The Economics of "When" Flexibility in the Design of Greenhouse Gas Abatement Policies

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Abstract

This paper focuses on the economic desirability of the fixed and relatively short-term greenhouse gas targets and timetables in the Kyoto Protocol. The Protocol provides flexibility in which greenhouse gases to control, where control can be implemented, and what domestic policy measures are used. However, the Protocol does not allow much flexibility in when emission reductions take place in pursuit of longer-term environmental goals. Nor does it allow more flexible shorter-term environmental targets through price-based policy instruments that balance environmental goals and compliance costs. The relative inflexibility of the Protocol with respect to these elements may derive, in part, from a misplaced analogy between the global warming issue and the highly successful effort to phase out CFCs under the Montreal Protocol. The lack of "when" flexibility may be a key barrier to achieving the broader goals of the Kyoto Protocol, particularly if "where" flexibility is constrained in implementing the Protocol.

Key Words: climate change policy, Kyoto Protocol

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1. INTRODUCTION

An intense debate surrounds the questions of when and how to restrict emissions of the heat-trapping "greenhouse gases" that, most scientists believe, are adversely altering the world's climatic system. While differences persist regarding the degree of climate change caused by human influences and the severity of the impacts, attention increasingly is shifting to what policies should be adopted internationally to slow and eventually reverse the build-up of greenhouse gases in the atmosphere.

A watershed event in the debate over greenhouse gas limitations was the negotiation of the December 1997 Kyoto Protocol to the 1992 United Nations Framework Convention on Climate Change. If it goes into effect, the Kyoto Protocol would establish, for the first time, legally binding ceilings on future greenhouse gas emissions by the advanced industrialized countries (essentially the OECD) and the industrialized countries in transition to market economies (most of the former East Bloc). According to the Protocol, these countries must reduce emissions to levels averaging about five percent below 1990 levels in the first "commitment period," 2008-2012. For the U.S. the target is a reduction to seven percent below 1990 levels; for Japan, six percent; and for the European Union as a whole, eight percent.

The degree of actual emission reduction required under these targets depends on one's views about "business as usual" emissions growth. A common point of reference for the U.S. is the *Annual Energy Outlook* forecast produced by the Energy Information Administration. According to this forecast, meeting the Kyoto target would require a cut in U.S. emissions by roughly *one-third* relative to what would otherwise prevail.

Some analysts argue that the overall cost to the U.S. of meeting the Kyoto target on this timetable is potentially quite high. Others argue that the exploitation of a large reservoir of cheap energy-efficiency opportunities plus the introduction of renewable energy technologies can deliver compliance with Kyoto at a negligible overall cost. Still others argue

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that the potential cost of Kyoto compliance is high, but that the "flexibility mechanisms" (discussed below) built into the Protocol bring down the cost to very manageable levels.[1]

In this paper we focus specifically on the desirability of setting fixed and relatively short term targets and timetables, such as those contained in the Kyoto Protocol, as a means of achieving longer term climate change mitigation goals. Specifically, we argue that, whatever climate policy goals are adopted, greater flexibility will mean greater cost-effectiveness in achieving them. Greater cost-effectiveness, in turn, will mean a greater likelihood that the policy will actually be followed and the goals achieved.

The literature has identified several important types of flexibility that may help reduce overall compliance costs. "What" flexibility allows for the inclusion and trading among multiple greenhouse gases and sinks. "Where" flexibility allows emission reductions to take place at the least-cost geographic location, regardless of nation-state boundaries. "How" flexibility allows the use of the most efficient policy instruments to achieve stated domestic policy goals. "When" flexibility allows emissions reductions to take place at a point in time when they can be achieved at lowest cost, as long as they are consistent with whatever long-term environmental goals are specified. A more expansive definition of when flexibility allows for the possibility to balance environmental goals and compliance costs in the design of policy instruments.[2]

While carbon dioxide is the single most important greenhouse gas, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are also contributors to the overall growth in greenhouse gas concentrations. The Kyoto Protocol includes all six of these anthropogenic greenhouse gases plus sinks and allows for trading among the gases and between gases and sinks on the basis of their potential contribution to global warming. Compared to the focus on carbon dioxide emissions, defining the "Kyoto basket" in these broader terms represents an important source of "what" flexibility which has the potential of significantly lowering overall compliance costs.

If developing countries and nations in transition face significantly lower greenhouse gas abatement costs, then action by industrialized countries to finance these reductions in exchange for emission reduction credits can generate benefits for all concerned. In fact, the Kyoto Protocol contains several specific mechanisms designed to achieve such "where" flexibility. The U.S. and other advanced industrial nations may purchase emission permits from the "assigned amounts" of countries in the former Soviet Union and Eastern Europe which have adopted targets. All of the so-called Annex B industrialized and transitional nations also may acquire permits from each other on a project-specific basis, or certified

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[1] A forthcoming special issue of *Energy Journal* provides a review of some of this literature. For two specific studies reaching quite different conclusions regarding the cost of Kyoto compliance in the U.S., see EIA (1998) and RIIA (1999).

[2] Strictly speaking it might be more accurate to call this "if" flexibility. However, because this terminology could easily be interpreted as suggesting that flexibility is antithetical to the achievement of environmental goals, which we believe is not the case, we refer to this balancing as an expansive notion of when emission controls would be applied.

emission reductions (CERs) from developing countries under the Clean Development Mechanism. Finally, Annex B nations may acquire CERs via emissions trading with developing countries which have adopted targets under the terms of the Protocol. Overall, these so-called Kyoto mechanisms have the potential to provide an important source of "where" flexibility, further reducing overall compliance costs. The degree to which this potential can be realized in practice is an open question, as discussed below.

The Protocol also allows for emissions averaging over the five year commitment period, and it allows countries complete freedom in designing their domestic strategies. Nonetheless, the Protocol is relatively inflexible both in the timing and the definition of its targets. This may reflect, in part, the modeling of the Kyoto Protocol on an earlier agreement, the Montreal Protocol, that was successful in achieving international control of chlorofluorocarbons and other ozone depleting substances. While neither the economics nor the politics of CFC controls warranted consideration of when flexibility, the case of climate change is quite different, as we discuss below.

Section 2 provides an overview of the economic premises upon which the argument for the advantages of greater policy flexibility rest. Section 3 provides a historical review of the negotiating processes that led first to the Montreal Protocol and then to Kyoto. In Section 4 we review pertinent literature on the timing of emissions abatement. Section 5 develops the related but distinct issue of fixed versus more flexible targets at any point in time. The sixth and concluding section pulls together the arguments in the paper and their implications for the Kyoto Protocol.

Issues involving developing countries are largely beyond the scope of this paper. It can be said, of course, that as in any market the efficiencies of trade arise from the differences in the circumstances among the participants. The greater the differences, the greater the advantages of trade. Trade among Annex B countries, as contained in the Kyoto Protocol, promises greater efficiencies than trade merely within countries. Similarly, worldwide trade promises far greater efficiencies than trade restricted to industrial countries. However, the focus of the numerical emission targets in the Kyoto Protocol is on industrialized (Annex B) countries. Accordingly, we focus on the numerical limits imposed on Annex B nations.

Technology and the way it responds to incentives is another important aspect of this issue. We do not attempt to judge specific technologies and their potential to contribute to reduced GHG emissions. Nor do we discuss broader economic analyses of the circumstances most conducive to technological development. However, the economic models used to analyze the potential gains from enhanced flexibility do reflect actual experience in how energy use and investment responds to economic incentives, and they provide some guidance as to the relative costs of various response patterns engendered by different climate policies.

2. AN OVERVIEW OF ECONOMIC ARGUMENTS FOR POLICY FLEXIBILITY

Most economic analyses of climate change policy agree on two fundamental considerations. The first is that the long-term nature of climate change requires *sequential* *decisionmaking*. One does not make an all-at-once decision as to what targets and policies should be implemented. Instead, one formulates a contingency plan that can be updated as new information is available. A long-term view inherently includes taking into account alternatives regarding the timing of emissions control.

The second consideration is that climate policy requires a portfolio of actions: changes in the capital stock, new technology development and diffusion, improved risk assessment, and investment in strengthening adaptive capacity. The desired mix of options in the portfolio may change over time, as information about the options is updated.

In analyzing the debate over the cost and adequacy of the Kyoto approach, we start with the premise that it is ultimately the long-term concentration of greenhouse gases that reflects the threat of climate change, not just the short-to-medium term rate of greenhouse gas emissions.[3] An atmospheric stabilization goal can be pursued in a number of ways. First, given any long-term target for the control of greenhouse gas concentrations, there exist multiple pathways for the world's economic system to reach that goal. In particular, the goal can be approached slowly or more rapidly. Second, different kinds of policy measures can be used to pursue the atmospheric goal. In particular, interim goals for GHG emissions can be specified as strict quantitative limits, or they can be more aspirational, with options for relaxation of targets if the incremental costs of meeting the targets seem unjustifiably high relative to the environmental benefits.[4] Table 1 presents a simple schematic diagram of the issues.

Table 1: Elements of "When" Flexibility in a GHG Reduction Strategy

	Flexibility of emission limits	
Timeframe for environmental goals	Short-term focus, flexible limits	Short-term focus, inflexible limits (less cost-effective)
	Long-term focus, flexible limits (more cost-effective)	Long-term focus, inflexible limits

In this 2x2 characterization of policy design options, the approach in the Kyoto Protocol (which fits into the upper right quadrant) represents the least "when" flexibility in that it calls for relatively ambitious and strict goals to be achieved over a relatively short

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3 Ultimately, of course, it is the change in various parameters describing the climate system itself (temperature, precipitation) that influence the threat of climate change. These parameters in turn are related to GHG concentration through complex relationships that global climate models attempt to capture. For our purposes, however, it suffices to focus on atmospheric GHG concentration goals.

4 Analogies can be found in U.S. domestic environmental policies. For example, in the Clean Air Act purely scientific (health) concerns govern the setting of primary ambient air quality standards but economic and technical factors are considered in the implementation process.

period of time.[5]. More flexible approaches within the industrialized countries could be pursued by phasing in targets more slowly, with relatively sharper cuts in greenhouse gases in the future to reach any particular long-term goal. Or the targets themselves could be made softer or more aspirational, reflecting the uncertain costs of achieving them.

One of the important elements of the Kyoto Protocol is the opportunities it provides to undertake emission reductions at the least-cost geographic locations, regardless of nation-state boundaries. This inclusion of where flexibility is unique in international environmental agreements. As noted above, where flexibility offers the *potential* for substantially lowering the cost of GHG control. At the same time, by not allowing emission reductions to take place at a point in time when they can be achieved at lowest cost (when flexibility), the Protocol risks causing higher costs than more phased-in emission targets in achieving a long-term goal for atmospheric stabilization of GHG concentrations. Similarly, by not allowing the use of price-based policy instruments as opposed to more rigid quantity controls, the Protocol risks putting too much weight *at the margin* on environmental risks over economic risks.

The importance of these possible shortcomings depends critically on one's assessment of how costly Kyoto compliance will be. If one takes the view that there are substantial opportunities for low-cost or even no-cost reductions in energy use endemic to the energy-economic system, then neither where nor when flexibility is as important as it would be if GHG abatement costs are substantial. The importance of when flexibility also depends crucially on how well where flexibility might work in real practice. Many modeling studies of where flexibility assume ideal conditions for the implementation of international trading in emissions allowances or credits. If, as seems likely, these mechanisms in practice fall considerably short of the ideal, then where flexibility is less of a boon for bringing down the cost of meeting Kyoto commitments. Our view is that the success of where flexibility is not assured for several institutional and political reasons, making when flexibility an important component to continue considering in a climate policy regime.[6] In fairness we should also acknowledge that there are also practical concerns with the implementation of when flexibility; we address these points subsequently in the paper.

The emphasis on marginal comparisons in the above discussion is critical, since we are *not* suggesting that the economically more efficient alternative to Kyoto would necessarily involve less ambitious environmental goals. In fact, the basic argument is that comparable long-term protection of the earth's climatic system could be achieved at lower cost. While

[5] The notion of a "short" time period is open to some interpretation. An emission reduction of one-third below baseline over a decade seems to most economists like a relatively ambitious approach. Yet it is also the case that other environmental agreements, e.g., the Montreal Protocol, have achieved even greater reductions over a comparable period. The next section analyzes the similarities and the differences between the Kyoto and the Montreal Protocols.

[6] For example, the European Union favors limiting the use of emissions trading (and the other "Kyoto mechanisms"). At the same time, most developing countries oppose the notion of taking on any sort of targets for the first budget period, i.e., 2008-2012. This limits the participation of these countries in a trading regime to what can be achieved through the Clean Development Mechanism, a mechanism that at best will be cumbersome.

there are important caveats surrounding these conclusions, the strong implication from the economics literature reviewed in this paper is that the Kyoto approach to greenhouse gas control is likely to be less cost-effective than alternatives, perhaps significantly so, and that justifications for Kyoto must be found in noneconomic arguments.

To conclude this overview, we note that it is widely understood that developing country participation in limiting GHGs ultimately is crucial to meeting long-term global targets for atmospheric GHG concentrations. While our focus here is on the Kyoto Protocol and the Annex B countries, many of the same issues also arise in connection with incentives for developing country participation. For example, a longer-term approach could increase the prospects for developed countries to assume modest emission reduction goals early while constraints on developing country emissions are phased in over time. Similarly, greater attention to the cost of meeting policy goals reduces the risk for developing countries of compromising their legitimate development goals through accession to GHG emission targets.

3. TARGETS AND TIMETABLES: TWO CASES OF ENVIRONMENTAL DIPLOMACY

To examine the Kyoto approach, it is useful to look at the ways in which it originated and how it developed. In the decade of international discussion that led up to the Kyoto conference, negotiators made a series of key policy decisions that were generally not informed by the extensive economic analyses developed concurrent with or subsequent to the Protocol. At least in the U.S., most of the public debate focused on the scientific issues associated with global warming. Limited public discussion occurred on the economic implications of alternative emission reduction strategies. One key policy decision involved the targeting of annual emissions of greenhouse gases over a relatively short period of time, rather than the long-term path of GHG emissions. Another was the decision to adopt goals expressed in fixed target quantities rather than in terms of the level of effort expended to implement GHG reductions. Although national views on these issues have varied, the final outcome of the Kyoto negotiations seems to have been significantly influenced by the example of the highly successful negotiations to protect the stratospheric ozone layer, culminating in the Montreal Protocol of 1987 and the subsequent London revision of it.

The Montreal Protocol was a great and unprecedented triumph of international cooperation to protect the environment worldwide. Great triumphs can be dangerous, however, for they establish policies and perspectives that may get applied to other cases without adequately examining the differences between them. This, we believe, may have been a factor in the current policy approach to climate change. The two processes involved the same institutions and many of the same people. As it turned out, there were deep and important differences between regulating the chlorofluorocarbons (CFCs) that attack the ozone layer and the greenhouse gases implicated in global warming.

Two central facts underlay the economics and politics of the Montreal Protocol. One was that the public, and the governments representing them, saw the preservation of the ozone layer as a health issue. The erosion of the ozone layer evoked the threat of rampant skin cancer. The other was the emergence at a critical juncture of credible technologies that allowed most ozone-depleting chemicals to be phased out without severe economic harm.[7] Associated with these two developments were a number of other catalytic factors, including an increasingly unequivocal message from scientific and policy élites about the feasibility and advantages of a phase-out. That gave the ozone treaty a political momentum that the climate change treaty has not yet achieved, at least in the United States and perhaps in other countries as well.

The threat of stratospheric ozone depletion became a focus of public policy in the middle 1970s. In 1976 the National Academy of Sciences published a report confirming the process by which ozone-depleting chemicals operated, and the resulting increased melanoma risk posed by increased exposure to ultraviolet radiation. In the United States, consumers began to boycott aerosol sprays that used CFCs as propellant. Manufacturers scrambled to find substitutes. In 1978 the EPA, pushed by Congress, banned most aerosols using CFCs. Several other countries--Canada, Sweden and Norway--enacted similar bans. In 1980 the European Community enacted limits on CFCs in aerosols. In 1983, the United States proposed an international prohibition on CFC sprays.

As they considered an international agreement, negotiators wanted to avoid the bad experience of the Law of the Sea Treaty which, it seemed clear in retrospect, attempted to cover too much ground at once and settle too many details. In developing a CFC treaty, diplomats proposed instead to go one step at a time, emphasizing flexibility, producing first only a very general agreement that could be supported by everyone and tightened subsequently as circumstances required (Reifsnyder, 1992; Sebenius, 1994).

That strategy led to the Vienna Convention for the Protection of the Ozone Layer, signed in March 1985. It contained no real controls, committing signatories only to take undefined "appropriate measures" to control activities "should it be found" that they had adverse effects. But that was soon followed by new scientific revelations about damage to the ozone layer and the risks of increased UV exposure, causing another surge of public anxiety.[8] The United States Senate unanimously ratified the Vienna Convention, and policymakers began thinking about adding a protocol with binding commitments to regulate CFCs worldwide. Because many scientific issues were still unclear, no one was yet willing to set a date for a complete phase-out. But negotiators for the United States, Canada and several other countries began pressing for language in the protocol that would at least set an eventual goal of zero for emissions (Benedick, 1998).

Ozone-depleting chemicals were produced by only a few very big corporations, and nearly all of the production was in the industrial countries. In the United States the producers,

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[7] See Morrisette et al. (1991).

[8] In November 1986 the U. S. Environmental Protection Agency published a draft assessment warning that American could suffer 40 million additional cases of cancer, leading to 800 thousand additional premature deaths over the next century because of depletion of the ozone layer. Deaths from skin cancer could double from the current level, the assessment said (quoted in *New York Times*, Nov. 5 1986, page 1).

suffering from consumer boycotts and the ban on sprays, saw no point in risking public hostility over a relatively small line of business. They also knew that the only real choice was between an international agreement to curb these products and American domestic legislation. They greatly preferred an international agreement that would also apply to their European competitors. Beyond that, the big American chemical producers had begun a search for substitutes after the first boycotts and they apparently sensed that they were well ahead of the Europeans in the race for that market. But in Europe, where CFCs were more important to some of the industry, companies in Britain and France lobbied strenuously to preserve their sales.

Although public and congressional anxiety was rising in the United States, the movement toward a binding agreement of CFCs created serious tension within a conservative Republican administration. Some officials fought the agreement as a precedent for international regulation. In the bureaucratic infighting, the American chemical industry gave crucial help to the idea of a strong international treaty (Benedick, 1998, pages 46-47, 64, 197). But in the spring of 1987 the dispute became public when the secretary of the interior, Donald Hodel, suggested that the danger was exaggerated and that people could easily protect themselves by wearing hats and sunglasses. That brought a deluge of ridicule down on the administration. The question was finally put to President Reagan at a White House meeting in June 1987. Secretary of State George Shultz and EPA administrator Lee Thomas supported a strong agreement and, to the great surprise of the antiregulators, Reagan agreed with them completely. (Not long before this meeting, surgeons had removed a small patch of skin cancer from the president's nose.)

Three months after the president's decision, the Montreal Protocol was signed. Unlike the Vienna framework convention, the Protocol contained real restrictions. The countries joining it were committed to freeze consumption of CFCs and several other compounds at 1986 levels of consumption, followed by a 20 percent reduction in 1993 and a 50 percent reduction in 1998. In early 1988, amidst a torrent of new findings from the stratosphere, the Senate voted, again unanimously, to ratify the Montreal Protocol. In 1990 the London Revisions to the Montreal Protocol were negotiated, committing the parties to a flat ban on CFCs and several other families of harmful compounds by the year 2000 for advanced industrialized countries, with a later phase-out in key developing countries. While the Montreal Protocol would only have slowed the rate of rise of CFC concentrations, the London rules would actually reduce the concentrations from the point at which its ban went into effect. Since London there have been two further revisions--at Copenhagen in 1992 and in Vienna in 1995--accelerating the phase-out of some compounds and adding restrictions on the use of others.

There are both important similarities and important differences between the stratospheric ozone case and climate change. Both involve global environmental interests and require international cooperation for a resolution. Both entered the policy debate at a time when the underlying science was still uncertain, and both issues involved actions that could adversely affect certain sectors of the economy. Both cases therefore required incremental policymaking and broad public support for action. Moreover, in both cases the developing countries raised alarms about the adverse effects on their economies of strict environmental measures and secured differential treatment: a longer compliance period for ozone-depletor phase-out, and as yet no concrete emission reduction targets for greenhouse gases.

However, the differences overshadow the similarities. In the stratospheric ozone talks, the early acceptance of zero as the ultimate target for CFC emissions meant that the distinction between shorter-term emission rates and longer-term emissions trends faded. The speed with which the chemical industry itself was moving away from CFCs meant that there was little need to devote effort to long-term regulatory instruments.[9] In addition, there had been talk of CFC taxes versus quantitative consumption caps, but those subjects lost relevance with the rising prospect of an early end to all CFC production.

There appear to be several reasons for the relatively rapid convergence of the stratospheric ozone talks to a goal of zero emissions, and thus a limited role for when and how flexibility, that are not present in the climate negotiations. Technological options easing the phase-out of ozone-depleting chemicals appeared at a critical juncture in the international policy process. No such affordable technological "magic bullet" has so far emerged for greenhouse gas control. In addition, in regard to protection of the ozone layer, the health benefits swamped all other factors. Hammitt (1997) describes the cost-benefit analysis published by the U.S. Environmental Protection Agency in December, 1987. For its base case it calculated that the total cost (in present value terms) to the United States of an 80 percent reduction in CFC consumption would be $31 billion.[10] The corresponding measure of benefits was estimated to be $6.4 trillion, nearly all of it representing the value of cancer deaths averted at $3 million per death. One look at figures like that by anyone making policy would immediately lead, not to further economic studies, but to a renewed attack on the pollutant. The same scientific and policy certainty about the magnitudes of global climate change risks and response costs does not yet exist.

The negotiations on climate change started somewhat later than those on ozone, but overlapped them. A meeting in Villach, Austria, in 1985 was the occasion on which the scientists decided that the record was strong enough to justify alerting their governments to the probability, as they put it, that human activity was changing the Earth's climate.

That message was heard by the World Commission on Environment and Development, a committee that had been established by the UN's General Assembly to consider long-term environmental issues and an agenda for action. Under the chairmanship of the Norwegian prime minister, Gro Harlem Brundtland, it was putting together a broad survey that appeared in April 1987 under the title, "Our Common Future." Regarding global warming, the Brundtland Commission proposed a four-track strategy: better monitoring, more

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[9] The question of the timing of emissions constraints came up during the ozone negotiations, although it was soon dropped as moot. To cite one example, a draft of a paper exploring the idea was presented to a workshop in September, 1986, preparing the Montreal Protocol (Hammit, 1987). Not all of the negotiators accepted the concept of present value discounting. Benedick (1998) commented acidly that "the current state of economics is not helpful" in analyzing environmental issues (p. 308).

[10] Although extremely small in comparison with the benefits, this estimate turned out to be generally accurate (see Harrington, Morgenstern, and Nelson, 1999).

research, an international agreement to reduce emissions (but it offered no target figures), and preparation for adaptation to a changing climate. The commission devoted only a few pages of its report to global warming, but that was sufficient to give new impetus to a subject of which the public was only beginning to be aware.

In response to the Brundtland Commission the Canadian government called a conference in Toronto in June 1988 that was attended by several hundred politicians and other public officials, scientists, and experts on the environment and on energy from 46 countries and 15 international organizations. In its final statement the conference proposed an action plan to cut global emissions of CO_2 by 20 percent of 1988 levels by the year 2005.

The Toronto conference turned out to be highly influential, providing the first outline of the approach that led to Kyoto. Its target of a 20 percent cut in emissions by 2005 was not rooted in economic analysis, since at that time relatively little analysis had been done. The conference knew that a much larger cut in emissions would be required to stabilize concentrations of CO_2 in the atmosphere, but it wanted a number within the range that governments would accept as plausible. It intended to send a strong signal of serious change, and yet it did not want its goal to be dismissed as unrealistic.[11] It is never a simple matter to establish the origins of people's ideas about the numbers that constitute a serious effort, or realism. But 20 percent was also the first cut in CFC consumption mandated by the Montreal Protocol, which had been signed in another Canadian city nine months earlier.

In December 1988 the General Assembly approved the establishment of an Intergovernmental Panel on Climate Change (IPCC) to review the science. The following summer at their annual summit meeting, the heads of the seven big industrial democracies' governments called for a framework treaty to limit the world's production of CO_2, and negotiations soon got under way.[12] This time Europe sought rapid action, and the United States resisted--the opposite of their relationship in the ozone case.

The first IPCC report appeared later in 1990, reflecting a broad consensus among scientists in the field that the possibility of global warming at least had to be taken seriously. The Framework Convention on Climate Change, signed at the 1992 UN "Earth Summit," set a voluntary goal of cutting CO_2 emissions back to the 1990 level by the year 2000. However, like the Vienna Convention on ozone, it contained no binding commitments to cut. In 1993 the Clinton Administration announced plans to adopt measures to meet the Rio aspiration. But Congress refused to go along with significant energy taxes, and the administration's Climate Change Action Plan turned out to be entirely voluntary. Few European governments were more successful, despite their pledges and exhortations to the Americans, though there was progress on energy market reforms and some countries have undertaken modest policy actions to limit GHGs.

In these unpromising circumstances, in early 1995 the UN held a conference in Berlin of the Parties to the Rio treaty--in the jargon of the negotiators, COP-1. The purpose was to

[11] Telephone conversation Sept. 17, 1998, with Howard L. Ferguson, in 1988 a senior civil servant in Environment Canada and director of the conference.

[12] For a useful summary of the history of these negotiations, see Paterson (1996), especially Chapters 2 and 3.

assess progress toward the grand promises made there. The 120 governments represented at COP-1 agreed to a plan, known as the Berlin Mandate, to negotiate a protocol setting specific and binding targets and timetables to reduce greenhouse gas emissions. These targets and timetables were to apply to the industrial countries, the conference agreed, but not the developing countries. While this exclusion had meant little in the context of CFCs, in the Kyoto process it turned into a major point of controversy. In the U. S. Congress, many members saw it as a huge benefit to newly industrializing countries that were emerging as significant competitors in trade and industry.

A few months later the IPCC brought out its second survey of the science of global warming. Its tone was much more conclusive than five years earlier. It declared that the statistical evidence. . . now points towards a discernible human influence on global climate." But in the next line it warned that given the state of present knowledge, "Our ability to quantify the magnitude of this effect is currently limited by uncertainties in key factors, including the magnitude and patterns of longer-term natural variability and the time-evolving patterns of forcing by (and response to) greenhouse gases and aerosols" (Houghton et al., 1996, p. 439). That was enough to encourage the politicians and diplomats who were working for a stronger treaty. But it wasn't enough to change many minds among the people opposing them. Unlike the Montreal Protocol, the climate change negotiations did not have the benefit of a steady drumbeat of increasingly urgent scientific findings directly related to health risks. Some participants in the debate have argued that global warming increases the prospect of extreme events such as destructive weather, rapid sea level rise, and epidemics of tropical diseases moving northward. But these warnings lacked the specificity, and the scientific consensus supporting them, that gave force to the predictions of more melanomas caused by reduction of the ozone layer.

When the climate change negotiators met again in the summer of 1996 for COP-2, the United States announced a clear and important change of policy. It would now support legally binding limits on emissions, it said, if other countries also did so. But there was still friction between the Americans and the Europeans. In subsequent meetings it was evident that the United States was going to push for flexibility through trading emissions permits to meet its targets more cost-effectively, and it cited the successful example of its sulfur dioxide trading program to control acid rain. European countries have less experience with market mechanisms and many are suspicious of such mechanisms as an instrument for reaching public objectives. Even more so than in the United States, there is a continuing debate between economists seeking efficiency and regulators who suspect that flexibility is simply a synonym for a loophole.[13] Here again, an issue that was insignificant in the Montreal process developed a central importance at Kyoto.

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[13] Interestingly, the Europeans initially pressed for a series of coordinated policies and measures. The U.S. rejected such an approach on the grounds that coordinating specific policies and measures would limit domestic flexibility and force the U.S. to accept domestic measures it did not favor.

To conclude, the articulation of concrete emission reduction goals over a relatively short time period became one of the central elements in the negotiating positions leading up to the December 1997 negotiation of the Kyoto Protocol. This pattern of limited when flexibility followed that laid down nine years earlier at the Toronto Conference, and in the ozone agreements before it. By 1997 that pattern had been absorbed into the language and symbolism of climate change politics. The environmental movement, and the public generally, had come to judge a government's intentions largely by its position on near-term emissions reduction targets. The economic analysis we review in the next two sections of the paper, while not of one mind in its conclusions, casts some doubt on this approach.

4. THE ECONOMICS OF FLEXIBILITY IN THE TIMING OF ABATEMENT[14]

How much effort should be put into limiting emissions in the near term versus the longer term? In the politics of the Kyoto Protocol, even raising this question may be seen as an excuse to avoid action and adopt a "wait and see" policy. However, since climate change is a long term problem requiring long term solutions, the subject of "when" flexibility cannot be avoided.

Many experts agree that at least three types of activities should be undertaken in the very near term: (1) efforts to begin reducing the carbon intensity of the capital stock; (2) investments in research, development and demonstration activities for new energy supply and use technologies; (3) no cost and low cost efforts to reduce current greenhouse gas emissions. Those calling for aggressive targets and timetables go further: they favor near term commitment to what most economic analyses indicate are higher-cost reductions. The question posed in this section is what economic case can be made to launch the nation or, more precisely, the industrialized world, on a path to undertake more aggressive emission reductions sooner rather than later. We defer to the next section discussion of how rigid either near-term or long-term emission reduction targets ought to be.

The ultimate objective of the Framework Convention on Climate Change (as expressed in Article 2) is to stabilize atmospheric concentrations of greenhouse gases at a level (yet to be determined) that would prevent dangerous anthropogenic interference with the climate system.[15] This is a significant challenge. The IPCC (1992) projects that emissions will increase by 50 to 800 percent over the next century absent mitigation policies. The long atmospheric lifetime of carbon dioxide and other important greenhouse gases means that future concentrations will depend on current as well as future emissions of greenhouse gases. The IPCC (1992) also developed a set of illustrative pathways for stabilizing the atmospheric

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[14] Portions of this section are taken from Toman (1998).

[15] The full text of Article 2 reads: "The ultimate Objective of this Convention…is to achieve…stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Such stabilization should be achieved within a time frame sufficient to allow ecosystems to adapt naturally, to ensure that food production is to threatened and to enable economic development to proceed in a sustainable manner."

concentration of CO_2 at levels of 350, 450, 550, 650, and 750 p.p.m.v. over the next several hundred years.[16] The IPCC profiles were developed under several constraints involving (1) prescribed initial (1990) concentration and rate of change of concentration; (2) a range of prescribed stabilization levels and attainment dates; and (3) the requirement that the implied emissions should not change too quickly. Inverse calculations were then used to determine the emission rates required to achieve stabilization via the specified pathways. These calculations show that stabilization requires an eventual and sustained reduction of emissions to substantially below current levels. The Kyoto agreement would *reduce emission levels* of Annex B countries within a period of about a decade, but it would only *slow the growth* of GHG concentrations.

However, to make significant reductions in GHG emissions over the long term does not automatically require aggressive reductions in the near term. A paper by Wigley, Richels, and Edmonds (1996, hereinafter WRE) shows that substantial early reduction of emissions, as is implied in many of the IPCC's original scenarios, is not required to achieve posited long-term GHG concentrations. The IPCC scenarios correspond to just one of a range of possible pathways toward a particular concentration target. WRE allow emissions trajectories to track a "business as usual" path longer than in the IPCC profiles, while still achieving the target long-term GHG concentration. This paper has attracted widespread attention since it helped stimulate a number of other papers indicating that pathways in which a long-term concentration target is met with some initial slowing down of abatement could have lower economic costs.[17] The WRE paper also stimulated several critiques of this thesis, as discussed below.

Cumulative emissions are higher in the WRE scenarios, reflecting the fact that the products of early emissions have a longer time to be removed from the atmosphere and the fact that the associated higher atmospheric concentrations generate stronger oceanic and terrestrial sinks. Thus later emission reductions allow greater cumulative CO_2 production, particularly for higher stabilization levels. WRE note that these differences in cumulative emissions, not considered by the IPCC, "may have important economic implications" (page 241).[18]

Article 3 of the Framework Convention states that "policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost." By its very nature a long-term perspective on the climate change problem offers increased opportunities for implementing low-cost strategies that can achieve ultimate goals. WRE and other analysts advance several economic reasons to justify deferral of significant

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[16] While the atmospheric concentration of GHGs is a more relevant target than annual emissions, it in turn is, of course, only a proxy for the rate of climate change, which is the ultimate object of climate policy. The rate of change of concentrations, as well as the absolute level, may possibly affect climate. This relationship is not yet well understood, which introduces another uncertainty into the science of this subject.

[17] For an early analysis of how mitigation costs may vary with the timing of emission reductions see Nordhaus (1979). More recent papers include Kosobud et al. (1994), Richels and Edmonds (1995), Richels et al. (1996), and Manne and Richels (1997).

[18] The *path* of climate change--for example, the expected rate of temperature response per annum--may differ between the IPCC and WRE paths. However, the differences are likely to be fairly minor.

and thus more expensive abatement efforts. One is *technical progress*, i.e., greater availability in the future of low-cost substitutes for carbon-intensive technologies. Another is the *cost of capital stock adjustment*, i.e., having more time available for the economic turnover of existing plant and equipment. A third is *discounting and a positive marginal product of capital*. Because people tend to value future costs less than current costs, and because the economy yields a positive return on capital, costs incurred in the future will impose a smaller burden.

A long-term perspective does not mean that all major policy actions are deferred to the future. Instead, it emphasizes the notion of sequential decisions that together contribute to the long-term objective of avoiding unacceptable damages from anthropogenic greenhouse gas emissions. Some actions will be appropriate in the short term as first steps down the longer-term policy path. Other actions may be most appropriate in the mid or longer term. Tradeoffs between earlier and later action will need to be considered. Unless one starts with a longer-term perspective, however, it is impossible to consider these tradeoffs.

WRE and other similar analyses caution that even from the perspective of a cost-effectiveness analysis, their results should not be interpreted as suggesting a "do nothing" policy. Current investments, they argue, should be shifted to existing technologies that are less carbon intensive. Similarly, efforts aimed at the research, development and demonstration of new technologies should be intensified, and so-called "no regrets" measures should be adopted immediately. Further, they emphasize that one cannot go on deferring emissions reductions forever.

A paper by Manne and Richels (1999) compares the Kyoto reductions to several alternative pathways. Using their MERGE model, which provides a general equilibrium formulation of the global energy system and economy, they find that achieving a long-term GHG concentration of 550 ppm by first implementing the Kyoto Protocol followed by least-cost reductions thereafter is 40 percent more expensive than embracing the most cost-effective mitigation pathway from the outset, which involves a slower implementation of emission limits. They conclude:

> "…unless the concentration target for CO_2 is well below 550 p.p.m.v., the Protocol appears to be inconsistent with a cost-effective long-term strategy for stabilizing CO_2 concentrations. Rather than requiring sharp near-term reductions, it appears that a more sensible strategy would be to make the transition at the point of capital stock turnover. This would eliminate the need for premature retirement of existing plant and equipment and would provide the time that is needed to develop low-cost, low carbon substitutes." (p. 20)

Several counterarguments to the slowing down of abatement efforts have been advanced. One broad concern is the extent to which issues of intertemporal credibility arise in postponing efforts to reduce emissions too far into the future. In a world in which binding intertemporal contracts across governments are impossible to write, and binding long-term regulatory contracts with private agents are difficult to enforce, there is a challenge in avoiding perpetual delay in emissions reduction that thwarts the long-term environmental goal.

However, policy also must be consistent with the incentives of those bearing the costs of GHG policy. Intertemporal credibility is a two-edged sword--imposing avoidable costs from excessively ambitious short-term targets does little to commend a policy. If haste further leads to wrong choices of technologies, the damage is compounded. If the populace becomes convinced that climate change is a serious long-term threat that requires long-term GHG-reducing actions to protect future generations and perhaps the planetary ecosystem itself, and if a more gradual approach allows technology to advance in ways that brings down the cost of GHG limits, then attempts to optimize the timing of such actions will not encounter the same self-serving delays that arise when motivation is lacking.

Critics of a more gradual approach (such as those referenced above) also believe it could increase, not decrease, the expected long-term cost of GHG abatement. This would occur, they argue, because delay allows more "lock-in" of long-lived capital based on GHG-intensive technologies; retards the development of new technologies that would be spurred by near-term abatement policies (at least those that are incentive-based); and exposes the economy to the risk of having to make costly rapid future decreases in GHGs in the face of investment and technological inertia if future scientific analyses revise upwards the risks of climate change.

The key questions that need to be addressed in sorting through this disagreement in the literature include the following: To what extent can taking gradual steps as part of a long-term approach toward significant GHG limits provide early incentives and credible long-term signals for investments that help deter lock-in? To what extent can policies supporting basic R&D help offset any shortfall in induced innovation? Are the cost savings from a more gradual approach large enough that some risk of needing to take rapid future action is justified? We have already addressed the last of these questions by noting that if where flexibility is not as successful in practice as in theory, the potential cost savings from when flexibility may be larger. We focus here on the other questions.

Economists' general understanding of the forces that drive the discovery, development and diffusion of new technologies remains limited. This is demonstrated by the use of ad hoc "autonomous energy efficiency improvement" rates in many top-down economic models. These rates represent exogenous trends in energy efficiency improvement that occur independently of energy price and other economic signals. Nevertheless, some recent economic studies shed light on the response of technology development to prices and other economic signals, referred to in the literature as induced technological change.

As already noted, some authors have claimed that induced technological change justifies more rapid GHG reductions. The argument is that policies to limit GHGs also yield the benefit of faster innovation, particularly in the supply of alternative technologies. A specific line of argument advanced by Grubb and co-authors (1995) is that the cost of inducing a technology switch, while nontrivial in the short run, is more of a transitional adjustment cost than a permanent loss.[19] When viewed in this fashion, strong climate policies that also induce changes in technology contain within them the seeds of longer-term cost decline. The illustrative modeling results presented by Grubb and his co-authors suggest that under this view of how technology and abatement cost behave, the optimal intensity of abatement (taking into account both avoided climate damages and response costs) is several times what more conventional economic models would suggest. By the same token, the cost of delaying abatement rises rapidly as the degree of deferral grows. In evaluating these results, it is important to keep in mind that the abatement cost function in the Grubb, et.al., model increases as the abatement rate is accelerated. Thus the model by construction penalizes the accelerating abatement path advocated by Manne and Richels.

As expected, more conventional economic analyses are less optimistic about the potential for induced innovation to lower costs. Goulder and Schneider (1999) show that induced innovation directed toward reduced GHG emissions may have indirect opportunity costs: if the supply of innovative effort is less than infinitely elastic, which seems a reasonable assumption, then increased innovation in GHG reduction necessarily will make other innovation more expensive and thus crowd it out to some extent. This, in turn, would reduce long-term economic growth prospects, and raise the long-term cost of GHG abatement.[20]

A paper by Nordhaus (1997) incorporates innovative behavior into a derivative of his well-known DICE model. His new model assumes that technological change reduces CO_2 emissions per unit of output; that the social rate of return on energy/carbon-saving R&D is approximately 50 percent per year; that the private rate of return on energy/carbon-saving R&D is equalized with the private rates of return on other investments; and that R&D is 2 percent of world output in both the energy/carbon and in other sectors. From a series of model simulations he finds that with these assumptions, induced innovation *per se* does not add much to the desired rate of GHG reduction over time.[21] Returns at least an order of magnitude larger than what he calls the "already supernormal" returns to R&D in the model are needed for induced

[19] Porter and van der Linde (1995) advance a somewhat different argument based on organizational inefficiency in seizing opportunities for beneficial technical change. For a view strongly contrary to their perspective see Palmer, Oates and Portney (1995). These and other critics of Porter counter that induced technological progress should be seen simply as providing a lower-cost way to achieve desired levels of abatement, and that induced innovation per se does not imply the existence of a substantial "free lunch."

[20] To avoid confusion, it is important to note that if existing rates of investment in GHG-reducing technologies are too low, for example because of concerns about appropriability of R&D benefits by the innovator, then GHG abatement policies that stimulate technical change will help to reduce this R&D market failure as well as addressing the environmental challenge of GHGs. The general equilibrium argument put forward by Goulder and Schneider points out that these combined gains must be compared to the consequences of any reduced R&D investment elsewhere in the economy (where rates may also be below the social optimum before the imposition of GHG policies) as well as to the direct costs of climate-related R&D.

[21] The "desired" rate of GHG control in the Nordhaus analysis reflects an intertemporal cost-benefit assessment in which the opportunity cost of GHG control is balanced against the cost of damages expected from future climate change.

innovation to rationalize a major increment to the rate of GHG reduction. The implication is that induced innovation is not a panacea for low-cost GHG control.

A paper by Goulder and Mathai (1998) represents a further attempt to model the effect of induced technological change on the optimal time path of GHG emission reductions. They develop a unified framework for considering the effects of two channels for knowledge accumulation, namely R& D activity and so-called learning by doing. They find that the presence of induced technological change generally lowers the time profile of the carbon taxes required to obtain alternative concentration targets. The impact of the induced technological change on the least-cost abatement path varies. When knowledge is gained through R&D investments, some abatement is shifted from the present to the future, thereby supporting the notion of backloading. However, when knowledge is gained through learning by doing, the impact on the timing of abatement is ambiguous. Further research is clearly needed on these issues.

Other factors could affect the desired timing of abatement. For example, the prospect of reduced conventional pollutants resulting from GHG curbs, so-called "ancillary benefits,"[22] could enhance the case for some frontloading of abatement efforts. However, at least in the United States, the expansion of the "no regrets" margin for GHG control implied by the existence of ancillary benefits cannot in itself justify an aggressive near-term GHG control policy. There also is a potential "double dividend" resulting from interaction between climate policies and existing taxes (Goulder, 1995; Morgenstern, 1996; Parry et al., 1997). In theory the presence of the double dividend could also enhance the case for frontloading abatement efforts. However, most empirical analysis of these interactions focus on full-employment economies like the U.S., where the estimated gains, if any, from substituting modest carbon taxes for existing taxes on labor and capital are likely to be small. Less is understood empirically about double dividends in underemployment economies, where the gains from tax substitution (and thus indirectly from more rapid GHG controls) may be larger.

5. POLICY DESIGN AND FLEXIBILITY OF TARGETS

International agreements designed to realize commonly held goals generally fall into two categories. There are those, like the Kyoto Protocol, that set agreed-upon national objectives but then leave each signatory country to pursue those goals in its own way; and those that define mutually agreed-upon policies or measures. Agreed-upon national objectives, often labeled targets and timetables, are often seen as simple, straightforward means of reducing emissions. At least in principle, they provide certainty about the environmental outcomes. The Montreal Protocol is a recent and successful application of this approach. Yet, as already noted, the differences in complexity and cost of controlling CFCs

[22] See for example Burtraw and Toman (1997) and Davis et al. (1997).

compared to GHGs are enormous. These differences argue for more flexible targets, which tend to be the norm in domestic environmental policies and many international agreements.[23]

In the case of GHGs an alternative to a fixed target and timetable is a set of mutually agreed-upon measures focused on particular emission sources or on economic activities that generate GHGs. The most widely discussed economic incentive measures are taxes on substances that emit GHGs, or tradable permits. Other approaches, including the practice of legally mandating specific technologies, while less efficient, are also possible.[24] Early in the negotiation process the European Union advocated the use of coordinated policies and measures as a complement, and possibly as at least a *de facto* substitute, for fixed targets. The U.S. and certain other nations objected to such an approach, largely on grounds that it was both less efficient and potentially more difficult to monitor and enforce. In particular, the notion of *coordinated* policies and measures raised the possibility that the countries would cede some control over their domestic policies--a notion that was politically unacceptable in the U.S. and certain other nations.

This section reviews some recent economics and policy research that considers the use of price-based policies as opposed to fixed targets as a means of controlling GHGs. A critical choice in environmental policy concerns whether to use control prices or quantities as a means for reducing emissions. Most of the current debate concerning the use of price versus quantity controls to reduce GHGs has focused on political, legal, and revenue concerns. In the United States, environmentalists' concerns for firm emissions control goals have combined with a broader political aversion to energy taxes to make an emissions trading program the leading method for implementing the Kyoto Protocol.

Consider the domestic implications of the Kyoto Protocol. In a tradable permit system where each permit gives the holder the right to emit a specified amount of GHG into the atmosphere, one can in principle precisely control GHG emissions. However, the cost of control, in terms of higher prices for fuel and reduced productivity, is highly uncertain under a permit system.

Part of the cost uncertainty arises from uncertainty about the level of future baseline emissions. As noted, the IPCC projects that emissions will increase by anywhere from 50 to 800 percent over the next century absent mitigation policies. In addition to the baseline issue, there is also considerable uncertainty about the cost of reducing emissions below baseline. To illustrate, a study by Nordhaus (1993) reports that a $30/ton tax on carbon might reduce emissions by anywhere from 10 to 40 percent.

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[23] Domestic policies are flexible in the sense that a sovereign country can choose at any time to alter its own targets. With respect to CFCs, fixed targets were actually not the initial policy of choice. In the late 1970s the U.S. and a few other countries acted to ban the use of CFCs in most aerosol dispensers. This ban ultimately resulted in a reduction in emissions of CFC11 and CFC12. However, these emission reductions were not the result of pursuing a target and timetable approach. Rather, they resulted from the specific measures introduced in the participating countries.

[24] See for example Edmonds and Wise (1997).

A quarter century ago, Weitzman (1974) drew attention to the fact that uncertainty about costs leads to a potentially important distinction between otherwise equivalent price and (fixed) quantity controls. With complete certainty concerning abatement costs, price and quantity controls can be used to achieve the same outcomes. For every price (tax) on emissions, there is an optimal emissions level for a firm. Similarly, for every conceivable emissions level there is a corresponding marginal abatement cost which maximizes the firm's profit.

Weitzman demonstrated that when abatement costs are uncertain the situation can be quite different. On the one hand, quantity restrictions can be critical when incremental damages increase rapidly with the level of emissions. In that case quantity restrictions may be preferred because they prevent emissions from rising above a "safe" level. Thus, quantity restrictions are generally appropriate for controlling toxic releases where small changes in emissions can be lethal. On the other hand, when health or environmental damages are not very sensitive to precise emission levels, the undesirable side effects of quantity restrictions may dominate. That is, if costs increase rapidly with the level of emissions, then rigid quantity controls can lead to an unanticipated sharp run-up in costs.

Weitzman showed that in the face of cost uncertainty, economic well-being is enhanced by selecting policies that provide levels of control close to what would be chosen after the uncertainty is resolved. His basic theoretical result was that price instruments would be favored when the marginal benefit schedule was relatively flat and quantity instruments would be favored when the marginal cost schedule was relatively flat. When marginal benefits are relatively flat fixing the price before the outcome is known leads to levels of control that are quite close to the levels of control that would be chosen after the uncertainty is resolved. In contrast, when marginal benefits are relatively steep, the optimal quantity is relatively invariant over the range of outcomes. In that case, fixing the quantity in advance leads to results close to what would be chosen after the uncertainty is resolved.[25]

Which of these situations applies to greenhouse gases? The first important observation to be made in addressing this question is that GHGs are, to a very substantial extent, an example of what is referred to as a "stock pollutant," i.e., one in which the damages are principally a function of total accumulation in the environment and annual emission flows are a small part of the total stock. In this case, because a short-term increase in emissions would contribute so little to either short-term damages or the long-term increase in GHG concentrations, it seems reasonable to treat the marginal damage of increased emissions in the

[25] Weitzman's original result used a model with linear marginal cost and damage relationships. We discuss below the implications of nonlinear benefits; the results are not greatly sensitive to nonlinearities in costs. Uncertainty in the overall scale of benefits (versus nonlinearity) also does not greatly affect the Weitzman result. Finally, the models addressing price versus quantity issues generally do not incorporate induced technical change; a full analysis would take into account how the signal strength of different policies would affect the evolution of technology. In one recent example of this work, Fischer, Parry, and Pizer (1998) show that there is no a priori reason to favor a price or quantity approach in terms of incentives for innovation; which policy performs better depends on the circumstances.

near term as approximately constant, though the marginal damage of increased cumulative emissions certainly may rise (Newell and Pizer, 1998).

What about the longer-term damages as concentrations rise over time? A great deal of attention has been given to the possibility of some "extreme event" (like major sea level rise from melting polar ice caps or a shift in the Gulf Stream that destabilized global temperature and weather). The most likely scenario is that climate change will occur gradually in response to growing atmospheric concentrations of greenhouse gases, and most evaluations of potential consequences of climate change are based upon this assumption. Clearly, however, the potential exists--with unknown probability--for disproportionately large responses to even small disturbances in the climate system. Even short of a catastrophe, damages could still increase much more than linearly as concentrations rise.

It is certainly possible that the long-term climate damage function could be convex enough, or exhibit a high enough likelihood of a major jump upward at some threshold level, to warrant a long-term preference for a quantity-based over a price-based approach. The choice of instruments is highly dependent on the rate at which future costs and risks are discounted and, more generally, on the degree of intergenerational altruism (or risk aversion) expressed by the current generation.

However, even if there is a high degree of concern for the future and a high degree of concern that future climate change damages might accelerate, a rigid short-term emissions quantity target may not be desirable. The reason, as Kolstad (1996) notes, is that we currently operate in an environment with a lot of uncertainty about abatement costs and technology as well as climate change damages. Given the long-term nature of the climate change problem, if we learn that climate change risks are more serious than we anticipate today we can accelerate future abatement (though as noted above, the costs of such acceleration will be higher to the extent that more energy-intensive fixed capital has been accumulated in the interim). In contrast, the decision to commit to a major change in the capital stock to satisfy a binding quantitative limit on GHGs is essentially irreversible, even if we find later that the climate change risk is less serious than anticipated or that new and significantly cheaper abatement opportunities present themselves.[26]

Pizer (1996, 1997) employs a modified version of Nordhaus' integrated climate-economy model (DICE) in order to analyze alternative assumptions about the shape of marginal cost and marginal benefit or damage curves. Following from Weitzman's intuition that relatively flat marginal damages favors taxes, Pizer finds that an optimal tax designed to control GHGs generates gains which are five times higher than the optimal tradable permit policy--in his model a $337 billion gain versus $69 billion at the global level. As a result of extensive model simulations, Pizer finds that ". . . the optimal permit policy involve[s] lower welfare gains . . . [and] setting the permit level incorrectly can lead to massive losses. The tax instrument, in contrast, leads to welfare gains over a much wider range of values" (page 29).

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[26] There is not yet consensus within the economics profession on this point; for dissents see Narain and Fisher (1998) and Heal and Chichilnisky (1993).

An apparent difference between tax and permit policies is that, in the face of cost uncertainty, tax policies do not yield a strict limit on emissions. Over the long-term, however, emissions could average out to those achieved with a quantity-based approach, if periods of unexpectedly high abatement cost are balanced by periods of unexpectedly low cost.[27] Moreover, it is possible to combine price and quantity policies in a hybrid approach that establishes binding emissions targets as long as costs remain reasonable and allows the target to rise somewhat if costs are unexpectedly high.[28]

Ideally one could devise a mechanism that responds to high abatement costs for individual countries and at the same time does not create an incentive for widespread noncompliance. What is needed is a penalty, specified in advance, and paid by the source in case its emissions exceed the quantity restrictions set for that source. One way to achieve this goal is to establish a penalty per unit of emissions in excess of the quantity restriction. Importantly, the policy must be fixed *before* any uncertainty is resolved. Such a hybrid policy (1) fixes emissions targets that are binding as long as costs remain reasonable, and (2) allows the target to rise somewhat if costs are unexpectedly high. In practical terms the hybrid or "safety valve" would involve an initial allocation of permits followed by the subsequent sale of additional permits to be made available at a fixed trigger price. The theoretical basis for the hybrid approach was first laid out in Roberts and Spence (1976) and Weitzman (1978). More recently this approach to control GHGs has been modeled by Pizer (1996, 1997). Specific policy proposals have also been advanced by McKibbin and Wilcoxen (1997a,b), and Kopp et al. (1997, 1999)

McKibbin and Wilcoxen (1997a,b) propose to set up a system of national permits and emission fees wherein each country would be allowed to distribute tradable emissions permits equal to its 1990 carbon emissions and governments would agree to sell additional permits at a fee specified in the treaty. They propose that the initial fee should be $10 per ton. They favor such a scheme over a fixed target and timetables approach for a number of reasons distinct from the Weitzman argument given above. First, McKibbin and Wilcoxen don't believe the economic case has been made for the more aggressive policy implied by the Kyoto agreement. That is, they don't believe the benefits of such a policy exceed its costs. Second, the fixed target and timetable approach with international trading of emissions permits would generate large transfers of wealth among countries. In the case of the U.S. they argue that it would increase the trade deficit by 25 to 50 percent. Third, an international tradable permits system would put enormous stress on the world trade system. For developed countries this would lead to substantial volatility in exchange rates and distortions in trade. For developing

[27] Emissions trading also provides these kinds of cost-smoothing opportunities if the initial stock of permits is sufficiently high that emitters can bank a significant number of them for use when abatement costs are unexpectedly high. This feature of the tax-permits debate has yet to be fully worked out.

[28] Because the policy provides relief when costs are high but does not tighten standards when costs are low, it will generate higher emissions on average over the longer term than a fixed quantity approach. As discussed below, however, an important question is whether this outcome is preferred to *no* controls because of political opposition to the risk of high abatement cost.

countries this would lead to exchange rate appreciation and a decline in exports other than GHG emission permits. Fourth, because the agreement allocates excess permits to the former Soviet Union and certain Eastern European nations which are already below 1990 levels for reasons related solely to their economic performance, the permit system would really amount to nothing more than an elaborate accounting mechanism to allow increases in emissions in the U.S. and other industrial countries. Fifth, in the absence of an elaborate and expensive international monitoring and enforcement system, individual governments would have little incentives to police the agreement since punishing domestic violators imposes costs on domestic residents in exchange for benefits that will accrue largely to foreigners.

Contrary to the view of many environmental advocates, McKibbin and Wilcoxen argue that ". . . the real choice is not between a sharp reduction and a more modest policy; it is between a modest policy and no policy at all" (page 6). Thus, they believe it is false to claim their proposed permit and fee system is environmentally inferior to the Kyoto Protocol since, in their view, the latter will never be implemented.

Kopp et al. (1997, 1999) also propose a hybrid permit and fee scheme but rely on a somewhat different rationale than McKibbin and Wilcoxen, one closer to the basic Weitzman argument. Whereas McKibbin and Wilcoxen stress the international trade implications and the enforcement difficulties of making a sharp reduction in emissions via the targets and timetables approach, Kopp et al. focus on the uncertainties in benefits and costs that lead to unnecessary reductions in economic welfare associated with a targets and timetables approach. Most consumers are interested in reducing their out-of-pocket expenditures for energy and goods and services, while most businesses are interested in maintaining a stable environment for planning and investment. The risk of unexpectedly high compliance costs under a strict permit system thwarts that stability. For that reason, most people would prefer some sort of contingent policy that would keep costs manageable and predictable.

The hybrid approach guarantees that emissions will not exceed the tradable permit limit as long as the price of the tradable permits (i.e., the marginal cost of GHG control) does not rise above the trigger price. For environmental advocates who believe that the cost of reducing GHG emissions is low, the permit price will never reach the trigger level and emissions will remain capped if their belief is borne out. Moreover, a focus in the short term on policies involving hybrid permit or tax schemes (with internal "recycling" of revenues) within the Annex B countries does not in any way preclude a later transition to more binding emission targets to stabilize the atmosphere, once uncertainties surrounding GHG control costs are reduced and participation is more global. We turn to this latter point below.

Based on Pizer's model simulations, the hybrid system turns out to be (very) slightly more efficient than a pure tax system. In addition, it allows a flexible distribution of the economic rents associated with emission control (the government has discretion in the allocation of base permits as well as collecting revenues from the sale of additional permits). Pizer (1997) notes that "perhaps most interestingly for current policy discussions, sub-optimal hybrid policies based on a stringent target and high trigger price have much better welfare outcomes than a sub-optimal permit policy with the same target" (page 2).

The discussion to this point has been concerned with policy design and target flexibility at the domestic level. At the international level the arguments are less clear-cut. Recently, Cooper (1998) authored a stinging attack on the Kyoto Protocol because of its reliance on national emissions targets and its failure to embrace mutually agreed-on measures. Specifically, he argues that the control of GHGs, unique among international environmental challenges, will involve behavior changes by billions of people, not merely the fiat of 180 or so governments. "No major legally binding regulatory treaty," he notes, "involves . . . th[is] characteristic . . . to a similar degree" (page 70).

Cooper's support of taxes over quantity targets and tradable permits rests heavily on the observation that the key to GHG reductions lies not in government exhortations or in international treaties per se, but in the incentives governments provide to their citizens and the exercise of their own economic self-interest. Aside from the fact that taxes induce cost-effective private sector responses, Cooper sees their primary advantage as the generation of revenue for governments whose usual revenue sources reduce productivity. Although Cooper raises the possibility of using some of the revenues for the direct benefit of developing countries, he posits that most of the new tax revenues would be used to reduce other taxes, notably those with the largest adverse effects on productivity. Cooper also argues that monitoring national compliance with a carbon tax would be relatively easy through the International Monetary Fund's ongoing national consultations.

In contrast, the Kyoto agreement requires the allocation of national rights to GHG emissions. Yet, Cooper argues, "there is unlikely to be any generally acceptable principle for allocating valuable emission rights between rich and poor countries" (page 68). Finally, he appeals to history in arguing that "international cooperation in other fields has progressed most successfully when there was agreement not only on the objective but also on how best to achieve it. . . . [T]he absence of scientific consensus on how [GHGs] translate into global warming and how these temperature changes in turn affect the human condition will make it difficult to agree on how to share the costly actions. . . . But taxes, like death, are inevitable as well as universal, and they can more profitably be imposed on harmful activities than on socially valuable ones" (page 79).

Not surprisingly, those favoring a tradable permits approach have launched a counter attack against the enthusiasts for carbon taxes (and the hybrids). Eizenstat (1998) notes the widespread public disdain for new taxes and suggests that Cooper's support for carbon taxes is "out of touch with political reality." He also cites history to argue that "no international agreement has ever imposed an obligation on countries to tax their citizens" (page 120). Unlike Cooper, he believes that the required level of international scrutiny on domestic tax decisions would prove to be extraordinarily difficult to implement. Further, he stresses the numerous flexibility mechanisms built into the Kyoto Protocol that would serve to achieve most of the efficiencies gains of a carbon tax. But neither Cooper nor Eizenstat satisfactorily addresses the long-term problem of broadening participation to include developing countries. Would the U.S. accept a recycling of carbon tax revenues internationally to favor developing countries? Would it accept a lopsided allocation of future GHG permits to developing countries?

Wiener (1998) adopts a somewhat different tack in support of tradable permits in contrast to a tax or hybrid approach. He examines whether the legal frameworks in force at the national level imply particular choices for regulatory instruments to be used at the global level. He suggests that the presumption favoring environmental taxes derives from a standard analysis of instrument choice in which it is assumed that the regulator can compel polluters to comply by fiat, and that the regulator can impose the instrument directly on polluters without any intermediate level of government in the way. Yet, he argues that neither coercion nor direct regulation applies to international treaties. Rather, such treaties depend on countries' voluntary assent, and on implementation through national governments.

Wiener examines the impact on regulatory instrument choice of two basic legal parameters that differ between the national and global settings: voting rules and implementation structures. He concludes that "the jurisdictional implementation structure poses obstacles especially to global environmental taxes." Like Eizenstat he believes that it will be much harder to monitor national agents' internal fiscal manipulation under a global tax regime than to monitor their agents' actual emissions under a global quantity-based regime.

Last, but not least, Wiener argues that international transfers to developing countries are crucial for expanding participation in GHG control and stabilizing the atmosphere, and that such transfers are much more effectively accomplished by the international allocation of GHG rights and their sale through market channels than through intergovernmental redistribution of carbon tax revenues. Wiener would characterize Cooper's objections to quantity policies as relating more to the limited degree of commitment developed countries actually feel to reduce GHGs over time than to an advantage of taxes over quantity-based policies. In Cooper's scheme the degree of quantitative policy coordination would be limited (developing countries are unlikely to accept tax rates as high as the OECD would need to meet their environmental and fiscal goals), and the degree of international resource transfer to poorer countries also would be limited, implying low GHG tax rates internationally and relatively little GHG reduction.

6. CONCLUSIONS

The more flexible and cost-effective the means pursued of achieving a particular goal, the more affordable the goal becomes and the more likely that it is achieved. Notwithstanding the extensive "what" and "where" flexibility contained in the Kyoto Protocol, and the flexibility countries possess in domestic policy design, the Protocol is relatively inflexible with respect to both the timing and specificity of the emissions targets. In contrast to the successful Montreal Protocol for protecting the stratospheric ozone layer, GHG control is inherently more complex, requiring much greater flexibility to reflect the costs and uncertainties associated with the control strategies.

In this paper we have reviewed a number of arguments in favor of providing more flexibility specifically in the timing of emissions control and in the degree to which shorter-term emission reduction targets are binding. While a consensus has yet to emerge in the literature, we believe that the balance of the evidence favors such increased flexibility for

Annex B countries in the short to medium term, compared to the requirements of Kyoto Protocol. Such modifications would include a slower ramping up of emission control obligations; a greater capacity to balance emission control costs with environmental objectives through price-based instruments, at least until more is understood about both costs and environmental risks; or a combination of these features. Such an increase in when flexibility is especially important if efforts to implement the where flexibility provisions of the Protocol come up short, a distinct possibility.

We believe this approach provides a practical and useful path for beginning the long-term effort to stabilize GHG concentrations over the longer term. And we emphasize again that the increased flexibility we advocate in the short to medium term is not inherently incompatible with stronger and more binding targets in the longer term. Legally, significant changes to the Kyoto Protocol would be required to incorporate elements of when flexibility. One possibility is to introduce a safety valve approach into the compliance portion of the Protocol. Negotiating these changes will not be easy, but they may become essential if the Kyoto process stalls or fails to achieve its objectives.[29]

There are important uncertainties that surround our conclusions about target and timing flexibility. The possibilities of extreme events and disproportionately large responses to even small increases in atmospheric concentrations of GHGs cannot be dismissed, although the limited modeling analyses to date do not hint at great concern on these grounds. Similarly, although much of the analysis to date suggests that induced technological change does not, on balance, undermine the case for some backloading of emissions reductions, the issue warrants further study. Concerns about intertemporal credibility when commitments are stretched out are also legitimate, but no more so in our view than the concerns about the credibility of an unnecessarily costly short-term policy target. A final area of uncertainty concerns the issue of how quantity-based policies might encourage broader international participation in emissions control over the longer term. While this seems like a reasonable argument, it presumes a stronger commitment to costly short-term emission control activities in the industrialized world than seems to exist today, implying the need to strike a balance. Certainly there is a need for more research on all these issues.

Support for aggressive and rigid short-term emission control targets ultimately can be couched also in noneconomic terms, e.g., the political argument that decisive early action by industrialized countries is needed to convince developing countries of the former countries' sincerity in protecting the global environment, so as to persuade the latter to join in. Without meaning to diminish the potential importance of such arguments, however, we think they give rise to their own debates concerning the true meaning of *decisive* early action; how, if at all, developing country interests would be served by such actions; and others. At a minimum,

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[29] Article 18 of the Kyoto Protocol, which refers to compliance, says only that Parties to the Protocol will develop whatever compliance measures are necessary to implement the Protocol. Clearly negotiating these measures will not be an easy task, even without changes to the Protocol. Indeed, negotiating compliance measures will be more difficult when targets are more rigid and thus less certain to be attained.

some of the recent developments in the economics literature regarding when and how flexibility need to be factored into the political calculus before nations undertake major commitments to GHG reductions.

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