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Framing A Coherent Climate Change Policy

by Frederick H. Rueter

Policy Study
Number 141
October 1997

Washington University in St. Louis

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CENTER FOR THE STUDY OF AMERICAN BUSINESS

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Executive Summary

An apparent objective of the forthcoming international conference on global climate change in Kyoto, Japan, is to obtain binding commitments from industrialized nations to reduce emissions of greenhouse gases to their 1990 levels or lower within the next one or two decades. There is some question whether commitments will be sought from developing nations, despite firm projections that several (most notably China and India) will become predominant emitters within the next century. This plan does not represent a coherent policy for dealing with potential changes in the global climate due to human activity.

First, binding commitments to reduce greenhouse gas emissions by specific amounts within the next 10 to 20 years would cause substantial adverse economic impacts. The impacts would be severe even if economic incentive mechanisms such as carbon taxes, tradable emission permits, or tradable emission quotas were used as the means for implementing the commitments.

- Binding commitments would decrease America's gross domestic product (GDP) and its employment by sizable amounts. The amounts would depend on the stringency of the commitments. Estimates from standard, multi-industry econometric models indicate that stabilizing annual CO_2 emissions at their 1990 levels by 2010 will reduce GDP by 0.2 to 0.7 percent and will decrease total employment by more than 900,000.

- The impacts on employment would differ substantially among industries and among geographic areas. Recent government estimates indicate that initially all major industry groups and all regions except New England would suffer decreases in aggregate employment. The decreases would persist and grow in most major industry groups (i.e., in mining, oil and gas extraction; manufacturing; transportation, communication, and utilities; and services), and throughout the central regions of the nation.

- Although the proposed economic incentive mechanisms would encourage firms to undertake pertinent technological research and development, they also would reduce firms' net revenues. The decline in net revenues would diminish firms' ability to *fund* research, development, and implementation of new technologies. Thus, on balance, the economic incentive mechanisms may *impede* crucial technological advancement instead of stimulating it.

Second, the available scientific evidence indicates the binding commitments under consideration would be premature.

- Any increases in temperature that are caused by anthropogenic (human-caused) *emissions* of greenhouse gases will result from increases in the atmospheric *concentrations* of the gases. Because greenhouse gases generally remain in the atmosphere long after they are emitted, reductions in their atmospheric concentrations will be determined mainly by the cumulative amount that emissions are reduced, and will not be very sensitive to the timing of the emissions reductions.

- The emission reductions required to stabilize greenhouse gas concentrations at small multiples of (e.g., double or triple) their pre-industrial levels would be large fractions (e.g., 65 to 80 percent) of their 1990 emission levels. In contrast, the reductions that have been proposed as binding commitments are small fractions (i.e., 0 to 20 percent) of the 1990 levels. Such modest reductions would not stabilize the atmospheric concentrations at low levels. Rather, they would merely defer the dates when the higher levels are achieved by, at most, a few decades.

- To sustain any specific stabilized concentration of greenhouse gases, annual emissions ultimately must be reduced to a specific low level. That level will be the same regardless of how much restraint, if any, is imposed on emissions during the next several decades.

- The scientific evidence does not justify concluding that small increases in greenhouse gas concentrations above their current levels will involve appreciable risk of severe damage from global climate change. Unless scientific research shows that such increases involve unacceptable risks, no commitments should be made to use technologies during the next several decades that are not cost-effective in performing their primary functions.

Third, given the existing technology, binding commitments to reduce greenhouse gas emissions to specific levels by specific dates would be extremely inefficient.

- The types and amounts of fuel that can be used in particular processes or activities are largely embodied in the existing stock of physical equipment. Opportunities for switching from high-carbon to low-carbon fuels are very limited in the short term.

- Because the useful life of physical equipment is generally quite long, only a small portion of the existing stock is replaced during any year. Since deferring the reduction of emissions is unlikely to involve appreciable risk of material harm, no apparent benefit would be realized by accelerating the normal, gradual replacement of existing equipment with less carbon-intensive or more energy-efficient equipment.

- The available alternative technologies that are less carbon-intensive or more energy-efficient than the processes now in use are often much more expensive than those processes. Obligating the prompt adoption of available technologies could lock businesses into expensive production methods that might shortly be superseded by superior options.

- To achieve at reasonable cost the large reductions in greenhouse gas emissions that will be needed to stabilize atmospheric concentrations at small multiples of their pre-industrial levels, it will be necessary to develop more cost-effective, more energy-efficient, less carbon-intensive technologies.

Fourth, unless binding commitments are uniformly obtained from industrialized nations and developing nations, their effectiveness will be greatly diminished.

- If commitments are not secured from developing nations, production would shift from industrialized nations to developing nations, especially in energy-intensive industries such as primary aluminum, steel, petroleum refining, pulp and paper, cement, and certain segments of the chemical industry.

- The relocation of production will be accompanied by analogous relocation of greenhouse gas emissions. The net international reduction of emissions will therefore be less, and could be much less, than the aggregate reductions achieved in the industrialized nations.

Because of the vast scientific and technological uncertainty, appropriate actions and objectives for dealing with the prospects of changes in the global climate due to human activities can only be determined as additional knowledge is gained and key uncertainties are reduced. This is an adaptive process that evolves over time.

- *The basic framework for coherent climate change policy should be sequential decision making.* This decision-making strategy has been characterized as an "act-learn-act" approach.

- *Initial actions should emphasize research* to reduce scientific uncertainties about climate change, and to develop improved technologies.

- *Flexibility in timing should be allowed in the adoption of new technologies.* Firms should be permitted to coordinate their innovations with the replacement of existing equipment.

- *Full cooperation* with the decision-making strategy *should be sought from all nations*, both industrialized and developing.

- Most important, *arbitrary timetables should not be established for attaining arbitrary reductions in greenhouse gas emissions.* It would be short-sighted and inefficient to divert scarce resources from important scientific and technological research to achieve currently practical decreases in emissions.

Background: The International Political Setting

In 1992, at the United Nations Conference on Environment and Development in Rio de Janeiro (the Rio Earth Summit), the environmental ministers of the participating nations developed the Framework Convention on Climate Change (FCCC). To date 166 nations, including the United States, have ratified this agreement and become members of the Conference of Parties to the FCCC.

The agreement calls for the parties to individually or jointly reduce their anthropogenic emissions of greenhouse gases, including primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) to the levels that occurred in 1990. No deadline for achieving this objective is established in the agreement, although the aim of attaining those levels by the year 2000 has been expressed.

Since then, two sessions of the Conference of Parties have been held: the first in Berlin, Germany, in March 1995 and the second in Geneva, Switzerland, in July 1996. The third session will convene in Kyoto, Japan, in December 1997.

An apparent objective of the third session is to obtain binding commitments from the industrialized nations to reduce their net emissions (emissions less removals) of CO_2 and other greenhouse gases to specific levels (targets) by specific dates (timetables). Targets are typically expressed as specific percentages (100 percent, 90 percent, 80 percent) of 1990 emission levels, and timetables are stated as specific years (2005, 2010, 2015, 2020). The industrialized nations include the members of the Organisation for Economic Cooperation and Development (OECD) and the nations from the former Soviet Union and Eastern Europe. There is some question whether commitments will be sought from developing nations to reduce their emissions during the term of the timetable, despite firm projections that several of them, most notably China and India, will become predominant sources of CO_2 within the next century.

As explained later, the binding commitments under consideration do not represent cost-effective elements of coherent policies to deal with potential changes in the global climate due to human activities. They will provide scant reductions in any risks associated with anthropogenic emissions of greenhouse gases, and will impose high costs that will be borne disproportionately by specific segments of the economy. In contrast, a coherent policy would incorporate sequential decision making, focus initially on pertinent scientific and technological research, allow flexibility in the timing of emission reductions, and seek full international cooperation in policy implementation.

The Scientific Situation

Although the commitments that have been advocated focus on stabilizing or reducing *emissions* of greenhouse gases, any increases in temperature that are caused by anthropogenic emissions of greenhouse gases will result from increases in the atmospheric *concentrations* of the gases. Clearly, the concentrations of greenhouse gases in the earth's atmosphere are related to their emissions into the atmosphere. The relationship, however, is complex.

Many greenhouse gases remain in the atmosphere for a long time after they are emitted. The Scientific Assessment Working Group (Working Group I) of the Intergovernmental Panel on Climate Change (IPCC) estimates that the atmospheric lifetime ranges from 50 to 200 years for CO_2, and averages 120 years for N_2O and 12 years for CH_4.[1]

As a result, any atmospheric concentrations that are eventually achieved will be determined more by the cumulative amounts emitted between now and then, than by the temporal patterns of the emissions. Reduction of the atmospheric concentration of CO_2 will therefore not be sensitive to the timing of emission reductions. Meager reductions in the short term can be offset by greater reductions later.

Analyses conducted by IPCC Working Group I demonstrate that stabilizing the atmospheric concentration of CO_2 at small multiples of the pre-industrial level will eventually require reducing annual anthropogenic CO_2 emissions to small percentages of their 1990 levels.[2] For example, stabilization at double (or triple) the pre-industrial concentration will require eventually decreasing annual anthropogenic emissions by roughly 80 percent (or 65 percent) from their 1990 level. The required decreases represent even larger percentage reductions in relation to the higher emission levels that are projected to accompany the economic and population growth expected in future years.

Most importantly, the reduction in annual anthropogenic emissions that will eventually be required to achieve any of the stabilized atmospheric concentrations considered in the IPCC analyses does not depend on the level of restraint imposed on emissions during the next several decades (i.e., until at least 2025 or 2030). So long as emissions remain at or below the levels that are currently projected to occur during that period, suitable progressive reductions thereafter will converge on the desired concentration without ever exceeding it, and the same stabilized level of annual emissions will ultimately be required.

Thus, the analyses reported by IPCC Working Group I indicate that, so long as moderate increases in the atmospheric concentrations of greenhouse gases do not involve unacceptable risk of severe consequences from global climate change, no major adverse effects will result from delaying reductions of greenhouse gas emissions for as much as several decades. Only if small increases above the current concentration involve unacceptable risk of adverse impacts will emission reductions be essential in the short term.

The available scientific evidence, however, does not justify dire conclusions about the risk associated with small increases in atmospheric concentrations of greenhouse gases above the current level. Rather, the current state of scientific understanding of potential climate change due to human activities involves substantial uncertainties.

In 1996, IPCC Working Group I published its second assessment of climate change science, summarizing the state of knowledge in 1995. The assessment states:

> Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long term natural variability and the time-evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land surface changes. Nevertheless *the balance of evidence suggests that there is a discernible human influence on climate change*. (Emphasis added.)[3]

Even this highly qualified statement — which lacks any finding about the magnitude or importance of the "discernible human influence"— has been challenged by several prominent scientists. These skeptics contend that the statement does not adequately communicate the absence of clear evidence that the observed climate changes can be attributed specifically to increased concentrations of greenhouse gases. The most prominent dissenting scientists are Dr. Frederick Seitz, former president of the National Academy of Sciences,[4] and Dr. Richard S. Lindzen, professor of meteorology at Massachusetts Institute of Technology.[5]

In their assessment, IPCC Working Group I has reviewed and synthesized the predicted changes in the global climate that computer simulation models have estimated will result from projected increases in the atmospheric concentrations of greenhouse gases.

Their assessment reveals that even the increases in mean annual surface air temperature that are predicted by the models involve substantial uncertainty. Specifically, the working group concludes that the increase in mean annual temperature between 1990 and 2100 that the models predict will occur due to anthropogenic emissions of greenhouse gases is between “about 1° C” and “about 3.5° C”, with a “best estimate” of “about 2° C”. These predictions are all substantially lower than the corresponding predictions made in 1990.

Predictions of changes in regional temperature exhibit greater variation. The assessment states that confidence in such projections “remains low”. It also declares that the temperature projections merit more confidence than the models' predictions of the possible hydrological consequences of projected temperature increases, such as changes in rainfall and evaporation patterns, shifts in ocean currents, changes in the frequency and intensity of severe weather, and increases in the average sea level. Predictions of the environmental and socioeconomic impacts that might be caused by the projected climate changes are even more uncertain.[6]

This uncertainty provides scant evidence that small increases above the present atmospheric concentrations of greenhouse gases will involve appreciable risk of severe damage from global climate change. Accordingly, it is unlikely that deferring reductions of greenhouse gas emissions for several decades will have major adverse consequences.

Technology

Any attempt to stabilize the atmospheric concentrations of greenhouse gases at small multiples of their pre-industrial levels requires reducing anthropogenic emissions of CO_2. The predominant cause of CO_2 emissions is the combustion of carbonaceous material, especially fossil fuels.

There are three basic technological options for reducing anthropogenic CO_2 emissions. First, switch from fuels with high carbon-content to fuels that contain little or no carbon. Second, increase energy-efficiency and thereby decrease the amount of CO_2 emitted per unit output. Third, capture and store CO_2 as it is emitted.

At present, the third option is technically feasible for removing CO_2 from the stack gases of electricity generating stations fired with fossil fuels. However, because it reduces the conversion efficiency in electricity generation and increases production costs substantially, it is not currently cost-effective.[7]

There also are important practical limits to exercising the first two technological options. Most notably, the types and amounts of fuel that can be used in processes or activities such as electricity generation, manufacturing, transportation, and space heating are largely embodied in the existing stock of physical equipment. As a result, opportunities for switching from high-carbon fuels to fuels with markedly lower CO_2 emissions are very limited in the short term. Similarly, in general, only comparatively small improvements in energy efficiency can be achieved by modifying existing physical equipment.

In addition, the useful life of physical equipment is quite long on average (typically, one or more decades). During any year, only a small portion of the existing equipment becomes obsolete or inoperative and is replaced. Consequently, new technologies are introduced gradually. Since deferring the reduction of CO_2 emissions is unlikely to involve appreciable risk of material harm, no apparent benefit would be realized by accelerating the normal, gradual replacement of existing equipment with less carbon-intensive or more energy-efficient technologies.

Moreover, the available technologies that are less carbon-intensive or more energy-efficient tend to be more expensive than the processes now in use. For example, despite great technological advances, renewable energy sources such as wind, solar, and biomass remain considerably more expensive than fossil fuels. Thus, in the short term, sizable reductions of CO_2 emissions can only be achieved at high cost. Accelerated adoption of available technologies could also lock businesses into costly production methods that might shortly be superseded by more cost-effective alternatives.

In addition, the potential market shares of some alternative technologies are severely restricted by the limited availability of essential resources. Wind power is limited by the scarcity of suitable locations; biomass and solar technologies require large amounts of land.

Consequently, to achieve large reductions in CO_2 emissions at reasonable cost, technologies must be developed that are more cost-effective, more energy-efficient, and much less carbon-intensive than those available or anticipated in the near future. Substantial engineering breakthroughs are needed to make many of the prospective alternative technologies cost-competitive with conventional processes.

Policies Under Consideration

Despite the scientific uncertainties and technological limitations discussed previously, the policies that apparently will be considered by the Conference of Parties in Kyoto, Japan, call for industrialized nations to make binding commitments to reduce their anthropogenic emissions of greenhouse gases to specified levels within 10 to 20 years. The annual emission targets commonly proposed range from 80 to 100 percent of the levels observed in 1990, and the timetables advocated range from 2005 to 2020.

Even if they were universally adopted by all industrialized and developing nations, such arbitrary targets and timetables would not be particularly effective tools in the stabilization of atmospheric concentrations of greenhouse gases at small multiples of (2 or 3 times) their pre-industrial levels. As discussed previously in relation to CO_2, such stabilization would require eventually reducing annual emissions to much smaller percentages (perhaps just 20 to 35 percent) of their 1990 levels.

Decreasing annual CO_2 emissions to only 90 or 80 percent of the 1990 level would not stabilize its atmospheric concentration at even the largest multiples of the pre-industrial level reported by IPCC Working Group I. Rather, reducing annual emissions by those comparatively small amounts will merely defer, by at most a few decades, the time when any elevated concentration will be reached.

Such brief delays in reaching specific concentrations ultimately provide little insurance against the risks associated with potential changes in the global climate. The prospective targets and timetables provide, at best, small initial portions of the cumulative reductions in emissions that would be required to stabilize concentrations at small multiples of their pre-industrial levels.

More importantly, the adoption of arbitrary targets and timetables would cause substantial adverse economic impacts. As will be explained subsequently, the impacts would be severe even if economic incentive mechanisms, such as a carbon tax, tradable emission permits, or tradable emission quotas, were used as the means for their implementation. Moreover, the consequences would be worse if, as anticipated, binding commitments are adopted by only a few nations than if they are applied by all nations collectively.

Carbon Taxes

Carbon taxes have been widely advocated to induce reductions in emissions of CO_2. A carbon tax is proportional to the amount of carbon contained in fossil fuels.

The primary advantage of a carbon tax is its ease of administration. The carbon-content of the fuels can be measured and the tax rates can be calculated and imposed at the wholesale level (i.e., at the minemouth for coal and at the wellhead for petroleum and natural gas). The taxes will be efficiently incorporated into the market prices of all products and services that directly or indirectly use fossil fuels, and the increased prices will discourage production and use of those products and services.

A carbon tax, however, is not an economically efficient mechanism for evoking reductions in CO_2 emissions. It is a tax applied to an input to discourage discharge of a by-product. It would only be efficient if use of the input invariably resulted in creation of a proportional quantity of the by-product, and if creation of the by-product invariably resulted in its total emission into the atmosphere (i.e., if capture and disposal of the by-product were technically infeasible).

A carbon tax is not an economically efficient mechanism for evoking reductions in CO_2 emissions

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Different uses of the same fossil fuels, however, can generate markedly different quantities of CO_2 and other greenhouse gases. For example, a major portion of the fossil fuels used in producing plastics is feedstock. Thus, much of the carbon contained in the fossil fuels is embodied into the plastics that are produced. As a result, fossil fuels used in the production of plastics typically generate much less CO_2 emissions as by-products than do fossil fuels used in combustion processes such as electricity generation or space heating.

The critical distinction among different uses of any fossil fuel is the degree to which a use generates CO_2 or other greenhouse gases (e.g., CH_4) as by-products either during production, during product use, or after product disposal. Establishing appropriate tax exemptions to account for these distinctions would greatly complicate the design and administration of a carbon tax.

In addition, carbon taxes do not stimulate research, development, and implementation of control technologies that would capture and dispose of CO_2 emissions. If research demonstrates that such technologies are technically feasible and cost-effective, they would be valuable additions to the array of emissions-reduction options.

Carbon taxes do, however, provide economic incentives for firms to undertake research and development on less carbon-intensive technologies. By increasing the cost of continuing to use carbon-intensive processes, they encourage firms to seek technologies that use less carbon and might, on that basis, be cost-effective.

Yet, by extracting tax payments from firms and thereby reducing their net revenues, carbon taxes also reduce the economic ability of firms to finance research, development, and implementation of such technologies. Decreased profits also limit a company's ability to obtain external financing and investment.

Carbon taxes reduce the economic ability of firms to finance research, development, and implementation of such technologies.

Thus, carbon taxes likely would systematically restrict firms' access to the financial resources needed to fund the research and development projects that are essential to identifying and demonstrating more cost-effective technologies for reducing CO_2 emissions. Paradoxically, whereas carbon taxes have been strongly advocated as cost-effective mechanisms for reducing carbon-intensiveness, they may, on balance, impede the technological advancement that is crucial to achieving cost-effective reductions in carbon use.

Carbon taxes would also have substantial adverse impacts on the economy. At the aggregate level, studies conducted for the Energy Modeling Forum using standard, multi-industry econometric models have, in general, estimated that stabilizing annual CO_2 emissions at the 1990 level by 2010 will reduce America's gross domestic product (GDP) by 0.2 to 0.7 percent, and that stabilization at 80 percent of that level will reduce GDP by 0.9 to 1.7 percent.[8] These estimates represent decreases ranging from tens of billions to hundreds of billions of dollars. Similar estimates have been derived for other OECD nations.[9]

Moreover, the taxes would have very different impacts on production costs in different industries, depending largely on the direct and indirect carbon-intensiveness of their production processes. Proportionately large cost increases would occur in the coal mining, oil and gas extraction, petroleum refining, public utilities, petrochemicals, hydraulic cement, aluminum, and steel industries. Carbon taxes would also have very different impacts on the demands for different modes of transportation; railroads and pipelines would suffer disproportionately large decreases.

Industries that incur increases in costs or decreases in demands will experience decreases in sales, production, and employment. These impacts will propagate to their direct and indirect suppliers and customers.

Table 1 contains estimates of the changes in employment that would occur in different broad industry groups if CO_2 emissions were reduced to, and stabilized at, their 1990 levels by 2010. These estimates were developed by the federal government's Interagency Analytical Team (IAT) using the DRI Energy/Economic Modeling System. The IAT is composed mostly of economists from the Department of Energy and the Environmental Protection Agency. It also includes members from the departments of Commerce, Treasury, Labor and State, and from the White House staff.

The IAT's estimates indicate that, if emissions were stabilized in that manner, decreases in employment would occur initially in all major sectors of the economy, and sizable decreases would persist throughout the forecasting period in most sectors. Total non-farm employment would decline by more than 900,000 in 2005, and would still be more than 200,000 lower than it otherwise would have been in 2020.[10] Further, the impacts will be distributed geographically near the locations of facilities operated by the affected industries.

Table 2 contains the IAT's estimates of the changes in employment that would occur in different regions of the nation if CO_2 emissions were stabilized at 1990 levels by 2010. The estimates indicate that initially all regions except New England will experience net decreases in employment, and that the decreases will persist throughout the forecasting period in the central regions of the nation.[11]

A substantial portion of the economic burden of the impacts will be borne by workers in the affected industries and regions. A small percentage will lose their jobs; others will suffer declines in wages and in other terms and conditions of employment. Low-skilled workers in basic industries such as coal mining and oil and gas extraction will be particularly affected.

The impacts of carbon taxes on the distribution of income among households would therefore derive principally from their impacts on employment and wages, rather than their impacts on prices and consumption. Although carbon taxes have sometimes

Table 1

Projected Changes in Employment in Individual Industry Groups (in thousands) If CO_2 Emissions Are Stabilized at 1990 Levels in 2010 and Thereafter

Industry Group	2005	2010	2020
Mining, Oil and Gas Extraction	-17.6	-31.6	-31.0
Manufacturing	-165.4	-161.5	-204.0
Transportation, Communication, and Utilities	-59.7	-82.6	-94.7
Construction	-6.1	250.8	312.5
Finance, Insurance, and Real Estate*	-221.6	-167.4	61.4
Services	-243.7	-288.4	-410.1
Trade	-191.9	69.4	165.7
Total Non-farm Employment	-906.1	-411.3	-200.3

* Calculated as the difference between the change in total non-farm employment and the changes in employment in the other industry groups. The IAT reports that its projections for this industry are inconsistent and are being reestimated.

Source: Interagency Analytical Team, *Economic Effects of Global Climate Change Policies*, draft report and supplemental tables, June 1997.

been characterized as incremental taxes that will cost everyone at most a few percent of their income, they actually impose very different burdens on different industrial, occupational, and geographic segments in the nation.

Tradable Emission Permits or Quotas

Recently, increasing attention has been paid to tradable emission permits or quotas to meet targets and timetables for reducing emissions of greenhouse gases. Individual permits or quotas would authorize the emission of specific volumes of greenhouse gases in specific years. The total amounts of emissions authorized by the permits or quotas created for any year would be commensurate with the targets and timetables. Permits would apply to individual sources of greenhouse gas emissions; whereas quotas would apply to nations. If tradable quotas were instituted, each nation would be responsible for establishing a mechanism for suitably reducing emissions from individual sources within its domain.

Sources or nations for which the cost of reducing emissions is high would be motivated to purchase permits or quotas from others

Table 2

Projected Changes in Regional and Total U.S. Employment (in thousands) If CO_2 Emissions are Stabilized at 1990 Levels in 2010 and Thereafter

Region	2005	2010	2020
New England	17.4	121.3	201.9
Middle Atlantic	-69.8	56.4	99.0
South Atlantic	-199.3	-116.2	-60.6
East North Central	-234.9	-250.7	-268.1
East South Central	-101.9	-148.0	-145.4
West North Central	-90.9	-89.6	-104.8
West South Central	-117.5	-105.4	-128.7
Pacific Northwest	-21.2	50.2	77.7
Pacific Southwest	-88.0	70.8	128.7
Total United States	-906.1	-411.3	-200.3

Source: Interagency Analytical Team, *Economic Effects of Global Climate Change Policies*, draft report and supplemental tables, June 1997.

for which the cost is low. Differences in costs between sources or nations would thus provide economic incentives for exchanging permits or quotas. In theory, exchange would continue until, at equilibrium, the cost of further reducing emissions became equal among all nations and sources.

In practice, however, it is unlikely that the equilibrium value attained for tradable emission quotas would correspond to the equalized value realized for tradable emission permits. That equivalence would probably not be achieved unless tradable emission permits were used within each nation to implement and establish the values that government officials set for their nation's quotas.

The values of tradable emission permits are determined by exchanges among emission sources. The operators of the sources bear, and hence are likely knowledgeable about, the costs involved in reducing their emissions. Without knowledge of the values of tradable permits, the government officials who negotiate exchanges of quotas among nations would, in general, have to rely on less accurate information about costs, and would doubtless arrive at equilibrium values that would not equalize the costs of further emission reductions among all sources and nations.

Because tradable permits and quotas are based directly on emissions of greenhouse gases, they would not entail the inefficiencies that inherently affect carbon taxes due to their basis in the use of inputs rather than the discharge of by-products. The direct relationship with emissions, however, greatly reduces the ease of administration.

Even within a single nation, administering a tradable emission permit policy would be difficult and expensive. It would involve monitoring the emissions of greenhouse gases from all sources, comparing the measured emissions with the amounts authorized for individual sources by the permits that they possess after all trading has been completed, and enforcing compliance with the terms of their permits by sources that have discharged excess emissions. These tasks would be exacting even if greenhouse gases were released only from stationary sources.

Administering the implementation of an emission permit policy would be even more difficult if the permits were tradable internationally

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A substantial portion of CO_2 emissions, however, is discharged from mobile sources. The administrative feasibility and cost-effectiveness of applying emission permits to mobile sources are doubtful. More than 200 million motor vehicles are currently registered in the United States alone.[12] Directly monitoring CO_2 emissions from each of those vehicles would be extremely expensive; and reliably estimating emissions from individual vehicles would be extremely difficult because of differences among vehicles in age, size, maintenance, physical condition, and travel patterns.

Moreover, administering the implementation of an emission permit policy would be even more difficult if the permits were tradable internationally. Different nations perceive different risks from prospective climate change, and face different domestic issues that are competing for their scarce resources and attention.

In addition, any nation would realize the same decrease in risk from a decline in aggregate emissions, regardless of which nations actually reduced their emissions. As a result, negotiating suitable inducements to achieve universal participation in such a policy among a group of sovereign nations and establishing adequate international sanctions to ensure uniform compliance with the policy by all nations would be arduous tasks. Obtaining full cooperation among developing nations would be particularly daunting. Yet, such cooperation is essential to coherent policy.

Tradable emission permits would also cause economic impacts that are analogous to those that would be caused by carbon taxes. So long as the costs borne by industries are greater than they otherwise would be, there would be economic impacts. How much costs increase would depend upon the method used to allocate the permits among emission sources.

If permits were allocated by auctioning them to the highest bidders, their impacts will be very similar to the impacts caused by carbon taxes that achieve the same aggregate emission reduction. Impacts would be minimized if permits were allocated at no charge to the exact sources that would generate the allowable emissions at minimum cost. The general unavailability of the information needed to identify those sources is, however, the fundamental justification for allowing permits to be traded. Thus, in practice, ample impacts like those caused by carbon taxes would inevitably occur.

Partial Cooperation

An apparent objective of the pending intergovernmental negotiations on global climate change is to obtain binding commitments to stabilize emissions of CO_2 and other greenhouse gases at specified levels in industrialized nations, but perhaps not in developing nations. Although industrialized nations discharge the major portion of current greenhouse gas emissions, it is projected that developing nations, particularly China and India, will become the major origins of emissions in the next century.

To reduce their emissions in compliance with their national commitments, businesses in industrialized nations would be required to adopt alternative technologies that, in general, are more expensive than the technologies that they would have used otherwise. As a result, the costs of goods produced in industrialized nations would rise in relation to their costs in developing nations. Moreover, the cost differentials would be magnified if the policy mechanisms used to achieve the reductions involved costs, such as tax payments or permit prices, in addition to the incremental resource costs associated with the alternative technologies.

In response to the differences in costs, production would shift from industrialized nations to developing nations. The shifts would be most pronounced in industries that are directly or indirectly carbon-intensive, and whose products are widely traded internationally.

In the short term, the relocation of production in specific industries would be limited by the amount of excess production capacity in existing facilities operated by those industries in developing nations. Over time, however, new production facilities would be constructed in developing nations and, because of their lower costs, would supplant facilities in industrialized nations.

A recent study conducted by the Argonne National Laboratory indicates that, depending on the stringency of the commitments and the precise forms of the mechanisms used to implement them, major relocations of production could occur in the primary aluminum industry, the steel industry, the petroleum refining industry, the pulp and paper industry, and energy-intensive segments of the chemical industry. Substantial relocation could even occur in the cement industry, despite its relatively high ratio of transportation costs to production costs.[13]

In addition, the relocation of production from industrialized to developing nations will be accompanied by analogous relocation of greenhouse gas emissions. As a result, the reduction in total emissions of greenhouse gases could be much smaller than the reductions achieved in industrialized nations.

Estimates of the likely magnitudes of such emission "leakages" vary widely. The estimated leakages vary directly with the stringency of the reduction required, and indirectly with the extent of cooperation in reducing emissions (e.g., The U.S. unilaterally, the European Union unilaterally, or the OECD nations collectively).

For joint reductions of CO_2 emissions to 80 percent of their 1990 levels by all OECD nations, estimated overall leakage rates range from 25 to 70 percent.[14] Similarly, within the context of an economic analysis of optimal international behavior, economists William Nordhaus of Yale University and Zili Yang of Massachusetts Institute of Technology estimate that optimal noncooperative behavior will produce aggregate emission reductions that are roughly one-third as large as those achieved with optimal cooperative behavior.[15] Unless all nations cooperate fully in climate change policy, the effectiveness of the initiative could be greatly diminished, and the adverse economic impacts of the initiative on the cooperating nations could be greatly intensified.

Coherent Policy

Because of the vast scientific and technological uncertainties associated with the prospects of changes in the global climate due to human activities, it is not feasible to specify either the precise actions that should be taken or the precise objectives that should be pursued in dealing with those prospects. Rather, appropriate actions and objectives can only be determined as additional knowledge is developed and key uncertainties are reduced. This is an adaptive process that evolves over time.

Accordingly, the basic framework for coherent climate change policy should be sequential decision making. First, provisional decisions should be made on the basis of the available information. Next, suitable actions should be taken to implement the decisions. Third, the results of the actions should be reviewed and evaluated. Then, the procedure should be repeated based on the updated information. This decision-making strategy has been characterized as an "act-learn-act" approach.[16]

The basic framework for coherent climate change policy should be sequential decision making — an "act-learn-act" approach.

In implementing this strategy, initial actions should emphasize research to reduce scientific uncertainties about climate change, and to develop improved technologies for reducing greenhouse gas emissions and for adapting to potential changes in climate. Ample expenditures on pertinent scientific and technological research are essential.

Scientific research should focus on reducing the large uncertainties about the likely magnitudes, causes, and consequences of specific changes to the global climate and, especially, to regional climates. The ultimate objective of the research program should be to determine the levels, if any, at which sound scientific evidence demonstrates that the atmospheric concentrations of greenhouse gases should be stabilized.

Technological research should address four basic issues. First, methods for improving energy efficiency in production, transportation, and space heating should be studied. Second, technologies for reducing emissions of greenhouse gases, particularly from processes that use fossil fuels, should be examined. Such technologies might include methods for capturing and permanently storing CO_2 emissions from fossil fuel combustion sources, and methods for collecting fugitive emissions of CH_4 cost-effectively for constructive use. Third, technologies based on energy sources other than fossil fuels should be investigated. The sources include non-carbon energy sources such as wind, solar, and nuclear power, and renewable carbonaceous (biomass) energy sources. Biomass involves zero *net* emissions of CO_2 because the volumes released from its combustion are recaptured through photosynthesis in its subsequent regrowth. Fourth, methods for *adapting* to any climate changes that might reasonably be expected to occur should be studied.

Based on the results of that research, two types of decisions should be considered. They are: decisions to undertake additional research, and decisions to encourage the application of alternative technologies developed to date.

No special incentives should be provided to stimulate the adoption of alternative technologies that would not be cost-effective.

Whenever it is decided that the adoption of particular technologies should be stimulated, flexibility should be allowed in the timing of the innovations.[17] Technology transfer programs should be employed to encourage their use. Firms should be permitted to coordinate their introduction with the replacement of existing equipment, and to defer replacement if prolonging the equipment's use will avoid locking into technologies that might shortly be superseded by superior methods.

Economic incentives should only be provided to accelerate the replacement of existing equipment if scientific research indicates that rapid reductions in greenhouse gas emissions are needed to avert the possibility that irreversible damage might be caused by increases in atmospheric concentrations that are expected in the short term. Otherwise, replacement should be allowed to occur when firms decide that it would be cost-effective.

At present, no special incentives should be provided to stimulate the adoption of alternative technologies that would not be cost-effective to implement on the basis of their technical attributes. Technology transfer programs would be appropriate, however, for encouraging the implementation of currently available, cost-effective ("no regrets") measures for improving energy efficiency.

Unless scientific research shows that small increases above the current greenhouse gas concentrations involve unacceptable risk of damage from global climate change, no appreciable benefits will be realized from reducing their emissions during the next several decades. Accordingly, in the absence of such evidence, no inducements should be offered during that period to stimulate the use of technologies that are not cost-effective in performing their primary functions.

It is also essential to seek full international cooperation with the decision-making strategy. Negotiations should strive for collective implementation of all policy initiatives and equitable transfer of all technologies.

Most important, arbitrary timetables should not be established for attaining arbitrary reductions in greenhouse gas emissions. It would be short-sighted and inefficient to divert scarce resources from important scientific and technological research to achieve currently practical decreases in emissions.

Regrettably, obtaining binding commitments from industrialized nations to achieve such arbitrary targets and timetables is the apparent objective of the forthcoming international conference in Kyoto, Japan. In the present state of scientific and technological knowledge, such commitments are not appropriate current actions for dealing with potential changes in the global climate due to human activities.

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