impacts will occur not only because of warming waters that, for example, directly kill coral reefs but also because the oceans are absorbing large quantities of CO_2 released by fossil fuel combustion. This in turn is leading to **ocean acidification**: the pH of the ocean has dropped markedly in the last century. As the ocean continues to acidify, life at the base of the ocean food chain could begin to die off. On both land and sea, massive disruption of ecosystems and widespread extinctions affecting life across the planet are thus likely.

Changes in patterns of drought are already affecting **agricultural output**. As the planet heats further, more northerly regions in Canada and Russia may actually experience an increase in precipitation and yields, but the current grain belts of the United States, Australia, and Central Europe will become drier, and agricultural output in these regions will probably fall. The net global effect through the mid-century is expected to be, on balance, negative. It will be particularly harsh in

[1] CFCs also deplete the earth's protective ozone shield. This is a separate issue from global warming and is discussed in more detail in Chapter 21.

many developing countries, which lack resources for irrigation and other adaptive measures. Tens of millions of people are likely to be at increased risk of hunger as a result of climate change.

Finally, **sea-levels rise** as ice caps in Greenland and Antarctica melt, and the warming ocean expands. An increase in sea level of 3 feet—well within the realm of possibility within your lifetime—would flood many parts of Florida, Louisiana, Boston, and New York City, as well as much of low-lying countries such as Bangladesh and the Netherlands, all unless they were protected by dikes. As many as 1 billion people live in areas that might be directly affected.

The globe is locked into a warming of at least 3 degrees F over the next 100 years. This warming will have far-reaching human and ecosystem effects, but if contained would be a manageable event. Increased warming beyond that would have steadily greater and greater costs and also could result in truly catastrophic outcomes from so-called **tipping points** in the earth's systems. One of these would be the collapse and melting of the Greenland and Antarctic Ice Sheets, events that over the course of several hundred years would raise sea levels by dozens of feet and inundate many of the world's major cities. Some scientists believe that a warming of 4 degrees F or more would significantly raise the probability of this event. Dr. James Hansen, NASA's former chief climate scientist, warned twenty years ago:

> *How far can it go? The last time the world was three degrees [C] warmer than today—which is what we expect later this century—sea levels were 25m [75 feet!] higher. So that is what we can look forward to if we don't act soon. . . . I think sea-level rise is going to be the big issue soon, more even than warming itself. . . . How long have we got? We have to stabilize emissions of carbon dioxide within a decade, or temperatures will warm by more than one degree [C]. That will be warmer than it has been for half a million years, and many things could become unstoppable. . . . We don't have much time left.*[2]

A catastrophic collapse of the ice sheets is far from certain, but as Dr. Hansen suggests, decisions about reducing greenhouse gas emissions not made in the last two decades, as well as decisions to come in the next two, could have dramatic consequences lasting for tens of thousands of years.

Climate change is an environmental reality that presents stark choices. On the one hand, substantial, short-term reductions in the human contribution to the greenhouse effect would require dramatic changes in energy use. In particular, our casual reliance on fossil fuels for transportation, heat, and power would have to be dramatically scaled back and new, clean-energy sources deployed very rapidly. On the other hand, the consequences of inaction are potentially disastrous. By continuing to pollute the atmosphere, we may be condemning the coming generations to severe hardship.

This book focuses on the economic issues at stake in cases such as global warming, where human actions substantially alter the natural environment. In the process, we examine the following four questions.

1. **How much pollution is too much?** Many people are tempted to answer simply: any amount of pollution is too much. However, a little reflection reveals that zero pollution is an unachievable and, in fact, undesirable goal. Pollution is a by-product of living; for example, each time you drive in a car, you emit a small amount of CO_2 to the air, thus exacerbating the greenhouse effect. The question really is, "At what level are the benefits of pollution (cheap transportation in the case we started with) outweighed by its costs?" Different people will answer this question in different ways, depending on their value systems: "costs" of pollution may be defined narrowly, as strictly economic, or they may be broadened to include ethical considerations such as fairness and the protection of rights. Costs may also be difficult to measure. Nevertheless, it is clear that a rough weighing of benefits and costs is a critical first step for deciding "How much is too much."

[2] See Johansen (2006: 38) and Hansen (2005).

2. **Is government up to the job?** After resolving the first question, we must then rely on government to adopt laws and regulations to control pollution. But, is our government able and willing to tackle the tough job of managing the environment? The costs and mistakes associated with bureaucratic decision-making, as well as the likelihood of political influence in the process, will clearly have an impact on government's ability to respond effectively to this challenge. As a pointed example, it took 30 years since the threat of climate change emerged in 1988 for the U.S. Congress to pass the first significant law reducing global warming pollution—in 2022. Yet, in other areas, most notably in reducing urban air pollution, government action has been very effective. What are the tools that government can use, working with industry and consumers, to reduce pollution?

3. **How can we do better?** Suppose that as a society we decide on a particular target: for example, reduce CO_2 emissions by 80 percent by 2050. Given the limitations that government might face, identified in the answer to the second question, how can we best achieve that goal? A long list of policies might be used: regulations, taxes, permit systems, technology subsidies (or their removal), research incentives, infrastructure investment, right-to-know laws, product labeling, legal liability, fines, and jail terms. Which policies will most successfully induce business firms and consumers to meet the target?

4. **Can we resolve global issues?** Finally, regulating pollution within a single nation is a difficult task. Yet problems such as global warming transcend national boundaries. Although the United States has only 4 percent of the world's population, we account for close to 17 percent of the greenhouse gases. Brazilians say that they will stop cutting down and burning their rain forests to create crop and rangeland as soon as we stop driving gas-guzzling cars. How can this kind of international coordination be achieved? Are economic development and environmental quality necessarily in conflict? And to what extent can population growth and rising per capita resource use, which ultimately drive environmental problems, be managed?

Let us return to our discussion of climate change and see what type of answers we might develop to these four questions. Global warming is a consequence of what is known as the **greenhouse effect**. Solar energy enters the earth's biosphere in the form of visible and ultraviolet light from the sun. The first law of thermodynamics—energy can be neither created nor destroyed—requires that this energy go somewhere, and much of it is radiated back into the biosphere as infrared radiation or heat. CO_2 and other greenhouse gases surrounding the earth let in the visible and ultraviolet light from the sun. Yet, like a blanket, these gases trap the reflected infrared radiation (heat) close to the earth's surface.

Until the present time, the naturally occurring greenhouse effect has been primarily beneficial. Without the planet's blanket of water vapor, CO_2, and other gases, the average temperature on the earth would be about 91 degrees F colder—well below the freezing point. The problem we face today is the steady increase in human-made greenhouse gases, which began with the Industrial Revolution but dramatically accelerated after World War II. Overall, the thickness of the CO_2 blanket in the atmosphere has increased by more than 40 percent, rising from 280 parts per million (ppm) in 1880 to over 420 ppm today. Every year the blanket gets thicker by about 2 ppm. The question facing humanity is, how thick should we let this heat-trapping blanket grow? Should we try to hold it to 450 ppm? 550 ppm? 650 ppm? Or even roll it back to 350 ppm?

As a result of human pollution, the earth's average temperature has risen more than 2 degrees F over the last century, and the warming has accelerated in the last few decades. The year 2024 was the hottest on record, and the last decade has been the hottest in the last several thousand years. Way back in 1995, the Intergovernmental Panel on Climate Change (IPCC), an organization of some 2,500 scientists operating under the auspices of the United Nations, declared that "the balance of evidence suggests that there is a discernible human influence on global climate." Since then, the evidence supporting human-induced warming has become overwhelming.[3] Today, scientists are virtually unanimous in their opinion that depending on our actions to cut emissions, the planet will heat up somewhere between 3 and 11 degrees F over pre-industrial levels. (Given where we are today, this means an additional 1 to 9 degrees over the 2 degrees we have already experienced.)

The extent of future warming depends both on the level of global warming pollution generated by humans but also on the influence of **positive and negative feedback** effects. Changing temperatures will in turn affect many different parts of the earth and its surface, which could lead to either an acceleration of warming (positive feedback) or a deceleration (negative feedback).

Two examples of negative feedbacks include the possibility that increasing cloud cover will reduce the amount of radiation entering the earth's atmosphere or that increasing amounts of CO_2 will lead to higher rates of plant growth and thus more trapping of CO_2. Negative feedbacks would clearly be welcome, but unfortunately, positive feedbacks appear more likely to occur. For example, higher temperatures may generate widespread forest fires and forest dieback in regions such as Amazon and the western United States; lead to the emission of methane and CO_2 currently trapped in frozen bogs and peat fields at high latitudes; expose heat-absorbing darker earth under ice shields; or reduce the capacity of ocean organisms to fix CO_2 in their shells. These and other positive feedbacks have led some researchers to believe that at some point, global warming will trigger a **runaway greenhouse effect**, in which the initial warming will feed on itself. Under this scenario, policymakers no longer face a continuum of temperature possibilities: a total warming of somewhere between 3 and 11 degrees. Instead, there are only two options: either hold total warming to the low end, 3 to 5 degrees, or risk triggering positive feedback loops that quickly drive the planet's temperatures up by 9 to 11 degrees, the equivalent of a swing of ice-age magnitude, only in the opposite direction.

In the face of this uncertainty, what action should be taken to prevent or mitigate the consequences of global warming? Following the outline described, we can begin to tackle this daunting question piece by piece.

1.3 How Much Pollution Is Too Much?

To answer this first question, let us first see where we stand on targets to reduce global warming pollution. At a UN-sponsored meeting in France in 2015, almost all the countries in the world agreed to the **Paris Climate Agreement**, a set of voluntary commitments to cut global warming pollution. The Paris goal: hold global warming to at most 4 degrees F above pre-industrial levels, and preferably, 3 degrees F. The United States committed that it would reduce emissions 30 percent below 2006 levels by 2030. China committed to capping their emissions by 2030 and to subsequent reductions. Added together, if all the countries follow through on the actions they committed to in Paris, scientists estimate that this will hold planetary warming to a total of 6 degrees F above pre-industrial level. At the same time, world leaders also agreed to convene regularly with proposals for deeper global warming pollution cuts that would reduce the total warming to the official UN target of 4 degrees F or lower.

However, back in the United States, the major Republican candidates for President in 2016 were all opposed to any action on climate change. The reasons? First, most Republican candidates questioned the scientific consensus that humans are causing climate change. And second, they all argued that serious efforts to reduce fossil fuel emissions would be much too costly. Candidate Marco Rubio, reflecting the party's viewpoint, said that reducing fossil fuel use would have "a devastating effect on the economy."[4] For these two reasons, soon after Donald Trump

[3] See IPCC (1996) and IPCC (2023).

[4] Rubio is quoted in Carrol (2015). Of the sixteen Republican candidates originally in the field, only one, Lindsay Graham, was an advocate for action on climate change.

was elected President, he pulled the United States from the Paris accord—an action that officially took place in November 2020. Under President Trump, from 2016 to 2020, no U.S. national action was taken to meet the Paris targets on global warming pollution reduction, although many companies, states, and cities were reducing emissions on their own.

In 2022, under President Biden, the United States rejoined the Paris accord, and that year, Congress also passed the first major U.S. bill to tackle global warming. The law was called, oddly, "The Inflation Reduction Act" or IRA, and it authorized hundreds of billions of dollars of tax credit subsidies to support investment in wind farms, electric cars, and electric heat pumps. We will look closely at the IRA in Chapter 18. For now, recognize that the main goal of the bill was to get the United States headed toward meeting the Paris interim global warming reduction goals of 6 degrees F.

The U.S. political system has thus been expressing profound disagreement over climate change: Go for the Paris goals, or take no action. If the world follows the lead set by the U.S. government under Trump, taking no action in the next decades to reduce emissions and sticking with business-as-usual emissions, then this would likely lock the earth into at least an 8 degrees F of warming. So what is the "right" level of global warming pollution? Emissions leading to a 4-degree increase in global temperatures (the ultimate Paris goal), a 6-degree increase (the 2015 Paris commitments), or an 8-degree plus increase (the no-action outcome)?

Economists typically answer this type of question by weighing the benefits of pollution reduction against the costs of reduction. How big are the benefits of reducing global warming? And what would it cost—would phasing out fossil fuels really wreck the economy? Finally, are the overall benefits (what economists call **net benefits)** of reducing warming positive? In other world, do the benefits of action outweigh the costs? Weighing benefits against costs in this way is called **benefit–cost analysis**.

In the particular case of global warming, quantifying the benefits and the costs of reducing emissions is a very difficult task, primarily because uncertainties loom very large. A ton of carbon dioxide emitted into the air today will still be there 100 years from now. So on the benefits of reducing pollution side, analysts are required to estimate the damages that will be avoided over the next century by stabilizing CO_2 today, as it affects global agriculture, human health, species extinction, and so on. Moreover, across the planet, some regions will gain and others will lose; impacts will be proportionately larger in poor countries and smaller in rich countries. Developing countries will be hardest hit because they tend already to be in warmer and drier parts of the planet—but more importantly, because they have fewer financial resources for adapting their agriculture or building sea walls.

Putting a monetary value on such benefits presents difficult issues, among them: How do we deal with uncertainty and the possibility of cataclysmic change? How do we value damage to future generations? Can we measure the value of intangible or "priceless" benefits such as human suffering and death averted or forests saved? How do we weigh the fact that some countries will lose more compared to others in the warming process? These are all issues we explore in detail later in the book.

Bearing all this in mind, for over two decades, economists have been trying to assess what is called "the social cost of carbon" (**SCC**). This is a dollar measure of all the costs imposed on society of a ton of carbon dioxide released into the atmosphere today. In 2022, a major U.S. study concluded that, under a variety of future scenarios, the average value of the SCC was equal to $185 per ton. Put another way, the economists estimated that a ton of CO_2 emitted today will, over the next 100 years, do an average of $185 of damage in the form of deaths and destruction from hurricanes and heat waves, reduced agricultural output, forest and coral reef die-back, fires and droughts, and many other negative impacts.

What does this mean for our global warming target? The economists argue that any action that can reduce global warming pollution for a cost less than $185 per ton, the SCC, can be justified by benefit–cost analysis. This could include weatherizing buildings, building solar fields, or switching to regenerative farming methods. Any and all such actions would, in the average of their futures scenarios, make society as a whole better off. We know this since the benefits of each of these measures for reducing global warming pollution are greater than the cost. OK. Who should pay for all this? Polluters, consumers, or taxpayers? This is a critically important question that we will talk more about. For now, the point is that, for the benefit of society, someone should.

It appears we have now answered the question we started with: How Much Pollution is Too Much? Cut global warming pollution at all sources if it costs less than $185 per ton to do so! As noted, in Paris, the United States originally agreed to medium-term reductions in emissions of 30 percent below 2006 levels by 2030, and a 2050 goal of much deeper 80 percent cuts to drive toward holding warming to 4 degrees F or less. Based on their benefit–cost analyses of reducing global warming pollution, the economics team that developed the $185 per ton SCC would agree that the Paris Goals pass a benefit–cost test for global society as a whole: achieving the Goals would mean trade-offs, but would not wreck the economy.

Of course, this is not really the end of the story. Given the tremendous uncertainty in measuring the SCC, the study argued that the value might actually be much, much higher—as high as $413. In this case, a benefit–cost analysis would recommend many more actions to cut global warming pollution, and much deeper and faster decarbonization. Or, the SCC could be as low as $44, justifying a somewhat slower rate of investment in clean energy, and ultimately, a higher global temperature.[5]

All of this uncertainty nevertheless frames up a deadly serious economic debate: Is global warming a civilizational challenge demanding immediate and deep emission reductions or is it simply another in a list of serious problems, addressable with a committed, go-slow, and ramp-up approach? Those who argue for a low SCC and thus advocate modest emission cutbacks today believe that climate stability is important but not critical to the well-being of humanity. The argument is that people adapt to changing resource conditions. As emissions of greenhouse gases are regulated, the price of CO_2-based services will rise and new low-CO_2 technologies will come on board, ensuring that greenhouse gas concentrations eventually stabilize. Moreover, the development of new agricultural techniques will ensure that adequate food supplies are maintained even in the face of a changing climate and sea walls can be built to hold back rising sea levels. In addition, agriculture in some regions will gain from a warmer, wetter CO_2-enhanced climate, and cold-related deaths will decline. Some analysts even envision the winners from climate change assisting those (mostly in poor countries) who lose out from sea-level rise and flooding. Clearly, there will be significant losers from climate change, but on balance, it is believed that the quality of life for the average person in most countries can continue to rise even in the face of “moderate” climate change.

This benefit–cost perspective that begins with a low SCC maintains that a near-term policy of CO_2 cuts below correct levels is too costly. The logic is that “over investing” resources and person-power in clean energy and reducing greenhouse gas emissions today will divert much-needed investment from schools or health care, lowering living standards for future generations.

It is critically important to recognize that virtually all economists who research climate change issues today agree that government action is needed immediately to cut emissions of global warming pollutants. A survey of climate economists puts the number calling for action at 94 percent.[6] The debate is not over whether near-term emission reductions is required but by how much.

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[5]The average, low, and high values for the SCC are from Renner et al. (2022). The authors believe that their estimates are probably too low. “A limitation of this study is that other categories of climate damages—including additional non-market damages other than human mortality—remain unaccounted for. The inclusion of additional damage sectors such as biodiversity, labor productivity, conflict and migration in future work would further improve our estimates. Current evidence strongly suggests that including these sectors would raise the estimates of the SC-CO_2, although accounting for adaptation responses could potentially counteract some of that effect. Other costs of climate change, including the loss of cultural heritage, particular ways of life, or valued ecosystems, may never be fully valued in economic terms but would also probably raise the SC-CO_2 beyond the estimates presented here. . . . Although we approximate the effects of a rapid Antarctic ice sheet disintegration tipping point within the BRICK sea-level component, incorporating additional potential discontinuities in the climate system would further improve our SC-CO_2 estimates. We expect that, in total, the future inclusion of additional damage sectors and tipping elements will probably raise the estimates of the SC-CO_2, and therefore that the estimates from the present study are probably best viewed as conservative.”

[6]Holladay, Horne, and Schwartz (2009).

Climate economists also agree that the "no action" policy of the Trump administration cannot be justified on the basis of good benefit–cost analysis. Indeed, during the first Trump presidency, a prominent group of Republican economists and business and finance leaders repeatedly called for bipartisan polices to reduce global warming pollution. Despite this consensus among economists, President Trump's first-term EPA team lowered the SCC they used down to $4 per ton, in order to justify rolling back climate regulations to essentially zero.[7]

Stepping back from the U.S. case, recognize that the use of benefit–cost analysis by climate economists is implicitly endorsing an unstated ethical goal: control pollution only if the measurable monetary benefits of doing so are greater than the measurable monetary costs. This is one answer to the question "How much is too much?" It is called an **efficiency standard** for pollution reduction.

However, there are ways of thinking about pollution goals other than through a narrow comparison of economic costs and benefits. First, there are issues of fairness: inaction on our part—though it may provide for somewhat higher incomes today, particularly for citizens in affluent countries—may condemn future generations, in particular those in already poor countries, to even greater hardship. Can we justify actions today that, for example, will destroy entire island nations and their cultures? A second answer to the question "How much is too much?" emphasizes fairness. This is called a **safety standard**. Safety requires reducing pollution to (socially defined) "safe" levels, unless the costs of doing so are prohibitive.

Finally, there is the question of fundamental uncertainty regarding our impact on the planetary ecosystem. Benefit–cost analysts typically assume an intermediate case of predictable damages, but, of course, a worst-case scenario might emerge. In a related vein, can we even begin to put benefit numbers on things we know nothing about? For example, what would be the value to future generations of the unique genetic code that will be lost as species extinction accelerates? When uncertainties dominate benefit–cost analysis, it becomes a blunt, and sometimes misleading, tool. In the global warming case, a good number of economists argue that the future consequences of a destabilized climate are simply too uncertain—and potentially catastrophic—to justify making decisions based primarily on estimates of the SCC. In the face of this uncertainty, a third standard emerges—**sustainability**. This standard generally requires protecting major natural ecosystems from significant disruptions—again, unless the costs of doing so are prohibitive.

Such a precautionary recommendation is strengthened by a final argument we explore in Chapter 11 that lost consumption from controlling CO_2 emissions in an affluent country such as the United States really means very little over the long run. Because the happiness derived from consumption is in many ways a relative phenomenon, a general increase in income only accelerates the "rat race," leaving few better off in absolute terms. Put very simply, if fighting global warming reduces the level of U.S. GDP by 2 percent in 2050, then who would really care? Fighting global warming would only mean that we would all be becoming slightly less rich together. Real global GDP is expected by many economists to continue to grow at close to 2 percent per year, regardless of global warming. So the costs of stabilizing the climate would be that, as a world, we would need to wait until 2051 to be as rich as we otherwise would have been in 2050!

Regardless of whether formal benefit–cost analysis is involved, the public debate over global warming is generally framed in terms of costs and benefits. On one side, efficiency advocates will stress the measurable costs involved in reducing global warming and will advocate smaller reductions. On the other, proponents of safety and ecological sustainability will argue for major greenhouse gas cutbacks, focusing on uncertain but potentially devastating impacts on future generations.

The purpose of this book is not to sort out which answer is "correct," but rather to better understand the different positions. However, the first essential step in addressing any environmental problem is always to decide "How much pollution is too much?" Once this issue is resolved, it is then possible to move on to the next question.

[7] The Trump team got this low number by looking only at the benefits of reducing global warming pollution for U.S. citizens and also used a very high discount rate: see Chapter 8.

1.4 Is Government Up to the Job?

For reasons explored further in this book, an unfettered free-market economy will produce too much pollution by almost anyone's standards. This suggests that government needs to step in and regulate market behavior in order to protect the environment. But government itself has its own limitations. Is government up to the job?

There are two obstacles to effective government action. The first is **imperfect information**. Regulators often have a hard time obtaining accurate information about the benefits and costs of pollution reduction. Benefits such as reduced incidence of cancer, visibility improved, and ecosystems salvaged are hard to measure and even harder to quantify. Costs are also hard to gauge accurately because they depend on the details of how an industry actually operates. Under these circumstances, even well-meaning bureaucrats may have a difficult time imposing regulations that achieve cost-effective control of pollution.

The second obstacle lies in the **opportunity for political influence**. How much impact do ideology and raw political power have in determining what types of pollution are regulated, which natural resources are protected, and which polluters are punished? Evaluating the importance of this problem requires a theory of governmental action. Economics, like all social sciences, is not a "value-free" pursuit. This is most apparent in political economy, where scholars of different political persuasions are in the business of analyzing government activity.

Traditional **conservatives** view governmental intervention as a necessary evil and argue for as limited a government role as is possible in all affairs, including environmental affairs. Conservatives argue that government legislators and regulators are self-interested individuals who desire to maximize their own well-being rather than wholeheartedly pursue their stated public mission. Such officials, in theory, seldom act in the public interest but instead serve special interests such as, for example, coalitions of particular businesses, environmental groups, civil rights groups, or labor unions. In the extreme, conservatives worry that ambitious government efforts to address environmental challenges like climate change could lead undermine a free-market capitalism, leading to what they label (negatively) as "ecosocialism."

In contrast to this conservative view, **progressives** view government as capable of promoting an activist agenda to serve the general interest of the public. Like conservatives, progressives acknowledge the possibility of government failure. Yet in contrast to the conservative position, progressives argue that the problem with government involvement in the economy is not primarily the existence of pluralistic special interest groups but the dominance of big business and development interests in the legislative and regulatory process. For example, under the Trump administration in the United States from 2016 to 2020, many argue that regulatory bodies like the EPA were "captured" by the very industries that they are intended to regulate and thus are failing to act in the public interest: we will explore capture theory and its relevance to the United States in Chapter 12. Progressives believe that greater democratic accountability can ultimately force government to act in the public interest.

As the next section illustrates, these different perspectives on the potential for effective government action will determine views on the best policies for dealing with global warming.

1.5 How Can We Do Better?

As noted above, in 2015 in Paris, almost all the countries in the world committed to cutting or capping global warming pollution. CO_2 is the most important of the greenhouse gases, contributing about 60 percent of the total greenhouse effect. It is produced by the burning and decay of carbon-based materials: coal, oil, and plant matter. Given what we have just learned about the political economy of regulation, how do we set about controlling CO_2 emissions?

Government could take many possible actions to control CO_2 emissions. We can divide such measures into roughly three categories. First is **command-and-control regulation**, the current, dominant approach to environmental protection. Under command and control, government would regulate CO_2 emissions by mandating the adoption of particular types of CO_2 control technology on, for example, coal-burning power plants. Other types of technology would be required for automobiles, still others for natural gas plants.

As we shall see, command-and-control regulation has been widely criticized as centralized and inflexible, and thus, much more costly than necessary. Many economists have advocated a switch to **incentive-based regulation**. The name "incentive-based" flows from the fact that firms are provided incentives by government to reduce emissions: a tax on pollution is one example and cap-and-trade systems (discussed later) are another example. In incentive-based approaches, the government sets emission targets by putting a price on pollution, and they leave it up to industry to figure out the best way to cut emissions.

Finally, government can intervene more directly to encourage the development and diffusion of new **clean technologies**. For example, government can force firms to meet energy-efficient design standards, such as building codes. Or government could promote clean technological change through its investment activities—by favoring rail transport infrastructure over autos or providing research and development funding for solar energy. Which of these is the best approach?

Of these three methods, economists of all stripes believe that incentive-based approaches, where feasible, are the best foundation to reduce pollution and resource degradation. There are two major policy tools: **pollution taxes** and **cap-and-trade** systems. To deal with U.S. CO_2 emissions, for example, a tax based on the carbon content of fuels (a carbon or CO_2 tax) would be one of the most effective policies we could use. By raising the price of "dirty" (carbon-intensive) fossil fuels, the marketplace would promote "clean" (lower carbon) fuels such as renewable electric power. The alternative approach, cap-and-trade, would place a cap on total U.S. CO_2 emissions. Then the government would auction off just enough permits to emit a ton of CO_2, so that the auctioned permits add up to the cap's total. Just like a CO_2 tax, cap-and-trade would also place a price on pollution, in turn raising the price of dirty fuels. As we will discuss later, California is in the process of implementing a statewide cap-and-trade law for global warming pollution.

How high should the tax be? That depends on the underlying "How much is too much?" goal. Revisiting the SCC debate from the previous section, to help achieve 80 percent reductions by 2050 we could impose a tax of $185 per ton of carbon dioxide emitted into the air. What would be the impact? A tax of $185 per ton of carbon would raise gas prices by about $1.85 a gallon and coal-fired electricity by around 19 cents per kilowatt hour (kWh)—very significant increases in both gasoline and electricity prices here in the United States. While this would certainly drive rapid shifts toward cleaner power and transport, these kinds of energy price increases—if not cushioned—could pose serious hardship, especially for low-income Americans who spend a disproportionate share of their monthly paychecks on gasoline, heat, and electricity.

How to ease the blow to consumers and make this kind of policy politically possible? A CO_2 tax, or a government auction of CO_2 permits, would generate a lot of revenue. And to offset the problem of higher energy bills, much of this revenue could be rebated directly to taxpayers. One variant of a cap-and-trade system, dubbed "Cap and Dividend," would involve issuing one share of the total U.S. CO_2 quota, established by the government, to every person in the country.[8] A nongovernmental organization would then hold these shares in trust and, each year, auction them off to companies selling products that emit global warming pollutants (oil refineries, electric power producers, etc.). For each ton of CO_2 emitted annually, a company would have to buy a 1-ton permit at auction. At the end of the year, each citizen would receive a check equal to his or her share of permits in the annual auction. Estimates put the likely dividend at more than $600 per person each year. And it appears that under a Cap and Dividend system, most Americans would actually be better off economically—their dividend check would be larger than their increased energy bills. This would be a terrific way to make controlling global warming pollution a politically popular idea!

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[8] See Barnes (2001).

At the end of the day, putting a price on pollution—either through a tax or some form of cap-and-trade—is the number one general recommendation from economists for protecting the environment. And done right, this kind of policy can actually benefit low- and middle-income consumers. However, pollution taxes are still taxes. Around the world, increasing the price of basic commodities like transportation or energy is politically quite difficult regardless of rebate policies that cushion the blow. Given this political infeasibility, many economists now recommend direct government promotion of clean technologies to achieve ambitious pollution reduction goals.

This was the direction taken by the 2022 U.S. law, the Inflation Reduction Act. The IRA provided a series of tax incentives to reduce the cost of a whole suite of low-carbon technologies, ranging from the construction of electric vehicle and battery plants, to new solar and wind projects, to household measures to replace fuel oil and natural gas heating systems with electric heat pumps. Biden's EPA also took steps to directly cut pollution from the power sector and from automobile fleets, while reducing red-tape that slowed down the siting of clean energy infrastructure, including transmission lines and offshore wind. Other clean technology polices include revamping the transport system; promoting high-speed rail as a substitute for short plane flights; restructuring zoning laws to encourage denser urban development; and increasing investment in mass transit. In addition, government-funded research and development (R&D) of new energy technologies, in particular those that utilize renewable, noncarbon-based sources, such as battery storage, baseload geothermal or modular nuclear reactors could be promoted.

In Chapter 18, we will look at how a 50-year effort by governments across the world to incubate renewable energy has now brought many of these technologies to a point where they are as cheap, or cheaper, than fossil power. Combining significant carbon taxes with substantial government-sponsored policies to promote clean-energy technologies and an aggressive approach to promoting efficient energy use is the route to achieving deep reductions in global warming pollution by 2050.

Conservative economists would be suspicious of government regulations mandating energy efficiency or government-funded support of clean-energy technologies. The question they would ask about such an agenda would be, can the government do a better job developing appropriate technologies than the market already does? First, conservatives would charge that the R&D pool is likely to become just another government pork barrel. Second, even granting efficient operation, some would maintain that government bureaucrats would have a hard time picking winners and determining which potential technologies are feasible, cost-effective, and environmentally benign.

Progressive economists would respond that existing government decisions such as energy tax breaks for fossil fuels, highway construction funds and other subsidies for auto transport, tax, and zoning policies that encourage suburbanization, and high levels of poorly targeted R&D funding already constitute a de facto plan with major negative environmental and economic effects. The choice, therefore, is not between free markets and central planning but rather between myopic and farsighted government policies.

Progressives maintain that on energy policy, our market system (which is *already* affected by substantial government involvement) has failed miserably to deliver appropriate technology. Because private investors do not take into account the tremendous costs to society of carbon-based fuels, incentives do not exist to develop appropriate technologies. In addition, a network of vested interests, inappropriate government subsidies already in existence, and substantial economies of scale all justify government involvement. Due to the massive nature of the market failure, the argument is that picking winners would not be hard: among the obvious candidates are energy efficiency technologies, batteries, solar cells, and off-shore wind power, to name a few.

How can we do better? Most economists argue that a greater reliance on incentive-based approaches, such as pollution taxes or cap-and-trade systems, makes sense. Economists who hold a progressive viewpoint and/or who believe deep cuts in global warming pollution are needed argue that government should also take a much more active hand in promoting the development and diffusion of clean technologies.

1.6 Can We Resolve Global Issues?

The last of the four questions focuses on global environmental challenges like climate change. Whether a government relies primarily on traditional regulatory mechanisms to achieve greenhouse gas reduction targets or employs more incentive-based regulations and direct investment tools, its efforts will be in vain if other nations do not also reduce emissions. Global warming requires a global solution.

CO_2 reduction is what is known as a **public good**, a good that is consumed in common. This means, for example, that if Europe cuts back CO_2 emissions by 20 percent, the whole world benefits. But since emission reduction is costly, each country would prefer to see the other cut back and then get a “free ride” on the other’s action. Because every country is in this position, there is great incentive for signatories to a treaty to cheat on any agreement. One reason that nations are reluctant to commit to substantial CO_2 reductions is the fear that other countries will not comply, and, thus, their sacrifice will be meaningless in the long run.

However, economists would welcome being proven wrong in this logic. The fact that most countries are moving ahead with reductions in greenhouse gas emissions under the Paris framework suggests that under a sufficient environmental threat, nations can work together to at least mitigate the impact of the free-rider problem. With global warming, however, a major, long-run challenge will be balancing the needs of low- and medium-income countries to continue to raise their citizens out of poverty. Rapid economic growth (led by China), increasing per capita energy use, and, in some places, accelerated deforestation, are all quickly increasing the share of global warming pollution arising in the developing world (More on these issues in Chapters 18–20.). At the same time, developing countries have more to lose from global warming because they have fewer resources to finance adaptive measures, from resettlement to irrigation to building sea walls.

Beyond climate change, economic growth in low-income countries has its own environmental costs and may prove **unsustainable**. The economic growth process is often rooted in exploitative colonial relationships that have encouraged the establishment of lopsided, resource-dependent economies. In the modern context, debt has replaced colonial status as the mechanism by which wealth flows from the poor to the rich. Deforestation, overgrazing, and massive pollution from mineral and oil development persist, reinforced by a network of government policies favoring local elite and multinational corporate interests, all occurring in an environment where common property resources are available for exploitation.

When economic growth fails to compensate for natural resources depleted in the process, the economic development process is unsustainable; put another way, growth today comes at the expense of future generations. (For a more careful definition of sustainable development, see Chapter 19.) And ultimately, the core global challenge around climate and other environmental issues is meeting the needs of what will soon be ten billion people on earth who are all aspiring to a better quality of life. These aspirations were captured in a UN agreement in 2015—the adoption of seventeen different UN Sustainable Development Goals (SDGs). These range from ending energy poverty and hunger, to gender equity, climate action and protecting life on land and in the ocean.

Addressing the UN goals requires developing technologies and lifestyles that radically reduce environmental impact in the production and use of goods and services. As we will see in Chapter 19, there are good reasons to think that global population will stabilize in the second half of the century, so the critical need going forward is to dramatically reduce the *environmental footprint per person* in high consumption countries.

Consumption impacts are very unequal. The average American contributes about 20 times the amount of global warming pollution as the average person in India: this means that American consumption is much more of climate problem than India’s population growth, at least for now. But as India works to bring more than half a billion people out of poverty, what will be the impact on the climate? The good news on this front is that renewable energy (solar and storage in particular) is rapidly becoming cheaper than fossil fuels for energy production and that electric vehicles are rapidly and affordably replacing gasoline powered cars as a way to reduce conventional air pollution in megacities across the planet. India's Paris commitment, for example, involves installing massive amounts of solar power, and the country is ahead of schedule. So, at least on the energy side of climate change, it appears that low-income countries do not need to face a trade-off between growth in power production or mobility and reducing CO_2 emissions.

This opportunity over the coming decades to end energy and transport poverty in countries like India sustainably has been made possible by the innovation of clean technologies like wind, solar, and electric vehicles. Beyond energy though, climate change is also significantly driven by deforestation—with forests falling daily to be replaced with international commodities like soybeans, beef and palm oil. To fully answer the global roots of global environmental challenges will also require businesses and consumers across the world to innovate sustainable methods of production that are centered around sustainable consumption choices. International agreements like the Paris Accord are one tool to help spur action not only to reduce fossil fuel energy use but also to reduce emissions from deforestation and unsustainable agricultural practices, helping nudge the global economy toward progress on the SDG's.

1.7 SUMMARY

This chapter has provided an introduction to the scientific issues surrounding the buildup of greenhouse gases in our atmosphere and the resultant global warming. But global warming is only one of the myriad environmental challenges posed by human activity. From the siting of landfills at the local level to regulations on chemical emissions from manufacturing plants that are issued by national governments to international agreements designed to preserve species diversity, the need for a public that is informed of the underlying scientific issues is great.

Environmental economists must also rely on scientific assessment of the dangers posed by environmental degradation to ourselves and our descendants. However, this book is *not* focused on specific environmental concerns arising from our economic activity. Instead, the point is to *illustrate the framework that economists use* for approaching pollution problems. For any such concern, from landfill siting to chemical regulation to loss of species diversity, three general questions must be answered:

1. How much pollution is too much?
2. Is government up to the job?
3. How can we do better?

When, as is increasingly common, the issue is an international one, a fourth question must also be addressed:

4. Can we resolve global issues?

To this point, Chapter 1 has both outlined the questions raised and provided a sketch of the answers that arise when grappling with the economics of environmental protection. As indicated, there is often lively debate among economists regarding the right answers. But what we do agree on is the centrality of these four questions. The rest of the book moves on to explain and explore a number of possible solutions. We hope that the reader will come away better equipped to address the local, national, and global environmental problems that we and our children will have to overcome in the 21st century.

APPLICATION 1.1

Setting Goals for Greenhouse Gas Pollution, Take One

Through UN treaties, countries have agreed that greenhouse gases be stabilized at a level that prevents "dangerous anthropogenic interference" with the climate system. In an effort to help define what this means, O'Neil and Oppenheimer (2002) relate certain physical effects to rising temperature:

- At 2 degrees F, we can expect "large-scale eradication of coral reef systems" on a global basis.
- At 4 degrees F, an irreversible process leading to the collapse of the West Antarctic Ice Sheet and a sea-level rise of 25 feet becomes significantly more likely.
- At 6 degrees F, the shutdown of the Gulf Stream leading to dramatic changes in weather patterns throughout Europe, and accelerated warming in the South Atlantic becomes significantly more likely.

The authors conclude that it is impossible to prevent a 2-degree warming. Based on the estimated impacts of different levels of warming, they call for holding global temperature increases to less than 4 degrees.

a. Is this an efficiency, ecological sustainability, or safety standard? Why?

APPLICATION 1.2

Setting Goals for Greenhouse Gas Pollution, Take Two

In 2018, the U.S. government released a study that estimated the costs to the country of two different global warming scenarios: one in which temperatures rose 9 degrees F above pre-industrial levels, and another with a temperature increase of 4.5 degrees F. Table 1.1 estimates some of the increased costs Americans will bear as a consequence of this planetary warming.

Table 1.1 Costs of Climate Change in the United States

Temperature increase in 2090 (degrees F)	9	4.3
Economic costs in 2090 ($billions/year)		
Heat-related deaths	141	59
Coastal property losses	118	92
Lost wages in outdoor industries (construction, agriculture, etc.)	155	81
Deaths related to bad air quality	26	18
Winter recreation	2	0

Source: USGCRP (2018:1349).

a. For these five categories, what are the estimated benefits in the year 2090 of holding global warming to 4.3 degrees F?

b. If we compared the monetary costs of reducing warming versus the monetary benefits of the kind you identified in part (a) to decide whether or not to reduce warming to 4.3 degrees, would our goal be efficiency, safety, or sustainability?

c. Consider the category related to winter recreation. The study projects a $2 billion per year decline in this sector by 2090 under the 9 degree F warming. Curiously, there is no predicted decline under the 4.3-degree scenario. The reason: with milder winters, more people are assumed to move north, and so more people recreate during the shorter winter season! Looking at outdoor recreation as a whole, economist William Nordhaus argued in a different study that by 2100 there would actually be cumulative "net benefits"—adding up all the yearly benefits and subtracting the yearly costs from now until 2100—of +$17 billion to outdoor recreation in the United States from a 4.3-degree warmer planet. How is this possible?

   (Hint: what might happen to outdoor recreation in the medium term, as winter gets shorter? Consider golf for example.)

d. Digging deeper: in thinking about the costs of the planet heating up, is it fair to compare the losses to skiers and sledders of shorter seasons against the gains of golfers of longer seasons? Is it fair to compare the benefits gained in say the next 30 years when overall outdoor recreation may increase because winters are shorter, to the next thousand years, when overall outdoor recreation will decrease because summers are too hot? If not, how do we decide what the overall costs of global warming will be?

KEY IDEAS IN EACH SECTION

1.1 This book explores four key economic questions about the environmental challenges of the twenty-first century, starting with the civilizational challenge posed by climate change. We focus on global climate change to illustrate the framework.

1.2 **Global warming**, arising from the accumulation of **greenhouse gases** and the resulting "carbon blanket" surrounding the planet, poses a severe threat to human welfare and natural ecosystems from heat, droughts, flooding, more intense storms, fire, ocean acidification, and sea level rise. Changing rainfall patterns that accompany warming may lead to reductions in **agricultural output**, particularly in poor countries, and major changes in **natural ecosystems**, including accelerated species extinction and higher rates of pests and disease. **Sea level** will also rise. Although scientists agree that *global warming is already a reality*, the magnitude of future warming will ultimately depend on human emissions of greenhouse gases going forward, as well as on **positive and negative feedback** effects. Crossing **tipping points** in the earth's climate system could trigger positive feedback impacts leading to a **runaway greenhouse effect.** Economists need to answer **four questions** to address a problem like global warming.

1.3 The first question is **How much pollution is too much?** Economists answer this question by comparing the costs and benefits of action. How to weigh the two? There are three basic standards. An **efficiency standard** relies solely on **benefit–cost analysis** without regard to who wins and who loses; **safety** and **sustainability standards** argue for reducing pollution to much lower levels. This is fundamentally an ethical debate over the proper way to weigh both costs and benefits. With respect to global warming pollution, **The Paris Accords** specify a target of holding warming below 4 degrees F on the basis of sustainability. Recent estimates of the **Social Cost of Carbon (SCC)** at $185 per ton justify any and all actions to reduce global warming pollution that cost less than $185 as efficient, that is, passing a benefit–cost test. For the United States, doing this would drive results that exceed the interim Paris target of 30 percent reductions below 2006 levels by 2030.

1.4 Government action is necessary to reduce pollution in a market economy—but, **is government up to the job?** Two basic obstacles to effective government action are **imperfect information** and the **opportunity for political influence**. **Conservatives** view environmental regulation as a necessary evil best kept at the absolute minimum; they believe that government action primarily serves special interests. By contrast, **progressives** see no way around an activist government role in environmental protection. From the progressive point of view, government failure results primarily from the influence of big business and development interests that can be reduced through greater transparency and democracy in government.

1.5 **Command-and-control regulation** is the dominant approach to pollution control today. In response to the question **How can we do better?** many economists have advocated adoption of **incentive-based** regulatory approaches, such as **pollution taxes** or **cap-and-trade**. Another option is the direct promotion of **clean technology** through actions such as investment subsidies, R&D funding, infrastructure investment, zoning laws, and efficiency standards. Conservatives dispute the ability of government to achieve environmental goals by promoting clean technologies.

1.6 **The final question of resolving global issues** often requires international agreement. Such agreements, in turn, face two major obstacles. The first of these is the **public good** nature of environmental agreements. Once an agreement is signed, the incentives to free-ride are great. Second, poor countries often cannot afford to invest in environmental protection. At the same time, they cannot afford not to; economic growth may lead to **unsustainable development**. The key to long-run sustainability, defined as achieving the **UN Sustainable Development Goals**, is to develop production and consumption practices that dramatically reduce humanities environmental footprint. One example is the current transition underway from fossil fuels to renewable energy.

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