made by many researchers representing different disciplines over a period of many years. What I have done is to pull these many disparate ideas together, and to combine and package them in a coherent fashion.[15] There is an intimate connection between each of the chapters, and a consistent approach is used throughout. As well, I have tried to connect the theory to practice—and practice to the theory. Indeed, knowledge of the statecraft of treaty-making has played a major role in shaping the theory.

My aim has been to provide a theory of treaty-making, with an emphasis on strategy, not negotiation skills, that can help practitioners. My aim also has been to build a platform on which other researchers can build (and, where appropriate, disassemble and rebuild). Admittedly, it is unusual for a book to have both aims, but this is an applied subject. The theory of international cooperation has to provide an approach for the conduct of policy, or otherwise it is of no use. And practitioners need to think deeply about these problems. They are hard, and it is no good to pretend otherwise. The problems addressed by this book are too important.

In the next chapter, I demonstrate how the theory can be used to improve treaty-making. My focus is the most difficult environmental treaty negotiation ever attempted.

[15] Barrett (2002*b*) and Michael Finus (2001) offer more formal treatments of the subject. See also the survey article by Ulrich Wagner (2001).

15

Global Climate Change and the Kyoto Protocol

The pages of history are filled with stories of important and worthy international efforts that took years to triumph, and suffered many setbacks along the way. Some said the superpowers would never limit their nuclear arsenals–but they did. Some said we would never rid the world of smallpox; that we would never join together to take action to fix the ozone hole in the atmosphere. But we did.

Likewise, I am confident that world efforts to fight global warming will continue. I am equally confident that the United States will continue to be a leader in this fight. We will not give up. The stakes are too high; the science too decisive; and our planet and our children too precious. Frank E. Loy, Under Secretary for Global Affairs and Head of the US Delegation to the COP6 negotiations, speaking after the negotiations held in The Hague collapsed on November 25, 2000.

15.1. INTRODUCTION

There is a joke—told, I think, by President Ronald Reagan—that the economist, having seen something work in practice, tries to show how it could be made to work in theory. It might be argued that this is all that I have done in this book, but I hope that I have shown much more.

I began this book by demonstrating that it is not even obvious how to tell whether a particular agreement really "works." I have presented a theory capable of explaining why the more obvious successes of international cooperation have worked—and in the course of doing so I have also explained why other treaties have failed. The theory is simplistic but it also makes sharp predictions.

It shows, for example, that there is not a magic formula for success, and that different environmental problems must be approached in different ways. It also shows that enforcement is critical. It cautions against the view that countries can solve the enforcement problem simply by appealing to a state's responsibilities, by exhortation, by naming and shaming, and by offering assistance. These measures may be helpful; and, diplomatically, they may be necessary; but they will not suffice for remedying the hardest cooperation failures. To address these, countries must be able to make credible threats both to deter free-riding and to enforce compliance. The problem is that the threats needed to sustain full cooperation will not always be credible. In hurting the countries that fail to cooperate, the countries seeking to enforce an agreement typically injure themselves—and this is an outcome they would rather avoid. If there is one aspect of my approach that distinguishes it from the rest of the literature it is that I have taken the constraint of self-enforcement very, very seriously. Every important result in this book springs from the assumption of state sovereignty.

Though I have emphasized successes like the Montreal Protocol and the Fur Seal Treaty, international cooperation more often fails. On occasion, this is due to bungled diplomacy. More upsetting, however, is the lesson that there may not exist a silver bullet solution to every crossborder environmental problem. And, yet, a more positive message also emerges from this work. We might do better if we acknowledged that the constraint of sovereignty is not easily disarmed or pushed aside. If we took this constraint more seriously, we might approach cooperation problems differently. Though we may be unable to sustain a first best, we might improve on unilateralism. We might sustain a kind of second best.

Since I began writing this book, an unprecedented amount of diplomatic energy has been spent on the latest global environmental threat: climate change. As explained later in this chapter, the treaty negotiated to deal with this problem—the Kyoto Protocol—was consciously styled after Montreal (see Table 15.1 for a comparison of the two treaties). This was for obvious reasons. Climate change became a political issue shortly after Montreal was negotiated. And, like ozone layer protection, climate change mitigation is a global public good. It was natural to think that the remedy that worked for the ozone layer could be made to work, after a little rejigging, for the global climate. Upon closer examination, however, it turns out that these problems are very different (Barrett 1999*b*). Montreal was the wrong model, and the Kyoto Protocol is unlikely to sustain meaningful cooperation.

This is not for the reasons usually given—that Kyoto will do little to moderate climate change, that monitoring of the agreement will be imperfect, that its mechanisms are too complicated, and that its implementation will be too costly—though these criticisms are also valid. The main strike against Kyoto is the most crucial of all: the agreement fails to solve the enforcement problem.

Indeed, enforcement did not even attract the full attention of diplomats until quite late in the process—at the negotiating session held in The Hague in November 2000, almost three years after the Kyoto framework was first negotiated. At later sessions held in Bonn and Marrakech in 2001, an enforcement mechanism was agreed, but as I shall explain later, it has a number of design faults. This would not matter that much if a better enforcement mechanism could be devised, but it is not obvious how the Kyoto framework could be enforced effectively. However, if the negotiators had reflected on the need for enforcement and on the difficulty of devising an effective enforcement mechanism earlier in the process, they may have negotiated a different kind of treaty—one that sustained more cooperation. The need to do this is a central message of this book.

How could a treaty of such importance fail to address the enforcement problem earlier? Both before and after Kyoto was negotiated (the essential plan of Kyoto was mapped out years before the treaty was negotiated in late 1997), I put this question to actual negotiators and academics playing supporting roles. And always I received the same unsatisfying response: Enforcement was something that was best addressed later, I was told. You cannot solve every aspect of this problem in one stroke. Better

Table 15.1. *A comparison of the Montreal and Kyoto Protocols*

	Montreal	Kyoto
Quantitative emission limits:		
–for industrialized countries	Yes.	Yes.
–for developing countries.	Yes.	No.
Emission offsets.	Yes; subtracts from production the amount destroyed.	Yes; subtracts from gross emissions removal by sinks.
Comprehensive treatment of gross emissions.	Yes; trade-offs allowed within ODS categories.	Yes; limitation applies to an aggregate of six pollutants.
Non-uniform emission limits.	Yes; developing countries have different limits, though limits are uniform within country categories.	Yes; limits are country-specific, and economies in transition allowed to use an alternative base year.
Permanent emission limits.	Yes.	No; limitation only for 2008–12; future limitations by amendments.
International trading in emission entitlements.	For purposes of "industrial rationalization"; EC treated as a bubble.	Yes.
Intertemporal trading in emission entitlements.	No.	Yes; emission limits over the period 2008–12 must be met *on average* and additional reductions can be credited to the next control period.
Joint implementation.	No; not needed since all signatories subject to emission ceilings and trading is already allowed.	Yes, between Annex I countries and, through the CDM, between Annex I and non-Annex I countries.
Reporting requirements.	Yes.	Yes.
Verification procedure.	Yes.	Yes.
Side payments.	Yes; pays incremental costs for developing countries, and the Global Environment Facility (GEF) offers assistance to economies in transition.	Transfers would be effected by trading and the CDM. Funds are also made available by the Convention through the GEF; and Kyoto establishes an adaptation fund.
Compliance procedure and mechanism.	Yes, though specific punishments are not mandated.	Yes, though mechanisms with "binding consequences" can only be adopted by amendment.
Free-rider deterrence mechanism.	Yes; trade restrictions with non-parties in ODSs and products containing ODSs, plus the threat to ban trade in products made using ODSs.	No, with the possible exception of the minimum participation clause.
Leakage prevention mechanism.	Yes; in the form of trade restrictions between parties and non-parties.	No.
Minimum participation for entry into force.	Ratification by at least 11 countries making up at least two-thirds of global consumption of ODSs in 1986.	Ratification by at least 55 countries, accounting for at least 55 percent of total Annex I CO_2 emissions for 1990.

to build a framework and then, over time, give it the support it needs to develop. The reason Kyoto failed to address the enforcement problem at an early stage is that the negotiators and others involved in shaping this agreement believed it could be added on later. This, in my view, was a mistake. And I hope that this book has shown that it is a mistake that could have been foreseen when the negotiations first commenced.

Of course, a climate treaty does need to evolve. As explained in Section 1.9, a treaty addressing a problem of such complexity and about which so much is uncertain needs to be flexible; it needs to be able to adapt to new knowledge; and it needs to add in procedures over time that assist implementation. But as also explained in Chapter 1, these changes must be built on a firm foundation. And this, to my view, is Kyoto's main flaw. It provides a framework but not a foundation. That is, Kyoto fails to restructure the climate game.

The theory told in this book offers a different perspective than the one embraced by the Kyoto negotiators: the negotiators should have begun by asking what kind of enforcement was practicable, and then designed an architecture to suit this foundation. International cooperation in this area, as in others, must strategically manipulate the incentives states have to participate in and to comply with a treaty. Kyoto does not do this.

No one, not even the people most involved in negotiating the Kyoto Protocol, believe it to be perfect. But the flaws in this agreement have been tolerated for the simple reason that, in the words of John Prescott, the British Deputy Prime Minister, Kyoto has been "the only game in town."[1] So it will not suffice only to criticize Kyoto. I must rather take the joke that introduced this chapter to heart and propose a plausible alternative to Kyoto. The purpose of this chapter, and the final task of this book, is thus not only to use the theory to expose Kyoto's flaws but to demonstrate how the theory can help in constructing a superior treaty design.

Let me be clear about this. The theory does not point to a single solution. It only guides design. It prompts us to ask critical questions. More important than the specifics of my proposal is the thinking that lies behind it.

My proposal is given in this chapter's penultimate section, but first I need to give some background to this important and vexing environmental problem, beginning with the science.

15.2. CLIMATE SCIENCE

Pick any spot, and monitor the weather over a 24-hour-period. It is likely that the temperature will be cooler in the evening than in the day. The skies may be clear or cloudy, the air humid or dry. It may rain or snow, be calm or blustery. Over the course of a week, the weather will be even more variable. Over an entire year it will change more still. Now move from this spot, perhaps further inland, or nearer to the coast, or to a higher altitude, or to a different latitude. The weather will change again—and

[1] G. Lean, "UK To Go It Alone on Global Warming," *The Independent*, 2001 April 1.

the further you move from where you are, the greater (likely) will be the change. Even small changes in time and location can reveal a dramatic change in the weather.

The global climate is different. It is a measure of the earth's *average* weather—an average calculated over both space and time. The global climate is less variable and more stable than the weather. Some years may be warmer than others, and some may be wetter, but changes in the global climate are generally tiny compared to changes in the weather.

And yet the global climate isn't fixed. Even when the climate is stable it varies around some mean. And the climate can also shift—to a new mean; possibly to a new variance. Indeed, the climate has changed in this way in the past, and it will do so in the future whether a climate treaty succeeds or fails. Over the last two and a half million years, the earth's climate has oscillated between warmer and cooler periods (the last cool period was the so-called Little Ice Age, which ended about 1650), largely due to interactions between the atmosphere and the oceans, variability in the heat output of the sun, and volcanic eruptions. The worry now, however, is that the climate may be changing for a different reason: the accumulation of greenhouse gases in the atmosphere, caused by human activities. This new disturbance might best be called *human-induced* global climate change.

The atmosphere is rich with gases that trap the sun's heat, especially water vapor and carbon dioxide (CO_2). These create a natural "greenhouse effect," keeping the earth about 34 °C warmer than it otherwise would be, a temperature difference that is needed to support life. Human activities have increased the concentration of these gases in the atmosphere. Today, they are about 30 percent higher than they were before the industrial revolution.

By how much should this increase in the concentration of greenhouse gases warm the earth? In 1896, Svante Arrhenius, a Swedish chemist, tried to answer this question. He figured that a doubling in CO_2 concentrations would increase mean global temperature by about 5 °C (Rowlands 1995: 66). In hindsight, this was a remarkable calculation. A century's advancement in atmospheric science and generous application of the world's most powerful computers produces only a slightly different estimate. The best guess today is that a doubling in CO_2 concentrations would increase mean global temperature by about 1.5–4.5 °C.

Is this prediction being realized? It is impossible to know for sure. Mean global temperature has risen by about 0.3–0.6 °C since the late-nineteenth century. But this change could reflect natural variability. Knowing whether the increased concentration of greenhouse gases is causing the warming is like trying to determine whether the Helsinki Protocol made any difference to European acid rain. To answer both these questions requires a counterfactual that we do not have. To prove that human-induced climate change was real, you would have to construct another earth with an atmosphere identical to our own except for holding atmospheric concentrations of greenhouse gases to their pre-industrial level. Then you would have to take measurements of, say, global mean temperature over a long period of time for both earths and compare the data. Only then could you be sure that the increased concentration of greenhouse gases really was changing the earth's climate.

Obviously, this kind of experiment cannot be done. The best that atmospheric scientists can do is to create a computer model of the earth and its climate system, just as I have used simple theoretical models to determine the effects of a treaty on environmental protection. When the Intergovernmental Panel on Climate Change (IPCC) claims that human-induced climate change can be detected in the climate record what they mean is that their models show that it is unlikely that the earth would have warmed like it has in the last century were it not for the increase in atmospheric concentrations. Essentially, the models are supplying the needed counterfactual. The important point to make here is that this approach can't be conclusive. You can show that a model is not wrong; you cannot prove that it is right. Nevertheless, the IPCC felt sufficiently sure of the relationship to declare, in its 1995 report, that "the balance of evidence suggests a discernible human influence on global climate;" and in its follow-on report, issued in 2001, the IPCC strengthened this assessment, claiming that "most of the observed warming over the last fifty years is likely to have been due to the increase in greenhouse gas concentrations."[2]

This uncertainty about the past may seem substantial, but it is nothing compared to the uncertainty about the future. The IPCC has not changed its basic prediction that a doubling in CO_2 concentrations would increase mean global temperature by about 1.5–4.5 °C. But its predictions for mean global temperature change a century ahead have varied. The first, second, and third assessment reports (issued in 1990, 1996, and 2001, respectively) predicted temperature changes of 2–5 °C, 1–3.5 °C, and 1.4–5.8 °C, respectively, by 2100 (the latest report also predicts that sea level will rise about half a meter by 2100, mainly because of thermal expansion). These variations are fairly large; and, remarkably, these changes are mainly due to a pollutant that is not even a greenhouse gas: sulfate aerosols.

These tiny particles, emitted primarily from coal burning, are a little like volcanic dust. They reflect light away from the earth and so have a cooling effect. The first assessment report took no notice of aerosols. But after determining that the relatively cool temperatures observed in 1992 and 1993 were due at least in part to Mt Pinatubo's eruption, climatologists added sulfates to their models. The effect was striking. The models now came much closer to replicating the earth's climate history. They also predicted a reduced rate of warming. This is the main reason that the IPCC's second assessment report predicted a smaller change in mean global temperature.

Why did the third assessment report predict a larger change as compared with the previous report? The main reason is that the latest IPCC report assumes that the developing countries will reduce their emissions of sulfur dioxide, a potent local pollutant, in line with the kinds of cuts made previously by industrialized countries. This seems a reasonable assumption, but it is noteworthy that changes in our understanding of just one piece of the climate puzzle could cause such a substantial change in our prediction of future climate change.

[2] IPCC (2001: 10). Note that the expression "likely" is a judgmental estimate, defined by the IPCC to mean a 66–90 percent chance; see IPCC (2001: 2).

Indeed, other aspects of the climate are much less well understood. A number of feedbacks, some positive and some negative, could cause sudden jumps. The IPCC predictions for changes in global mean temperature are relatively small. However, they may mask bigger regional changes and the potential for very big changes, even if only with very small probability.

The phenomenon most discussed in this regard is the circulation of the North Atlantic—sometimes referred to as the thermohaline circulation. The Gulf Stream carries warm, salty water from the southern Atlantic Ocean northwards, along the eastern shore of the United States up to the elbow of Cape Cod and thence over to the seas between Greenland, Iceland, and Norway. Here, the frigid air cools the surface water, causing the dense, salty water to sink into the deep ocean. This sinking creates a kind of vacuum, and the warm, salty water from the Gulf of Mexico rushes in to fill it. It is by this means, scientists think, that the Gulf Stream conveyor belt is powered, in the process sending warm air over the continent of Europe. London, England and Battle Harbor, Newfoundland are both near 52° latitude, but London is about 10 °C warmer on average—due partly to the winds that blow warm air from the Atlantic over the British Isles.

Human-induced climate change might alter this system. Greater snow melt feeding the rivers that empty into the North Atlantic would lower the density of the surface waters, causing the conveyor belt to weaken (fresh water is lighter than salt water, which explains why small island nations can obtain fresh water from wells). A wave of positive feedbacks might then be set off. If the surface waters were to cool enough (and less salty water freezes at a higher temperature), sea ice would form, putting a lid over the ocean. This would result in even less cooling of the surface, and so weaken the Gulf Stream even more. The sea ice would itself increase the albedo (reflectivity) of the ocean surface, resulting in more cooling. And this greater cooling would in turn leave more of the surface of Europe covered in snow, increasing the albedo of the earth's surface, and so reinforcing the cooling effect. It is possible that the northern extent of the Gulf Stream (the so-called North Atlantic Drift) might even switch off. Europe might get cooler, not warmer (but note that Europe is predicted to be warmer as a result of climate change at least through 2100; see IPCC 2001). The term "global warming" implies a general warming everywhere, but plainly this is not inevitable. "Climate change" is the better term.

A "flip" in regional climate is not the only possibility. The climate might also become less stable. A warm summer might cause the sea ice to melt, cooling the North Atlantic's surface waters, and so starting up the conveyor belt again. Warmer air over the continent could then trigger a new influx of fresh water, forcing the Gulf Stream to weaken once more, and so on in a kind of cycle. Perhaps the *average* climate will not change very much. Perhaps the bigger effect will be an increase in temperature *variation*.

These kinds of changes are not just theoretical. Flips have already been found in the climate record. According to Adams *et al.* (1999: 20), "There is evidence from the study of ocean sediments that deep-water formation in the North Atlantic was diminished during the sudden cold Heinrich events and other colder phases of the last [130,000] years ... " An IPCC Workshop on Rapid Non-linear Climate Change (IPCC 1998: 6) also found evidence in the palaeoclimatic data "that an increase in the surface freshwater flux into the North Atlantic, could lead to a significant weakening or even a complete collapse of the [thermohaline circulation, or THC]," and that this could be "triggered by warming and increased precipitation associated with increasing greenhouse gas concentrations." The latest IPCC assessment report is no more encouraging. Though "current predictions using climate models do not exhibit a complete shut-down of the [THC] by 2100 ... [after this time the THC] could completely, and possibly irreversibly, shut-down in either hemisphere if the change in radiative forcing is large enough and applied long enough" (IPCC 2001: 16).

Though this uncertainty about the Gulf Stream is large, there are many other features of the climate system, including the dynamics of the Southern Ocean, that are *less* well-understood. Uncertainty is a central feature of climate change. Indeed, it is as well to recall that scientists were concerned about the prospect of global *cooling* in the early 1970s (Rowlands 1995). Further research can reduce the uncertainties, but it cannot eliminate them.

This is important for understanding the international negotiations. One reason often given for the failure to build an effective climate regime is uncertainty about the science. As noted in Chapter 8, however, the science of ozone depletion was also uncertain at the time that the Montreal Protocol was negotiated, and yet this did not block negotiation of an effective treaty. Uncertainty may not be the real reason that the climate change talks have taken so long and achieved so little. Uncertainty may rather be masking a more fundamental obstacle.

15.3. CLIMATE NEGOTIATIONS

The so-called anthropogenic greenhouse gases include not only CO_2, but also methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and (tropospheric) ozone (all but the last of these gases are controlled by the Kyoto Protocol). Halocarbons, including CFCs and HCFCs, are another kind of greenhouse gas, though it is now known that the direct warming effect of these gases is partly offset by a cooling effect caused by the reduction in stratospheric ozone. Partly for this reason, but mainly because these substances are already being controlled by the Montreal Protocol, the climate negotiations have focused on the other gases, especially CO_2, which accounts for about 80 percent of the aggregate warming potential (Nordhaus 1994). The key challenge for these negotiations has been to decide by how much these emissions should be reduced.

15.3.1. Toronto Targets

In 1988, participants at a semi-political conference on climate change recommended that, as a first step, CO_2 emissions should be reduced 20 percent from the 1988 level by 2005. As the conference was held in Toronto, this target became known as the "Toronto target." Though the 20 percent figure was plucked from the air, the idea that climate policy should be directed at meeting a *target* coupled with a *timetable* has had a lasting influence on the negotiations. It dominated negotiations up to the Kyoto meeting, and it remains the most fundamental feature of this agreement. The idea of setting targets and timetables really began a few months before, however, in another Canadian city. In setting targets and timetables for reducing emissions, the Montreal Protocol served as the model, or focal point, for climate change diplomacy. This turned out to be a mistake. As Richard Benedick (2001*a*: 13), who participated in the Toronto conference, later recalled, the Toronto participants (and Benedick takes co-responsibility for their decision) "took precisely the wrong lesson from the ozone experience."

15.3.2. Unilateral Targets

Following publication of the IPCC's interim first report in May 1990, a number of OECD countries announced their intention to reduce CO_2 emissions, and nearly all of these unilateral pledges were expressed in Toronto-like terms.[3] Some, including Austria, Denmark, Italy, and Luxembourg, pledged to meet the Toronto target precisely. Others, like New Zealand, set a goal of meeting the target by 2000 rather than 2005. Some countries set a goal of stabilizing their CO_2 emissions at the 1989 level by 2000 (Norway) or at the 1990 level by 2000 (Finland, Switzerland, United Kingdom) or to reduce emissions 3–5 percent by the year 2000 (the Netherlands). Germany, helped by reunification, set the most ambitious target: a 25–30 percent reduction in CO_2 emissions from 1987 to 2005. Australia aimed to reduce its emissions of *all* greenhouse gases not controlled under the Montreal Protocol (that is, not only CO_2, but also methane and nitrous oxide), while the United States and Canada pledged to stabilize their emissions of all greenhouse gases, *including* those covered by the Montreal Protocol. France and Japan set targets for stabilizing CO_2 emissions at the 1990 level by 2000 in *per capita* terms (allowing emissions to increase as population increased), while Spain promised only to limit *growth* in its CO_2 emissions to 25 percent. Finally, some countries did not set a national target at all. They rather agreed to play a part in achieving a collective target, the most important being the one announced by the European Community (EC) in October 1990. The EC target aimed to stabilize Community-wide emissions at the 1990 level by 2000, a target to which all its member states were collectively bound. Members of the European Free Trade Association, including Iceland and Sweden, in turn negotiated a separate agreement in which they pledged jointly to meet the EC target.

It is interesting to recall that the initial, unilateral responses to the emerging science of ozone depletion were mainly action-based, not target-based. The United States, for example, banned the use of CFCs in aerosols; it did not set a specific target for production and consumption. The EC did set a target but, as explained in Chapter 8, the EC target was more akin to the Helsinki 30 percent club target; the EC target was chosen because it was going to be met anyway. This would not be true of most of the greenhouse gas targets pledged in the early 1990s. Indeed, very few of these pledges were actually fulfilled.

[3] The International Energy Agency (1992) has compiled a comprehensive listing of climate change policies, and I am drawing here from this report.

The main reason for this is that only a few countries implemented policies to meet their targets. And this lack of action reflected the fact that no country was truly committed (in the sense explained in Chapter 3) to meeting its target. In some cases, the target was specified merely as a goal, but even where the targets were intended to be more than this there were problems. Targets were to be met unilaterally in some cases, but in other cases achievement of a target was conditional on other countries taking similar action. Though New Zealand set an ambitious goal of reducing its CO_2 emissions 20 percent from the 1990 level by 2000, it simultaneously insisted that any policy adopted should have a net benefit for New Zealand. These more cautious declarations reflected an awareness that a game was being played—a game broadly compatible with the prisoners' dilemma (PD).

The history of the European Community's target is especially telling. When the target was agreed in 1990, no decision was made as to how it would be met, and as it was a collective target, no country was individually responsible for meeting it. A collective policy was needed, and the European Commission proposed a mix of measures to include an energy conservation program and a carbon/energy tax. The tax, which was to be set at a rate equivalent to $3 per barrel of oil, rising over time to $10 per barrel, probably would have sufficed to meet the stabilization target.[4] But in May 1992, shortly before the Rio Earth Summit convened, the Community announced that its tax policy was to be conditional on other OECD countries (especially the United States and Japan) adopting the same policy themselves. As the chances that the United States would do so were nil, this meant that Europe was not prepared to implement the policy needed to achieve its own target.

Conveniently for European politicians, conditionality shifted the blame for inaction to the United States, which was heavily criticized for not adopting a CO_2 emissions target of its own. But the first Bush Administration studied the problem, and concluded that the nation's interests would be ill-served by targets. The President's Council of Economic Advisers (1990), in arguing the administration's case, cited a study predicting that the Toronto target, if extended to the year 2100, would cost the United States between $800 billion and $3.6 trillion. The Council noted that this was 35–150 times greater than the cost of complying with the Montreal Protocol, and argued that the benefits did not seem to justify the cost. The report concluded that the "highest priority in the near term should be to improve understanding in order to build a foundation for sound policy decisions. Until such a foundation is in place, there is no justification for imposing major costs on the economy in order to slow the growth of greenhouse gas emissions."[5] This comparison with Montreal is relevant. I shall return to it later in this chapter.

15.3.3. Rio

Because of the refusal by the United States to accept a target, the final text of the Framework Convention on Climate Change, which was signed by over 150 countries

[4] See Barrett (1992*d*). Note, however, that with (carbon-intensity neutral) economic growth the tax would have to be progressively increased over time if the emission ceiling were to be met indefinitely.

[5] Council of Economic Advisers (1990: 223).

at the Rio Earth Summit in June 1992, did not specify precise targets for any country.[6] Article 4 of the agreement says that developed country parties recognize "that the return by the end of the present decade to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases" would be desirable. It also urges parties to devise policies "with the aim of returning individually or jointly to their 1990 [emission] levels." But it does not require that any party meet any target. Indeed, it is precisely for this reason that the agreement was signed by so many countries (as of September 2002, by 189 countries, more than any other international environmental agreement; see Appendix 6.1) and came into force so quickly (in March 1994).

15.3.4. Berlin

Like many treaties, the Framework Convention initiated a process that included annual meetings called Conferences of the Parties (COPs). At the first of these, held in Berlin in 1995, the parties (including the United States, under a new administration) agreed that the industrialized parties should set emission limits within specified time-frames, such as 2005, 2010, and 2020, and that these should be incorporated within a protocol, possibly to be ready for signing by the end of 1997. This is where the idea of Kyoto was given birth.

It is worth noting that by this time most countries had still not devised, let alone implemented, effective policies for meeting their earlier "commitments." Some countries, like Norway, Finland, and Australia, conceded that they did not expect to meet their targets (Grubb 1995). Other countries were on course for meeting their targets, but this was because of a fortuitous confluence of circumstances—in the case of Germany, reunification; in the case of Britain, privatization of the coal and electric utility industries, hastening a substitution of natural gas for coal. Most importantly, the European Union signally failed to adopt a collective policy sure of meeting its collective target. In a letter to the chairman of the European Parliament's environment committee, leaked on the eve of the Berlin conference, Jacques Santer, the president of the European Commission, conceded that "a single tax ... applicable in all member states [was] no longer conceivable".[7] Evidence supplied to the European Commission suggested that at most three of the EU's fifteen member states—Germany, the United Kingdom, and tiny Luxembourg—would stabilize their own CO_2 emissions at the 1990 level by 2000.[8]

In the summer of 1997, the US Senate protested against the Berlin Mandate (and the Clinton administration's endorsement of it), voting 95–0 in favor of a resolution that the United States should not be a signatory to an agreement that: (1) would require that the industrialized countries reduce their greenhouse gas emissions, unless the agreement imposed similar obligations on developing country parties; and (2) would harm US economic interests. It is worth recalling, by the way, that the Senate voted by a similar margin (96–0) in favor of a non-binding resolution supporting a *faster* phase-out of CFCs than prescribed by the Montreal Protocol and the

[6] For an excellent discussion and analysis of this convention, see Bodansky (1993).

[7] *The European*, March 17–23 (1995: 1). [8] *Ibid.*

London Amendment. This is one of many indicators pointing to a huge difference between these two global problems.

15.3.5. Kyoto

A two-thirds majority of the Senate would be needed to secure ratification by the United States, and so the Senate's views needed to be heeded this time. They were not. The agreement negotiated in Kyoto in December 1997 imposed quantitative emission ceilings on the industrialized countries only. It did not impose any such ceilings on developing countries like China and India, though a mechanism was included in the treaty that could support emission reductions in developing countries through the back door as it were (the Clean Development Mechanism, discussed later in this chapter).[9]

Immediately after the negotiations ended, a number of Republican Senators demanded that the agreement come up for ratification immediately so that they could vote it down. President Clinton, however, having disregarded the Senate's earlier advice, declined to seek its consent. He knew that he could not get a two-thirds majority. And yet he signed the treaty anyway in November 1998.

Some countries not only signed but ratified the agreement soon after its adoption. As of March 2001, 33 states had ratified Kyoto. However, only one of these countries belong to the so-called "Annex I"group of countries—the countries that are obligated by the treaty to limit their emissions. The other ratifying countries—almost half of which were small island states—are not required by the treaty to limit their emissions. Why did so few industrialized countries ratify to this point?

15.3.6. The Hague

Remarkably, the main reason is that Kyoto was at this time still an unfinished document. Key issues were left unsettled in Kyoto, including the rules governing the calculation of an Annex I party's assigned amount of emissions, the so-called "flexible mechanisms," and compliance. These issues were still being negotiated in November 2000 in The Hague, at the same time that the ballots for the US presidential election were being recounted in Florida. The unresolved issues are of little importance to the non-Annex I countries, for the treaty will not restrict their emissions. Indeed, and as I shall explain later, Kyoto will also not *really* limit the emissions of a substantial number of industrialized countries. But for the other countries—for Australia, Canada, the European Union, Iceland, Japan, New Zealand, Norway, Switzerland, and the United States—the unresolved issues would determine both the costs and the benefits of participation. It would be irresponsible for these countries to ratify an agreement when it was not even known what they were agreeing to.

Another reason for the slow pace of ratification may have been the realization by the other Annex I countries that there was little to gain, and perhaps much to lose, by building a regime that ultimately failed to secure the support of the United States—the world's only superpower and the biggest emitter of CO_2 (in 1998, the United States emitted almost 65 percent more CO_2 than the European Union). In many ways, the post-Kyoto stalemate was reminiscent of the standoff that existed in 1992, when the European Community declined to implement policies to reduce its own emissions, proposing instead a multilateral remedy (a carbon-energy tax) contingent on US approval—an approach that stood no chance of succeeding.

[9] Depledge (2000) gives an article-by-article, official history of the negotiations.

15.3.7. Bonn/Marrakech

In March 2001, President George W. Bush rejected the Kyoto Protocol, effectively withdrawing the United States from the Kyoto process.

The manner in which this decision was communicated, perhaps even more than the decision itself, irked other world leaders, especially in Europe. It is possible that, had the style of his rejection been different, the response of other countries may have been different. Had he shown sincere interest in addressing the climate change problem and not implied that, because the science is uncertain, little action was justified; had he acknowledged the responsibility of the United States as the world's leading polluter, and not just complained about the cost of Kyoto to the United States; had he said that the aims of Framework Convention, negotiated under his father's administration, were worthy, but that Kyoto was not obviously the best device for realizing those aims—had he said all of this, and had he done so first by communicating directly and in private to the other leading countries on this issue, the response by these countries may have been different. By the time President Bush denounced the treaty, support for Kyoto even within Europe was already showing signs of fracturing (Benedick 2001*b*). It is possible that at least some other countries would have welcomed a fresh approach. However, in rejecting the treaty in the way that he did—and, crucially, in doing so without offering an alternative—President Bush only reinforced the view that Kyoto had to be the only way forward; and he only made other signatories, especially members of the European Union, *more* determined to conclude the negotiations and bring the treaty into force.

With the United States a declared non-participant, ratification by most of the remaining Annex I countries became essential to the treaty's entry into force. And so, at the negotiations held in Bonn in July 2001, the Europeans conceded on many issues that, only a few months before, they had been unwilling to yield to the United States. In particular, they made a generous allowance for "sinks"—credits for the absorption of carbon dioxide by forests, cropland management, and revegetation—and retreated from an earlier insistence that most emission reductions be achieved domestically rather than through international trading.

Japan, with a large share of Annex I emissions, now became a pivotal player. As the EU environment minister, Margot Wallström, admitted before the Bonn meeting, "We are fully aware of the fact that we will have to look at how to keep Japan on board in order to keep the Kyoto process alive."[10] And so Japan was offered a sweetener: a

[10] "Pronk Urges Japan to be Independent of US in Climate Policy," *The Japan Times* Online, June 13, 2001.

credit for its carbon sinks. According to Benedick (2001*b*), the concessions given to Japan in Bonn effectively lowered its required emission reduction from six to just one percent. Canada also was accommodated. It was now effectively allowed to *increase* its emissions by five percent (Benedick 2001*b*).[11] Of course, a more generous allowance for sinks would lower the price of allowance trading, harming countries like Russia. But Russia's participation was also essential to the treaty's entry into force, and so Russia was also given a concession, after a delay, at the seventh Conference of the Parties, held in Marrakech in November 2001—a huge quantity of

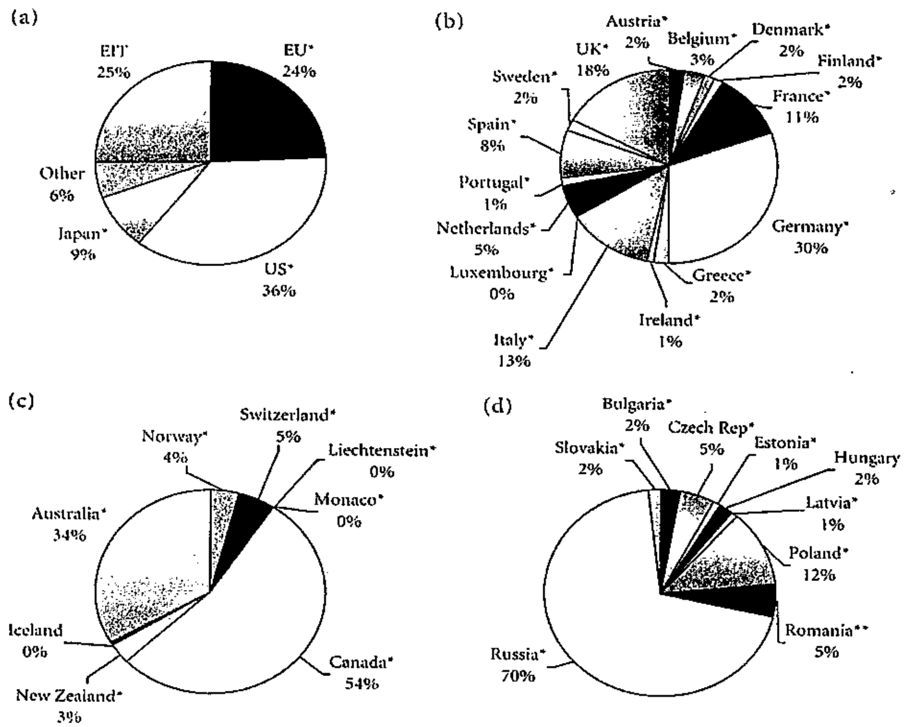

Figure 15.1 *Shares of Kyoto Protocol Annex I 1990 CO_2 emissions*
(a) Shares of 1990 Annex I CO_2 emissions, (b) Member state shares of 1990 EU CO_2 emissions, (c) Shares of other Annex I 1990 CO_2 emissions, (d) Shares of total EIT CO_2 emissions

[11] Australia was given a concession earlier. Article 3.7—the so-called "Australia clause"—allows a country to include net positive land-use emissions in calculating their base year emissions. For Australia, this is calculated to have increased base year emissions by 19 percent, making achievement of the Kyoto target much easier. See Victor (2001: 63).

forest credits that essentially added to its already huge quantity of "hot air." At both of these meetings, an agreement was also reached on a compliance mechanism—discussed at length later in this chapter.

Today, the Kyoto Protocol is substantially complete. The institutions created by the treaty will have to be developed, and the treaty will need to be superceded by subsequent agreements, specifying emission limitations for future periods. But there is no longer a reason for the Annex I countries to delay ratification.

15.4. PROSPECTS FOR KYOTO'S ENTRY INTO FORCE

Will Kyoto enter into force? To do so, it must be ratified by at least fifty-five countries, accounting for at least 55 percent of the total CO_2 emissions for 1990 of the thirty-eight Annex I countries—the industrialized countries subject to emission ceilings and listed in Figure 15.1. The first trigger for entry into force has already been met. As of September 2002, 94 countries have ratified Kyoto. But most of these countries belong to the non-Annex I group of countries—the countries that are *not* subject to an emissions ceiling—and they have nothing to lose and something to gain by ratifying Kyoto. The second trigger for entry into force has not been met yet.

As of September 2002, the Annex I ratifying countries make up only 37.1 percent of total Annex I emissions. Given non-participation by the US, entry into force depends on Russia ratifying the agreement. But even Russia's participation is not sufficient to satisfy the second trigger. Another moderately large country (Canada, Poland, or Australia) must also ratify. Alternatively, at least two small Annex I countries must ratify (Switzerland, Estonia, New Zealand, Liechtenstein, and Monaco).

Though Australia has said that it would not ratify,[12] and other countries have given mixed messages, at the second earth summit, held in Johannesburg in August–September 2002, Russia and Canada both pledged to ratify. It would thus seem that Kyoto will enter into force. We shall know for sure around the time that this book is published.

However, even if Kyoto enters into force (and these pledges to ratify may not be fulfilled), victory for the treaty cannot be declared. Like all the other transition countries, Russia has nothing to lose by ratifying, given its hot air. And Canada, already given generous credits in Bonn/Marrakesh, announced after the Johannesburg summit that it would unilaterally claim a further thirty percent credit for exports of "clean" energy (hydropower and natural gas) to the United States.[13] This last

[12] See, for example, "Australia: Kyoto Climate Accord is Defunct," *The Washington Post*, April 16, 2001, p. A13.
[13] See, for example, Steven Chase, "Liberal MPs Threaten to Withdraw Kyoto Votes," *Globe and Mail*, September 13, 2002, p. A4.

manoeuvre hints at even worse to come. If a country like Canada can claim credits in violation of the agreement and get away with it, more deceitful ways of breaking with the agreement can easily be found by other countries.

Even without any cheating or Enron-inspired emissions accounting, entry into force may make little difference. With all the concessions already given thus far, with the generous rules for emissions trading, and with the United States a non-participant, the treaty could end up having no effect at all on global emissions (Buchner *et al.* 2001).

Of course, if Kyoto does not constrain emissions, countries like Russia will have little reason to sell their surplus entitlements (Manne and Richels 2001). They may thus choose to bank these for a subsequent control period (2013–2017, say). This would make it necessary for many of the other Annex I countries to undertake real reductions. However, we cannot be sure that they would respond in this way. They might play with the accounting rules, or withdraw, or just plain fail to comply. The latter possibility is taken up later in this chapter.

It is worth recalling the experience with Montreal. The Montreal Protocol entered into force on January 1, 1989, the earliest date allowed by the treaty. If ratification of Kyoto had proceeded as quickly, the Kyoto Protocol would have entered into force in March 1999. Of course, and as explained in Chapter 8, entry into force of the original Montreal Protocol was helped by a favorable cost–benefit ratio for the main producers and consumers of CFCs. However, Montreal also created a foundation for building in greater and greater sacrifices, by these and other countries. As explained later in this chapter, Kyoto fails to do this. The real problem with Kyoto is not that it starts off achieving little. The real problem is that it doesn't provide a structure for both broadening and deepening cooperation over time.

The theory suggests that part of the explanation for Kyoto's failure is to be found in the payoffs. I turn to these below.

15.5. IMPACTS, DAMAGES, ADAPTATION

The *impacts* of climate change include physical and ecological effects: erosion of shoreline; possible bleaching of coral reefs; changes in disease prevalence due to an improved climate for disease vectors; damage from more extreme weather events; and so on. Different impacts are likely to be measured in different units. Shoreline losses, for example, might be measured in miles or square miles, whereas changes in disease prevalence would be measured in mortality, years of life lost, or disability-adjusted lost years. Knowing the individual impacts is important. But we also need a sense of the *aggregate* impact, and this can only be obtained by putting the different measures of impacts in a standard metric. This is normally done by attaching economic values to the impacts. These values are called *damages*.

Calculation of damages requires an understanding both of the expected effects of climate change on economic and ecological systems as they exist now *and on how these systems can be expected to adjust or adapt to climate change.* Forest ecosystems, for example, may move toward the poles. Similarly, farmers are sure to change the

crops they grow and the date of first planting. Adaptation, especially by economic systems, is likely to limit the impacts of climate change. This is especially true if you think of the potential for technological change. Biotechnology, for example, may engineer new crop varieties that perform better in an altered climate. Similarly, new pesticides and vaccines may prevent malaria from becoming re-established in areas like the Southern US and Europe. Ecological systems are generally slower to adjust than economic systems, and so are more vulnerable. The same may be true of the economies of developing countries. In the American Midwest, farmers already harvest their wheat using huge, air-conditioned combines; in Ethiopia they still use hand tools.

Adaptation reduces damages, but is also costly. An efficient response to climate change would thus minimize the sum of damage and adaptation costs (I consider mitigation below). Put differently, efficient adaptation will balance the benefits of small changes in adaptation—measured as reductions in damage—with the associated costs. In a market economy, much adaptation can be expected to be done automatically. Ignoring subsidies, farmers, for example, could be expected to reap nearly all the gains from adaptation (of course, farmers may still be worse off as a consequence of climate change; adaptation only reduces damages). The exceptions to this market-led adaptation are local public goods like dikes and sea walls. These would almost certainly need to be provided by the state. Crucially, however, adaptation will not normally require international cooperation. Adaptation by poor countries may be funded in part by the rich, but this assistance is a side payment—an important and justified one, as explained later in this chapter.

An essential feature of climate change is that it may actually *benefit* some sectors of some economies, at least in the medium run (for a doubling in CO_2 concentrations, say). For example, the IPCC's third assessment report predicts increases in mean stream flow in the high latitudes and Southeast Asia, but decreases in Central Asia, the Mediterranean, Southern Africa, and Australia. Recent estimates compiled by Nordhaus and Boyer (2000) show losses to agriculture in tropical countries like Brazil and India, but gains in the northern temperate climates of Canada and Russia. Seasonal effects will also vary. Warmer temperatures would increase the demand for air conditioning in the summer, but reduce the demand for space heating in the winter. Finally, the increased concentration of CO_2 may amplify plant growth (a phenomenon known as the "CO_2 fertilization"), giving a boost to agriculture and forestry nearly everywhere. Notice the contrast with stratospheric ozone depletion. This would harm some countries more than others but it would not benefit any country or economic sector.

Estimates of the damages (including adaptation costs) to the United States of a doubling in CO_2 concentrations, expressed as a percentage of Gross Domestic Product (GDP), are shown in Table 15.2. With two exceptions, the estimates are very similar (although these total figures mask substantial variability in particular categories of damage like forest loss). The Titus study is at the high end, but this analysis assumes that mean temperature will rise 4 °C, whereas most of the other studies assume an increase closer to 2.5 °C (recall that the IPCC predicts a mean global

Table 15.2. *Selected estimates of total climate change damage and CO_2 abatement costs for the United States (Percent of GDP)*

Damage study	2 × CO_2 damage	Cost study	Abatement cost	
			Stabilization	20% cut
Cline	1.1%	Jorgenson–Wilcoxen[1]	0.6%	1.7%
Fankhauser	1.3%	Edmonds–Reilly[1]	0.4%	1.1%
Tol	1.5%	Manne–Richels[1]	0.7%	1.5%
Nordhaus (1994)	1.0%	Martin–Burniaux[1]	0.2%	0.9%
Titus	2.5%	Rutherford[1]	0.2%	1.0%
Mendelsohn–Neumann (1999)	−0.1%	Goulder[1]	0.3%	1.2%
Nordhaus–Boyer (2000)	0.5%	Jorgenson *et al.* (2000)	1.25%	NA

[1] Cost estimates are from a study by the Energy Model Forum of Stanford University, which ran 14 different cost models using common assumptions and standardizing for the emission reduction scenarios shown above.

Sources: IPCC (1996), tables 3.4 and 4.1.4; Nordhaus (1994), Nordhaus and Boyer (2000), and Jorgenson *et al.* (2000).

temperature increase of 1.5–4.5 °C for a doubling in CO_2 concentrations). Mendelsohn and Neumann (1999) are at the low end. They conclude that the United States would benefit on balance from a 2.5 °C increase in temperature, due largely to gains in agriculture and forestry.

These estimates may be the best available, but it is worth underlining that they are highly uncertain. To derive them, you have to start with the science, which is uncertain, add in the impacts, which are uncertain, predict adaptation responses, which are uncertain, and then value all these changes—adding another layer of uncertainty; and one that is particularly large in the case of effects (like biodiversity loss) that are not priced by the market. And, as speculative as even these estimates may be, much less is known about the damages that might be suffered by countries other than the United States. Also important is whether the changes are gradual or sudden—slow changes imply smoother and less costly adjustment. Finally, the extent of climate change is likely to be key. The common wisdom is that damages are likely to be non-linear (Nordhaus and Boyer 2000). This means that, if climate change proves to be one percent greater than expected, damages would likely increase by more than one percent.

15.6. MITIGATION COSTS

Climate change can be mitigated by reducing atmospheric concentrations of greenhouse gases—by reducing emissions and by sucking CO_2 out of the atmosphere, a process known as "sequestration." Growing trees eat CO_2, and carbon is also stored in the soils and the oceans. Just as damages can be reduced by adaptation, so mitigation

can be achieved most efficiently both by limiting emissions and by sequestering CO_2. The two activities together limit *net* emissions.

Estimates of the costs of reducing CO_2 net emissions in the United States, expressed as a percentage of GDP, are shown in the right hand column of Table 15.2. Here again there is broad agreement among all the studies cited.

However, as with the estimates of damages, estimates of mitigation costs are uncertain and controversial. A number of people believe that mitigation costs could be very low, that some quantity of net emission reductions could be obtained for free or even at a negative cost. This is possible. It requires that people behave irrationally or that there exist structural or regulatory barriers to energy efficiency. There is some evidence that people do behave irrationally, and regulatory barriers also exist. However, the so-called "bottom-up" models that produce optimistic estimates of mitigation costs assume that irrational behavior and regulatory obstacles can be corrected at no cost. The evidence cautions against such optimism. Sweden is as environmentally conscious as any country. It also has adopted the world's highest carbon tax (International Energy Agency 1992). And, yet, Sweden's CO_2 emissions *increased* from 1990 to 1998.[14] If reducing emissions were cheap and easy, it is belied by this evidence.[15] Interestingly, Sweden's carbon tax is not the kind advocated by economists. Industrial polluters are offered a tax break relative to households, partly to defend their international competitiveness. A better designed tax would be more efficient at lowering Sweden's emissions, but it has little chance of becoming law.

15.7. BENEFIT-COST ANALYSIS

Table 15.2 tells us that the total damages (including adaptation costs) from climate change for the United States are of about the same magnitude as the total cost of reducing emissions 20 percent from the 1990 level.[16] This implies a very different cost-benefit ratio than for ozone protection. But the difference is even greater than suggested by comparing Tables 15.2 and 8.1. For the *benefits* of reducing CO_2 emissions would be substantially smaller than the total damages of a doubling in CO_2 concentrations.

The reason for this is that the benefits are the damages *avoided* by a policy or action, and it simply is not possible to avoid all climate change damages. We have been increasing the concentration of greenhouse gases for more than two centuries,

[14] According to the web page of the Climate Change Secretariat, Sweden's CO_2 emissions increased from 55,443 to 56,953 Gg over this period.

[15] It is sometimes argued that there may exist a "double dividend" to reducing emissions by means of a carbon tax. Such a tax would not only reduce emissions, but (depending on the tax and the pre-existing distortions) provide a revenue base that would allow inefficient taxes to be reduced; see Goulder (1995). An improvement in the efficiency of public finance would certainly be welcomed. But my view is that, unless we can explain why the potential (second best) efficiency gains to tax reform remain unexploited, and develop a theory that can explain how introduction of a carbon tax could lead to an improvement in the tax code, it would be imprudent to associate the "double dividend" with global climate change policy.

[16] Note that these estimates of damages and costs are independently derived. As explained in the next paragraph, the 20 percent cut in emissions cannot eliminate climate change damage.

Table 15.3. *Selected estimates of global marginal abatement benefit and global CO_2 marginal abatement cost ($US per ton C)*

Benefit study	Marginal benefit	Cost study[2]	Marginal cost	
			Stabilization	20% cut
Ayres & Walter	$30–$35	Jorgenson-Wilcoxen	$20	$50
Nordhaus	$6.8	Edmonds–Reilly	$70	$160
Cline	$7.6–$154	Manne–Richels	$110	$240
Peck & Teisberg	$12–$14	Martin–Burniaux	$80	$170
Fankhauser	$22.8	Rutherford	$150	$260
Maddison	$8.25	Cohan–Scheraga	$120	$330

[1] For most studies, the marginal benefit increases over time. The estimates presented here correspond to the period 2001–10.
[2] Cost estimates are from the Energy Models Forum simulations; see Table 15.2.
Source: IPCC (1996), tables 6.11 and 9.4.

and it is not technically feasible to return atmospheric concentrations to pre-industrial levels in the short term. Some climate change is virtually guaranteed to occur no matter what we do now. All we can hope to do is dampen the effects.

Table 15.3 provides estimates of the marginal benefit from reducing net emissions. This is defined as the present value reduction in future damages (including adaptation costs), associated with a one ton reduction in CO_2 net emissions today. To convert damages into marginal benefits requires a number of assumptions, perhaps the most important being the rate of discount. The benefits of reducing emissions today will only be felt decades, even centuries, into the future. The more the future is discounted, the lower will be the benefit of reducing emissions today. For example, Nordhaus (1991, 1994) discounts future benefits at a rate of about 4–5 percent, while Cline (1992) employs a discount rate of about 2 percent, and this difference in discounting explains most of the difference in their estimates of marginal benefits. (For purposes of comparison, the EPA's analysis of the benefits of abating ozone-depleting substances employed a 2 percent discount rate.)[17]

Full cooperation requires that countries reduce their emissions up to the level at which the global marginal benefit of abatement equals the marginal cost (if the marginal benefit exceeded marginal cost, one more ton of abatement would increase benefits by more than costs and so increase the aggregate payoff). Though the estimates vary widely, the evidence presented in Table 15.3 suggests that a 20 percent cut

[17] Choice of the appropriate discount rate is a contentious and complicated subject; see the papers in Weyant and Portney (1999). The rate is normally derived exogenously, based either on market returns or utility-related considerations. However, for a problem like climate change, the discount rate should be determined endogenously. That is, future consumption will depend in part on climate change damages and the actions taken to mitigate these, and so the discounting of consumption needs to reflect this; see Dasgupta *et al.* (1999).

Table 15.4. *Global climate policy costs and benefits (billions of $US 1990)*

	Optimal policy in 2005	Global stabilization	2 × CO_2 concentration limit
Benefit	$283	$1512	$681
Cost	$92	$4533	$1365
Net benefit	$192	−$3021	−$684
Benefit–cost ratio	3.08	0.33	0.50

Source: Nordhaus and Boyer (2000), table 7.3.

from 1990 levels is almost certain not to be justified. It is not even obvious that stabilization of CO_2 emissions could pass a benefit–cost test.

What level of mitigation would be justified? For many years, Yale economist William Nordhaus has produced estimates of the optimal climate policy. His latest estimates are presented in Table 15.4. These show that full cooperation yields a benefit–cost ratio (as compared with the base case in which nothing is done to reduce emissions) of just 3 : 1. This requires that a carbon tax be set at about $9/ton C in 2005, rising to just under $13/ton C in 2015. This is a very modest tax. It would reduce global emissions by just over 5 percent in 2015 relative to the business-as-usual level and by 11 percent by 2100.

It is interesting to compare these results with the benefit–cost estimates for ozone protection. According to Table 8.1, the benefits to the United States alone of the Montreal Protocol exceed $3.5 trillion in present value. Hence the *damages* from ozone depletion to the United States would exceed this value (the Montreal Protocol still allows some depletion). The damages to the *world* would be greater still, since no country can gain from ozone depletion. Nordhaus and Boyer (2000) estimate that the total global damages from climate change would be close to $4 trillion in present value. Obviously, both sets of estimates are subject to substantial error, but the basic message is that ozone depletion may be the more serious environmental problem. One reason for this is that ozone depletion kills people. Current studies do not show climate change to be as deadly.

However, the bigger difference between the two environmental problems is that climate mitigation is much more costly than substitution for ozone-depleting chemicals. Nordhaus and Boyer (2000, table 7.4) estimate that the optimal climate program would yield the United States a net benefit of just $22 billion. The net benefit in present value terms to the entire world of the optimal climate program is just $192 billion. This is less than the global net benefit of ozone layer protection given in Table 8.2—and it must be remembered that this estimate excludes the most important category of benefit—avoidance of skin cancers and cataracts. If you add the benefits, including health benefits, for the United States only ($3,575 billion from Table 8.1) to the global monetized benefits ($459 billion from Table 8.2), and divide by the global cost of phasing out all ozone-depleting substances ($235 billion from

Table 8.2), you get a benefit–cost ratio of over 17 : 1. Adding the health benefits to the rest of the world would raise this ratio substantially. Hence, not only do the economics of ozone layer protection recommend elimination of all ozone-destroying emissions (i.e. 100 percent abatement), but the benefit–cost ratio of this ambitious objective far exceeds the benefit–cost ratio to the more modest climate policy (demanding just 5 percent abatement in the short run and 11 percent in the long run). The economics of ozone and climate policy are really very different.

15.8. ECONOMICS OF THE KYOTO PROTOCOL

What are the economics of the Kyoto Protocol? Does Kyoto offer a benefit in excess of the cost? Does it approximate full cooperation?

According to an analysis undertaken by the Clinton Administration, the marginal cost to the Annex I countries of implementing Kyoto would range from $14 to $23/ton C (Clinton Administration 1998). This lies close to the expected marginal benefit of mitigation (see Table 15.3), implying that Kyoto is indeed a good deal for the world.

However, this analysis rests on a key assumption: that the Kyoto emission limits are met in a globally cost-effective manner. To achieve an overall emission target at minimum cost, marginal costs must be equalized over all polluters (if marginal costs were $20 for one country and $15 for another, the total cost of limiting emissions could be reduced by $5 if the latter country reduced its emissions by an extra ton while the former reduced its abatement by this same amount), and Kyoto's "flexible mechanisms" are meant to effect this outcome.

15.8.1. FLEXIBLE MECHANISMS

If trading in the allowances given to Annex I countries were perfect, all gains from trade would be exhausted, and marginal abatement costs would be equalized among these countries.[18] The non-Annex I countries are not obligated to reduce their emissions, and so their marginal mitigation costs will be near zero. However, the Clean Development Mechanism (CDM) is intended to bring marginal costs between Annex I and non-Annex I closer together. It allows an Annex I country to offset its emissions by undertaking abatement within a non-Annex I country. For example, a US company might convert a power station in China from coal to natural gas, claiming credit for the associated savings in greenhouse gas emissions. If the CDM also worked perfectly, trading would essentially be extended to the non-Annex I countries, and marginal abatement costs would be equalized everywhere—an assumption in the Clinton Administration's analysis.[19] Relying on this assumption, the Clinton Administration calculated that the total costs to the United States of implementing

[18] In addition to trading, Kyoto also allows Annex I countries to make project-based trades: an approach referred to as "joint implementation."

[19] For a more detailed critique of the Clinton Administration analysis, see Hahn and Stavins (1999).

Kyoto would be about $7–$12 billion a year (Clinton Administration 1998). For comparison, George W. Bush's global climate change initiative budgets $4.5 billion in total climate-related spending in 2003. Not a big difference, it would seem. However, President Bush claims that the Kyoto Protocol would have cost the United States up to $400 billion (Bush 2002).

There are good reasons for thinking that the Clinton Administration substantially underestimated costs. Though its analysis assumes that the market for emission entitlements would be perfect, up to the meeting in The Hague, Europe insisted that trading be "supplemental to domestic actions," implying that trading would be restricted. This would have increased compliance costs (though it might also increase environmental benefits since it would limit transactions in "hot air;" see below). As matters turned out, the agreement reached in Bonn only requires that "a significant effort" be made for achieving emission reductions domestically. However, it is unlikely that international trading would be perfect.

The rules for operating the CDM are also problematic. Because non-Annex I parties do not face an emission ceiling, incentives are created for "paper trades." The non-Annex I seller would gain by not having to do anything. The Annex I buyer would gain by not having to pay much for complying. The losers would be the other countries. But precisely because the other countries would lose from paper trades, they will want to monitor such transactions very carefully. This is why Kyoto requires that parties ensure "transparency, efficiency and accountability through independent auditing and verification of project activities." However, certification of CDM transactions will entail transactions costs, and these will limit CDM trading. The Clinton Administration's analysis of the CDMs assumes zero transactions costs.

What would have been the actual costs of implementing Kyoto for the United States? It is impossible to say for sure, but the Clinton Administration estimated that, without Annex I trading and the CDM, both marginal and total costs would increase by a factor of about ten.[20] At this level of cost, Kyoto would not be a good deal, either for the Annex I countries or for the world as a whole.

The assumption that there will be no international arbitrage, either through emissions trading or the CDM, may be extreme. However, analyses like the one by the Clinton Administration assume that emission reductions will be achieved cost-effectively at home, and this is almost certain not to happen either. Cost-effective domestic implementation would require a uniform carbon tax (or, equivalently, a perfectly competitive market in domestic emissions trading, encompassing all of the country's sources). Even the countries that have adopted a carbon tax vary the tax rate by sector (energy-intensive export industries are often exempt from paying the tax). Similarly, the domestic trading systems designed thus far are not models of market efficiency. The United Kingdom's trading program, for example, relies on voluntary participation, and Denmark's is limited to the power sector (Rosenzweig *et al.* 2002).

Moreover, the costs of implementing Kyoto will depend on the time frame. If less time is allowed for implementation, costs will rise. Manne and Richels (1998)

[20] Nordhaus and Boyer (1998) and Manne and Richels (1998) obtain similar estimates.

estimate substantial savings to a gradual transition to the Kyoto targets, with marginal costs falling by a factor of ten or more in 2010 (short lead times require that capital be retired early, and this is costly). Kyoto's design, however, fixes the end-date at 2008–12. Delays in negotiating the final agreement, and in bringing it into force, have shortened the available implementation time, and so will increase implementation costs. This will, in turn, discourage ratification.

15.8.2. Hot Air and Minimum Participation

Though emissions trading will lower overall costs, by design it will also lower the environmental benefit of the treaty. As explained previously, the emissions of the economies in transition (EIT) are substantially below their allowed levels. According to David Victor (2001, Figure 2.1), the EIT will have a surplus of about 6 billion tons of CO_2 over the period 2008–12. The other Annex I countries, by contrast, will have a deficit about 10 billion tons over the same period (assuming full participation and before taking account of the Bonn/Marrakech agreements). In the aggregate, and assuming full participation, the Kyoto constraints would bind—that is, marginal costs would be positive even with "hot air" trading. But emissions trading with the EIT will also cut the reduction in emissions achieved by Kyoto by some 40 percent. This is one reason why Europe wanted to limit the extent of trading.

Of course, participation will not be full with the United States a declared non-participant. And the concessions given in Bonn/Marrakech will limit the overall reduction in emissions achieved by Kyoto even further. These changes will lower the costs of implementing Kyoto. But, as mentioned before, they will also limit the benefit.

The Annex I countries that can trigger Kyoto's entry into force account for about 56 percent of global CO_2 emissions.[21] The second trigger for entry into force only requires that enough of these countries, making up just 55 percent of this total amount, ratify the agreement. This means that the treaty can enter into force when the countries that must actually limit their emissions account for just 31 percent of global emissions.

In fact, the problem is even worse than this. Recall that, with the United States a non-participant, entry into force will require ratification by the economies in transition, including Russia. But the Kyoto limits will not bind on these countries, and so Kyoto will only demand reductions by the remaining Annex I parties—the European Union and Japan, and Norway—plus the other Annex I countries that ratify. These countries make up only about 19 percent of global emissions. Small reductions in emissions by such a small part of the problem over such a short period of time will make little difference to the climate. Global emissions will continue to rise, even if Kyoto enters into force.

[21] The list of countries, shown also in Figure 15.1, is from FCCC/CP/1997/7/Add.1. The data on CO_2 emissions are from Nordhaus and Boyer (2000), table 3.1. Note that the trigger list of countries excludes a few countries that had not submitted data on their 1990 emissions by the time the Kyoto Protocol was being negotiated. Most importantly, the list excludes Ukraine, which accounts for just under two percent of global emissions, according to the Nordhaus and Boyer (2000) data.

15.8.3. LEAKAGE

Even this may overstate what Kyoto can accomplish. If Kyoto succeeds in reducing the emissions of these Annex I countries, the consequence may be to *increase* the emissions of other countries—including the non-Annex I parties—because of leakage. Will leakage be severe? We do not know; the literature that is available offers conflicting evidence on the magnitude of leakage for climate change.[22] But so long as leakage is positive (and, in the case of climate change, leakage will be compounded by the workings of the international energy market—a reduction in CO_2 emissions by Annex I parties would depress the world price of traded, carbon-intensive fuels, and so increase consumption of these fuels by other countries), it will dampen the environmental benefit of Kyoto.

Leakage is certainly a political worry, though it is usually expressed as a concern about a loss in competitiveness rather than in environmental effectiveness. In the debate that preceded the vote on the Byrd–Hagel Senate Resolution, Senator Byrd, a co-sponsor of the resolution, criticized the climate negotiations for not capping the emissions of developing countries: "I do not think," he said, "the Senate should support a treaty that requires only half the world—in other words, the developed countries—to endure the economic costs of reducing emissions while the developing countries are left free to pollute the atmosphere and, in so doing, *siphon off American industries* (emphasis added)." And after President George W. Bush rejected Kyoto, the European Commissioner for the Environment, Margot Wallström, when asked if the European Union should proceed without the United States, responded: "Why should we put European business and European companies under such pressure and let American Companies off the hook? Why should they play by other rules than European companies?"[23]

It was, of course, this same concern that led to Kyoto being negotiated in the first place. Recall that Europe set a collective target for reducing emissions back in 1990, and proposed meeting this target by means of a carbon/energy tax. Recognizing that this minilateral policy would have little environmental benefit, and that leakage could damage European competitiveness, Europe made adoption of this policy conditional on Japan and the United States adopting the same tax—which, of course, never happened. Kyoto was meant to fix this problem, but it has proved to be the wrong solution. It has not fundamentally changed the incentives; Kyoto has not restructured the game.

15.9. KYOTO ENFORCEMENT

How would Kyoto enforce compliance? Article 18 says that procedures and mechanisms for compliance should be determined by the parties at their first meeting and

[22] Estimates of the magnitude of leakage for climate change vary widely. In the case of a unilateral reduction in carbon emissions by the European Union, estimated leakage rates range from 2 to 80 percent (see Fisher *et al.* 1996). That is, for every 100 tons of carbon abated by the EU, global emissions could fall by from 20 to 98 tons. This is a big range. If the 80 percent figure is right, leakage would render unilateral abatement virtually impotent.

[23] S. Castle and P. Peachey, "Europe Struggles to Contain Fury at Bush's Betrayal," *The Independent*, March 30, 2001.

should include "an indicative list of consequences." Though the treaty postpones the design of a compliance mechanism, the Montreal Protocol also put off the decision of how to enforce compliance. Like Kyoto, Montreal only required that compliance enforcement mechanisms be determined by the parties at their first meeting.

However, there are two important differences between these agreements. The first is that, according to Article 18 of the Kyoto Protocol, compliance "procedures and mechanisms ... entailing binding consequences" must be approved by amendment. As required by Article 20, an amendment would require approval of at least three-fourths of the parties present and voting at the meeting of the parties. Moreover, the compliance amendment would only be binding on the parties that ratified the amendment, provided at least thee-fourths of the parties to Kyoto also ratified the amendment.

Since this is a crucial point, and one that has been little noticed, let me emphasize that the Kyoto Protocol expressly prohibits compliance enforcement with "binding consequences" except by means of an amendment. Since any party could decline to ratify a compliance amendment, it can avoid being punished for failing to comply. Montreal did not provide such an easy means of escape.

The second difference between the compliance provisions of the two treaties is that, from the beginning, Montreal included a measure for promoting participation—the trade restriction. Kyoto provides no comparable incentive. The minimum participation clause does provide a small incentive for countries to participate: the Annex I country whose ratification just makes Kyoto enter into force has an incentive to participate, for in ratifying the agreement this country would benefit from the abatement undertaken by the other Annex I parties. However, participation by any more Annex I countries would have no effect on the abatement undertaken by others. The minimum participation clause in Kyoto is not a tipping point. It is more like a linchpin.

However, it is unlike the linchpin equilibrium studied in Chapter 7. Since compliance cannot be enforced, the ratifying party that triggers entry into force could not be sure that its participation really would change the behavior of any of the other parties. These other countries could not comply and still avoid "binding consequences."

When I pointed out this fundamental weakness to a European negotiator before the meeting in The Hague, I received a cold response. "We will deal with the compliance problem later," he said. "But how?" I asked. "We are working on it," he said.

15.9.1. Compliance Negotiations

In fact, negotiators on all sides recognized the need for effective compliance, and a US negotiator told me that this was the issue on which there was the most agreement in The Hague. Though an agreement on compliance could not be reached at this conference, a proposal tabled by the president of COP6, Jan Pronk, the Dutch Environment Minister, received broad support. This required that a party that failed to comply with its emission limitation obligations in the first control period, reduce its emissions by *more* than required otherwise in the second control period. This extra reduction was meant to make up for the non-compliance and penalize the delay in reducing emissions. The "penalty" for non-compliance proposed by Pronk would begin at 1.5 and then rise by 0.25 "after the subsequent commitment period if the Party concerned is not in compliance at the end of the subsequent control period" (Pronk 2000).

An example might make the proposal clearer. According to the emissions data given in Kyoto's annex, the US emitted 4,957,022 Gg of CO_2 in 1990. By agreement, emissions must fall to 93 percent of this level by 2008–12. This means that US emissions over this period must not exceed 4,610,030 Gg annually. Suppose, however, that the United States falls short of this target, emitting an average of 4,710,030 Gg per year. Then the United States will have exceeded its emission limitation by 100,000 Gg per year, or by 500,000 Gg in total. According to the Pronk proposal, the United States would have to reduce its emissions in the next control period (2013–17) by an additional 750,000 Gg (1.5 times the 500,000 Gg shortfall), on top of the reduction needed to comply with the limits set for this control period. Essentially, the penalty for not controlling in the current period is a tighter emission limit in the next period.

As with the original approach of setting targets and timetables, there was broad agreement with the Pronk approach. Countries only disagreed about the magnitude of the penalties.[24] The response by the so-called "Umbrella" group of countries (including Australia, Canada, Japan, and the United States) merely suggested a change in the penalties, with the United States bearing a penalty of 1.3, Japan of 1.1, Australia of 1.0 (no penalty), and with Canada accepting a graduated penalty that increased to 1.3 (none of these penalties would be escalated in a future control period). The G77 and China—countries that are not bound by Kyoto to any emission limit—proposed an increase in the penalty for non-compliance to 2.0, and adding a penalty of 0.5 *per year* for as long as the party is in non-compliance (and, why not, since these countries would be exempt from the penalties![25]). After receiving these responses, Pronk revised his earlier proposals, but only in the details. His compromise proposal (Pronk 2001) established a graduated penalty, beginning at 1.1, and then rising to 1.5 and 2.0 in steps, with each step based on the size of the discrepancy between actual and allowed emissions.

In Bonn, a classic compromise was worked out, with countries agreeing to a fixed penalty of 1.3—ironically, the value advocated earlier by the United States, before it effectively withdrew from the negotiations. More important than the value, however, is the design of the enforcement mechanism. It is remarkable that countries should have debated the value of the penalty rate when the mechanism itself was so obviously flawed.

15.9.2. Design Faults

There are, in particular, five problems with the compliance mechanism agreed in Bonn.

[24] These responses are contained in FCCC/CP/2001/MISC.1.

[25] As noted by Daniel Bodansky (2001), Kyoto not only exempts the non-Annex I countries from having to meet an emission limit. It also allows these countries to have a say in determining the rules that would apply to other countries.

First, the punishment prescribed by this mechanism is forever delayed. If a party fails to pay its penalty in the second control period (presumably, 2013–17), it is assigned a new penalty for the third control period (with the penalty rate in future commitment periods to be determined by an amendment), and so on. A punishment that is always delayed is never carried out.

Second, the magnitude of the penalty depends not just on the compliance failure and the penalty rate, but on the emission limit for the follow-on control period. Importantly, this emission limit must be accepted by the party in non-compliance (otherwise this country will not participate in the next control period). If a country has any reason to think that it will not meet its first commitment period emission limit, it will insist on a generous emission limit for the next period, weakening if not wiping out the effectiveness of the penalty.

Third, the proposal relies exclusively on self-punishment. Using the framework developed in Chapter 11, it can be shown that, by abating more in a punishment phase than in a cooperative phase, the non-complying country aids enforcement. By increasing its own abatement, it makes punishment by the other parties more attractive and, thus, more credible. But this is only one ingredient of an effective strategy of reciprocity. The other parties must actually punish the party that failed to comply. Put differently, compliance with the compliance mechanism must itself be enforced, and the compliance mechanism agreed in Bonn and Marrakech fails to do this. A country that fails to comply with its emission limitation obligations can avoid paying a penalty by failing to comply with the compliance provision itself.

Fourth, the agreement reached in Bonn/Marrakech ignores the participation problem. If the compliance penalty worked as intended, it would increase the costs of participation for a country that did not comply, making non-participation by this country, either by withdrawal or by failure to ratify an amendment establishing a future control program, *more* attractive. Alternatively, a country that believed it might not comply with a given emission ceiling will make its participation conditional on being assigned a more generous emission ceiling (just as Japan and Canada won concessions in Bonn). As shown in Chapter 10, compliance and participation are joint problems requiring a joint solution.

Finally, and as mentioned previously, the compliance mechanism agreed in Bonn/Marrakech is not (legally) binding. It could only be made (legally) binding by means of an amendment, and the countries most likely not to comply will also be the countries least likely to approve of such an amendment.

I should note that Kyoto does not rely entirely on the penalty rate for enforcement. The agreement also suspends the right of the party not in compliance to sell emission credits; requires that the party explain why it was in non-compliance; and demands that it provide a plan for complying in the future. The latter two requirements especially are of the type that would be recommended by the so-called managerial approach to compliance advocated by Chayes and Chayes (1993, 1995). However, the negotiators obviously perceived these measures to be inadequate. Otherwise, why would they also want to incorporate a compliance penalty?

15.9.3. Summary

To sum up, the focus of the Kyoto negotiations was on the setting of targets and timetables. When the treaty was first negotiated, little attention was given either to compliance or participation. In a sense, the treaty at this time resembled the Helsinki Protocol. It specified targets and timetables without restructuring the game.

In contrast to Helsinki, however, the targets and timetables agreed in Kyoto required real emission reductions by some countries. To take an example, the United States is required to reduce its emissions seven percent from the 1990 level by 2008–12. Because US emissions have been rising, achievement of the Kyoto limits would require a reduction in emissions in 2008–12 of about 30–35 percent from the business-as-usual level (Bodansky 2001). For this particular problem, this is a substantial level of reduction–too substantial for the US Senate; and too substantial for President George W. Bush, as we now know.

The environmental ambition of the 1997 agreement created pressures for change; in the language of Chapter 10, Kyoto was not renegotiation-proof. Non-participation by the United States was the most dramatic consequence of the original design, but this decision set in motion other changes, especially generous allowances for sinks credits for particular countries whose ratification was needed to bring the treaty into force. Having attempted to do more, Kyoto eventually had to retreat toward Helsinki-type emission ceilings—limits that would not be very costly to meet but that also would not alter behavior very much.

Reading the newspapers, you would think that President Bush's rejection of the treaty was the spoiler. But it is very unlikely that Kyoto would have been ratified by the US Senate even if Kyoto-friendly Al Gore had been elected president. As this became increasingly clear, a number of people began to think that the Kyoto targets needed to be renegotiated. Richard Benedick (2001*b*: 5), for example, even proposed "a new, tailor-made protocol article applying to the 'special circumstances' of the United States" *after* President Bush rejected the treaty. Easier-to-meet targets would obviously have helped. But this need to renegotiate emission limits even before the treaty enters into force points to a fundamental flaw in the Kyoto approach of setting targets and timetables. Without strong enforcement, the treaty is incapable of sustaining a cooperative climate policy, except by allowing parties to do little more than they would have done without a treaty.

Daniel Bodansky (2001) has proposed an alternative to renegotiation of the Kyoto targets. He believes that the problems with the treaty could have been addressed by incorporating a "safety valve" in the negotiations held at The Hague. A safety valve would allow polluters to purchase emission allowances at a fixed price—ensuring that the price of allowances would not exceed this price. If abatement turned out to be inexpensive, the binding constraint would be the quantity of emissions established by the targets and timetables. If abatement turned out to be expensive, the binding constraint would be the escape valve price. When there is uncertainty about abatement costs—and there is for climate change—this hybrid approach is superior to a plain cap-and-trade approach.[26] The safety valve would also aid compliance and participation by limiting marginal compliance costs. However, it would not eliminate the compliance/participation problem. Bringing the Kyoto Protocol more in line with the policies commended by cost–benefit analysis is only a necessary condition for successful cooperation. To sustain full cooperation also requires effective enforcement.

15.10. TRADE RESTRICTIONS

So, how could the Kyoto Protocol be enforced? The obvious alternative to the approach agreed in Bonn is the use of trade restrictions. After all, trade restrictions enforced the Montreal Protocol, and Kyoto is in many ways a similarly styled treaty.

To be effective, trade restrictions would need to be severe (so that, when imposed, behavior will be changed) and credible (meaning that, given that a country chooses not to participate, or not to comply, the cooperating countries are better off for imposing the restrictions). It would be easy enough to make trade restrictions severe. The manufacture of virtually all goods releases greenhouse gases, and a restriction in trade in all goods would be even more severe than the Montreal restrictions. But restricting trade in all goods between parties and non-parties would probably not be credible. Even if leakage were severe—and as noted earlier, it is not obvious that it would be—the cost–benefit figures shown earlier suggest that countries would gain relatively little environmentally from a trade restriction. They would, by contrast, have much to lose by restricting all trade.

More limited trade measures would be more credible. Indeed, border tax adjustments (BTAs) are the most effective means of neutralizing trade leakage. But imposing BTAs would require calculating the CO_2 emitted in the manufacture of every traded good (how much CO_2 was emitted in the production of this book, including all the computer time spent writing it?), and this would be costly and impractical. Recall from Chapter 8 that the parties to the Montreal Protocol considered restricting trade in goods manufactured using CFCs, but decided that it would be impossible to do so. Even when Europe was thinking of imposing a common carbon tax, the Commission did not make BTAs a feature of its tax proposal. Instead, it exempted the energy using industries from having to pay the tax, to address concerns about leakage. This diluted the power of the tax in reducing emissions, and helped kill the idea of imposing a common tax.

A rough approximation of the appropriate BTA may seem a practical alternative. However, as explained in Section 12.5, crudely calculated BTAs work less well at correcting leakage. They are also susceptible to political manipulation: a convenient tool for protectionism.

Even carefully calculated BTAs are prone to manipulation, either for reasons of improving the terms of trade or for enhancing climate mitigation (a higher tax adjustment would shift carbon-intensive production toward the cooperating countries, increasing the effectiveness of the treaty). The latter motive may seem desirable, but if non-parties believe that climate mitigation is a poor investment for them or that the treaty incorporating the BTAs was unfair to them, then the interests of these countries may be harmed by application of the BTAs. As explained in Chapter 12, trade restrictions should only be used to enforce "fair" treaties.

[26] Roberts and Spence (1976) explain the superiority of the mixed regulatory system; see also Dasgupta (1982). For an application to climate, see Pizer (1999).

Finally, application of trade restrictions to the climate change problem would strain the multilateral trading system. BTAs would violate the principle of not restricting trade based on production and process methods. They may also violate the non-discrimination principle of the World Trade Organization (WTO). Of course, the WTO also allows exceptions for the purpose of environmental protection. So the use of trade restrictions in the Kyoto Protocol would expose a tension between the interests of liberalized trade and environmental protection, and between the participants and non-participants of the Kyoto Protocol. Montreal created a milder problem for the trading system. As mentioned above, it did not implement the trade restriction that would have violated the rule on production and process methods. It had also secured the participation of most of the GATT members, and all of the large ones. And it addressed a problem that harmed all states, and yet was relatively inexpensive to ameliorate.

15.11. KYOTO ALTERNATIVES

To sum up, the Kyoto Protocol is a poorly designed treaty. It may not enter into force. It may enter into force but not be fully implemented. Or it may enter into force and be fully implemented, but only because the parties would have undertaken the emission reductions required by the treaty anyway. Kyoto does not restructure the game of climate change mitigation in a way that will change international behavior materially. More importantly, Kyoto does not provide the supporting incentives needed to effect a change in behavior over time.

Can Kyoto be improved upon? A number of alternatives to Kyoto have been proposed, and these are summarized in Table 15.5.

I shall not comment in detail on these proposals.[27] The most important observation is that few of these proposals address the compliance/participation problem directly. Many will lower costs, in some cases by incorporating a safety valve/escape clause. But as noted previously, this kind of approach does not address the compliance/participation problem directly. The proposals by Aldy *et al.* (2001) and Nordhaus (1998) recommend application of trade restrictions as a means of enforcement. However, and as noted above, there are reasons to be cautious about using trade restrictions in a climate change treaty.

David Victor's (2001) proposal is different from all the others in addressing the enforcement problem directly—and creatively. Recognizing the limitations of international enforcement, Victor emphasizes the importance of domestic enforcement, arguing that the advanced industrial democracies could be relied upon to enforce

[27] For a fuller discussion of these proposals, see Barrett and Stavins (2003).

Table 15.5. *Proposals for alternatives to Kyoto*

Author(s)	Proposal
Aldy *et al.* (2001)	International cap-and-trade system coupled with a safety-valve, implemented by an international agency making additional permits available at a fixed price, the proceeds from which would finance R&D and abatement in developing countries.
Benedick (2001*b*)	United States to develop a modest domestic cap-and-trade system. A relatively small number of leading polluting countries to coordinate policy measures. Expansion in state-funded energy R&D, financed by a small carbon tax. Technology targets and technology transfer to developing countries, financed as foreign aid rather than through a trading system.
Bradford (2001)	All countries allocated permits corresponding to their business-as-usual emissions path. An international authority is given funds for purchasing such permits, with individual contributions based on criteria like per capita income and the expected benefits from climate change mitigation.
Cooper (1998, 2001)	Agree internationally on a set of actions, especially a common carbon tax, rather than targets. Developing countries allowed to phase-in the tax. Revenues to be retained by governments.
Hahn (1998)	Rather than develop a single system, allow experimentation with a number of different approaches, including cap-and-trade systems, coordinated measures, a carbon tax, and so on.
McKibbin and Wilcoxen (1997, 2000)	Establish a permit price by international agreement every ten years. Each country issues emission permits (permits that last a year) and emission endowments (permits that last in perpetuity). Developing countries given surplus endowments in early years, creating some incentive for long-term emission reductions.
Nordhaus (1998, 2002)	Harmonized carbon tax, with the level of the tax established by benefit-cost analysis, and implemented by an international voting mechanism. Developing countries participate after their per capita incomes pass a threshold. Compliance promoted by countervailing duties applied to imports from non-participating countries.
Schelling (1998, 2002)	Like the Marshall Plan, countries focus on mutually agreed actions, without international enforcement.
Schmalensee (1998)	Begin with a broad but shallow treaty, rather than with Kyoto's narrow but deep approach, and build in depth over time.
Stavins (2001)	A global approach, in which developing countries take on "growth targets," triggered by per capita income; with targets for all countries becoming more ambitious over time; and with international trading, perhaps supplemented by a safety-valve.
Stewart and Wiener (2001)	Modify Kyoto by enabling participation in a cap-and-trade system by developing countries, with targets for all countries tightened over time. Trading and CDM rules to be simplified. Compliance to be enforced by financial penalties imposed by the Compliance Committee.
Victor (2001)	Trading accompanied by a safety-valve. Developing countries to participate in trading system by adopting growth targets. Compliance promoted by buyer liability rule for permit trading.

international obligations. However, a treaty that limited participation to these countries only would be ill-suited to the climate mitigation problem, which demands a global remedy. Victor argues that the way around this problem is to change the rules for international emission trading by incorporating "buyer liability." Under this arrangement, if the seller of a permit did not reduce its emissions as promised, the buyer could not claim the emission credit. This arrangement would aid enforcement, Victor argues, because the buyers would be private entities in the liberal democracies, and their obligations, spelled out in domestic implementing legislation, could be reliably enforced by domestic institutions. Victor is right that domestic enforcement can help—we saw this most clearly in the case of the Fur Seal Treaty. But it can only help if the country participates in the treaty in the first place. As I have repeatedly argued, compliance and participation are linked problems and need to be considered jointly. Buyer liability does not solve the participation problem, and so cannot, on its own, solve the compliance problem. Looked at differently, enforcement of Kyoto would be problematic even if trading were prohibited. Turning the tables on liability does not change this basic fact.

Thomas Schelling's (1998, 2002) proposal is characteristically singular in its approach. It explicitly eschews international enforcement. It would also abandon the targets and timetables approach, relying instead on the implementation of policies and measures—that is, on actions rather than outcomes. Schelling would invite countries to pledge to adopt policies and measures, and open these to international review. The policies and measures proposed might create a kind of yardstick by which countries would be judged—providing a small incentive, perhaps, for mitigation beyond the non-cooperative level. Without international enforcement, however, his proposal cannot effect substantial mitigation. Essentially, his proposal would only improve on unilateralism by appealing to the kind of "tote board diplomacy" highlighted by Levy (1995), and noted in Chapter 1.

What we need, it seems to me, is an approach that gets around the enforcement problem, but that also provides a long-term solution to what is, after all, a long-term problem. Richard Benedick's (2001*b*) proposal has the same aim and shares common features with my own proposal, which is outlined below.[28]

15.12. THE LONG-TERM SOLUTION

In the very long term, scarcity will force us to substitute away from fossil fuels, whether we do anything to mitigate climate change or not. A climate mitigation policy needs to accelerate this substitution—and it must do so even while substantial quantities of fossil fuels remain ready to be tapped, at relatively low cost. In the short term, natural gas can be substituted for oil and coal, nuclear power may possibly be substituted for fossil fuels, and energy can be conserved. In the long run, however, new technologies will be needed, and the development of these will require substantial R&D.

[28] See also Barrett (2001*b*).

Like Montreal, Kyoto is meant to provide a "pull" incentive for R&D. In capping emissions, Kyoto raises the cost of polluting, and so creates a demand for carbon-saving technologies, just as Montreal created a demand for CFC substitutes. The difference between the two situations, as already shown, is that the cost of substituting for CFCs was low. The cost of climate change mitigation will be much higher, and this matters. When the costs of supplying a global public good are high, the incentive not to participate is high, and the burden on enforcement very great. If the treaty cannot support that burden, the result will be very weak incentives for innovation and diffusion of new technologies.

If the enforcement problem could be solved, what kinds of technical progress would we require? As indicated in a report by Battelle (2001), nearly all commercial energy is either converted into electricity for stationary uses or refined and processed for mobile uses. Basically, emissions must be cut in power plants and in automobiles. More radical possibilities also exist, but any climate mitigation policy has to contend with the fact that our economies have developed around these technologies. We have a huge installed base of equipment that runs on electricity. And our economies are automobile-based. Just as climate change damages will be high because our economies have been designed to suit our current climate, so mitigation costs will be high if we move away from our existing economic structure. Here as in other areas, our history will to some extent determine our future.

For power plants, there are two basic paths. One involves substituting away from fossil fuels. The other involves carbon capture and sequestration.

Alternatives to fossil fuels exist today. They include hydro, nuclear, solar, and wind power. But each of these alternatives has problems of its own (whether economic, environmental, or safety-related). R&D needs to address these concerns.

Carbon capture is a technology that "scrubs" the flue gases of a power plant using chemical processes to remove CO_2. The captured CO_2 must then be put somewhere—it must be sequestered—and there are a number of ways in which this might be done.[29] One is to liquify the CO_2 and inject it deep into the ocean. Water at depths greater than a thousand meters is cool and dense, and would not reach the surface for centuries. CO_2 can also be injected into the ground, in depleted oil and gas wells, coal mines, and salt domes. Carbon capture and sequestration has the advantage of allowing fossil fuels to be burned. Special interests in old energy would be protected. And, in allowing fossil fuels to be consumed, the prices of these fuels would be raised. High prices would in turn discourage non-participants from increasing their emissions, squeezing shut one of the important channels of trade leakage.

However, both storage remedies may also cause environmental damage. Ocean storage would raise the pH level, possibly harming zooplankton and bacteria. Underground storage could leak, returning CO_2 to the atmosphere. Worse, a massive leak could kill. CO_2 is heavier than air, and a sudden release would displace oxygen, suffocating everything in the neighborhood of the release.

Note that both means for reducing CO_2 emissions pose risks. In reducing one risk—the risk of climate change—we create others. Substitution of nuclear power

[29] See United States Department of Energy (1999) and Herzog *et al.* (2000).

creates risks to safety both in the short- and long-term because of the need to store the wastes. Carbon capture and storage poses similar risks. It is easier to be *for* climate change mitigation until one has considered the consequences of effecting the mitigation—not just in terms of dollars and cents but in terms of risks. Risk–risk trade-offs are a familiar feature of environmental regulation (see Viscusi 1998). They need to be incorporated in our decision-making.

A number of alternatives already exist for the conventional automobile. One is the electric car. If CO_2 emissions can be eliminated from power production, electric cars would, at a stroke, eliminate CO_2 emissions from automobiles. Another possibility is the fuel cell, especially the type fueled by hydrogen. The production of hydrogen fuel, however, would itself increase CO_2 emissions unless produced by non-carbon energy sources like nuclear power or fossil fuel energy accompanied by CO_2 separation and capture.

Mitigation can also involve sequestering the CO_2 already in the atmosphere—and, here again, there are a number of alternatives. The approach most often discussed, and already embodied within the Kyoto framework, is forest, plant, and soil sequestration. Photosynthesis fixes CO_2, and stores it in the biomass and the soil. Some sequestration by this means is already economic (see Stavins 1999). But sequestration can also be enhanced technologically. Genetic engineering could potentially augment the natural bioconversion process, and make CO_2 biomass storage more durable. An even greater source of sequestration is the oceans. Phytoplankton in the surface waters fix CO_2, and by means of the "biological pump" much of this gets stored in the deep ocean, where it is slowly mineralized by bacteria. Some areas of the ocean contain little phytoplankton and, as a consequence, fix little CO_2. The reason is often a deficiency of iron. Fertlizing these areas with iron could promote phytoplankton growth—and, hence, CO_2 sequestration.

These approaches also entail new risks. If carried out on a large scale, genetic engineering and iron fertilization could change the structure of important ecosystems. Another problem with sequestration is measurement—not only measurement of how much CO_2 is sequestered by a particular action, but also of whether an action would have occurred anyway. In the discussion to follow, I focus on the other alternatives.

15.13. A TECHNOLOGY-CENTERED APPROACH

As noted before, Montreal was the wrong model for a climate treaty. A better model may be the MARPOL treaty. This agreement, discussed in Chapter 9, abandoned the approach tried earlier that set quantitative emission limits but without the ability to monitor or enforce them. Instead, MARPOL imposed a technology standard (segregated ballast tanks). In my view, a climate agreement needs to do something similar.

15.13.1. Research and Development

But a climate treaty must also help create the kind of technological breakthroughs discussed above. As already noted, the kind of "pull" incentive created by Kyoto can only be supported by strong enforcement. And a "pull" incentive is not always sufficient to effect a change in technology. Commercial innovation often builds on government-funded research. For example, drug and vaccine development typically builds on the basic research done by the National Institutes of Health in the United States and similar institutes in other countries. Basic research needs to be a part of any climate program. Remarkably, however, all the while that Kyoto has been negotiated, government-funded energy R&D decreased. Ironically, it decreased the most in the countries most (vocally) committed to Kyoto (Battelle 2001). This situation needs to be reversed.

The knowledge obtained from basic research is a public good, and would best be supplied cooperatively. Examples of "big science" collaborative research include the International Space Station, governed by an international agreement involving the United States, Russia, Canada, Japan, and the European Space Agency, and the new Large Hadron (particle) Collider, funded by Europe, the United States, Japan, and Canada. However, the research required for climate-centered technological breakthroughs requires a broader base of support. From this perspective, a better model for R&D cooperation may be the Consultative Group on International Agricultural Research (CGIAR), funded by twenty-one industrialized nations, nineteen developing countries, several foundations, and nearly a dozen international organizations.

Richard Benedick (2001*b*) also stresses the need for R&D. However, he believes more can be achieved, at least in the near term, by agreements involving a smaller number of countries rather than a global treaty—an approach that also finds some support in game theory (Carraro *et al.* 2002). However, for reasons of legitimacy, it would be hard to defend an exclusionary treaty. And the problem itself demands a global remedy. As explained in Chapter 11, a problem like climate change is better addressed by a broad-based agreement. At the same time, the Kyoto Protocol has been justly criticized not only for exempting developing countries from having to bear similar obligations as industrialized countries but for allowing developing countries to shape the kinds of obligations only industrialized countries are expected to bear. As suggested by Daniel Bodansky (2001), this approach gives representation without taxation. An effective climate change treaty must be global, but it must also be fair—and from the perspective of all countries, both poor and rich.

Consistent with the approach outlined in Chapter 11, financing of collaborative R&D should be contingent, with each country's contribution to the global R&D fund depending on: (i) an agreed total expenditure level, assuming full participation; (ii) a share for each country determined by its circumstances (shares may be based on the UN scale of assessments or on measures of each country's historic contribution to greenhouse gas concentrations or perhaps on historic or current emissions); and (iii) the other countries contributing. The last component is especially important. It ensures that, if country *i* accedes, then all the other parties will increase their funding by a specified amount. Alternatively, if *i* withdraws, the others will lower their funding.[30] This creates an incentive to participate. It builds in a strategy of reciprocity. The

[30] This proposal is reminiscent of Guttman's (1978) proposed "matching mechanism" for the supply of public goods.

proposal also imposes a cap on the *total* financial obligation of every country. In contrast to Kyoto and a cap-and-trade system with a safety valve, parties to the R&D protocol would know the maximum total cost of participation before deciding to ratify.

Having financed the required R&D, the agreement needs also to create incentives for commercializing the technologies that can be developed from this knowledge. In contrast to basic research, commercialization is best done by the private sector. This requires a "pull" incentive.

15.13.2. Technology Standards

A pull incentive is normally best provided by the price mechanism, and Kyoto creates such a mechanism indirectly, by putting a "shadow price" on emissions. In limiting emissions, Kyoto imposes an implicit price penalty on carbon—and so creates an incentive for reducing carbon emissions. However, as explained previously, Kyoto's weak enforcement creates only a weak incentive for innovation. Somehow, a better pull incentive needs to be created.

Following the MARPOL example, this could be done by mandating standards. Standards are adopted for many reasons. First, and as explained in Chapters 4 and 9, when there are network effects, demand for a technology will depend on the number of others that use it or that can be expected to use it. Network effects can be direct (with the demand for a new fuel cell technology depending on the availability of refueling stations) or indirect (with the demand for the technology depending on the availability of replacement parts and service). Second, where there are switching costs, buyers may be reluctant to purchase a technology that locks them in, making them an orphan of a failed technology.[31] Finally, where there are substantial economies of scale, costs will be lower with technological specialization.

The setting of standards often creates a tipping effect. If enough countries adopt a standard, it may become irresistible for others to follow, whether because of network effects, cost considerations (as determined by scale economies), or lock-in.

Standards can be open or proprietary. Standards protocols should prescribe open standards, which promote competition. A relevant example of an open standard is the vehicle emission standard that created the market for the catalytic converter.[32]

Open standards are public goods. No country can be excluded from using them, and no country's use of a standard reduces the availability of the standard to others. But how should open standards be chosen, by the market or by governments? Governments are not always good at picking standards. They often pick a standard to protect a national champion, for example, but proprietary standards only yield a return if they get diffused—and, by their very nature, they tend not to be. At the same time, *de facto* standards determined by the market place are often not very good either. The free market may select the "wrong" standard[33]; or it may force companies to bring a technology to market too early—that is, before it is perfected; or it may

[31] Possibly for this reason, electric cars in the United States are leased rather than sold.
[32] An example of a proprietary standard is the Windows® operating system.
[33] This is the so-called QWERTY problem; see David (1985).

prevent any one standard from attaining the market share needed for it to tip; or it may allow a single proprietary standard to dominate, depriving users of variety. A hybrid system relying on committees comprising both government and industry representatives may be best (Farrell and Saloner 1988). The standards agreement for automobiles discussed in Section 4.13 was negotiated with substantial input from industry, as were the production and consumption limits of the Montreal Protocol.[34] A public–private partnership for climate change mitigation technologies is also needed.[35]

Standards protocols should be non-exclusionary. They are intended to promote wide adoption of a technology. Since all countries will be affected by the protocols, all should have a say in their design.

Standards also need to evolve. The standards protocols and the collaborative R&D protocol should thus be mutually reinforcing, with the R&D protocol helping to identify new standards, and with the standards protocols suggesting future directions for R&D.

The main advantage in this approach is its strategic effect on behavior. Provided that the minimum participation level were set appropriately, a strong incentive would be created for more and more countries to participate. It is likely that the tipping point would have to include Europe, Japan, and the United States at a minimum.

Tipping would also be helped by an almost automatic trade restriction. In prescribing a new standard, parties would essentially be banning imports of technologies that failed to meet the standard, just as many countries today effectively ban imports of cars not meeting their domestic vehicle emission standards and power plants not meeting their prescribed emission standards. The minimum participation level would thus not only ensure a large market for the new technology but a shrinking market for the old technology. Note that, in contrast to trade restrictions applying to a Kyoto-type agreement, trade restrictions based on standards are legal.[36] They would also be easy to administer.

Another advantage of this approach is that compliance would be easy to monitor and verify. As explained in detail by Victor (2001), monitoring of the sources and sinks controlled by the Kyoto Protocol is difficult and subject to considerable uncertainty. Effective monitoring will often require intrusive inspections—an approach not usually welcomed by the anarchic international system. Monitoring of standards agreements, by contrast, is relatively easy. And as explained in Chapter 4, compliance enforcement is almost unnecessary. Once enough countries adopt a standard, none will have an incentive to break from it.

Though the agreement to effect a technological transition needs to be global, the developing countries should not be expected to pay all their costs. These should

[34] See also Funk and Methe's (2001) case study of how global industry standards were established for mobile telecommunications.

[35] This should include technology *users* as well as producers. The interests of producers and consumers are not always consonant.

[36] Technical standards must conform to the rules of the Agreement on Technical Barriers to Trade. Note that some kinds of standards would not be allowed. For example, the WTO has ruled against the Corporate Average Fuel Economy standards adopted by the United States. However, it is relatively easy to design a standard that achieves the environmental aim while at the same time complying with the requirements of the multilateral trading system.

rather be financed by a multilateral fund, akin to the Montreal Protocol's fund, with contributions to the fund being based on arrangements similar to the R&D fund. Compensation based on incremental costs would reduce transfers as compared with emissions trading, and thus promote participation by industrialized countries. As with the Montreal Protocol's Multilateral Fund, the effect of these transfers would be to "ratchet up" the cooperation problem (see Chapter 13).

15.13.3. In the Short Term

The best thing we can do in the short run is to invest in a long-term technological transition, but further actions could also be taken. Policies and actions are more important than targets and timetables, and countries could develop a system of pledge-and-review akin to Schelling's (1998, 2002) proposal. The pledges would be unilaterally-based, but declared within a multilateral framework. One of the problems with Kyoto is that it has deflected attention from what countries can and should do on their own to mitigate climate change. This approach would shift the short run focus back to the country level. It would be enforced by domestic institutions only. These policies and measures could be incorporated in another protocol.

15.13.4. Adaptation Assistance

Finally, given that the climate is almost certain to change no matter what we do, in the medium run and in the long run, consideration needs to be given for the industrialized countries to assist the developing countries in adaptation. An adaptation fund was incorporated into the Kyoto Protocol in Bonn, financed by a tax on CDM transactions and voluntary contributions, and something like it needs to be incorporated in an alternative climate change treaty. An acknowledgment needs to be made, in my view, that the industrialized countries are mainly responsible for the accumulation of greenhouse gases; and that, while cost–benefit analysis may not commend a radical climate change policy given current knowledge, developing countries should not be made to bear the cost associated with a more modest approach.

15.13.5. Summary

To sum up, the proposal sketched here acknowledges that a climate treaty needs to think about the long run and the technological transition that will reduce greenhouse gas concentrations, as instructed by the Framework Convention. It would involve collaborative R&D in developing new technologies, follow-on protocols establishing technology standards, a multilateral fund to help spread the new technologies to developing countries, a short-run system of pledge-and-review, and a further protocol for adaptation assistance.

To be sure, the proposal outlined here is not of an ideal climate treaty.[37] Like the technology-based treaty examined in section 9.8.3, it is unable to sustain full cooperation, mainly because it is not fully cost-effective. On paper, Kyoto appears

[37] For a preliminary evaluation of this proposal, which first appeared as Barrett (2001*b*), see Buchner *et al.* (2002).

superior. But the Kyoto approach cannot be supported by the international system. Though the technology-based approach has a number of weaknesses, it recognizes that the constraint of self-enforcement must be obeyed; that incentives need to be built into the treaty such that, the more some countries do to mitigate climate change, the greater is the incentive for others to do more; that mitigation must be done globally if it is to be effective; and that, though developing countries have a responsibility to reduce their emissions, industrialized countries have a responsibility to assist them in making the required technological transition as well as in adapting to the climate changes that will occur in any event. Though the proposal suggested here is not a first best, it may be better than the alternatives in satisfying the requirements I laid out in the preface to this book: that a treaty be individually rational, collectively rational, and fair.

Finally, let me state again that the value in this proposal lies less in its details than in the thinking that lies behind it. Kyoto incorporated enforcement as an after thought. My proposal begins by asking what kinds of behavior can be enforced. As this book has shown, this is the better way to approach international cooperation problems.

15.14. CONCLUSIONS

Coming from an economist, my proposal must seem especially curious. The usual prescription suggested by economics is for the state to establish an environmental outcome (justified by cost–benefit analysis, of course), leaving it to the market to decide how best to achieve this outcome. This is how Kyoto was designed.

Kyoto actually had two role models, the Montreal Protocol, as noted previously, and the US Clean Air Act amendments. As explained in Chapter 1, the latter policy set a national ceiling for SO_2 emissions, allocated a share to every major polluting plant, and allowed these pollution entitlements to be traded. It has been a successful program. But a climate treaty has to be implemented within the anarchic international system, and this makes all the difference. The total volume of SO_2 permits is fixed by the US Congress, whereas the total volume of Kyoto permits depends on the participation level. And, of course, Kyoto cannot be enforced in the same way as a US law can be. Yes, the US government can enforce a *domestic* law implementing Kyoto. But it cannot make other countries comply let alone participate.

The usual aversion to standard-setting stems from a domestic model of regulation, one that can rely on the strong arm and visible hand of the state for enforcement. International agreements need to be self-enforcing, and so must restructure incentives. This requires strategic thinking, and the proposal for incorporating standards protocols derives from a strategic approach to treaty-making, one that is styled to suit the climate problem (different environmental problems, as I have repeatedly argued, will have different, usually second best, international remedies). That the theory should recommend an approach so contrary to conventional reasoning confirms my motivation for writing this book in the first place.

Afterword to the Paperback Edition on Global Climate Change and the Kyoto Protocol

A lot has happened since I finished writing this book in late 2002. Unfortunately, little has changed.

The main news event was Russia's decision to ratify the Kyoto Protocol, which brought this agreement into force. Romano Prodi, president of the European Commission, called this "a huge success for the international fight against climate change." However, history may judge the moment differently. Entry into force may only expose Kyoto's fundamental weaknesses.

This brings me back to the three fates I predicted for this agreement: that it would not enter into force; or that it would enter into force but not be fully implemented; or that it would enter into force and be implemented but only because it fails to reduce global emissions appreciably. Obviously, the first fate has been avoided. The latter two remain possible.

The emissions of the 15 members of the European Union—the countries that ratified the Kyoto Protocol as a block—were 1.7 percent below the 1990 level in 2003, the latest year for which data are available.[1] Kyoto requires that they be eight percent below the 1990 level by 2008–2012. To meet their collective Kyoto target, the EU-15 will thus need to reduce their emissions by an additional 6.3 percent. Since 1999, however, emissions of the EU-15 have increased in three out of four years; in 2003 they increased 1.3 percent above the 2002 level. If this is a trend, it is heading in the wrong direction.

Individual country data for Europe are more revealing. Only four of the EU-15 countries are within their Kyoto targets, as agreed in the EU burden sharing agreement: France, Greece, Sweden, and the UK. Three of these four have a current surplus of less than two percent, and the emissions of each of these four countries increased between 2002 and 2003. Many EU countries are very far from meeting their targets. Denmark is supposed to reduce its emissions by 21 percent from the 1990 level by 2008–2012, but its emissions are now 6.3 percent above the 1990 level: a gap of 27.3 percent. The gap for Austria is 26.6 percent. Spain is now 25.6 percent short of its target.

Japan's emissions were almost 13 percent above the 1990 level in 2003, about eight percent above the revised base year figure (Ministry of the Environment, Japan 2005). Kyoto requires that Japan's emissions be cut six percent from this level: a gap of 14 percent. New Zealand's emissions were almost 23 percent higher in 2003 than they were in 1990, whereas Kyoto requires that they be stabilized at the 1990 level by 2008–2012.[2] Canada's situation is worse. According to a recent government report (Government of Canada, 2005: 42), Canada's emissions in 2010 will be about 45 percent

[1] The estimates given here and in the next paragraph are from the European Environment Agency (2005).
[2] See http://www.climatechange.govt.nz/resources/reports/nir-apr05/index.html.

above its Kyoto target, in the absence of anything being done to reduce them—a figure that the report says is "currently being revised upwards."

Some countries will have no trouble meeting their Kyoto targets. According to the latest figures made available by the Framework Convention's Secretariat, Russia's emissions are 38 percent *below* its Kyoto target.[3] Of course, this is not because Russia has done anything specifically to limit greenhouse gas emissions. Russia was simply allocated "hot air" surplus entitlements in the Kyoto treaty.

Trading with Russia and the other countries with "hot air" emission limits would lower the costs to the other parties of meeting their targets, and so it might seem unimportant that so many countries should be so far off the compliance path at this stage. The problem is that trading will also lower the quantity of emissions reduced by the treaty. And think about this: such trades will mean that one country would avoid reducing its emissions by paying another country *not* to reduce *its* emissions. Will taxpayers accept this? Will voters? We shall see.

It is too early to tell what will happen. However, we can draw lessons from a recent experiment of a similar nature.

THE STABILITY AND GROWTH PACT: A LESSON FOR THE KYOTO PROTOCOL?

Like Kyoto, the Stability and Growth Pact (SGP) of the European Economic and Monetary Union was intended to address a collective action problem. The European Central Bank aims to achieve price stability, but this can be undermined by poor fiscal discipline: a cut in taxes or a rise in public spending—just the kinds of economic measures needed in a recession. Though a problem for every economy, the members of the Monetary Union have an additional incentive to overspend: the effects of their fiscal policies are borne partly by the other members of the Union. The SGP was intended to correct this free riding incentive.

The SGP prohibited countries from incurring a deficit greater than three percent of GDP when real GDP fell by less than 0.75 percent (a "mild" recession). The EU Council (including non-members of the Euro zone) was to determine by a qualified majority whether a country had an "excessive deficit," and persistent violators were to be punished by financial sanctions—a decision also to be decided by the EU Council (this time, by a two-thirds majority of the Euro members, excluding the country against which sanctions might be applied). Initially, a country found to be in non-compliance was required to make a deposit (of between 0.2 and 0.5 percent of GDP) for which it would earn no interest. If the excessive deficit persisted for two consecutive years following imposition of the initial sanction, the country in non-compliance could then be made (by the same two-thirds majority) to lose its deposit. Both penalties—the interest on the deposit and the fine—were to be redistributed to EMU countries that did not run an excessive deficit in the same year as when the infraction occurred. The idea was not only to punish the country that violated the agreement. It was also to reward the countries that imposed the punishment.

[3] See http://ghg.unfccc.int/index.html.

The SGP was tested when Germany and France, both with stagnant economies, exceeded the three percent ceiling three years running. Their violations should have triggered the sanctions mechanism—and, indeed, the European Commission recommended that the enforcement provisions of the SGP be applied. But when the time came to impose the sanctions, soon after this book was published in 2003, the Council gave both countries more time to comply. The threatened punishment was not imposed. As a consequence, the SGP collapsed.

The rules of the SGP have been criticized—among other reasons, for being too constraining. Whatever the merits of these criticisms, however, the essential point is that an agreement was negotiated, and backed by a sophisticated enforcement mechanism. When tested, it failed.

The history of the SGP illustrates the essential challenge of collective action: threats, to change behavior, must be both credible and severe. The SGP's punishments were severe. They were not credible.[4] As explained in Chapter 15, I believe the same is true of the Kyoto Protocol's enforcement mechanism.[5] Will Kyoto share the same fate as the SGP? We won't know for sure until it is tested.

PARTICIPATION

There is one major difference between these two agreements. The Euro zone consists of just 12 countries, and participation in the SGP was full. Greenhouse gases are emitted by almost 200 countries, and yet important countries like the United States, China, and India are unconstrained by the agreement, either because they failed to participate or because they participated but were not required by the agreement to reduce their emissions (perhaps that is *why* they participated!). Even if compliance with the Kyoto agreement is secured, the treaty will make little difference.

A key result of the theory developed in this book is that compliance and participation are determined jointly. Kyoto has already demonstrated that it cannot enforce participation. Will it be able to enforce compliance? Chapter 15 explains the flaws in the compliance mechanism, and how they are linked to Kyoto's failure to promote participation (a country can always avoid complying by failing to participate or by pulling out of the agreement). Here is another way to think about these connections: Will the parties making sacrifices to implement and comply with Kyoto wonder if the

[4] The SGP and the Kyoto Protocol are more alike than you might think. With a common currency, the deficits run up by individual countries are irrelevant. What matters are the deficits run up by *all* the members of a monetary union. Alessandra Casella (1999) has proposed creating a market for deficits—allocating per-country entitlements to run up deficits, and allowing these to be traded. This way, a country can exceed its deficit threshold, and purchase the difference from countries that met their thresholds. This proposal looks even more like the Kyoto Protocol. But it shares the same problem as the SGP. Casella's proposal would impose a financial penalty just at the time when a country's finances were already fragile. If the country refused to purchase deficit credits, would it be punished? Trading cannot get around the fundamental need for enforcement.

[5] Christoph Böhringer and Michael Finus (2005: 276) agree that enforcement is a challenge for Kyoto, but they argue that the agreement provides "a framework of a punishment architecture that may be developed further." Perhaps they are right, but these authors do not offer suggestions for an enforcement mechanism that would work within the Kyoto framework.

effort is worth it, when the emissions of so many other countries are unconstrained? Will they worry that their efforts may only cause emissions to rise elsewhere? Again, we will not know until Kyoto enters the implementation stage.

GOALS

Reliable data on global emissions are unavailable, but we do know the level of atmospheric concentrations. This value has been rising steadily. Before industrialization it was at about 280 parts per million (ppm). When Kyoto was being negotiated in December 1997, it was at 364 ppm. Today it is nearly 378 parts per million (ppm).[6]

How high should we let this level rise? The Framework Convention says that concentrations should be stabilized "at a level that would prevent dangerous anthropogenic interference with the climate system." This would seem a reasonable goal. (Who could be in favor of dangerous interference with the climate system?) Indeed, nearly every country supports it. Today, the only non-parties to this agreement are Andorra, Brunei, Holy See, Iraq, and Somalia. Nevertheless, I believe it is the wrong goal.

A "dangerous" concentration level implies a discontinuity (presumably, a smaller concentration is not dangerous). O'Neill and Oppenheimer (2002) try to show how such a level could be identified by focusing on three discontinuous changes that would be very serious indeed: the destruction of large scale coral reef ecosystems, the disintegration of the West Antarctic Ice Sheet (WAIS), and the collapse of the thermohaline circulation (THC). They then suggest that these three changes can probably be avoided by limiting long term warming to 1°C; that the last two can probably be avoided by limiting change to 2°C; and that the last can probably be avoided by limiting change to 3°C above 1990 global mean temperature. Noting that carbon dioxide stabilization at 450, 550, and 650 ppm would correspond roughly to a century's long warming of about 1.2°–2.3°C, 1.5°–2.9°C, and 1.7°–3.2°C, respectively, O'Neill and Oppenheimer conclude:

> "Full protection of coral reefs is probably not feasible for this concentration range. It is plausible that achieving stabilization at 450 ppm would forestall the disintegration of WAIS, but it is by no means certain, because additional warming would occur beyond 2100. Avoiding the shutdown of the THC is likely for 450 ppm."

Though O'Neill and Oppenheimer aim to demonstrate how we might identify the level of atmospheric concentrations that would trigger dangerous interference, their analysis only shows how difficult the task is. Why adopt a goal of 450 ppm if this will not protect coral reefs, if this will possibly forestall but not avoid disintegration of the WAIS, if this will likely, but not definitely, avoid a shutdown of the THC? Why not aim for 280 ppm? Or 550 ppm? Or some other level? The answers do not emerge from their analysis. To be clear, this is not a criticism. I am simply pointing out how difficult the task is of setting any particular goal for atmospheric concentrations.

[6] The December 1997 and annual 2004 estimates of CO_2 concentrations are taken from air samples at the Mauna Loa Observatory in Hawaii; see http://cdiac.esd.ornl.gov/ftp/trends/co2/maunaloa.co2.

Another problem with this approach is that it ignores the consequences of mitigation. Reducing greenhouse gas emissions will be costly. Reducing emissions by enough to stabilize concentrations at 450 ppm will be very costly.

Consider the more modest goal of limiting concentrations to a level close to twice the pre-industrial level (550 ppm)—the goal advocated by the European Union. According to a report by the UK's Department for Environment, Food and Rural Affairs (DEFRA; 2000: 17)

> "The challenge of meeting this level of reduction cannot be over-stated. Achieving it would almost certainly require a major shift away from fossil fuels. Restraining emission levels to a small increase on present levels during the 21st Century would require major cuts in emissions from developed countries, as well as action by developing countries to reduce the growth in their emissions. But developing countries rightly expect economic growth, which will increase their emissions if they follow similar patterns of industrialisation to developed countries. In order to accommodate this, developed country emissions may have to be reduced by more than the 60–70% that will ultimately be required globally; reductions of as much as 90% may be required. For comparison, the targets agreed in the Kyoto Protocol will only cut developed country emissions by 5.2% over a five year period."

One of the great challenges posed by climate change is that, while the damages from climate change could be high, the costs of substantial mitigation will definitely be high.[7] As I explain in Section 15.7, this makes the economics of a climate treaty very different from protection of the ozone layer.

To see why this matters, consider the choices we face as regards just one aspect of climate change: a possible increase in the incidence of malaria. This is sometimes mentioned as providing an imperative for substantial mitigation, and the risk is certainly important.[8] But we must also acknowledge that malaria prevalence is high today and can be reduced, both now and in the future, by means other than mitigation. Environmental controls, widespread use of combination antimalarials, bed nets—all these interventions can help reduce the burden of malaria and all can be implemented now, yielding immediate benefits. Like mitigation, R&D into an effective malaria vaccine or new vector control technology could also help in the long run. So, how should we decide as between these alternatives? As Thomas Schelling has long argued (see, for example, Schelling 1992), this is the relevant question to ask. A simple truth is that a dollar spent doing one thing cannot also be spent doing something else. Although the case for undertaking substantial mitigation is often made on moral grounds, not least because of the potential consequences for the

[7] David Pearce's (2005) survey of the estimates for the "social cost of carbon" (what I have termed the marginal benefit of mitigation) suggests a value of about \$4–\$9. If adjustments are made for equity and time-varying discounting, the range would be about \$7–\$50. Mendelsohn puts the range at about \$1–\$7 per ton. Tol (2005) says that a marginal damage of about \$15 per ton is justified, but that an estimate of \$50 is not. All these estimates are close to the range of values shown in Table 15.3.

[8] Seasonal weather changes are associated with outbreaks of many diseases, including meningococcal meningitis in sub Saharan Africa and Rotavirus in the US. Stronger El Nino events have been linked to cholera prevalence in Bangladesh, the spread of Rift Valley fever in East Africa, and malaria incidence on the Indian subcontinent. However, while the spread of disease is influenced by the weather, the connection between global climate change and the spread of disease has not yet been established (Patz, 2002).

spread of diseases like malaria, the moral consequences of the choices we have to make are more complex than this.

Here is another way to see the same point: Mitigation will introduce risks. It is inconceivable, for example, that emissions will be reduced substantially without an expansion of nuclear power. To consider the risks of climate change and not the risks of climate change mitigation is wrong headed. The question we must ask is, How should we balance these risks?

Questions like these demand our attention, and yet they continue to be unheeded. The International Climate Change Task Force, jointly chaired by Stephen Byers, MP, and Senator Olympia Snowe, concluded that global mean temperature should not be allowed to rise more than 2°C (3.6°F) above the pre-industrial level—a level "associated with a CO_2 concentration of about 400 [ppm]" (International Climate Change Task Force 2005: 4). This is only slightly higher than today's level. To get there would require much greater sacrifices than mentioned in the DEFRA report.

Why *this* level? The reasoning given by the Task Force is familiar. "Beyond the 2°C level, the risks to human societies and ecosystems grow significantly. It is likely, for example, that average temperature increases larger than this will entail substantial agricultural losses, greatly increased numbers of people at risk of water shortages, and widespread adverse health impacts. Exceeding a global average increase of more than 2°C could also imperil a very high proportion of the world's coral reefs and cause irreversible damage to important terrestrial ecosystems, including the Amazon rainforest." And what about the opportunity costs? According to the Task Force (2005: 13), "the cost of taking smart, effective action to meet the challenge of climate change should be entirely manageable." To the Task Force, the risks of climate change are huge, the costs and risks of mitigation insignificant. The report presents no evidence to support this conclusion.

If a dangerous level of atmospheric concentrations cannot be identified, then what should be the goal of policy? Interestingly, the Vienna Convention for the Protection of the Ozone Layer—the agreement that laid the foundation for the successful ozone regime—does not establish even a qualitative goal in terms of atmospheric concentrations, depletion, or emissions. Article 2 instead enjoins parties to "take appropriate measures . . . to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer." In my view, a similar approach is needed to address the climate change challenge. *Attention should focus on the taking of appropriate measures.* The idea that we can identify a "dangerous" concentration level, and back out from this an acceptable emissions trajectory, has been a distraction. Among other things, the idea suggests that a targets and timetables approach is preferable to a policies and measures approach. It is not.

A NEW CLIMATE CHANGE TREATY SYSTEM

My proposal for an alternative climate treaty system, sketched out in Section 15.13, seemed radical when I wrote this book.[9] Today it seems a little less so. The global

[9] For a more recent analysis, see Barrett (2005).

discussion about the way forward—what is sometimes called a "beyond Kyoto" or "post-2012" future—has changed. There is less talk today of negotiating another protocol styled after Kyoto, more talk about R&D and technology.

To some extent, this change reflects an awakening to realities: a recognition that meeting Kyoto will not only be challenging but will do little good; that the US, China, and India, just for starters, need to be participants; that substantial reductions in the long run are more important than small reductions in the short run; that to sustain both economic growth and climate mitigation will require new technologies; and that these new technologies will only become available with substantial investment in R&D.

Less understood are the real reasons why a different approach is needed. It is not only because of the direct effects of R&D and technology on mitigation. It is also—indeed, mainly—because of the *strategic* effects.

If Kyoto could be enforced, it would create incentives for technology development and diffusion. Support for R&D would still be needed, since the knowledge produced by R&D is itself a global public good.[10] But Kyoto could be relied upon to provide the needed pull incentive. An R&D agreement would only be needed to create the complementary push incentive.[11]

Chapter 15 emphasizes that R&D also has a strategic purpose. Spending money on R&D now—a sunk cost—lowers the cost of mitigating emissions later. It will therefore create an incentive for more countries to undertake more mitigation in the long run.

New technologies are also needed, and they will (for both technical and commercial reasons) inevitably conform to some standards. But developing new technologies to reduce greenhouse gas emissions is not enough. Unless by good fortune these happen to be less expensive than existing technologies, means will need to be found to promote their diffusion. This is the rub; this is where the free riding problem asserts itself.

Chapter 15 emphasizes that technology standards have a strategic purpose. If the right conditions are satisfied—if there are economies of scale and learning in production, and network economies and climate-unrelated benefits (such as environmental and energy security benefits) in consumption—then as more countries adopt a standard, an incentive will be created for still more countries to adopt it. Standards must be chosen with this purpose in mind, helped by a minimum participation threshold sufficient to push countries over the tipping point. R&D must also be directed at fulfilling this ultimate aim.

[10] Formal analysis by Goulder and Mathai (2000) shows that, when integrated with R&D, abatement should be reduced in the short term but increased overall. The reason is simple: it is better to put some money into R&D in the short term, to lower the cost of abatement over time, than to put all of it into reducing emissions in the short run.

[11] How much money should be spent on R&D? Interestingly, while a huge amount of effort has gone into estimating the "optimal" carbon tax, or the equivalent (under some circumstances) quantity of emission entitlements, almost no work has been devoted to calculating the optimal R&D budget. A recent paper by Popp (2004) comes closest to trying to estimate this value, but his analysis only considers R&D meant to improve energy efficiency, not to effect a technological revolution.

The essential challenge of any treaty is to change the behavior of nation states—an outcome that, in a world of sovereignty, can only be achieved by manipulating incentives. As I have demonstrated, this requires a strategic approach to treaty making. My proposal for an alternative climate treaty system seeks to address *this* challenge and not only to address the climate change problem directly. This is what makes my proposal unique. This is the reason I wrote this book.

Of course, my own proposal has many flaws. But it needs to be compared to the alternatives. We should not ask what is the ideal way forward. We should ask which is the best way forward.

To make progress, one more thing is needed: the important players must believe that climate change mitigation is a goal for which they are willing to make sacrifices. If countries do not believe this—if the United States, especially, does not believe this—then no approach to treaty design will succeed. This book has explained that having the will to change behavior is not sufficient, that understanding the means by which behavior can be changed is essential. But the reverse is also true. To know the means but to lack the will implies the same outcome: no change. Will a more universal desire for change materialize? Time will tell.

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