AEI STUDIES ON GLOBAL ENVIRONMENTAL POLICY

THE ECONOMICS & POLITICS OF CLIMATE CHANGE

Robert W. Hahn

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COSTS AND BENEFITS OF GREENHOUSE GAS REDUCTION
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MAKING ENVIRONMENTAL POLICY: TWO VIEWS
Irwin M. Stelzer and Paul R. Portney

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Foreword

This volume is one in a series commissioned by the American Enterprise Institute to contribute to the debates over global environmental policy issues. Until very recently, American environmental policy was directed toward problems that were seen to be of a purely, or at least largely, domestic nature. Decisions concerning emissions standards for automobiles and power plants, for example, were set with reference to their effect on the quality of air Americans breathe.

That is no longer the case. Policy makers increasingly find that debates over environmental standards have become globalized, to borrow a word that has come into fashion in several contexts. Global warming is the most prominent of those issues: Americans now confront claims that the types of cars they choose to drive, the amount and mix of energy they consume in their homes and factories, and the organization of their basic industries all have a direct effect on the lives of citizens of other countries—and, in some formulations, may affect the future of the planet itself.

Other issues range from the management of forests, fisheries, and water resources to the preservation of species and the search for new energy sources. Not far in the background of all those new debates, however, are the oldest subjects of international politics—competition for resources and competing interests and ideas concerning economic growth, the distribution of wealth, and the terms of trade.

An important consequence of those developments is that the arenas in which environmental policy is determined

are increasingly international—not just debates in the U.S. Congress, rulemaking proceedings at the Environmental Protection Agency, and implementation decisions by the states and municipalities, but opaque diplomatic "frameworks" and "protocols" hammered out in remote locales. To some, that constitutes a dangerous surrender of national sovereignty; to others, it heralds a new era of American cooperation with other nations that is propelled by the realities of an interdependent world. To policy makers themselves, it means that familiar questions of the benefits and costs of environmental rules are now enmeshed with questions of sovereignty and political legitimacy, of the possibility of large international income transfers, and of the relations of developed to developing countries.

In short, environmental issues are becoming as much a question of foreign policy as of domestic policy; indeed, the Clinton administration has made what it calls "environmental diplomacy" a centerpiece of this country's foreign policy.

AEI's project on global environmental policy includes contributions from scholars in many academic disciplines and features frequent lectures and seminars at the Institute's headquarters as well as this series of studies. We hope that the project will illuminate the many complex issues confronting those attempting to strike a balance between environmental quality and the other goals of industrialized and emerging economies.

CHRISTOPHER DEMUTH
IRWIN M. STELZER
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Executive Summary

A fundamental issue is what steps, if any, countries should take to control greenhouse gas emissions. The economics literature generally suggests that there is no reason to panic and take drastic action now to reduce greenhouse gases. The political economy literature suggests that such action is infeasible because of the serious problems in getting countries to cooperate.

This volume argues that the best strategy for addressing climate change over the next decade is to help build institutions that can address climate change in the future. Those institutions include systems established at the nation-state level to measure greenhouse gas emissions, to implement cost-effective approaches for limiting those emissions, and to enforce those approaches. Over time, supervising the achievement of those objectives might evolve so that it would come under the jurisdiction of an international body, although sovereignty issues would have to be addressed. That international body would assess greenhouse gas inventories and review national policies and measures.

This study recommends that the developed nations of the world craft an agreement for the next decade that provides a slight emission limitation and allows for a series of case studies. The case studies would allow for the participation of developing countries.

The case-study approach would take into account the interests of particular countries. For example, the Scandinavian countries, which have already implemented carbon taxes, could continue on that path, perhaps working on

harmonization issues. The United States and other countries interested in tradable permits or a hybrid system could use that approach. Other European countries may want to try a combination of regulation and market-based approaches. The case studies suggested in this volume underscore the need to design national institutions. Such national institutions are crucial if novel market-based mechanisms are to be implemented effectively.

The appeal of the case-study approach is that it preserves diversity and builds useful institutional experience and knowledge. The last thing we should be doing now, in our state of ignorance about the warming problem and institutional responses, is to narrow the range of response mechanisms. Thus, the case studies cover a fairly wide range but focus on the development of cost-effective approaches for limiting greenhouse gas emissions.

1
Introduction

Over the next century, our progeny will learn whether the average global temperature increases from 1°C to 3.5°C, as has been suggested by the Intergovernmental Panel on Climate Change.[1] If the actual change is at the high end of that range, people around the world will be forced to adapt to potentially major climatic changes associated with the change in temperature. The choice we have now is how best to address the possibility of human-induced climate change on a global scale.

The current projections of temperature increase are based on a widely accepted theory that naturally occurring gases, such as water vapor and carbon dioxide, help trap heat in our atmosphere. The retention of heat by those "greenhouse gases" increases average temperatures by about 30°C and moderates temperature variations, thereby allowing life to exist as we know it.[2]

Human activity, such as burning fossil fuels, deforestation, and raising livestock, has greatly increased the amount of carbon dioxide, methane, and other greenhouse gases released into the atmosphere. Although atmospheric con-

1. See Intergovernmental Panel on Climate Change, Working Group I (1996).

2. See Tucker (1997). The major greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

centrations of greenhouse gases are determined by a complex set of factors, they are correlated with industrialization. Greenhouse gas concentrations have increased more in the past two centuries than in the preceding 10,000 years.[3] Scientists theorize that further increases in the concentration of greenhouse gases from human activity will allow less heat to escape the earth's atmosphere, thus increasing average global temperature.[4]

Great debate arises over the likely effects of rising global temperatures. Indeed, the concern about rising greenhouse gas concentrations stems not so much from their impact on global mean temperatures as from their impact on climatic changes that affect humans, animals, plants, and ecosystems. For example, regional weather patterns could undergo major changes, including the amount of rainfall, temperature variation, and storm patterns.

Some people have expressed concerns about extinction of species through habitat loss and damage to ecosystems, the loss of land due to sea level rise, and the increased incidence of tropical disease and natural disasters. Moreover, some are concerned that the changes in climate could lead to some unpleasant "surprises," such as a shift in ocean currents that could alter regional climates, possibly freezing Western Europe.[5] At the same time, some modeling predicts that specific regions could benefit from the warming, such as colder regions of Canada and Russia, which would have increased agricultural productivity. If all of that

3. See Intergovernmental Panel on Climate Change, Working Group II (1996).

4. Although correlation does not prove causation, historical data show a positive relationship between temperature and fluctuations in atmospheric carbon dioxide concentrations. For example, glacial records indicate that carbon dioxide and local temperature rose together at the end of an ice age 130,000 years ago, then declined concurrently at the beginning of a new glacial period, and then rose again together 10,000 years ago (Schneider 1990).

5. See Schelling (1992).

sounds uncertain, it does so because determining the precise implications of the changes in global average temperature is difficult.

Limiting greenhouse gas emissions is far from simple since they are inevitable byproducts of industrialization. The numerous sources of greenhouse gas emissions include all activities that utilize fossil fuels, such as automobile travel. Moreover, fossil-fuel use is expected to grow rapidly throughout the world as the developing countries industrialize, especially China, which has large coal reserves.[6]

Because the sources of rising greenhouse gas concentrations are ubiquitous and the consequences of those increased emissions are global, effective mitigation strategies will require a high degree of international cooperation. If only a small number of countries agree to limit their emissions of carbon dioxide, the impact of that action is likely to be small. Yet, getting widespread cooperation is unlikely in the short term because most developing countries do not believe that the climate-change issue is a high priority for them and because they fear that emission controls could slow their economic development.

Stringent limits on greenhouse gas emissions could involve major changes in lifestyle for billions of consumers, such as modifying how we heat and light our homes, what foods we eat, and how we transport ourselves. For example, consumers may need to use more efficient insulation, light bulbs, appliances, and vehicles. Reducing greenhouse gas emissions could also involve switching to energy and power sources such as nuclear power, solar

6. To keep things simple, I use the old nomenclature of developed country and developing country. A developed country generally refers to an "industrialized" country with a relatively high per capita income. A developing country refers to a country with a relatively low per capita income. In thinking about climate change, it is also sometimes useful to identify countries on the verge of becoming developed or industrialized.

power, and natural gas, which release fewer greenhouse gas emissions per unit of energy.

A fundamental question is what steps, if any, countries should take to control greenhouse gas concentrations. This volume answers that question by carefully reviewing the economics and politics of climate change and then offering a new policy approach. The analysis accepts the likely existence of a problem and suggests that the best strategy for addressing climate change over the next decade is to help build institutions that can deal with climate change in the future.[7]

The development of institutions is necessary because institutions do not currently exist to address a global environmental issue of that kind, if we assume that significant action is warranted.[8] Those institutions include developing a capacity at the level of the nation-state for measuring greenhouse gas emissions, implementing cost-effective approaches for limiting those emissions, and enforcing those approaches. They also include improvement of the capacity of an international body to assess greenhouse gas inventories and review national policies and measures.

This volume recommends that the developed nations of the world craft an agreement for the next decade that provides a slight emission limitation and suggests conducting a series of case studies. The proposed case studies would help nurture the development of institutions that could effectively address the climate-change issue at a reasonable cost. The volume also recommends a particular market-based approach for imposing slight limitations on greenhouse gas emissions in developed countries—either as one of the case studies or as a general policy if the case-study approach turns out to be impractical. That market-based approach would

7. See Victor and Salt (1995), Schmalensee (1996), and Stavins (1997a).

8. The definition of *significant* is arbitrary. By *significant*, I mean emissions that do not exceed 1990 levels.

involve international tradable permits along with a price ceiling that limits the costs of control and a price floor that ensures that the system will be operational.

To develop a strategy for addressing climate change and to make policy recommendations, it is useful first to examine the economics and politics of climate change. After reviewing the basic findings, the volume suggests areas for research.

2

The Economics of Climate Change

The economics of global warming is concerned primarily with the costs and benefits of limiting green house gas concentrations in the atmosphere. The concentration of greenhouse gases in the atmosphere can be limited in two ways—by limiting emissions sources or by enhancing storage capacity through the use of "sinks," such as planting forests. Here, *costs* will typically refer to mitigation costs. Mitigation costs include costs of limiting sources of greenhouse gas emissions as well as costs of creating sinks. The benefit category includes a wide variety of market and nonmarket factors such as changes in consumer welfare resulting from impacts on different sectors of the economy, changes in recreation, and changes in ecosystems.

A variety of ways exist to aggregate costs and benefits for the purpose of defining desirable policies. One approach that has been advocated for use in climate change is the so-called precautionary principle. The precautionary principle essentially says that it is better to be safe than sorry by erring on the side of caution. Thus, some people argue that it is better to act now on climate change to avoid potentially serious consequences later on. But how much to err on the side of caution? The principle provides little, if any, guidance.

The precautionary principle is flawed as a criterion for policy making because it is impossible to err on the

side of caution on all problems—even all environmental problems. The reason is that resources are finite—when more resources are spent on one serious problem, fewer resources are available to address other problems. The challenge, then, is to make a judicious allocation of finite resources, rather than simply to follow a rule of thumb such as the precautionary principle. For example, excessive expenditures on the environment could adversely affect funding for education, disaster relief, and other worthy concerns.[9]

Many alternatives to the precautionary principle exist. Economists, while not in complete agreement on a particular objective, believe that it is useful to weigh the costs and benefits in developing a strategy for addressing climate change. Here, I highlight some important economic considerations for designing that strategy.

The Nature of Costs and Benefits

Timing of Costs and Benefits. The costs will occur early, while the benefits accrue later on. Climate change is a problem with a relatively long time scale. If action is taken, the costs will be incurred when action is taken; in contrast, the benefits will accrue more slowly because emissions released now will influence global climate over a

9. While the precautionary principle does not provide a firm basis for policy, specific decision criteria could provide a justification for acting on climate now. One such criterion is the so-called minimax regret principle, which tries to minimize the chance of a particularly undesirable outcome. Even when the objective is to maximize expected net benefits, one can make a case for investing in preserving his options if a bad policy outcome is not easily reversed, as might be the case with climate change (Arrow and Fisher 1974; Manne and Richels 1992; Chichilnisky and Heal 1993). As Kolstad (1994) points out, however, the investments in climate change abatement also have some characteristics of irreversibility, thus serving as a counterbalance to the potentially irreversible impacts of greenhouse gas emissions.

much longer time scale as greenhouse gases build up in the atmosphere.[10]

Uncertainties. Both the costs and benefits of limiting greenhouse gas emissions are highly uncertain. Individual cost estimates are subject to great uncertainties that reflect underlying uncertainties in the availability of different technologies, their costs, and their effectiveness. Accurate emissions predictions also depend on estimates of population growth, rates of economic growth, the elasticity of demand for carbon-based fuels, and unforeseen political events.

The Intergovernmental Panel on Climate Change presents estimates for stabilizing U.S. carbon emissions at roughly the 1990 level that range from .4 to 2.2 percent of U.S. gross national product.[11] Using 1 percent of GNP as an order of magnitude estimate for the developed countries suggests that costs could be in the hundreds of billions of dollars annually. Schelling has argued that those costs are affordable in the sense that they are unlikely to have a huge impact on growth.[12] The costs, however, may not be desirable if the likely future benefits are small in comparison.

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10. The atmospheric "lifetime" of carbon dioxide is roughly 100 years, which means that about one-third of the carbon dioxide emitted today will still be in the atmosphere 100 years from now.

11. See Intergovernmental Panel on Climate Change, Working Group III (1996). The Intergovernmental Panel on Climate Change cites costs of U.S. abatement from –1.2 percent to 10.9 percent of GDP, which underscores the uncertainty of cost estimates. The negative costs, while possible in principle, are unlikely in practice because they presume relatively high levels of inefficiency in markets that can be corrected with government intervention.

12. See Schelling (1992). Schelling argues that developed countries can easily absorb that size loss since a 2 percent reduction in GNP per capita would mean that a doubling of income per capita would occur in roughly sixty-two years rather than in sixty years. Alternatively, the reduced growth rate would "lower the GNP curve by not much more than the thickness of a line drawn with a number-two pencil."

Moreover, major shifts in employment could occur as sectors that rely heavily on fossil fuels, such as steel, primary metals, coal production, and petroleum refining, decline.[13]

Studies of future benefits do not shed much light on the benefit-cost comparison because of the difficulty of quantifying and monetizing benefits. Quantifying benefits is difficult because of the absence of good data on the regional effects of climate change. Without such data, one must assume a temperature increase and then examine the likely regional impacts.[14] Measuring potential nonmarket damages, such as damages to unmanaged ecosystems and biodiversity, is extremely problematic because they are difficult to specify in quantitative terms and consumers do not value them directly.

Distribution of Benefits. The benefits of avoiding climate change are likely to be unevenly distributed across time and space. Many small islands are at risk from sea level rise; on the other hand, Canada and Siberia could benefit from warmer temperatures.[15] Moreover, Mendelsohn finds that the market impacts on the United States are likely to be beneficial.[16]

Not only will some regions benefit more than others, but the people who will benefit the most from abatement are those who are vulnerable to climate change—primarily the future poor in developing countries. They will be more vulnerable to climate change because they will lack adequate resources and they will be more dependent on agriculture. In the United States, for example, agriculture represents only 3 percent of gross domestic product, while in the developing world the total is closer to 30 percent.[17]

13. See Jorgenson and Wilcoxen (1990).
14. See Mendelsohn (1996).
15. See Schelling (1992).
16. See Mendelsohn (1996).
17. See Schelling (1992).

It is difficult to predict the precise pattern of benefits across time. To the extent that demand for environmental improvements increases with wealth, so too will the demand for addressing climate change. Yet the nature of concerns may change over time. For example, current worries about disruptions in agriculture and increased disease, which are legitimate concerns now, may be resolved in the future as technology evolves to address those threats.

Locational Considerations. The location of a particular source of emissions or sink is not important for total benefits. A ton of carbon dioxide or methane emitted from the United States has the same impact on climate change as a ton emitted from China. That property has important economic and political implications. For example, it means that decreasing greenhouse gas emissions in developed countries will have no impact on climate change if there is a commensurate increase in developing countries.

Additional Benefits. Measures to reduce greenhouse gases often reduce other pollutants as well and thus yield additional benefits. Steps to limit greenhouse gases could also reduce sulfur dioxide, nitrogen oxides, carbon monoxide, particulate matter, and tropospheric ozone, thus benefiting particular regions. The value of those benefits per ton of carbon reduced has been estimated to be between $3 and $80 per ton.[18] Those benefits should be counted only if they are truly incremental. Burtraw and Toman argue that those benefits are likely to be modest.[19]

Stringency Considerations. Costs increase more than proportionally with the increasing stringency of targets and

18. See Burtraw and Toman (1997). Unless otherwise noted, year dollars reflect those used in the study cited. Most estimates fall in the time period 1990 to 1995.

19. See Burtraw and Toman (1997).

timetables. Several analyses have shown that climate change costs increase dramatically as the target reduction in net greenhouse gas emissions increases. The marginal cost of control rises from $10 per ton to $80 per ton as reductions increase from 5 percent to 25 percent.[20] In addition, the timing of reductions can have a critical effect on costs. Making reductions now can be much more costly than making reductions later because of the emergence of new technologies as well as the natural turnover of the capital stock. Under some stabilization scenarios, it is possible to reduce mitigation costs by over 80 percent by deferring most reductions until near the end of the next century.[21]

Interestingly, the Framework Convention on Climate Change calls for fairly significant reductions now. That may not make good economic sense.[22] The best economic strategy appears to be to start small and increase the target gradually, if such increases are warranted on the basis of the science and economics.[23]

Strategies to Reduce Abatement Costs

Use of Economic Instruments. Costs could be reduced substantially by using economic instruments. Table 2–1 compares various command-based systems for achieving targets with market-based approaches, such as tradable-permit systems, under various assumptions.[24] Both fees and permits

20. See Parry, Williams, and Goulder (1996). That pattern is consistent with others noted in the Intergovernmental Panel on Climate Change, Working Group III (1996), including studies by Barns, Edmonds, and Reilly (1992), Martin et al. (1992), Manne (1992), Oliveira-Martins et al. (1992), and Rutherford (1992).

21. See Manne and Richels (1997).

22. See Manne and Richels (1997).

23. See Nordhaus (1979) and Manne and Richels (1997).

24. The savings are identified as being derived from tradable permits. An alternative interpretation is that the savings result from an emissions tax–subsidy approach that is revenue neutral.

TABLE 2–1
COST SAVINGS FROM ECONOMIC INSTRUMENTS BY REGION

Policy Goals and Instruments	*Region Realizing Savings*	*Cost Savings*[a]	*Cost without Trading (% of GDP and $ trillion)*
Carbon reductions range from 10% to 20% below 1990 only in OECD. Trading ranges from OECD only to worldwide.	OECD	18%–69%	.4%–4.0% $.9–$6.0[b]
Carbon reductions range from lowering to 1990 levels to 20% below 1990 levels. Trading ranges from OECD only to worldwide.	United States	15%–98%	.2%–.5% $.1–$.6[c]

Carbon reductions range from 10% below 1990 to stabilizing at 550 ppmv only in OECD. Trading ranges from Annex 1 only to worldwide.	Eastern Europe and the former Soviet Union	35%–83%	$.3–$1.3[b]
Carbon reductions range from 10% below 1990 to stabilizing at 550 ppmv only in OECD countries. Trading regime options include Annex 1 only or worldwide.	Non–Annex 1 countries	25%–96%	$.7–$1.4[c]
Carbon emissions cut 2% per year from projected growth worldwide. Trading allowed worldwide.	World	6%–47%	1.9%–8.0%

a. Cost savings, expressed as a percentage, are defined as the difference in the cost of abatement with trading and without trading divided by the cost without trading. Those savings could result from an equivalent system of carbon taxes.
b. In 1990 dollars.
c. In 1994 dollars.
SOURCES: Jacoby et al. (1997); Nordhaus (1997); Manne and Richels (1997); Interagency Analytical Team (1997); Mullins and Baron (1997); Dean and Hoeller (1992).

have the potential to reduce costs relative to a command-and-control system by providing an incentive to search for the lowest cost reductions first. Those simulations, which are based on the assumption that markets work efficiently, suggest that nations could save huge sums of money by moving to an international tradable-permit system if significant reductions were required. For example, if the Organization for Economic Cooperation and Development countries were required to stabilize emissions at 1990 levels early in the twenty-first century, savings relative to the case with no trading with the rest of the world would range from $10 billion to $300 billion annually. Those savings would represent about 50 percent of the costs without trading.

Use of Sinks. We could substantially reduce costs by using sinks. Although we face significant challenges in implementing a carbon sink program as part of a national or international greenhouse gas policy, we may realize substantial savings for a net emissions approach relative to a program that is limited to reducing energy-related emissions.[25] The Intergovernmental Panel on Climate Change indicates that carbon sequestration could cost-effectively contribute 15 percent to 30 percent of the reductions of a net emissions stabilization program.[26] Stavins argues that carbon sequestration is best seen as a short-term strategy for reducing net greenhouse gases because the strategy will eventually have diminishing returns.[27]

Recent work suggests that some of the relative advantages of the carbon-sequestration option will be lost if issues related to leakage, measurement, and credible commitment cannot be fully addressed. For example, monitoring the net level of emissions resulting from both sources

25. See Richards et al. (1993) and Stavins (1997b).

26. See Intergovernmental Panel on Climate Change, Working Group III (1996).

27. See Stavins (1997b).

and sinks will be more difficult and costly. Even when those additional costs are taken into account, the cost savings of including sinks, relative to strategies limited to energy emissions, are likely to be substantial.[28]

Reducing Distortionary Taxes. We could substantially reduce costs by using instruments that generate revenues if the revenues are used to reduce highly distortionary taxes. A growing literature suggests that emissions taxes offer significant benefits over a comparable system of nonauctioned tradable permits, provided that the tax revenues are used to reduce highly inefficient taxes. For example, Parry, Williams, and Goulder find that the cost of reducing emissions by 10 percent in the United States is 300 percent higher when using nonauctioned tradable permits than when using a carbon tax that recycles revenues.[29] They show that a nonauctioned quota cannot increase efficiency unless the marginal benefits from reductions of carbon dioxide are at least $25 per ton of carbon, while a tax that recycles revenues judiciously improves efficiency as long as marginal benefits are positive. That analysis highlights the need to consider the revenue and taxation consequences of different approaches to limiting greenhouse gases.[30]

Savings from Economic Approaches. Actual cost savings from economic approaches are likely to fall far short of their theoretical potential. That is primarily so because the design of economic approaches is intimately connected with

28. See Richards (1997). The estimates of the marginal costs of carbon removal in the United States range from approximately $10 to $15 per metric ton for relatively small amounts of carbon removal (25 to 75 million tons per year) up to $60 per ton for a program that averages 440 million tons per year. See Richards, Moulton, and Birdsey (1993) and Moulton and Richards (1990).

29. See Parry, Williams, and Goulder (1996).

30. For a similar analysis of the U.S. acid rain program, see Goulder, Parry, and Burtraw (1996).

politics. For example, in a tradable-permit system, governments may initially be given the permits with no requirement to allocate those permits to private-sector participants. If governments are central actors in trading, cost savings are likely to be lower because governments have less of an incentive to minimize costs than participants in the private sector. In addition, governments may need to play a central role in certain activities, such as the creation of carbon sinks on government land.

Government behavior could have a dramatic impact on the performance of the market and hence on the degree of cost savings achieved with a market.[31] If a government is a major trader, private traders may fear that the government will be more likely to change the trading rules to address short-term political concerns. In addition, even if a government stays on the sidelines, traders may fear that rule changes will occur that diminish the value or security of property rights, as occurred with emissions trading in the United States.[32] A government can address that problem by clearly defining the nature of the property rights. Good examples include the market for phasing out lead in gasoline and the market for reducing sulfur dioxide in the United States.

Defining Emission Baselines. The environmental impacts of allowing flexible approaches for trading emissions when emission baselines are poorly defined are questionable. One of the proposals for reducing the cost of achieving net greenhouse gas emission reductions is "joint implementation."[33] *Joint implementation* refers to a system in which a country may meet its abatement commitments by financing emissions reduction or sink augmentation in another country. In some joint implementation proposals, the coun-

31. See Harrison and Rutherford (1997).
32. See Hahn and Hester (1989) and Foster and Hahn (1995).
33. See Andrasko, Carter, and van der Gaast (1996).

try in which greenhouse gas reductions are being made may not be a participant in an agreement nor have well-defined emission limits.

Joint implementation has some serious practical defects. It is frequently very difficult to determine a baseline for emissions when countries do not have emission limits.[34] To award credits to the investing nation for emission reductions, we must calculate how much higher emissions would have been without the investment. Since developing nations do not face specific targets, estimating what would have happened without the project is difficult. In addition, it is hard to know whether reductions from a project will lead to any net reductions globally.

Furthermore, negotiations over the environmental value of each transaction could result in very high transaction costs.[35] Such a case-by-case approach makes it easier for firms and governments to claim net reductions after merely shifting the distribution of emissions. Parties to those transactions also have incentives to overstate their environmental benefits so as to receive more credit and to select projects that are more difficult for an oversight authority to audit. To counteract those potential biases, the authority charged with giving credits will need to be very careful in defining criteria for acceptable projects. If the criteria are stringent, however, that could lead to a program of very limited scope.

The experience in the United States with emissions trading suggests that joint implementation is likely to have limited usefulness because determinations will be on a case-by-case basis. Moreover, the problems with defining a baseline are even more significant than those encountered in some U.S. trading programs.[36] By the same token, joint

34. See Harvey and Bush (1997) and Schmalensee (1997).

35. See Jackson (1995).

36. See Hahn and Hester (1989), Foster and Hahn (1995), and Stavins (1997b).

implementation may offer some constructive applications when emission reductions are reasonably well defined.

Because of the potential problems with defining baselines, it may be necessary to divide joint implementation projects in accord with how easily a baseline can be determined. For example, it is probably easier to define baselines for some kinds of power plants and methane leakage projects than for the planting or preservation of forests. For projects where baseline determination is relatively easy, it is probably possible to include them in a tradable permits system or a credit system. For projects where baseline determination is more difficult, it will be necessary to have more monitoring to ensure that baseline manipulation does not occur—a measure that increases transaction costs. For some projects, such as planting a forest, the relevant baseline may be too uncertain to provide a meaningful estimate of likely emission reductions.

While joint implementation has serious defects, it also has some advantages. One is that the process allows some experience that is relevant to designing a tradable-permit system without actually creating that system.[37] Another advantage is that joint implementation is a relatively simple extension of current policy based on the Framework Convention on Climate Change, and thus it is feasible.

Proponents of joint implementation see it as a low-cost way to reach abatement targets because energy use is often inefficient in developing countries and the cost of abatement is projected to be low.[38] Some also see joint implementation as an effective way to build support for a climate agreement in developing countries by giving participants a financial incentive to develop better inventories, find

37. See Palmisano (1996).

38. On the other hand, Jackson (1995) argues that low and even negative cost abatement options will be more readily found in developed countries. That partly depends on the levels of reductions that are required in the various countries.

mitigation opportunities, improve monitoring, and sell reductions to the developed world.

To the extent that joint implementation helps build institutions and support in developing countries, we should evaluate the system primarily on those criteria. The best gloss one can put on joint implementation is that it could serve as a transitional strategy for developing cost-effective approaches for addressing climate change. I remain skeptical because the problems with establishing a baseline are significant in many cases.

If the choice were between joint implementation and no trading with developing countries initially, the choice would be difficult. But *another option* that policy makers have largely ignored exists. That option is to apply the same rules to all countries in the trading system. In principle, policy makers could accomplish that by negotiating an initial allocation of permits that is acceptable to participating developing countries. Allocating a large number of permits to those countries could, however, encounter political resistance as a result of the potentially large resource transfers required.[39]

Narrow Agreements. The costs of achieving net greenhouse gas reductions increase as the sources covered under an agreement narrow. As more sources and sinks for greenhouse gas emissions are covered, the potential for leakage is less. For example, if the effect of an agreement is simply to transfer tree planting from an area not covered by an agreement to an area covered by the agreement, that leads to no net reduction in greenhouse gas emissions.

39. See Schelling (1998). The resource transfer problem can be addressed by setting initial reduction targets that are modest—a subject I address below.

General Principles

Range of Policies. One can justify a wide range of policies by using benefit-cost analysis because of the large uncertainties in benefits and costs. Estimates of an "optimal" policy weighing benefits and costs are in the range of $0 per ton to $40 per ton in 2005 with an expected value of about $15 per ton.[40] That suggests that some action on climate change is probably justified provided that a large number of developed and key developing countries participate in an agreement. Yet, reasonable people are likely to disagree markedly about the appropriate way to measure and quantify benefits and costs.[41] Analysts are also likely to disagree about whether benefit-cost analysis is the best decision-making criterion for a problem with such large uncertainties and long time horizons.[42]

Widespread Participation. Doing anything significant will require widespread participation. While estimating the precise numbers of sources and sinks is difficult, they easily number in the hundreds of millions (counting vehicles alone) and are spread throughout the world. Moreover, controlling sources or sinks in one small area may not make any appreciable difference in the total level of emissions. Suppose, for example, that several island nations concerned with sea level rise agreed to freeze their greenhouse gas emissions, but that all other countries continued business as usual. That freeze would have virtually no impact on

40. See Nordhaus (1994). Nordhaus provides a range of estimates. The tenth percentile estimate is $0 per ton; the ninetieth percentile estimate is $37 per ton; and the median value is $6 per ton. The optimal tax increases over time. In contrast to Nordhaus, Cline (1992) estimates that an optimal tax would be in the range of $50 to $250 per ton. Cline's estimates are based on relatively high estimates of environmental damages and a low discount rate.

41. See Lave and Dowlatabadi (1993).

42. See Page (1978) and Arrow et al. (1996).

greenhouse gas emissions because those nations account for such a small fraction of emissions.

Even if developed countries agreed to limit carbon dioxide emissions, the impact of such limitations is likely to be relatively small over the long term for two reasons. First, the emissions from the developing world are expected to exceed those from the developed world in the coming century. Between 1990 and 2050 non–Annex 1 emissions will grow from under a third of the world total to 58 percent while non-OECD emissions will grow from half the total to 74 percent.[43] Second, some of the carbon-intensive industries could be expected to move to the developing world because it would be cheaper to operate there. Estimates of such "leakage" vary widely.[44] For example, reasonable estimates of the increase in carbon emissions outside the OECD nations resulting from stabilizing OECD emissions at 1990 levels range from 1 percent to 25 percent of total abatement in the OECD countries.[45]

Unilateral Action. Unilateral action by a small group of countries is not likely to be in the narrow economic interest of those countries, unless those actions serve to increase the chances that a significant number of countries will eventually participate in such an agreement. Countries that ex-

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43. See Martin et al. (1992). The Annex 1 countries include the OECD countries, the former Soviet Union, and the countries of Eastern Europe.

44. The leakage rate is defined as the increase in emissions from nonparticipating countries divided by the reductions by participating countries. For example, if the OECD countries reduced emissions by ten tons and the rest of the world increased emissions by two tons, the leakage rate would be 20 percent. Leakage may also result if the demand for carbon-based fuels increases from nonparticipating countries as the demand drops in participating countries.

45. See Babiker, Maskus, and Rutherford (1997), Jacoby et al. (1997), Oliveira-Martins et al. (1992), Manne (1993), and Manne and Martins (1994). Estimates of leakage range widely—from negative to over 100 percent. See Pezzey (1991) for a particularly high estimate. Barrett (1994) and Winters (1992) provide good surveys of the literature.

pect to benefit from warming gain no benefits from reducing greenhouse gases. Countries that expect to benefit from reductions in worldwide greenhouse gases are likely to receive minimal benefits from unilateral or small-group action because such action will have a minor effect on total emissions. Countries such as the island states, whose survival is at stake, may pursue vigorous actions in hopes that other countries will follow suit.

Cost-Effective Institutions. We need to design institutions that can help achieve greenhouse gas reductions cost-effectively. If action is taken on global warming, market-based approaches have the *potential* to achieve reductions cost-effectively. But the degree to which cost savings are achieved depends critically on the design of such an approach. Economists are divided on the best approach to that problem; nevertheless, a consensus is forming in the economics community that we need to focus on designing institutions that will help promote cooperation and achieve greenhouse gas reductions at a "reasonable" cost.

Four particularly important policy insights emerge from the review of the economics. First, the ubiquitous nature of sources and sinks suggests that a coordinated response to the problem will be necessary. Second, we can justify some action now, provided we have a strategy for gaining widespread participation in an agreement to limit greenhouse gases. Third, institutional design, such as the approach taken to limit greenhouse gas emissions, can have a dramatic impact on the cost of achieving particular environmental goals. Fourth, global warming is a long-term problem that requires solutions that operate over the long term.

3

Politics

While economics provides some important insights into the nature of appropriate policies, an analysis of climate-change politics can identify the kinds of policies that are likely to be feasible—and not feasible—and the kinds of actions different countries are likely to take. Before identifying some of the political constraints, it is instructive to review the evolution of climate negotiations along with the key interest groups in that debate.

The primary vehicle used to promote cooperation on the climate issue has been international negotiations. At the June 1992 "Earth Summit" in Rio de Janeiro, 165 states signed the Framework Convention on Climate Change, and 160 of them ratified it over the next two years. That treaty called for the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." In meeting that goal the treaty requires developed countries and countries in transition to begin national programs to report and reduce greenhouse gas emissions. The target for developed nations is to reduce emissions to 1990 levels by 2000. No limits were placed on other nations. Most developed countries will not meet the target, in part because the agreement lacks an effective enforcement mechanism.[46] Notwithstanding the failure to meet targets, the Berlin conference

46. See Cooper (1996).

in 1995 set more ambitious goals. In the Berlin mandate, the nations agreed to strengthen their commitments and put forth new, alternative targets, including a 20 percent reduction in carbon dioxide emissions by 2005.[47]

In December 1997 over 150 countries met in Japan for the Third Conference of the Parties to agree on specific targets and timetables for reducing emissions. The Kyoto Protocol requires differentiated commitments by the Annex 1 countries, with the ultimate goal of reducing emissions to 5.2 percent below 1990 levels in the period 2008 to 2012.[48] The final agreement reflects the U.S. proposal to include six gases instead of one or three.[49] Countries will be able to claim emissions reductions by reducing sources of pollution, such as fossil-fuel combustion, or by increasing sinks, such as forests, which absorb greenhouse gases from the atmosphere. The protocol also includes a "Clean Development Mechanism," in which Annex 1 countries help developing countries implement clean energy technologies and use any resulting emission-reduction credits to meet their national emissions target. The Clean Development Mechanism described in the Kyoto Protocol is a kind of joint implementation program that a central body will oversee.[50]

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47. See Richels et al. (1996) and Tucker (1997).

48. Individual commitments range from a 10 percent emissions growth in Iceland to an 8 percent reduction in the European Union nations. The United States agreed to reduce emissions by 7 percent.

49. The six gases covered are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride as opposed to just carbon dioxide or carbon dioxide, methane, and nitrous oxide. See Framework Convention on Climate Change (1997). Nations will have the option of using 1995 as a baseline for hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.

50. See Framework Convention on Climate Change (1997). A very strong likelihood is that that central body will be subject to political pressures that cause it to select some control strategies that are not cost-effective. In addition, the central body will have multiple objectives, including setting aside funds for countries that are most vulnerable to climate change.

Some of the most contentious debate at the negotiations centered on the instruments that will be used to achieve national emissions targets. In the end, the important issues of emissions trading and enforcement were postponed until the November 1998 meeting of the nations of the world in Buenos Aires, Argentina. Although the U.S. proposal of an international system of emissions trading was not accepted in Kyoto, the protocol contains the principle of using flexible, market-based instruments.[51]

Key interest groups in climate-change policy include environmentalists, business, international negotiators, and political leaders from developed and developing countries. Environmentalists have a strong interest in arguing that climate change is a very serious problem because of their concerns for the environment and because it would enhance the influence of environmental advocacy groups.[52] In contrast, most businesses have an incentive to understate the importance of that issue—particularly those businesses relying heavily on fossil fuels. At the same time, businesses that are likely to be more directly affected by the impacts of global warming, such as insurance and banking, can be expected to support action to limit greenhouse gases.[53]

Another important group in the policy process comprises the international negotiators and bureaucrats, frequently drawn from agencies dealing with diplomacy, the environment, or both. Examples include staff representatives of the United Nations Framework Convention on Climate Change Secretariat and the Global Environment Facility. Those individuals usually have an incentive to overstate the view of the narrow constituency or constituencies

51. The protocol contains clauses permitting countries to cooperate in reaching their goals and to transfer emission reduction credits. See Framework Convention on Climate Change (1997).

52. See Lindzen (1996), Wildavsky (1992), and Hahn (1993).

53. See Warrick and Baker (1997).

that they represent. Justice Stephen Breyer refers to that narrow perspective as "tunnel vision."[54] Such vision frequently results in overemphasizing the importance of the particular issue under consideration without thinking through its broader implications for the economy and consumers. That focus stems in part from benefits that accrue to civil servants and appointed officials who negotiate those agreements in the form of staff, travel, and promotions.[55]

The interests of nations vary dramatically. For example, in most developing countries, the issue of climate change is a relatively low priority compared with putting food on the table. The impetus for doing something on climate change has come largely from the developed countries and those developing countries that expect to be at greatest risk. Other developing countries, not surprisingly, have also encouraged the developed countries to take significant action.

While the impact of key interest groups on climate-change policy is complicated, it is possible to sketch some important political features of the climate-change issue. Here, I offer my views and predictions.

The Present Generation's Interests. Political decision making will tilt toward the interests of the present generation. In general, politicians are motivated by short-term electoral considerations and discount the long term more heavily than economists would in analyzing benefits and costs. The politicians will be more inclined to focus on the costs of averting global warming, which could appear during their tenure, and to discount heavily the benefits, which are far off in the future. While there are exceptions to that rule, it is probably true for most developed countries. Thus, although it could be rational from an economic standpoint for all nations to participate in an agreement now, it may not be rational from a political standpoint. That is true

54. See Breyer (1993).
55. See Hahn and Richards (1989).

even if there were no free-riding problem because of how politicians weigh benefits and costs over time.

Short-Term Strategy. A winning short-term strategy for developed country politicians is to talk tough on climate change but to do relatively little. The appearance of doing something can go a long way toward assuaging the concerns of most citizens while helping to neutralize pressures from environmental groups. Moreover, such a strategy will be supported by many parts of the business community that expect to bear most of the costs of controlling greenhouse gas emissions. In justifying the strategy selected, politicians are unlikely to cast the argument in terms of benefits and costs; instead, they will appeal to emotional issues, such as saving the planet.[56]

Existing Stakeholders' Power. Any instruments used to reduce greenhouse gases are likely to be based in part on the current distribution of political power. For example, if tradable permits are used in the United States, they are likely to be "grandfathered" to existing producers or users of fossil fuel. Thus, if there were a carbon permit market, oil and coal producers could receive many of the permits. That result suggests that revenue recycling options may be limited, even if they promote greater economic efficiency. Indeed, to the extent revenues are recycled, such as in the case of an emissions tax, a significant share may go to existing stakeholders.[57]

Costs to Developed Countries. If anything is done in the short term, developed countries are likely to bear virtually all the costs. That follows from the fact that climate change is generally not a high priority for developing countries. According to the World Health Organization, 4 million chil-

56. See Gore (1992) and Hahn (1993).
57. See Hahn (1989).

dren under the age of five died of air pollution–related respiratory diseases in developing countries, and another 3.8 million died from diarrhea caused by polluted water.[58]

If the developed countries bear the initial costs, as expected, they will have to explain to voters why such expenditures are warranted. Schelling makes the point that those expenditures are likely to benefit mainly future citizens from countries that will be relatively poor, but better off than today's poor.[59] It may be difficult to justify such transfers on political and economic grounds given the pressing needs of today's poor.

Likelihood of Significant Measures to Address Global Warming. It is unlikely that anything significant on global warming will be done for at least the next decade and possibly longer. That statement assumes that our understanding of the economic benefits and costs of reducing greenhouse gas emissions does not change dramatically. The existence of the free-rider problem makes it highly unlikely that most developed countries will find it in their interest to do anything significant. Moreover, as noted, developing countries do not see that issue as a priority.

Consider the case of the United States' reducing emissions to 1990 levels. A plausible estimate of the costs is in the range of $100 per ton.[60] That translates into an increase in gasoline prices of roughly $.25 per gallon. Congress had trouble passing legislation that resulted in a $.05 per gallon increase. Thus, unless the costs are well hidden, Congress is unlikely to approve such a target.

Outcome of International Negotiations. The most likely outcome of international negotiations over the next decade is that a select group of developed countries agrees to

58. See Easterbrook (1995).
59. See Schelling (1998).
60. See Dean and Hoeller (1992) and Nordhaus (1994).

do something that has a relatively low cost. The reason is simple: developing countries have no incentive to sign an agreement now unless the developed countries foot the bill, and developed countries face no political imperative to take drastic action. At the same time, the United States could be held more accountable than other countries if it signs an agreement with binding targets because environmentalists may be more effective in using the U.S. legal system to achieve their desired end.

The likelihood of an agreement with significant net emissions reductions will increase with time, assuming that climate change is still perceived as a problem. We can expect changes in technology to lower the cost of achieving net emission reductions. Those include the development of alternative energy sources and increased energy efficiency. In addition, growth in world per capita income should increase society's willingness to pay for reducing greenhouse gases, thus increasing political pressure to act.

Problem of Free Riding. Free riding is a major obstacle in reaching an agreement where a large number of countries must make significant reductions in greenhouse gases. There is no way to force a sovereign country to participate in an international agreement. A country is unlikely to participate in an agreement unless it believes that its participation will help bind other countries to an agreement or unless it perceives that the costs of not participating are unacceptable.[61] In the case of a climate change, countries will have a strong incentive either to free ride by not joining the agreement or not to comply. The key to avoiding such problems is structuring an agreement with appropriate sanctions; unfortunately, that may be impossible in some cases and not worth it in others.[62]

61. See Barrett (1997a) and Parson and Zeckhauser (1995).
62. See Barrett (1997b).

Credible Sanctions. Sanctions can help induce countries to participate in an agreement, provided that they are credible. The precise nature of appropriate sanctions will depend on the kind of agreement that is desired and the general level of political support for an agreement. The agreement needs to be self-enforcing in the sense that countries that are parties to an agreement are worse off if they do not comply with or drop out of the agreement. That property of self-enforcement hinges on devising a system of rewards and sanctions that make it in a country's interest to remain in the agreement.[63]

For countries that sign an agreement, the sanctions for not complying should increase gradually.[64] Such sanctions would make it easier to bring a country back into compliance. Monitoring should also be transparent because that makes it easier to impose sanctions when a country is out of compliance and may put more pressure on the country to comply. Table 3–1 shows examples of different approaches to the enforcement problem when economic instruments are used. Cooper effectively assumes that enforcement will not be an issue for a tax if there is support for the treaty and if actions are transparent so that they can be easily monitored.[65] Dudek and Goffman and Stewart, Wiener, and Sands suggest specific penalties in the case of tradable permits.[66] Tietenberg and Victor suggest negotiating a mechanism for dispute resolution.[67] Victor

63. The Montreal Protocol, which banned ozone-threatening chlorofluorocarbons, has been successful by banning the import of controlled substances and controlling nations' access to international funds. But significant differences exist between the Montreal Protocol and a climate change agreement, including support from key industries, the number of firms involved, and the cost of abatement. See Hahn and McGartland (1989) and Victor (1997).

64. See Stewart, Wiener, and Sands (1996).

65. See Cooper (1996).

66. See Dudek and Goffman (1997) and Stewart, Wiener, and Sands (1996).

67. See Tietenberg and Victor (1994).

TABLE 3–1
DIFFERENT APPROACHES TO MONITORING AND ENFORCEMENT

Author	*Instrument*	*Monitoring*	*Enforcement*
Cooper (1996)	Tax	Regular reporting and external monitoring of actions relevant to the treaty are required.	Most treaty violations are due to misunderstandings, so a commitment to treaty objectives and transparent actions are the key to compliance.
Dudek and Goffman (1997)	Tradable permits	Members submit annual report detailing their emissions budget, actual domestic emissions, domestic offsets, exported reductions, imported reductions, emissions savings, and end-of-period net.	Any country with excess greenhouse gases will have that number of greenhouse gases deducted from their next budget and any permits a violator has exported will be discounted in the *current* budget. Shifting risk to buyers will effectively exclude noncomplying members from greenhouse gas trading. Paper rules out general trade sanctions.

(Table continues)

TABLE 3–1 *(continued)*

Author	*Instrument*	*Monitoring*	*Enforcement*
Stewart, Wiener, and Sands (1996)	Tradable permits	Members make standardized annual reports of emissions and permit trades to an international monitor. The monitor checks self-reporting systems, checks annual reports, and certifies members.	Excess greenhouse gases will trigger a reduction in the next period's budget. Larger violations will result in larger than 1 to 1 reductions. Repeated noncompliance will draw fines, and finally offenders will forfeit financial securities held by organizing body. Also, domestic environmental groups and holders of greenhouse gas permits will apply political pressure to avoid violations.
Tietenberg and Victor (1994); Victor (1997)	Tradable permits	Self-reporting of emissions and permit trades, layered with veracity checks, will produce transparent information. Public opinion and normative pressure will deter violations. Most action and capacity should be built at the national level.	Rely heavily on domestic enforcement of international standards. Develop mechanisms for dispute resolution through negotiation. Egregious violations may be rare; enforcement of those violations is possible through linkages to other issues and sanctions.

argues that to gain compliance, the threat or use of trade sanctions can alter countries' behavior.[68] On the basis of the implementation of the Montreal Protocol to reduce stratospheric ozone, he contends that linking international aid from other sources to compliance also can be an effective enforcement mechanism.

One of the critical challenges for a climate-change agreement is structuring sanctions for nonparticipating countries. Many analysts have suggested that trade sanctions may be necessary for nonparticipating countries. Such sanctions have the potential to reduce free riding; they could also escalate trade barriers, however. If, for example, China and India chose not to comply with or participate in an agreement, imposing trade sanctions could have very large costs. Moreover, defining the precise form of the sanctions will not be easy.[69]

The sanctions need to have teeth to be effective. Chayes and Chayes have suggested that countries rarely violate international treaties on purpose.[70] Moreover, they argue that strong sanctions can discourage participation in an agreement. Both observations may be true for the agreements they examine; but for treaties with high costs, such as a greenhouse gas agreement with a stringent target, one cannot assume that compliance will occur without sanctions. The argument about the nature of sanctions affecting participation rates is also valid and points to a limitation of agreements. Indeed, one can imagine a voluntary action-based treaty achieving more initially (in terms of green-

68. See Victor (1997).

69. See Dudek and Goffman (1997) and Stewart, Wiener, and Sands (1996). One might like to define the sanctions in terms of the increased greenhouse gases—that is, the damages—that arise as a result of country behavior. Those will be difficult to measure, even for carbon. One possibility is to approximate the number of tons of carbon and multiply that by a number at least as large as the price of permits (Nordhaus 1997).

70. See Chayes and Chayes (1995).

house gas reductions) than a treaty with enforceable limits because countries may do more under an action-based treaty if the costs turn out to be lower than expected. That finding is consistent with the conclusions of Victor and of Victor, Raustiala, and Skolnikoff.[71]

Corruption. Corruption in some countries could pose a significant problem. Consider a country with leadership that does not make good on its promises related to climate change. For example, imagine a country that is given an allocation of tradable permits: the country could sell the permits, and the leader could take the money and leave the country after a coup. The country could then ignore its previous obligations related to the sale of permits. Problems like those have solutions, such as deflating the value of the permits from the seller country, but the solutions could affect the integrity of the system if corruption occurs on a large scale. Moreover, to the extent corruption is endemic to a political system, such as in some developing countries, it is also likely to appear in the administration of an agreement to limit greenhouse gases, where large wealth transfers could be involved.

The preceding analysis of the politics reveals that the range of "sensible" actions is likely to be severely constrained in the short term. At the same time, significant room exists for fashioning an agreement within those constraints.

71. See Victor (1997) and Victor, Raustiala, and Skolnikoff (1997).

4

Policy Recommendations

The science of climate change suggests that it could present a significant problem in the future, but not immediately, because the cumulative buildup of greenhouse gases is what matters. The economics suggests that the problem may be worth addressing, but that a broad coalition of the world's countries will need to participate in an agreement for it to be effective in significantly limiting greenhouse gases. The politics suggests that the range of instruments for addressing the issue is likely to be severely constrained in the short term. Given that little is likely to be done in the short term and given that climate change is an important issue, the best approach over the next decade is to build institutions that help set the stage for broad-based action in the future, should it be necessary.[72]

A key question is how to develop a useful long-term institutional capability at a modest cost. That depends on the objectives of the institution-building exercise. One objective could be to bring as many countries into an agreement as possible so that they buy into the idea that address-

72. Victor, Raustiala, and Skolnikoff (1997) show that even in a relatively simple case where there was strong political will—the development of the monitoring and modeling system for limiting transboundary air pollution in Europe—it took more than a decade to build the necessary international institutions.

ing climate change is worthwhile and begin building the necessary institutions. A second objective might be to help build the capability to enforce agreements with clear targets at a national and international level. A third objective might be to learn more about the potential for making cost-effective greenhouse gas reductions on an international scale. The institution-building exercise needs to take place primarily at the national level, given the constraint of national sovereignty.

More than the practitioners of any other discipline, economists have focused on the institutional objective of achieving greenhouse gas reductions in a cost-effective manner. The evidence from application of economic instruments and from essentially every economic analysis of the issue shows that those instruments can substantially reduce the cost of limiting greenhouse gas emissions. Thus, economic approaches should play a central role in the response to climate change, and it is useful to think about building institutions that will foster the development of economic instruments.

Table 4–1 shows a range of proposals by economists for addressing the climate-change issue. The table, while not comprehensive, provides insight into the kinds of institutional issues that the economics community is debating. One of the fundamental issues addressed by those proposals is the extent of coverage in an initial agreement—the number of countries participating in an agreement and their responsibilities. Schmalensee makes a cogent argument for an approach that includes as many countries as possible (broad), but does not require major greenhouse gas reductions (shallow).[73] The rationale for that approach is that getting a large number of parties to agree to make a commitment now—even a small commitment—is the most appropriate strategy for building the depth and breadth necessary for a durable institution to address climate change. The goal can be

73. See Schmalensee (1996).

changed later on as new information becomes available and the demand for taking action changes.

Schmalensee contrasts the broad and shallow approach with a "narrow and deep" approach implicitly advocated in a draft protocol from the State Department.[74] The protocol calls for the Annex 1 nations, plus any others that wish to join, to take significant actions now.[75] Schmalensee suggests that implementing a broad and shallow approach now, or at least one that maximizes participation at a reasonable cost, is the best way of getting to a broad and deep approach later.

The broad and shallow approach is appealing, but it has a couple of drawbacks. First, it is unlikely to be feasible, except in a very limited sense. The developing countries are unlikely to participate unless they receive resource transfers, such as through an initial allocation of permits. It is hard to see the value of getting the developing countries to sign an agreement that simply requires resource transfers from the developed world unless a credible promise can be extracted from them to do more later if the situation warrants. For example, in exchange for some transfers now, the developing countries might agree to enter into an agreement that requires more significant reductions as their per capita income rises beyond a certain level. While that idea sounds appealing, one must question whether future governments will feel bound by such promises. Second, as I argue below, there may be reasons to prefer an agreement that is narrow for the purpose of learning how to design institutions. In short, a broad and shallow approach has the advantage of bringing many parties on board (by definition), but I am not sure that that is such a great advantage, since there is little assurance that many of

74. See Schmalensee (1997).

75. To the extent that leakage occurs and emissions grow more rapidly in the countries outside the protocol, countries may be asked to do more later. That could increase their political resistance to joining an agreement and could require relaxing their emission-reduction goals.

TABLE 4–1
POLICY PROPOSALS BY ECONOMISTS

Author	*Instrument*	*Coverage*	*Mechanism to Decide Target*
Schelling (1998)	Agreed-upon actions that can be monitored	OECD; China and India must be included soon	Uses abatement actions, not abatement targets
Schmalensee (1996)	A hybrid between a tax and a tradable permit; does not prescribe domestic policies	Maximum participation at an acceptable cost	Internationally negotiated emissions targets aimed at getting broad participation
McKibbin and Wilcoxen (1997)	System of national permits and emission fees	OECD now; hope to expand	Permits based on historical emissions and a fee for emissions exceeding permit holdings
Cooper (1996)	Agree on international actions, not national targets; carbon tax preferable; revenue neutral	All countries	Agree on actions, not target
Nordhaus (1997)	National targets; countries choose domestic instruments	Partial participation above $5,000 per capita and full participation above $15,000 per capita	Targets updated on basis of voting mechanism that balances costs and benefits

TABLE 4–1 *(continued)*

Level of Greenhouse Gas Target	*International Trading*	*Monitoring*	*Enforcement*
Not specified, but modest abatement now; more later if necessary	Not addressed	Not addressed	Not addressed
Not specified, but modest abatement now; more later if necessary	Not addressed	Ex ante international evaluation of policies	International public opinion
Permits equal to 1990 emissions; actual emissions expected to be higher	No	Individual governments	Individual governments
Reduce projected emissions 2% per year; in 2050 tax would be $208 per ton and emissions would be reduced 25% from 1990	No, but tax should yield cost-efficient result	IMF could monitor	Individual governments; international pressure
Not specified; it would depend on country preferences	Yes	Not addressed	Carbon import duties on nonparticipating and noncomplying countries

those parties will participate in the future if they are asked to bear significant costs.

Schelling takes a different tack. He argues for what might be called a narrow and shallow approach.[76] Unlike Schmalensee, who calls for emission targets, Schelling believes that "targets and timetables" are unworkable at this point because governments cannot easily be held responsible for their nations' emissions, which depend on many variables, including random shocks. Uncooperative nations would explain away their failure to meet stated goals as bad luck.

Instead, Schelling argues for agreeing on a set of actions for which nations could be held accountable, even though the impact of those actions on greenhouse gases is uncertain. Those actions could be monitored by an international oversight entity more easily than actual emissions. Schelling dismisses international tradable permits on the grounds that if permits are allocated relative to a baseline, no country will ever export any permits for fear that it will provide grounds to reduce their allocation in future negotiations. He also objects to distributing permits on a per capita basis because the transfers would be huge.[77] One advantage of Schelling's approach is that it is feasible. OECD countries could specify actions and monitor them.

Another proposal in the "narrow and shallow" category is by McKibbin and Wilcoxen, who advocate a system of tradable domestic permits with a fee collected by national governments for their own use.[78] The fee would put an effective cap on the cost of emission reductions by placing an upper bound on the price of a permit.[79] Their proposal

76. See Schelling (1998).

77. See Schelling (1992).

78. See McKibbin and Wilcoxen (1997).

79. For example, if the fee were $10 per ton, the permit price would never exceed that amount because firms would simply pay the fee in lieu of purchasing a permit.

does not allow international trading because they believe that the huge transfers between countries are politically infeasible and undesirable. I think that such a proposal represents a step in the right direction because it is feasible; it does little, however, to develop the institutional architecture needed for enforcing agreements among nations.[80]

Cooper argues for a broad and incremental approach using emission taxes, steadily reducing carbon emissions from projected increases by an additional 2 percent per year.[81] He contends that tradable permits are not feasible because it will be politically impossible to agree on a baseline. Cooper's critique of international tradable permits also applies to his own tax proposal. It is hard to see how a taxation approach would be feasible in the short term for the developing world, unless the tax were set very low and the developed countries paid for most of it. Cooper argues that developing governments will embrace the tax as a revenue source. Of course, nothing would prevent them from auctioning the permits to obtain revenues.

Nordhaus advocates a broad agreement but recognizes that that may not be feasible in the short term.[82] He suggests linking the level of participation to a country's per capita income. Specifically, Nordhaus advocates that countries set national emission targets. Countries would be allowed to meet them by using their own choice of instruments. A novel feature of Nordhaus's proposal is that it calls for revising the overall target periodically by using a voting mechanism that would help balance benefits and costs. While the details need to be worked out, as Nordhaus

80. For a very similar, more recent proposal, see Kopp, Morgenstern, and Pizer (1997), who highlight the potential improvements in welfare that could result from such a policy. Their proposal does not explicitly address international trading.

81. See Cooper (1996).

82. See Nordhaus (1997).

notes, the general idea of revising targets over time while taking into account benefits and costs is intriguing.

The preceding proposals serve to underscore the richness of ideas swirling around the economics community on the climate-change issue. I believe that all the proposals have merit, and I do not have a single preferred proposal. But I do have a conceptual framework that I would like to offer for thinking about the problem. Within that framework, I would also like to offer some proposals that I think are worthy of consideration.

The framework involves experimental institutional design. In the best of all worlds, we would like to learn how to design adaptive institutions that can address the climate-change issue in a sensible manner. As a social scientist, I would like to conduct a series of controlled experiments on planet Earth. We might, for example, choose to compare policies suggested in table 4–1 in terms of their efficiency, equity, and environmental impact.

If we could run such experiments, what might they look like? One might feature voluntary targets; a second might feature a taxation system; a third might feature a tradable-permit system; a fourth might feature a tradable-permit system with a tax that places an upper bound on costs. The permutations are virtually endless and could include different rules on international trading, gases covered, monitoring approaches, and enforcement regimes. The important point would be to design the experiments to shed light on key elements of institutional design.

Of course, in the real world, we do not have the luxury of conducting a series of controlled experiments that would yield the kind of clean information on institutional design that social scientists crave. At the same time, we could have the opportunity to learn from some uncontrolled case studies. Social scientists should explicitly address the kind of case studies they think are most useful within realistic political constraints. For example, if the United States is wedded to a tradable-permit approach, it should be allowed to

pursue that; if the Europeans wish to use a standards-based approach or a combination of standards and taxes, they should be allowed to do so. Moreover, different regions, such as the United States, Europe, and Japan, need not have similar reduction targets. The key is to help shape those case studies in a way that allows for learning.

Researchers need to be explicit about the goals of the case studies as well as performance measures. I believe that it is important to learn how different market-based systems perform under relatively hard emission targets that involve more than one country. That line of inquiry is important because significant actions on climate change, if they are required, should be achieved in a way that does not waste hundreds of billions of dollars.

Six suggestions for possible case studies appear in table 4–2. All involve a few developed countries, and in two cases, a few developing countries as well. They include a suggestion for coordinated policies and measures along the lines proposed by Schelling;[83] a modest tax; a tradable-permit approach with a few developed countries; a tradable-permit approach with a few developed and developing countries; a tradable-permit approach along with joint implementation in a few developed and developing countries; and a hybrid approach that incorporates both taxes and tradable permits (described in more detail below). The case studies would be designed to impose modest costs on the participating countries. Important aspects of each system, such as precise emission targets and taxes, monitoring, and enforcement regimes, are not specified and would need to be worked out.

83. See Schelling (1998). That proposal is similar to a proposal from the European Union calling for the coordination of policies and measures. See Schmalensee (1997). But the European Union has maintained that such coordination should be legally binding, although in practice it might be easier—and more consistent with Schelling's proposal—to coordinate through nonbinding agreements. See Victor (1997).

TABLE 4–2
THE CASE STUDY APPROACH

Instrument	*Countries*	*Learning*
Coordinated policies and measures	A few developed countries	Ease of administration; extent of emissions reductions
Modest tax	A few developed countries	Ease of revenue collection; ability to harmonize taxes; efficiency gains and losses
Tradable permits	A few developed countries	Performance of international and domestic trading
Tradable permits	A few developed and developing countries	Same as tradable permits
Tradable permits and joint implementation	A few developed and developing countries	Same as tradable permits; performance of joint implementation
Tradable permits and taxes	A few developed countries	Same as tax or tradable permits

The cases would provide different kinds of insights, as the table suggests. For example, coordinated policies could yield information on the possibility of getting significant reductions from agreed-upon actions. The tax system could provide insight into the problems with harmonizing taxes across countries, if we assume that to be a goal of the system.[84] The tax system could also provide insight into possible efficiency gains and losses associated with actual revenue recycling. The tradable-permit approaches could give insights into the potential of joint implementation, the problems associated with enforcement, and possible debasement of the currency.[85] All systems could be helpful in improving the information base on inventories. If data were collected on administrative costs, those could be compared across different approaches. Finally, the relative merits of different approaches may become more readily apparent.

Note that the preceding set of case studies need not require a binding agreement across nations; but such an agreement might be helpful in encouraging the developed countries to experiment with a variety of approaches. It could also be helpful in setting broad parameters related to the expected cost of the system.

Such a case-study approach underscores the need to design *national institutions*. Those national institutions are crucial if novel market-based mechanisms are to be implemented effectively. Most of the existing literature on institution building suggests the need to focus on international institutions.[86] Yet action at the national level matters most,

84. Countries may take steps to undercut the effectiveness of a harmonized carbon dioxide tax by reducing other taxes on fossil fuels, which will raise prices less than the full amount of the new carbon tax. The government could also subsidize complements to fossil fuels or raise taxes on substitutes to lessen the impact of the agreement on the economy. See Hoel (1992). Less well appreciated is that countries could adopt similar policies to reduce the effectiveness of a tradable permit system.

85. See Wiener (1997).

86. See Chayes (1991) and Chayes, Skolnikoff, and Victor (1992).

even though there is obviously a need for some kind of international institution as well.

One objection to that experimental or case-study method is that it is unlikely to be politically acceptable. In many ways though, the case-study approach is more acceptable than adopting a single approach to limiting greenhouse gases. Many groups are wary of supporting large institutional reforms, such as a large-scale tradable-permit or harmonized-tax approach. For example, political support for international tradable permits or even for joint implementation with credits remains lukewarm. The case-study approach allows practical demonstration of the benefits of those approaches without first requiring all nations to agree. More important, it permits the ironing out of design details before committing major economies to potentially costly and practically irreversible effects. Finally, the case-study approach need not be an excuse for taking no action to regulate emissions—if it were, then it would encounter significant political resistance.

The case-study approach would take into account the interests of particular countries. For example, the Scandinavian countries, which have already implemented carbon taxes, could continue on that path, perhaps working on harmonization issues. The United States and other countries interested in tradable permits or a hybrid system could use that approach. Other European countries may want to try a combination of regulation and market-based approaches. The key is to design studies that take account of the political constraints while promoting learning about the design of robust institutions.

To advance the case-study approach, one could have an agreement that includes the developed countries and any developing countries that wish to join.[87] The key would

87. In principle, one could conduct the case studies without any overarching agreement; I believe, however, that participation would be less likely.

be to allow individual countries and groups of countries to tailor instruments to their economic and political needs. The agreement could center on verifiable actions that countries agree to take and could also include binding commitments.[88] Those actions would include not only concrete measures, such as plans to change power sources, but also instruments, such as those suggested in my case studies.[89] The overarching agreement could also call for extensive review of the case studies.

The case studies presented in table 4–2 are quite broad. Table 4–3 considers one proposal in more detail that is really a variant of the last case study shown in table 4–2. That hybrid proposal includes emission targets, international tradable permits, and a price floor and a price ceiling on emission permits.

Fixed targets are central to learning how to monitor emissions and enforce agreements. Trading internationally is critical for learning how to trade across nations to help achieve a given goal at a lower cost. A novel feature of such a proposal is its reliance on both a ceiling price and a floor price for permits. Acting as a safety valve, a ceiling price on permits would limit the costs imposed on participating countries and businesses.

I would not make that price higher than $10 per ton.[90] The ceiling price effectively limits the maximum price of a

88. See Schelling (1992) and Victor (1997). A relevant precedent for such an agreement is the North Sea regime. See Victor, Raustiala, and Skolnikoff (1997).

89. If the case-study approach is not feasible among countries, it may be feasible within a country such as the United States. One might want to consider the potential for learning about different institutions by having groups of states experiment on a voluntary basis with different approaches to limiting greenhouse gases.

90. If one is interested in ensuring that the tradable-permit price will be binding, it may be necessary to use a higher ceiling price. A tax of $10 per ton translates to about $.024 per gallon of gasoline, but it would apply to all major sources of carbon dioxide and not just to gasoline.

TABLE 4–3
PROVISIONS OF TRADABLE PERMIT PROPOSAL WITH PRICE CEILING AND PRICE FLOOR

Fixed domestic emissions targets at a level thought to be binding (e.g., at 1997 emission levels)
International tradability of permits among the countries participating in the agreement
A ceiling price and a floor price on permits
A focus on sources of carbon dioxide initially, with an agreement on conditions under which sinks and other gases could be included
Readily available information on the emissions of countries and market participants
An agreed-upon enforcement mechanism that has teeth

permit to that value. Conversely, a floor price limits the minimum price of a permit. That price, which could be set around $1 per ton, would ensure that the system was operational, even if the initial emission targets turned out not to be binding.

The remaining parts of the proposal address monitoring and enforcement issues. Sources of carbon dioxide from fossil-fuel combustion are the focus initially because that is the part of the problem that is most easily monitored.[91] The provisions to extend the agreement to other gases and sinks would encourage the development of new monitoring technologies. Making information readily available on emissions can be a useful way of encouraging compliance with the agreement and also assessing the effectiveness of

91. See Victor (1991).

the agreement. The enforcement mechanism would consist of a set of graduated sanctions, beginning with a fine.[92] Thus, the effective price ceiling would be raised for noncomplying nations.

A fundamental issue relates to the credibility of the enforcement mechanism—that is, making countries and firms believe that they will have to incur significant costs in the case of noncompliance. That problem has no simple solution. It will inevitably involve a willingness on the part of individual nations to give up some degree of control over their policies—as is currently done with trade policy.

Specifically, some policing mechanism and some central organization will be needed to aid with enforcement in the case of noncompliance. The nature of that governing body is likely to be an extremely sensitive issue. I envision such a body's emerging slowly, as knowledge concerning emissions, control costs, and institutional mechanisms evolves. In the short term, countries could agree to self-enforcement with reporting and see how that works.

Finally, serious thought needs to be given to the finer structure of that and other proposals, including the nature of monitoring and enforcement. Consider the problem of monitoring carbon dioxide in the energy sector that most schemes propose to address. Table 4–4 shows some possible choices for the U.S. energy sector. The task for policy makers is to minimize the costs of administration, monitoring, and enforcement while ensuring that the system's environmental goals are achieved. It is clear from the table that it makes sense to focus on some point upstream rather than on the millions of users downstream.[93] One may not want to focus on the point furthest upstream, however. For example, in the case of natural gas, it may make more sense to monitor and enforce at some points in the pipeline net-

92. For example, if the ceiling price were $10 per ton, the fine on excess emissions could be $15 per ton.

93. See Hahn and Richards (1995) and Smith et al. (1992).

TABLE 4–4
NUMBER OF POTENTIAL SOURCES OF GREENHOUSE GASES IN THE U.S. ENERGY MARKET

	Petroleum	*Natural Gas*	*Coal*
	Upstream		
Extraction			
Wells/mines	594,189	301,811	2,104
Companies	2,000[a]	2,000[a]	3,114
Processing/refining			
Processors	164 Refineries	686 Gas processing plants	3,600 Blending/cleaning facilities
Distribution			
Distributors	14,127 Bulk stations, terminals, and wholesalers	133 Pipelines	900

		Downstream	
Users			
Residential units	20,000,000[b]	Up to 102,264,000[b]	400,000[b]
Commercial units	Up to 4,528,000	4,409,699	25,000
Industry	Up to 368,897 manufacturers	209,616 Facilities	130,000 Boilers
Transportation	120,347,000 Cars; 61,172,000 trucks	1,033 Fuel stations	Negligible
Electric utilities[c]	Up to 3,232 (3,239)	Up to 3,232 (2,115)	Up to 3,232 (1,238)

a. Number of petroleum and natural gas companies combined.
b. Residential units as listed here may contain two or more individual units (e.g., apartment buildings).
c. Figures in parentheses are the number of generators using the specified fuel.
SOURCES: Energy Information Administration (1997a, 1997b, 1997c, 1997d, 1997e), U.S. Bureau of the Census (1993), U.S. Department of Commerce (1994), American Automobile Manufacturers Association (1993), Bell (1993), Smith et al. (1992).

work or at the processing plants; for oil, refineries represent a logical monitoring point; and for coal, a logical point is at the coal mine. The most efficient system will depend on the specific objectives of the policy maker.

The goal over the next decade or two should be to learn how to design institutions that are capable of addressing the climate problem on a large scale if significant actions are desired in the future. The goal should not be to implement the lowest-cost system right now, but rather to introduce approaches that will help develop sensible policies in the future.

Some may object to the seemingly modest emission-reduction goals embodied in the case studies. I recommend that approach on the basis of political considerations as well as an interest in developing durable institutions. Consider two instructive analogies—the evolution of a free trading system and the possible emergence of a European monetary union. Rules and institutions governing free trade among nations have been evolving for several decades. A European monetary union involves a smaller group of countries and a higher level of political support than the climate-change issue, yet there are huge practical problems in implementation.[94]

Policy makers and analysts have barely examined—much less agreed upon—the details of economic instruments for addressing climate change, such as currency, trading rules, and rules for changing the rules.[95] Thus, if one wants a workable system, it makes sense to start small. And since we do not know how best to start, why not try a few case studies?

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94. I am indebted to David Victor for that example.

95. Many papers on the subject of economic instruments in that area exist, but good "how to" manuals that work out the details of enforcement and monitoring are virtually nonexistent because the problems are quite formidable—with respect not just to market-based approaches but to all approaches.

It is of some practical interest to compare and contrast the case-study approach here with the Kyoto Protocol developed in late 1997. The case studies recommended here are consistent with the 1997 Kyoto Protocol in allowing individual countries freedom to decide how best to achieve emission reductions. The studies differ from the protocol, however, in terms of the stringency of the targets. I fear that by setting stringent targets, the designers of the protocol may deflect attention away from the more fundamental problem of building durable institutions. Politicians are likely to make largely symbolic gestures rather than to engage seriously in the quiet work of building the necessary institutions.[96]

The case-study approach suggested here implicitly recognizes that no single instrument dominates all others. We can expect institutions to have different strengths and weaknesses both economically and politically. It would be instructive to identify the relative strengths and weaknesses of those approaches as they actually perform in the real world.

96. The administration's proposed $6.3 billion package of tax cuts and research and development investments over the next five years may provide a good example. See Bureau of National Affairs (1998).

5

Conclusion and Areas for Research

A common thread runs through the recent economics literature and political economy literature on climate change. The economics literature generally suggests that at the current time we have no reason to panic and take drastic action to reduce greenhouse gases. The political economy literature suggests that such action is infeasible because of the serious problems in getting countries to cooperate. Scholars disagree, however, about the kind of approaches that should be taken in the short term and the countries that should be involved.

After reviewing some of the key economic and political factors likely to affect a climate-change agreement among nations, I have suggested an approach primarily involving developed countries that would be useful in building institutions to address climate change. The approach rests on two ideas: first, action is likely to occur now only if the developed countries pay the bill; and second, it is best to learn about the development of institutions for addressing climate change through a case-study approach.

The case-study approach is appealing because it preserves diversity and builds useful institutional experience and knowledge. The last thing we should be doing now, in our state of ignorance about the warming problem and institutional responses, is to narrow the range of response mechanisms. Thus, the case studies I suggest cover a fairly

wide range but focus on the development of cost-effective approaches for limiting greenhouse gas emissions.

In a sense, the suggestion by several economists that countries be allowed to decide for themselves on specific actions or goals is an implicit endorsement of the case-study approach.[97] But I believe that most case studies should involve binding constraints, because they would eventually be needed if climate change is perceived as a serious issue meriting a serious response.

My approach builds on Schmalensee's insight concerning the need to think about the design of institutions for addressing climate change.[98] It differs from Schmalensee's in its primary focus on developed countries and on the design of multiple cases or experiments. The policy design I suggest also borrows from Schelling, who argues for a shallow approach centered on developed countries.[99] My approach differs from Schelling's design primarily in my emphasis on learning about the properties of market-based approaches for addressing climate change.

One of the messages of this volume is that policy makers should not set their sights excessively high, given the political constraints on getting countries to participate in an agreement. It is safe to say that the solution that maximizes collective net benefits for climate change is unlikely to be attained in the short term, even if there were agreement on the nature of that solution, which there is not. Moreover, no obvious target or focal point around which parties can easily coalesce exists. The goal of stabilizing emissions at 1990 levels was once advanced as an initial target, but that goal has no strong economic, political, or scientific appeal.

This volume has argued that in the near term it is imprudent to take significant action and that such action is

97. See Schelling (1992), Hahn and Stavins (1995), and Schmalensee (1996).

98. See Schmalensee (1996).

99. See Schelling (1992).

unlikely to occur. An agreement among developed countries is feasible if it is not inordinately expensive. Persuading developing countries to reduce greenhouse gases in the current political environment without providing substantial side payments to induce allegiance to the common goal will be very difficult. Yet it is possible and appropriate to think through important choices in the structuring of agreements and institutions so that nations can better address the climate-change issue over the next century.

Academics and policy makers should begin to engage the institutional design question more seriously. So far, most academics have focused on a single preferred case without considering the possibility of addressing more than one. I believe that there could be great gains to the case-study approach suggested here, especially if the cases were designed to take account of political constraints.

Designing institutions that can achieve significant greenhouse gas reductions from a number of countries will be a formidable task. Although we have been at that task for only a decade, some innovative approaches have already emerged. Experimenting with market-based approaches for environmental control as well as coordinated policies and measures will make the task easier. Designing those approaches will be difficult because enforcement capabilities and political interest vary tremendously across nations. Experience strongly suggests that it is not reasonable to expect to achieve a particular greenhouse gas goal in a least costly manner. Nonetheless, a wide range of options exists, some of which are likely to be much more costly than others. It behooves countries to explore the low-cost ones now. The best way to learn about the potential of market-based designs is to consider implementing some case studies. In addition, one can build on the practical experience that has been gained from those approaches.[100]

100. See Hahn (1989), Stavins (1997b), and Joskow and Schmalensee (1998).

While this volume identifies a particular set of cases for building institutions, we need to continue to make progress in several other areas to aid in institutional design. First and foremost, we need to develop a better inventory of emissions of greenhouse gases. That would include sources of emissions as well as "sinks" such as forests that store emissions. Second, we need to make that information readily available to interested parties. Low-cost information on emissions by country and source could serve as a powerful tool for encouraging countries to comply with an agreement.

In addition, we need to couch the institutional design issue more broadly in terms of a portfolio of investments that could best address the climate problem. Manne and Richels characterize the problem in terms of "finding the right blend of options."[101] It is also important to continue investing in research that will provide a better understanding of the climate problem, research that fosters new technologies, and research that sheds light on the merits of different strategies for adaptation.[102]

It is also useful to continue research on key political and institutional factors that will make it easier to attain a more far-reaching agreement if one is necessary. Clearly, as countries become wealthier, they are more likely to find it in their interest to address long-term problems. But, beyond that, we need to design agreements so that countries have an incentive to participate. The nature of feasible carrots and sticks deserves further study.[103]

Institutions should not only strive to be cost-effective; they should also help to produce and adapt to new information. We must achieve a delicate balance. One would like to be able to change the rules periodically but still get

101. See Manne and Richels (1997).

102. See Lave (1988), Toman (1997), and Tucker (1997).

103. See, for example, Barrett (1997a), Victor (1997), and Victor, Raustiala, and Skolnikoff (1997).

people to take actions that are based on sound science and economics.

As Nordhaus notes, climate change is truly "the granddaddy of all public goods."[104] But it is not without solutions. In the short term, the strategy is clear: help design institutions that can better respond to the problem.

104. See Nordhaus (1991).

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