Introduction and a Road Map

An economist's guess is liable to be as good as anybody else's.
Will Rogers, American humorist

Scope and Focus

Global warming is *the* environmental issue of the twenty-first century. Many believe it ranks with war and poverty as one of the greatest challenges to human well-being. But unlike war and poverty, which humanity has confronted for millennia, global warming is a recent concern. And unlike war and poverty, global warming is mainly a prospective threat and one that can in principle be met with pre-emptive action.

Understanding and responding to global warming requires many scientific disciplines including meteorology, climatology, and oceanography; the full array of biological and ecological sciences; and the engineering disciplines. But while science is a necessary component of policy, it is not sufficient.

Global warming presents both old and new political challenges. Measures to limit global warming involve near-term costs with only a promise of benefits, often far in the future. Such actions are inherently difficult for politicians focused on the next election. More fundamentally, virtually all measures to address global warming will affect existing de facto property rights and create winners and losers. And the distribution of the tens of billions of dollars in gains and losses depends on the specifics of policy – abatement targets chosen, economic sectors

penalized or subsidized, the market and regulatory tools employed. Politics permeates the rearrangement of property rights.

Confronting global warming is also an international political problem of great complexity and will require statecraft of the highest order. All countries, large and small, North and South, rich and poor, generate greenhouse gas emissions and contribute to the problem, albeit at very different historical, current, and projected levels. At the same time all countries and virtually all groups within countries will be affected by global warming – a few positively, most negatively. The daunting international political challenge is to reconcile these greatly divergent interests and capabilities, and to undertake a potentially costly program of mitigation and adaptation measures, all within an international political system that lacks an international environmental protection agency with the authority to compel emission reductions.

Global warming raises profound ethical issues. The most serious of these is the responsibility of this generation to bequeath to future generations an acceptable environmental inheritance. This question of stewardship is present in many environmental decisions – maintaining wilderness areas, conserving genetic diversity, and the long-term management of nuclear wastes. But the magnitude of our ability – this generation's ability – to affect future well-being through global climate change is unprecedented and raises ethical issues to a new level of concern. What trade-offs exist and what balance should be struck between inter-generational equity and efficiency? What do we owe the future? On the other hand, ethical concerns have a double edge. Should we sacrifice our use of cheap fossil fuel energy today so that generations yet unborn, who presumably will be richer than we are, can avoid adjusting to a warmer world?

Other, more practical ethical questions arise. How should the near-term costs of mitigating global warming be allocated among countries in a fair and efficient fashion? A global effort is needed, but without at least a perception of fairness, governments will not participate. Much the same question arises within countries. Both a concern for social justice and a need to secure political support for mitigation efforts will require some protection or compensation for those that will bear the heaviest abatement and adaptation costs. Ethics are again conflated with efficiency.

The science, politics, and ethics of global warming are not the whole story. This book is primarily about the economics of global warming. Economics offers a powerful set of theoretical and empirical techniques for formulating appropriate responses. But the economics of global warming are not detached from the scientific, political, and ethical dimensions. On the contrary, they are closely linked. Economic modeling of global warming and mitigation policies employs the results of scientific work as a starting point. These combinations of science and economics are known as integrated assessment models and are discussed later. The point here is that economic analysis of the costs and benefits is critically dependent on the underlying scientific research. Moreover, there is a close connection between political analysis and economics in devising global warming policies that are economically efficient and that have some prospect for success. Political economy is central to evaluating the policy instruments and tools to accomplish greenhouse gas abatement. And international political economy is the starting point for analyzing international environmental agreements to limit global warming.

Finally, economics rests on certain value (ethical) assumptions and can help clarify ethical choices. Although economics cannot determine an optimal distribution of wealth and income – an ethical question within the domain of moral philosophy – it can trace out the distributional consequences of policies at a point in time and over future generations. It can also trace the distributional impacts of doing nothing, or following a "business as usual" path. In short, economics can help us understand: Which countries and groups will bear the costs of global warming? Which generations? Are these distributional results equitable? How would various policies change the distributional consequences? The interplay of efficiency and equity comes out most sharply in inter-generational questions. Economics uses the tool of discounting to express future monetary values in terms of present values. It is, in effect, an inter-temporal exchange rate. Discounting has an efficiency objective – the efficient use of resources over time. But as we shall see, it also lies at the heart of the inter-generational distribution of welfare, and hence has an unavoidable ethical dimension.

To summarize, this book is primarily about the role that economics can play in the global warming debate, but it is set within a richer

matrix that includes the contributions of science, national and international politics, and equity.

Motivation and Audience

The concept underlying this book is that major events in the world are powerful drivers of advances in economics. The development of national income accounting in the 1930s was closely related to needs created by the Great Depression. Economic planning in World War II contributed to the development of input-output analysis. The burst of public interest in environment in the early 1970s led to major advances in the theory of environmental policy. Events can also overturn conventional economic wisdom. Ricardo wrote of "the inherent indestructibility of the soil," but the Dust Bowl more than 100 years later laid that idea to rest. In the seventeenth century, Grotius, the father of the freedom-of-the-seas doctrine, asserted that the vagrant waters of the sea should necessarily be free as neither navigation nor fishing could exhaust their services. That claim rings hollow with today's fishing technology and fleets.

This book contends that global warming is having a similar impact on economic research. The areas directly affected include discounting and inter-generational efficiency and equity, situating economic systems within an environmental matrix and examining interactions, the design of policy tools in second-best situations, policy formation under extreme uncertainty and potential catastrophe, and our understanding of coalition theory and the supply of global public goods.

These recent advances rest on foundations carefully laid down earlier. We believe that collecting and organizing them in a coherent fashion serves two purposes. First, it underlines how far economics has come and how far it still needs to go to successfully address global warming. Second, much of the recent analysis is appearing in working papers and technical journals or in collected volumes dealing with a narrow slice of the issues and addressed to economist colleagues who are working in this field. It is useful to organize, consolidate, and interpret these advances for those who have not had the opportunity to follow the issues in detail.

We have avoided a technical exposition to reach a wide audience, but have attempted to be accurate and current in terms of

presenting the economic underpinnings. Much of the specialized literature relies on mathematical presentation of underlying models and extensive charts and tables to present results. Because this book does not report new research, but synthesizes and interprets recent advances, we have chosen a different route. Our goal is to present complex theory in the simplest fashion possible while respecting the basic logic. We have also summarized the results and policy implications of many different empirical studies and assessed their strengths. For readers who wish to dig deeper, we have included references to the detailed studies on which this manuscript is based. If we are successful, the readers will emerge with an appreciation for the complexities of the economics but also with a firmer foundation for their own beliefs.

Structure

The book contains ten chapters. Chapter 1 starts with a brief review of the science of global warming and of international efforts to moderate climate change. It simply sets a context for readers unfamiliar with the problem and policy initiatives to date. The following chapters are structured around three questions: What amount of global warming is acceptable and what is too warm? What strategies and tools for moderating warming can be deployed? How can we mount a global effort at limiting warming in a world of sovereign states pursuing their narrow self-interest?

Chapter 2 considers whether benefit cost (BC) is an appropriate technique for framing the global warming problem and devising policy. In the BC approach, the benefits of actions to mitigate global warming are the costs averted – the monetary value of future global warming damages that are avoided by reducing greenhouse gas emissions now. The costs of the policy are opportunity costs, the valuable goods and services that the world forgoes by using real resources such as labor, physical and human capital, and technology to reduce emissions. These costs include economic output lost as less polluting but more expensive fuels and energy are used, the costs of sequestering greenhouse gas emissions, and the costs of prematurely scrapping physical capital to reduce emissions. A comprehensive framework also allows consideration of the costs and benefits of *adapting* to

global warming, the actions taken to minimize damages occurring when warming takes place. The deceptively simple conclusion from BC – that a policy is justified if the marginal costs of the policy equal marginal benefits, and total benefits exceed total costs, all properly discounted – is shown to conceal many profound complexities. An understanding of the weaknesses as well as the strengths of benefit-cost analysis is needed.

The chapters immediately following elaborate on the benefit-cost approach. Chapter 3 examines the contentious issue of discounting, a procedure that frequently divides economists and environmentalists, but one that also is hotly debated among economists in the context of global warming. As it turns out, the inter-generational equity dimension of discounting is closely linked to the issue of social (equity) weighting – the practice of giving different weights to costs and benefits accruing to individuals at different income levels. Benefit-cost analysis was originally designed to evaluate projects and policies *within* a country and *within* a single generation. But global warming is necessarily *international* and *inter-generational* in scope. This creates additional problems for discounting and social weighting of costs and benefits.

Benefit-cost analysis requires monetary values. In the case of global warming, this means monetary values for the harm (damages) that global warming will produce and for the costs of mitigation or adaptation. Finding monetary values is inherently difficult as many of the effects involve non-marketed goods and services for which there are no market prices to indicate values. Other complications are the high level of scientific uncertainty, the very long time horizons, and our inability to fully anticipate technological advances. In short, it is not surprising that the estimates are contentious. They are, however, central to attempts for a rational policy response to global warming. Chapter 4 explains how the numbers are generated. It is not always reassuring.

Chapter 5 is a transitional chapter. Mitigation – reduction in the emissions of greenhouse gases – is the centerpiece of efforts to control global warming. Putting a price on emissions is at the center of efforts at reduction. However, mitigation takes place within a larger strategic policy space. This chapter considers the broader context,

including accelerated development, adaptation, the role of technology, the "green paradox," and the extreme response of geo-engineering.

The two chapters that follow concern policy and institutional arrangements with an eye on economic criteria. Chapter 6 starts by examining the confusing ways in which mitigation targets can be expressed. It then examines the tools available to governments to reduce emissions of greenhouse gases. The principal contenders are the so-called command-and-control or regulatory measures such as vehicle mileage standards to reduce carbon emissions, market-friendly measures such as carbon taxes and cap-and-trade (tradable permits) systems, and various subsidies to accelerate the development of clean technology and renewable energy sources. These approaches can involve very different efficiency and distributional effects that need to be sorted out. Some of these complications involve interactions with existing tax structures, the recycling of revenues in both a tax and in an auctioned cap-and-trade system, the differing effects of uncertainty, and the effectiveness of government mechanisms to induce technological change.

Chapter 7 considers the intersection of climate policy and trade policy. The principal questions center on the international competitive effect of policies to limit global warming, the possibility of "carbon leakage" through international trade, whereby production of carbon-intensive activities shifts to countries with minimal or no abatement program, and the usefulness of trade policy measures to induce or coerce participation in an international mitigation regime. The prospects of carbon leakage and competitive losses, and the general scarcity of tools to forge voluntary international environmental agreements, make trade policy responses attractive but potentially dangerous. Other trade-related issues include measuring the amount of carbon "embodied" in international trade, carbon labeling as a possible trade barrier, international permit trading leading to the "Dutch disease," and manipulations of the permit market itself.

Climate change is global in scope. Chapter 8 approaches it as a complex problem in the provision of a global public good or, alternatively, preventing a public bad. The theory and practice of providing international public goods takes us into considerations of free-riding, extortion, strategic behavior, and game theory. Even though much of the

professional literature is abstract and technical, sophisticated modeling using both game theory and integrated assessment models (IAMs) can provide important lessons to inform post-Kyoto negotiations.

The evolution of climate policy through Cancun and its likely direction in the post-Kyoto period is the subject of Chapter 9.

Chapter 10 provides a brief summary, the main conclusions, and prospects.

1

Climate Change

Background Information

This chapter is for readers who are not familiar with the basic facts of climate change and climate change policy. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), released in 2007, provides comprehensive information. It consists of a Synthesis Report and reports from three working groups: WG I (The Physical Science Basis), WG II (Impacts, Adaptation, and Vulnerability), and WG III (Mitigation of Climate Change). The fifth Assessment Report is due in 2014.

The Science

The scientific basis of climate change is well established, although many quantitative relations are subject to great uncertainty. Briefly, certain gases emitted into the atmosphere change the earth's energy balance[1] by allowing incoming shortwave solar energy to enter but inhibiting exit of longwave energy. The result is that increases in the concentration of these gases in the atmosphere change the energy balance, resulting in a rise in temperature.

Global surface temperatures are climbing at an increasing rate. Since 1920, the increase has been about 0.78 °C. The linear trend for the past 50 years (1956–2005) of 0.13 °C per decade is nearly twice the rate for the past 100 years. In 2007, the IPCC reported that the eleven of the twelve warmest years on record (since 1850) occurred in the last twelve years (IPCC AR4 2007a).Other evidence includes the annual

[1] Measured by radiative forcing (watts per sq meter).

melting rate of glaciers, which has doubled since 2000 as compared to the rates in the previous two decades. The decline in Arctic sea ice has accelerated from 3 percent per decade in 1979–1996 to 11 percent in the past ten years (Füssel 2008).

The principal greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and a collection of man-made halocarbons. Carbon dioxide accounts for more than 60 percent of atmospheric emissions and is therefore central to any mitigation strategy.[2]

The principal anthropogenic sources of CO_2 emissions are consumption of fossil fuels (about 78 percent of the total) and land use changes, mainly deforestation. About half the carbon released from fossil fuel combustion goes into the atmosphere. Most of the remainder is absorbed by the oceans. There is some evidence that the oceans may be slowing their uptake of CO_2, further increasing the atmospheric burden (Schuster and Watson 2007).

The main sources of methane are solid-waste landfills, coal mining and oil and gas production, wet rice agriculture, and livestock. Sources of nitrous oxides are nitrogen fertilizer, biomass burning, and fossil fuels.

The carbon content of fossil fuels per unit of energy differs. Coal emits about 25 tons of carbon per million BTUs; oil about 20 tons; and natural gas 15 tons. Thus fuel switching is an essential part of mitigation strategy. Unfortunately, coal is by far the most abundant of the world's supply of fossil fuels.[3]

The lifetime of various gases in the atmosphere also differs. It is estimated that 50 percent of carbon emitted today will remain in the atmosphere for 100 years and 20 percent will remain for more than 1,000 years, although there is considerable uncertainty due to the complex carbon cycle.[4] Nitrous oxide has been estimated to have a fifty-year lifetime, and methane's lifetime in the atmosphere is relatively short, at twelve years. Some halocarbons, such as perflurocarbons, will persist for 50,000 years. The global warming potential of the

[2] Water vapor in the stratosphere also acts as a greenhouse gas. Variations in its concentration are not well understood.

[3] One ton of carbon is equivalent to 3.67 tons of carbon dioxide.

[4] Archer and Brovkin (2008) state the literature presents ranges from 20 to 60 percent still in atmosphere after 1,000 years. There has been confusion between the residence time of a specific carbon molecule, which may be short due to interchanges among sinks, and how long it will take for the bulge of anthropogenic atmospheric CO_2 to dissipate.