CLIMATE CHANGE: ECONOMICS, POLITICS AND POLICY

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Climate Change: Economics, Politics, and Policy*

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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 paper 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. These institutions include developing a capacity at the level of the nation-state for measuring greenhouse gas emissions, implementing cost-effective approaches for limiting these emissions, and enforcing these approaches. They also include improvement of the capacity of an international body to assess greenhouse gas inventories and to review national policies and measures.

The paper 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 U.S. and other countries interested in tradeable 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 the paper 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.

Climate Change: Economics, Politics, and Policy

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1. Introduction

Over the next century, our progeny will get to see if the average global temperature increases from 1 to 3.5°C, as has been suggested by the Intergovernmental Panel on Climate Change (IPCC, Working Group I, 1996). If such increases occur, they 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. This will be the central topic of discussions later this year, as countries of the world gather in Kyoto, Japan to see if they can hammer out an agreement.

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 these "greenhouse gases" (GHGs) increases average temperatures by about 30°C and moderates temperature variations, thereby allowing life to exist as we know it (Tucker, 1997).[1]

Human activity, such as the burning of 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 concentrations of GHGs 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 (IPCC, Working Group II, 1996). Scientists

1. The major greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

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.[2]

There is great debate over the likely impacts of rising global temperatures. Indeed, the concern about rising greenhouse gas concentrations stems not so much from their impact on global mean temperatures as their impact on climatic changes that affect humans, animal, plants and ecosystems. For example, there could be major changes in regional weather patterns, including the amount of rainfall, temperature variation, and storm patterns.

Concerns have been expressed 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, there is a concern that the changes in climate could lead to some unpleasant "surprises," such as a shift in ocean currents that could alter regional climate, possibly freezing Western Europe (Schelling, 1992). 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 this all sounds uncertain, it is because it is difficult to know the precise implications of the changes in global average temperature.

Limiting greenhouse gas emissions is far from simple since they are inevitable byproducts of industrialization. There are numerous sources of greenhouse gas emissions, including all activities that utilize fossil fuels, such as automobile travel. Moreover, fossil

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2. Although correlation does not prove causation, historical data shows 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).

fuel use is expected to grow rapidly throughout the world as the developing countries industrialize, especially in a country such as China, which has large coal reserves.[3]

Because the sources of rising GHG concentrations are ubiquitous and its consequences 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 is likely to be small. Yet, getting widespread cooperation is unlikely in the short-term because most developing countries do not feel the climate change issue is a high priority for them and because they fear 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 switch to using more efficient insulation, light bulbs, appliances and vehicles. Greenhouse gas emission reductions could also involve switching to energy and power sources that release fewer greenhouse gas emissions per unit of energy such as nuclear power, solar power, and natural gas.

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

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3. 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.

change in the future (Victor and Salt, 1995; Schmalensee, 1996).

The development of institutions is necessary because institutions do not currently exist to address a global environmental issue of this kind, assuming significant action is warranted.[4] These institutions include developing a capacity at the level of the nation-state for measuring greenhouse gas emissions, implementing cost-effective approaches for limiting these emissions, and enforcing these approaches. They also include improvement of the capacity of an international body to assess greenhouse gas inventories and to review national policies and measures.

The paper recommends that the developed nations of the world craft an agreement for the next decade that provides a slight emission limitation and points toward a series of *case studies*. The suggested case studies would help nurture the development of institutions that could effectively address the climate change issue at a reasonable cost. The paper 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. This market-based approach would involve international tradeable permits along with a price ceiling that limits the costs of control, and a price floor that ensures the system will be operational.

Section 2 examines the economics of climate change while section 3 addresses the politics. Based on the discussion of economics and politics, section 4 develops a strategy for addressing climate change along with some policy recommendations. Section 5 reviews the basic findings and suggests areas for research.

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

2. Economics

The economics of global warming is concerned primarily with the costs and benefits of limiting greenhouse gas concentrations in the atmosphere. The concentration of greenhouse gases in the atmosphere can be limited in two ways–by limiting emissions sources or 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 non-market factors such as changes in consumer welfare resulting from impacts on different sectors of the economy, changes in recreation, and changes in ecosystems.

There are a variety of ways 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 following 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.[5]

There are many alternatives to the precautionary principle. Economists, while not in complete agreement on a particular objective, believe it is useful to weigh the costs and benefits in developing a strategy for addressing climate change. This section highlights some important economic considerations in designing that strategy.

Nature 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 much longer time scale as greenhouse gases build up in the atmosphere.[6]

Both the costs and benefits of limiting greenhouse gases emissions are highly uncertain. Individual cost estimates are subject to great uncertainties, reflecting 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, elasticity of demand for carbon-based fuels, and unforeseen political

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5. While the precautionary principle does not provide a firm basis for policy, there are specific decision criteria that 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, there is a case to be made for investing in preserving one's 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.

6. 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.

events.

The IPCC presents estimates for stabilizing U.S. carbon emissions at roughly the 1990 level that range from 0.4 to 2.2 percent of U.S. GNP (IPCC, Working Group III, 1996).[7] 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 (1992) has argued that these costs are affordable in the sense that they are unlikely to have a huge impact on growth.[8] The costs, however, may not be desirable if the likely future benefits are small in comparison. Moreover, there could be major shifts in employment, as sectors that rely heavily on fossil fuels, such as steel, primary metals, coal production, and petroleum refining, decline (Jorgenson and Wilcoxen, 1990).

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 (Mendelsohn, 1996). Measuring potential non-market damages, such as damages to unmanaged ecosystems and biodiversity, is extremely problematic because they are difficult to specify in quantitative terms and they are not valued directly by consumers.

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7. The IPCC cites costs of U.S. abatement from -1.2% to 10.9% 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.

8. Schelling argues that developed countries can easily absorb this size loss since a 2 percent reduction in GNP per capita would mean a doubling of income per capita would occur in roughly 62 years rather than 60 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" (Schelling, 1992).

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 (Schelling, 1992). Moreover, Mendelsohn (1996) finds the market impacts on the United States are likely to be beneficial.

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, which is 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 U.S., for example, agriculture represents only 3 percent of GDP while in the developing world, the total is closer to 30 percent (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 these threats.

The location of a particular source of emissions or sink is not important for overall 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. This property has important economic and political implications. For example, this 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.

Measures to reduce greenhouse gases often reduce other pollutants as well, yielding 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 these benefits per ton of carbon reduced has been estimated between $3 and $80 per ton (Burtraw and Toman, 1997).[9] To the extent these benefits would not be obtained with current policies, they should be considered. Burtraw and Toman (1997) argue that these benefits are likely to be modest.

Costs increase more than proportionally with increasing stringency of targets and timetables. Several analyses have shown that climate change costs increase dramatically as the target reduction in net GHG 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 (Parry, Williams, and Goulder, 1996).[10] In addition, the timing of reductions can have a critical impact 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 (Manne and Richels, 1997).

Interestingly, the Framework Convention on Climate Change calls for fairly significant reductions now. This may not make good economic sense (Manne and Richels 1997). It appears that the best economic strategy is to start small and increase the target gradually, if such increases are warranted based on the science and economics (Nordhaus, 1979; Manne and Richels, 1997).

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9. Unless otherwise noted, year dollars reflect those used in the study cited. Most estimates fall in the time period 1990 to 1995.

10. This pattern is consistent with others noted in the IPCC including studies by Barns, Edmonds, and Reilly (1992), Martin et al. (1993), Manne (1992), Oliveira-Martins et al. (1992), and Rutherford (1992).

Strategies to Reduce Abatement Costs

Costs could be reduced substantially using economic instruments. Table 1 compares various command-based systems for achieving targets with market-based approaches, such as tradeable permit systems, under various assumptions.[11] Both fees and permits 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. These simulations, which are based on the assumption that markets work efficiently, suggest that potentially huge amounts of money could be saved in moving to an international tradeable permit system if significant reductions were required. For example, if the OECD were required to stabilize emissions at 1990 levels early next century, savings relative to the case with no trading with the rest of the world range from $0.5 to $3 trillion dollars annually. These savings represent about 50 percent of the costs without trading.

Costs could be reduced substantially using sinks. Although there are significant challenges to implementing a carbon sink program as part of a national or international greenhouse gas policy, there are likely to be substantial savings for a net emissions approach relative to a program that is limited to reducing energy-related emissions (Richards et al., 1993; Stavins, 1997). The IPCC indicates that carbon sequestration could cost-effectively contribute 15 to 30 percent of the reductions of a net emissions stabilization program (IPCC, Working Group III, 1996). Stavins (1997) argues that carbon sequestration is best seen as a short-term strategy for reducing net GHGs because the strategy will eventually have diminishing returns.

Recent work suggests that some of the relative advantages of the carbon

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

Table 1
Cost Savings from Economic Instruments by Region

Policy Goals and Instruments	Region Realizing Savings	Cost Savings[1]	Cost without trading (% of GDP and $trillion)
Carbon reductions range from 10%-20% below 1990 only in OECD. Trading ranges from OECD only to worldwide.	OECD	18% - 69%	0.4% - 4.0% $0.9 - $6.0[2]
Carbon reductions range from lowering to 1990 levels to 20% below 1990 levels. Trading ranges from OECD only to worldwide.	U.S.	15% - 98%	0.2% - 0.5% $0.1 - $0.6[3]
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%	$0.3 - $1.3[2]
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%	$0.7 - $1.4[3]
Carbon emissions cut 2% per year from projected growth worldwide. Trading allowed worldwide.	World	6% - 47%	1.9% - 8.0%

[1] Cost savings, expressed as a percentage, is defined as the difference in the cost of abatement with trading and without trading divided by the cost without trading. These savings could result from an equivalent system of carbon taxes.
[2] 1990 dollars.
[3] 1994 dollars.

Sources: Jacoby et al., 1997; Nordhaus, 1997; Manne and Richels, 1997; Interagency Analytical Team, 1997; Mullins and Baron, 1997; Dean and Hoeller, 1993.

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 and sinks will be more difficult and costly. Even when these additional costs are taken into account, the costs savings of including sinks, relative to strategies limited to energy emissions, are likely to be substantial (Richards, 1997).[12]

Costs could be reduced substantially by using instruments that generate revenues if the revenues are used to reduce highly distortionary taxes. There is a growing literature that suggests emissions taxes offer significant benefits over a comparable system of non-auctioned tradeable permits, provided that the tax revenues are used to reduce highly inefficient taxes. For example, Parry, Williams and Goulder (1996) find the cost of reducing emissions by 10 percent in the U.S. is 300 percent higher using non-auctioned tradable permits than when a carbon tax is used that recycles revenues. They find that a non-auctioned 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. This analysis highlights the need to consider the revenue and taxation consequences of different approaches to limiting greenhouse gases.[13]

Actual cost savings from economic approaches are likely to fall far short of their theoretical potential. This is primarily because the design of economic approaches is intimately connected with politics. For example, in a tradeable permit system, governments may initially be given the permits with no requirement to allocate these permits to private sector

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

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

participants. If governments are central actors in trading, cost savings are likely to be lower because they 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 the degree of cost savings achieved with a market. If a government is a major trader, private traders may fear that it 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 U.S. (Hahn and Hester, 1989; Foster and Hahn, 1995). A government can address this 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.

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 GHG emission reductions is "Joint Implementation" (Andrasko, Carter, and van der Gaast, 1996). 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 country in which GHG 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 (Harvey and Bush, 1997; Schmalensee, 1997). To award credits to the investing nation for emission reductions, it is necessary to calculate how much higher emissions would have

been without the investment. Since developing nations do not face specific targets, it is difficult to estimate what would have happened without the project. 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 (Jackson, 1995). This case-by-case approach makes it easier for firms and governments to claim net reductions after merely shifting the distribution of emissions. Parties to these transactions also have incentives to overstate their environmental benefits in order to receive more credit and select projects that are more difficult for an oversight authority to audit. To counteract these 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, this could lead to a program that is very limited in scope.

The experience in the United States with emissions trading suggests that Joint Implementation is likely to have limited usefulness because it will be determined 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 (Hahn and Hester, 1989; Foster and Hahn, 1995; Stavins, 1997). By the same token, there may be some constructive applications of Joint Implementation 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 the planting or preservation of forests. For projects where baseline determination is relatively easy, it is probably possible to include them in a tradeable 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, thus increasing 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 it allows some experience that is relevant to designing a tradeable permit system without actually creating that system (Palmisano, 1996). Another advantage is that it 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.[14] Some also see Joint Implementation as an effective way of building support for a climate agreement in developing countries by giving participants a financial incentive to develop better inventories, find 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, it should be evaluated 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.

The costs of achieving net greenhouse gas reductions increase as the sources covered under an agreement narrow. As more sources and sinks for GHG emissions are covered, there is

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

less potential for leakage. For example, if the effect of an agreement is simply to transfer tree planting from an area not covered by the agreement to an area covered by an agreement, this leads to no net reduction in GHG emissions.

General Principles

A wide range of policies can be justified using benefit-cost analysis given 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 (Nordhaus, 1994).[15] This 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, there are likely to be significant disagreements among reasonable people about appropriate measurement and quantification of benefits and costs (Lave and Dowlatabadi, 1993). There are also likely to be disagreements about whether cost-benefit analysis is the best decision making criterion for a problem with such large uncertainties and long time scales (Page, 1978; Arrow et al., 1996).

If anything significant is done, it will require widespread participation. While it is difficult to estimate the precise numbers of sources and sinks, 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 overall level of emissions. Suppose, for example, several island nations concerned with sea level rise agreed to freeze their greenhouse gas emissions, but all other countries continue business as usual. This would have virtually no impact on greenhouse gas

15. Nordhaus provides a range of estimates. The 10th percentile estimate is $0 per ton; the 90th 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,

emissions because these 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 (Martin et al., 1992).[16] 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.[17] For example, reasonable estimates of the increase in carbon emissions outside the OECD resulting from stabilizing OECD emissions at 1990 levels range from 1 to 25 percent of total abatement in the OECD (Babiker, Maskus, and Rutherford, 1997; Jacoby et al., 1997; Oliveira-Martins et al. 1992; Manne, 1993; Manne and Martin, 1994).[18]

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. For countries that expect to benefit from warming, there are no benefits from reducing GHGs. For countries that

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16. The Annex 1 countries include the OECD countries, the former Soviet Union, and the countries of Eastern Europe.

17. The leakage rate is defined as the increase in emissions from non-participating countries divided by the reductions by participating countries. For example, if the OECD reduced emissions by 10 tons and the rest of the world increased emissions by 2 tons the leakage rate would be 20 percent. Leakage may also result if the demand for carbon-based fuels increases from non-participating countries as the demand drops in participating countries.

18. There are a wide range of leakage estimates 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.

expect to benefit from reductions in worldwide GHGs, there are likely to be minimal benefits from unilateral or small group action because such action will only have a small 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.

There is a 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. As discussed in Section 4, economists are divided on the best approach to this problem; nevertheless, there is a consensus 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.

There are four particularly important policy insights that emerge from the review of economics--first, the ubiquitous nature of sources and sinks suggests a coordinated response to the problem will be necessary; second, some action can be justified now provided there is a strategy for gaining widespread participation in an agreement to limit GHGs; 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, which 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 this 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. This 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 this 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 (Cooper, 1996). Notwithstanding the failure to meet targets, the Berlin Conference in 1995 set more ambitious goals. In the Berlin Mandate, the Parties negotiated several targets to be considered in Kyoto, including a 20 percent reduction by 2010 (Richels et al., 1996; Tucker, 1997).

In December of 1997, the Parties meet in Kyoto, Japan for the Third Conference of the Parties. In Kyoto the Parties will discuss specific targets and timetables for reducing emissions. Their aim is to deliver a legally binding instrument that will actually achieve the specified targets. President Clinton has proposed reducing GHG emissions to 1990 levels between 2008 and 2012, with additional reductions by 2017. A system of tradeable permits would be incorporated within ten years (Warrick and Baker, 1997).

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 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 (Lindzen, 1996; Wildavsky, 1992; Hahn, 1993). In contrast, most businesses have an incentive to understate the importance of this 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 GHGs (Warrick and Baker, 1997).

Another important group in the policy process is the international negotiators and bureaucrats, frequently drawn from agencies dealing with diplomacy and/or the environment. Examples include staff representatives of the United Nations Framework Convention on Climate Change Secretariat and the Global Environment Facility. These individuals usually have an incentive to overstate the view of the narrow constituency or constituencies they represent. Justice Stephen Breyer refers to this narrow perspective as "tunnel vision" (Breyer, 1993). Such vision frequently results in over-emphasizing the importance of the particular issue under consideration without thinking through its broader implications for the economy and consumers. This focus stems in part from benefits that accrue to civil servants and appointed officials who negotiate these agreements in the form of staff, travel, and promotions (Hahn and Richards, 1989).

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 great 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.

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 would be done in an economic analysis of costs and benefits. They will be more inclined to focus on the costs of averting global warming, which could appear during their tenure, and heavily discount the benefits, which are far off in the future. While there are exceptions to this rule, it is probably true for most developed countries. Thus, even though 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. This is true even if there were no free-riding problem because of how politicians weigh costs and benefits over time.

A winning short-term strategy for developed country politicians is to talk tough on climate change, but do relatively little. The appearance of doing something can go a long way towards 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 GHG emissions. In justifying the strategy selected, politicians are unlikely to cast the argument in terms of benefits and costs, but more in emotional terms, such as saving the planet (Gore, 1992; Hahn, 1993).

Any instruments used to reduce greenhouse gases are likely to be based in part on the current distribution of political power. For example, if tradeable 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. This 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 (Hahn, 1989).

If anything is done in the short-term, developed countries are likely to bear virtually all of the costs. This follows from the fact that climate change is generally not a high priority for developing countries. According to the World Health Organization, 4 million children 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 (Easterbrook, 1995).

If the developed countries bear the initial costs, as expected, they will have to explain to voters why such expenditures are warranted. Schelling (1997) makes the point that these expenditures are likely to benefit mainly future citizens from countries that will be relatively poor, but better off than today's poor. It may be difficult to justify such transfers on political and economic grounds given the pressing needs of today's poor.

It is unlikely that anything significant on global warming will be done for at least the next decade and possibly longer. This statement assumes 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 this issue as a priority.

Consider the case of the U.S. reducing emissions to 1990 levels. A plausible estimate of the costs is in the range of $100 per ton (Dean and Hoeller, 1992; Nordhaus, 1994). This translates into an increase in gasoline prices of roughly $.25 per gallon. The U.S. 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.

The most likely outcome of international negotiations over the next decade is that a select group of developed countries agree to 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, there is a possibility that the U.S. 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 climate change is still perceived as a problem. Changes in technology can be expected to lower the cost of achieving net emission reductions. These 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 GHGs, thus increasing political pressure to act.

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 (Barrett, 1997a; Parson and Zeckhauser, 1995). In the case of a climate change, countries will have a strong incentive to either free ride by not joining the agreement, or not comply. The key to avoiding such problems is structuring an agreement with appropriate sanctions; unfortunately, this may be impossible in some cases and not worth it in others (Barrett,

1997b).

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 overall 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. This 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.[19]

For countries that sign an agreement, the sanctions for not complying should increase gradually (Stewart, Wiener, and Sands, 1996). Such sanctions would make it easier to bring a country back into compliance. Monitoring should also be transparent because this makes it easier to impose sanctions when a country is out of compliance, and may put more pressure on the country to comply. Examples of different approaches to the enforcement problem are summarized in Table 2, which highlights the role of enforcement when economic instruments are used. Cooper effectively assumes enforcement will not be an issue for a tax if there is support for the treaty and actions are transparent so they can be easily monitored. Dudek and Goffman (1997) and Stewart, Wiener, and Sands (1996) suggest specific penalties in the case of a tradeable permits. Tietenberg and Victor (1994) suggest negotiating a mechanism for dispute resolution. Victor (1997) argues that the threat or use of trade sanctions can alter countries' behavior in order to gain compliance. Based on the implementation of the Montreal Protocol to reduce stratospheric ozone, he contends that linking international aid from other sources to compliance also can be a

19. 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. There are, however, significant differences between the Montreal Protocol and a climate change agreement, including support from key industries, the number of firms involved and the cost of abatement (Hahn and McGartland, 1989; Victor, 1997).

Table 2
Different Approaches to Monitoring and Enforcement

Author	Instrument	Monitoring	Enforcement
Cooper (1996)	Tax	Regular reporting and external monitoring of actions relevant to the treaty is 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)	Tradeable 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 GHGs will have that number of GHGs 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 GHG trading. Paper rules out general trade sanctions.
Stewart, Wiener, and Sands (1996)	Tradeable 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 GHGs 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 GHG permits will apply political pressure to avoid violations.
Tietenberg and Victor (1994); Victor (1997)	Tradeable 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.

effective enforcement mechanism.

One of the critical challenges for a climate change agreement is structuring sanctions for nonparticipating countries. Many analysts have suggested trade sanctions may be necessary for nonparticipating countries. Such sanctions have the potential to reduce free riding; however, they could also result in escalating trade barriers. If, for example, China and India chose not to comply with or participate in an agreement, there could be very large costs to imposing trade sanctions. Moreover, defining the precise form of the sanctions will not be easy.[20]

The sanctions need to have teeth to be effective. Chayes and Chayes (1995) have suggested that countries rarely violate international treaties on purpose. Moreover, they argue that strong sanctions can discourage participation in an agreement. Both observations may be true for the agreements they examine; however, for treaties with high costs, such as a greenhouse gas agreement with a stringent target, one cannot assume 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 GHG 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. This finding is consistent with Victor (1997) and Victor, Raustiala, and Skolnikoff (1997).

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 tradeable permits, the country

20. One might like to define the sanctions in terms of the increased GHGs (i.e., the damages) that arise as a result of country behavior. This 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).

sells the permits, the leader takes the money and leaves the country after a coup. The country then ignores its previous obligations related to the sale of permits. There are solutions to problems like these, such as deflating the value of the permits from the seller country, but they 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 GHGs, 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, there is significant room for fashioning an agreement within these constraints.

4. Policy Recommendations

The science of climate change suggests that it could present a significant problem in the future, but not immediately because it is the cumulative buildup of greenhouse gases that matters. The economics suggests that it may be worth addressing, but that a broad coalition of the world's countries will need to participate in agreement for it to be effective in significantly limiting GHGs. 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, I think the best approach over the next decade is to build institutions that help set the stage for broad-based action in the future, if it should be necessary.[21]

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21. 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.

A key question is how to develop a useful long-term institutional capability at a modest cost. This 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 addressing 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 GHG 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 these 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.

A range of proposals by economists for addressing the climate change issue are reviewed in Table 3. The table, while not comprehensive, provides insight into the kinds of institutional issues that are being debated within the economics community. One of the fundamental issues addressed by these proposals is the extent of coverage in an initial agreement--i.e., the number of countries participating in an agreement and their responsibilities. Schmalensee (1996) makes a cogent argument for an approach that includes as many countries as possible (i.e., broad), but does not require major greenhouse gas reductions (i.e., shallow). The rationale for this 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

Table 3
Policy Proposals by Economists

Author	Instrument	Coverage	Mechanism to Decide Target	Level of GHG Target	International Trading	Monitoring	Enforcement
Schelling (1997)	Agreed upon actions that can be monitored.	OECD. China and India must be included soon.	Uses abatement actions, not abatement targets.	Not specified, but modest abatement now; more later if necessary.	Not addressed.	Not addressed.	Not addressed.
Schmalensee (1996)	A hybrid between a tax and a tradeable permit. Does not prescribe domestic policies.	Maximum participation at an acceptable cost.	Internationally negotiated emissions targets aimed at getting broad participation.	Not specified, but modest abatement now; more later if necessary.	Not addressed.	Ex ante international evaluation of policies.	International public opinion.
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.	Permits equal to 1990 emissions; actual emissions expected to be higher.	No.	Individual governments.	Individual governments.
Cooper (1996)	Agree on international actions, not national targets. Carbon tax preferable. Revenue neutral.	All countries	Agree on actions, not target.	Reduce projected emissions 2%/year. In 2050 tax would be $208/ton and emissions would be reduced 25% from 1990.	No, but tax should yield cost-efficient result.	IMF could monitor.	Individual governments. International pressure.
Nordhaus (1997)	National targets; countries choose domestic instruments.	Partial participation above $5,000 per capita and full participation above $15000 per capita.	Targets updated based on voting mechanism that balances costs and benefits.	Not specified; it would depend on country preferences.	Yes.	Not addressed.	Carbon import duties on non-participating and non-complying countries.

to address climate change. The goal can be changed later on as new information becomes available and the demand for taking action changes.

Schmalensee (1997) contrasts the broad and shallow approach with a "narrow and deep" approach implicitly advocated in a draft protocol from the State Department. The protocol calls for the Annex 1 nations, plus any others that wish to join, to take significant actions now.[22] 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 this idea sounds appealing, one must question whether future governments will feel bound by such promises. Second, as I will 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 this is such a great advantage, since there is little assurance that many of these parties will participate in the future if the are asked to bear significant costs.

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

Schelling (1997) takes a different tack. He argues for what might be called a narrow and shallow approach. Unlike Schmalensee, who calls for emission targets, Schelling believes "targets and timetables" are unworkable at this point because governments can not 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 these actions on GHGs is uncertain. These actions could be monitored by an international oversight entity more easily than actual emissions. Schelling dismisses international tradeable 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 (Schelling 1992). 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 (1997), who advocate a system of tradeable domestic permits with a fee collected by national governments for their own use. The fee would put an effective cap on the cost of emission reductions by placing an upper bound on the price of a permit.[23] Their proposal does not allow international trading because they believe the huge transfers between countries are politically infeasible and undesirable. I think this proposal represents a step in the right direction because it is feasible; however, it does little to

23. 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.

develop the institutional architecture needed for enforcing agreements among nations.[24]

Cooper (1996) argues for a broad and incremental approach using emission taxes, steadily reducing carbon emissions from projected increases by an additional two percent per year. He argues that tradeable permits are not feasible because it will be politically impossible to agree on a baseline. Cooper's critique of international tradeable 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 (1997) advocates a broad agreement, but recognizes that this may not be feasible in the short-term. 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 using their choice of instruments. A novel feature of Nordhaus' proposal is that it calls for revising the overall target periodically using a voting mechanism that would help balance benefits and costs. While the details need to be worked out, as Nordhaus notes, the general idea of revising targets over time 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 all the proposals have merit and I do not have a single preferred proposal. But I do have a conceptual framewc that I would like to offer for thinking about the problem. Within that framework, I wou

24. 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.

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 3 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 tradeable permit system; a fourth might feature a tradeable 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 important 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, there could be an opportunity to learn from some uncontrolled case studies. Social scientists should be explicitly addressing the kind of case studies they think are most useful within realistic political constraints. For example, if the U.S. is wedded to a tradeable 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 U.S., Europe and Japan need not have similar reduction targets either. The key is to help shape these 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 it is important to learn how different market-based systems perform under relatively hard emission targets that involve more than one country. This 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 are outlined in Table 4. 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 suggested by Schelling (1997)[25]; a modest tax; a tradeable permit approach with a few developed countries; a tradeable permit approach with a few developed and developing countries; a tradeable permit approach along with joint implementation in a few developed and developing countries; and a hybrid approach that incorporates both taxes and tradeable 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.

The cases would provide different kinds of insights, as the table suggests. For example, coordinated polices 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, assuming that is a goal of the system.[26] It could also provide insight into possible efficiency gains and losses associated

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25. This proposal is similar to a proposal from the European Union calling for the coordination of policies and measures (Schmalensee, 1997). However, 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 (Victor, 1997).

26.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

Table 4
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.
Tradeable Permits	A few developed countries.	Performance of international and domestic trading.
Tradeable Permits	A few developed and developing countries.	Same as tradeable permits.
Tradeable Permits and Joint Implementation	A few developed and developing countries.	Same as tradeable permits; performance of joint implementation.
Tradeable Permits and Taxes	A few developed countries.	Same as tax or tradeable permits.

with actual revenue recycling. The tradeable permit approaches could give insights into the potential of Joint Implementation, the problems associated with enforcement and possible debasement of the currency (Wiener, 1997). All systems could be helpful in improving the information base on inventories. If data were collected on administrative costs, these 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; however, 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.

This case study approach underscores the need to design *national institutions*. Such 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 (Chayes, 1991; Chayes, Skolnikoff and Victor, 1992). Yet, I believe it is action at the national level that matters most, even though there is obviously a need for some kind of international institution as well.

One objection to this 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 tradeable permit or harmonized tax approach. For example, political support for international tradeable permits or even for Joint Implementation with credits remains lukewarm. The case study

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tax. The government could also subsidize complements to fossil fuels or raise taxes on substitutes in order to lessen the impact of the agreement on the economy (Hoel, 1992). Less well appreciated is that countries could adopt similar policies to reduce the effectiveness of a tradeable permit system.

approach allows practical demonstration of the benefits of these approaches without first requiring all nations to agree. More importantly, it permits 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 U.S. and other countries interested in tradeable 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, but also promote 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.[27] The key would be to allow individual countries and groups of countries to tailor instruments to their economic and political needs. The agreement could be centered on verifiable actions that countries agree to take, and could also include binding commitments (Schelling, 1992; Victor, 1997).[28] These 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.[29]

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

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

29. If the case study approach is not feasible between 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 GHGs.

The overarching agreement could also call for extensive review of the case studies.

In all likelihood, if an agreement on climate change is reached in Kyoto or subsequent meetings, countries will be given considerable latitude in choosing policies to achieve greenhouse gas reductions. Thus, there will be room to consider the case study approach.

If the case study approach is deemed infeasible, an alternative is a single proposal involving a larger group of developed countries and a few developing countries or countries in transition.[30] Like the case studies discussed above, its primary purpose would be to focus on institution building. Table 5 summarizes a hybrid proposal that includes emission targets, international tradeable permits, and a price floor and price ceiling on emission permits. This proposal is really a variant of the last case study discussed in Table 4. While I do not advocate that a single case study be used, I present this as an alternative for those who believe the case study approach is either infeasible or not desirable.

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

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30. For the same reasons noted above, it would be desirable to have a relatively small number of countries engaged in this study because I think the problems with enforcement and preserving the integrity of the trading system may be easier to resolve in a way that allows for learning. If all the OECD countries chose to participate, that could still be workable, but cumbersome. The Group of Seven (G-7) countries might be a better group initially.

Table 5
Tradeable 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 tradeability 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.

I would not make this price higher than $10 per ton.[31] The ceiling price effectively limits the maximum price of a permit to that value. Conversely, a floor price limits the minimum price of a permit. This price, which could be set around $1 per ton, would ensure the system were 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 this is the part of the problem that is most easily monitored (Victor, 1991). 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 the agreement. The enforcement mechanism would consist of a set of graduated sanctions, beginning with a fine.[32] 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. There is no simple solution to this problem. 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

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31. If one is interested in ensuring that the tradeable 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 gasoline.

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

to aid with enforcement in the case of noncompliance. The nature of this governing body is likely to be an extremely sensitive issue. I envision such a body emerging slowly, as knowledge concerning emissions, control costs and institutional mechanisms evolve. In the short-term, countries could agree to self-enforcement with reporting and see how this works.

Finally, serious thought needs to be given to the finer structure of this and other proposals, including the nature of monitoring and enforcement. Consider the problem of monitoring carbon dioxide in the energy sector, which most schemes propose to address. Table 6 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 the millions of users downstream (Hahn and Richards 1995; Smith et al., 1992). 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 network 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 policymaker.

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 implementing the lowest cost system right now; but rather introducing approaches that will help develop sensible policies in the future.

Some may object to the seemingly modest emission reduction goals embodied in these case studies. I recommend this approach based on political considerations as well as an interest in developing durable institutions. Consider two instructive analogies--the

Table 6
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[1]	2,000[1]	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[2]	Up to 102,264,000[2]	400,000[2]
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[3]	Up to 3,232 (3,239)	Up to 3,232 (2,115)	Up to 3,232 (1,238)

[1] Number of petroleum and natural gas companies combined.
[2] Residential units as listed here may contain two or more individual units (e.g., apartment buildings).
[3] 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), AAMA (1993), Bell, ed. (1993), Smith et al. (1992).

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. As for the European Monetary Union, it 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.[33]

The details of economic instruments for addressing climate change, such as currency, trading rules, and rules for changing the rules have barely been examined, much less agreed upon.[34] 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?

The case study approach suggested here implicitly recognizes that there is not one single instrument that dominates all others. Institutions can be expected to have different strengths and weaknesses both economically and politically. It would be instructive to identify the relative strengths and weaknesses of these approaches as they actually perform in the real world.

5. Conclusion and Areas for Research

There is a common thread running through the recent economics literature and political economy literature on a climate treaty. The economics literature generally suggests that there is no reason to panic and take drastic action now to reduce greenhouse

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33. I am indebted to David Victor for this example.

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

gases. The political economy literature suggests that such action is infeasible because of the serious problems in getting countries to cooperate. Scholars disagree, however, on the kind of approaches that should be taken in the short term and the countries that should be involved.

This paper reviewed some of the key economic and political factors likely to affect a climate change agreement among nations. It then 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 only likely to occur now 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 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 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 (Schelling, 1992; Hahn and Stavins 1995; Schmalensee, 1996). But I believe most of the case studies should involve binding constraints because these 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 (1996). It differs from Schmalensee in its primary focus on developed countries and its focus on the design of multiple cases

or experiments. The policy design I suggest also borrows from Schelling (1992), who argues for a shallow approach centered on developed countries. It differs from Schelling primarily in its emphasis on learning about the properties of market-based approaches for addressing climate change.

One of the messages of this paper is that policy makers should not set their sights too 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, there is no obvious target or focal point around which parties can easily coalesce. The goal of stabilizing emissions at 1990 levels was once advanced as an initial target, but this goal has no strong economic, political or scientific appeal.

In the near term, this paper has argued both that it is imprudent to take significant action and that such action is unlikely to occur. An agreement between developed countries is feasible if it does not cost too much. It will be very difficult to induce developing countries to reduce GHGs in the current political environment without substantial side payments. 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.

It would be very useful if academics and policy makers began to engage the institutional design question more seriously. To this point, most academics have focused on a single preferred case without considering the possibility of doing more than one. I believe that there could be great gains to the case study approach suggested here, especially if the cases were designed taking account of political constraints.

Designing institutions that can achieve significant GHG reductions from a number of countries will be a formidable task. The task will be made easier by experimenting with market-based approaches for environmental control as well as coordinated policies and measures. Designing these 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 GHG goal in a least costly manner. Nonetheless, there are a wide range of options, 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 with these approaches (Hahn, 1989; Stavins, 1997; Joskow and Schmalensee, 1997).

While this paper identifies a particular set of cases for building institutions, there are several other areas in which we need to continue to make progress to aid in institutional design. First and foremost, a better inventory of emissions of GHGs needs to be developed. This would include sources of emissions and well as "sinks," such as forests, that store emissions. Second, this information needs to be made 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, the institutional design issue needs to be couched more broadly in terms of a portfolio of investments that could best address the climate problem. Manne and Richels (1997) characterize the problem in terms of "finding the right blend of options." 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 (Lave, 1988; Toman, 1997; Tucker, 1997).

It would also be useful to continue research on key political and institutional factors

that will make it easier to reach 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, it will be necessary to design agreements so that countries have an incentive to participate. The nature of feasible carrots and sticks deserves further study (see, e.g., Barrett, 1997a; Victor, 1997; Victor, Raustiala, and Skolnikoff, 1997)

Institutions should not only strive to be cost-effective, but they should also help produce and adapt to new information. There is a delicate balance to be achieved. One would like to be able to change the rules periodically, but still get people to take actions that are based on sound science and economics.

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

Appendix

The purpose of this appendix is to provide more detail on the costs of reducing net carbon dioxide emissions, and the cost savings from international trading of carbon dioxide permits. Cost savings are defined as the cost of abatement without trading minus the cost of abatement with trading. To allow comparison across studies, cost savings are expressed as a percent of cost without trading.

The savings are generated by allowing emissions trading between entities in different countries. The no-trading scenarios generally presume that the specified domestic reductions are achieved cost-effectively. Cost savings estimates may be an upper bound since they assume that all gains from trading are achieved. In practice, gains often fall short of expectations.

Table A-1
Cost Savings from Economic Instruments by Region

Region Realizing Savings	Carbon Dioxide Targets	Cost Savings (%)	Cost with No Trading		Region Participating	Year Savings Realized	Source
			% GDP	$Trillion			
OECD	20% below 1990 by 2010	69	3.95		OECD[1]	2050	Jacoby et al. (1997)
OECD	20% below 1990 by 2010	50	0.4		OECD[1]	2000	Jacoby et al. (1997)
OECD	550 ppmv using Working Group I profiles.	49		6.0	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
OECD	550 ppmv using Wigley, Richels, and Edmonds profiles.	44		0.9	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
OECD	10% below 1990 by 2010.	39		2.6	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
OECD	550 ppmv using Wigley, Richels, and Edmonds profiles.	33		0.9	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
OECD	10% below 1990 by 2010.	23		2.6	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
OECD	550 ppmv using Working Group I profiles.	18		6.0	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
Annex 1	1990 levels in 2030.	50	0.8		Annex 1	2030	Mullins and Baron (1997)
European Union	1990 levels in 2030.	0	0.8		Annex 1	2030	Mullins and Baron (1997)
U.S.	Reduced through international voting mechanism.	98		0.6	World	1990 on	Nordhaus (1997)
U.S.	Reduced through international voting mechanism.	89		0.1	World	1990 on	Nordhaus (1997)
U.S.	Carbon at 1990 levels in 2010.	50	0.2		Annex 1	2010	Interagency Analytical Team (1997)

Region Realizing Savings	Carbon Dioxide Targets	Cost Savings (%)	Cost with No Trading		Region Participating	Year Savings Realized	Source
			% GDP	$Trillion			
U.S.	Carbon at 1990 levels in 2010.	50	0.2		Annex 1	2020	Interagency Analytical Team (1997)
U.S.	1990 levels in 2030.	20	0.5		Annex 1	2030	Mullins and Baron (1997)
U.S.	Carbon at 1990 levels.	15		0.1	OECD	1990 on	Nordhaus (1997)
Japan	1990 levels in 2030.	75	2.1		Annex 1	2030	Mullins and Baron (1997)
Japan	Carbon at 1990 levels in 2010.	67	0.6		Annex 1	2010	Interagency Analytical Team (1997)
Japan	Carbon at 1990 levels in 2010.	67	0.3		Annex 1	2020	Interagency Analytical Team (1997)
Other OECD	1990 levels in 2030.	20	0.5		Annex 1	2030	Mullins and Baron (1997)
Western Europe	Carbon at 1990 levels in 2010.	57	0.7		Annex 1	2010	Interagency Analytical Team (1997)
Western Europe	Carbon at 1990 levels in 2010.	50	0.2		Annex 1	2020	Interagency Analytical Team (1997)
EEFSU[3]	550 ppmv using Wigley, Richels, and Edmonds profiles.	83		0.3	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
EEFSU[3]	550 ppmv using Working Group I profiles.	73		1.3	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
EEFSU[3]	550 ppmv using Wigley, Richels, and Edmonds profiles.	67		0.3	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
EEFSU[3]	10% below 1990 by 2010.	67		0.6	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
EEFSU[3]	10% below 1990 by 2010.	50		0.6	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
EEFSU[3]	550 ppmv using Working Group I profiles.	35		1.3	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)

Region Realizing Savings	Carbon Dioxide Targets	Cost Savings (%)	Cost with No Trading		Region Participating	Year Savings Realized	Source
			% GDP	$Trillion			
FSU[4]	1990 levels in 2030.	367	0.3		Annex 1	2030	Mullins and Baron (1997)
FSU[4]	Carbon at 1990 levels in 2010.	NA[5]	0.0		Annex 1	2010	Interagency Analytical Team (1997)
FSU[4]	Carbon at 1990 levels in 2010.	NA[5]	0.0		Annex 1	2020	Interagency Analytical Team (1997)
Eastern Europe	Carbon at 1990 levels in 2010.	NA[5]	0.0		Annex 1	2010	Interagency Analytical Team (1997)
Eastern Europe	Carbon at 1990 levels in 2010.	NA[5]	0.0		Annex 1	2020	Interagency Analytical Team (1997)
Non-OECD	20% below 1990 levels by 2010.	175	0.2		OECD[1]	2000	Jacoby et al. (1997)
Non-OECD	20% below 1990 levels by 2010.	25	0.4		OECD[1]	2050	Jacoby et al. (1997)
Non-Annex 1	550 ppmv using Working Group I profiles.	132		1.4	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
Non-Annex 1	10% below 1990 by 2010.	96		1.2	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
Non-Annex 1	550 ppmv using Wigley, Richels, and Edmonds profiles.	86		0.7	Annex 1 before 2030[1,2]	2050	Manne and Richels (1997)
Non-Annex 1	550 ppmv using Working Group I profiles.	61		1.4	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
Non-Annex 1	10% below 1990 by 2010.	54		1.2	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
Non-Annex 1	550 ppmv using Wigley, Richels, and Edmonds profiles.	43		0.7	Annex 1 before 2030[2]	2050	Manne and Richels (1997)
Australia	Carbon at 1990 levels in 2010.	50	0.2		Annex 1	2020	Interagency Analytical Team (1997)

Region Realizing Savings	Carbon Dioxide Targets	Cost Savings (%)	Cost with No Trading		Region Participating	Year Savings Realized	Source
			% GDP	$Trillion			
Australia	Carbon at 1990 levels in 2010.	40	0.5		Annex 1	2010	Interagency Analytical Team (1997)
Canada	Carbon at 1990 levels in 2010.	82	1.1		Annex 1	2020	Interagency Analytical Team (1997)
Canada	Carbon at 1990 levels in 2010.	64	1.1		Annex 1	2010	Interagency Analytical Team (1997)
UK & Poland	20% below 1988 in 2005.	7		0.0	UK and Poland	2005	Jackson (1995)
UK, Poland, & Denmark	20% below 1988 in 2005.	7		0.0	UK, Poland, and Denmark	2005	Jackson (1995)
World	Reduced from projected growth by an additional 2% per year.	47	1.9		World	2020	Dean and Hoeller (1993)
World	Reduced from projected growth by an additional 2% per year.	19	2.6		World	2050	Dean and Hoeller (1993)
World	Reduced from projected growth by an additional 2% per year.	16	1.9		World	2020	Dean and Hoeller (1993)
World	Reduced from projected growth by an additional 2% per year.	11	3.7		World	2050	Dean and Hoeller (1993)
World	Reduced from projected growth by an additional 2% per year.	11	5.7		World	2095	Dean and Hoeller (1993)
World	Reduced from projected growth by an additional 2% per year.	6	8.0		World	2100	Dean and Hoeller (1993)

[1] Joint Implementation allowed.
[2] Participating region after 2030 is the world.
[3] Eastern Europe and the Former Soviet Union.
[4] The Former Soviet Union.
[5] Not applicable due to a zero in the denominator. In these cases the region's profits from selling permits exceed the cost of meeting the initial target.

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