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Climate Change Modeling Including Discussion of Administration's Analysis [2]

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NATIONAL BUREAU OF ECONOMIC RESEARCH, INC.

SUMMER INSTITUTE 1998

Public Economics
Workshop on Public Policy and the Environment
Don Fullerton and Lawrence Goulder, Organizers

Royal Sonesta Hotel
5 Cambridge Parkway
Cambridge, Massachusetts

August 3-4, 1998

PRELIMINARY PROGRAM

MONDAY, AUGUST 3:

8:00 AM Coffee and Doughnuts

8:20 AM Welcome and Introductions

8:30 AM **ENVIRONMENTAL REGULATION AND TECHNOLOGICAL CHANGE**

WINSTON HARRINGTON, RAY KOPP, RICHARD MORGENSTERN, WILLIAM PIZER
and JHIH-SHIANG SHIH, Resources for the Future
*The Diffusion of New Technologies: A Microeconomic Analysis of Firm
Decisionmaking at the Plant Level*

CAROLYN FISCHER, IAN PARRY, WILLIAM PIZER and MICHAEL TOMAN,
Resources for the Future
*Instrument Choice for Environmental Protection When Technological Change Is
Endogenous: Analytical and Empirical Results*

DAVID POPP, University of Kansas
The Effect of New Technology on Energy Consumption

10:45 AM Break

11:15 AM RESEARCH SKETCHES (2-5 minute presentations)

12:15 PM Lunch

1:15 PM ELENA IRWIN and NANCY BOCKSTAEEL, University of Maryland
*Interacting Agents, Spatial Externalities, and the Endogenous Evolution of Land Use
Patterns*

2:00 PM GEOFFREY HEAL, Columbia University and NBER
Environmental Degradation and the Measurement of National Income

MONDAY, AUGUST 3: cont.

- 2:45 PM Break
- 3:15 PM LISANDRO ABREGO, University of Warwick,
JOHN WHALLEY, University of Western Ontario and NBER
Labor Mobility and the Costs of Environmental Damage
- 4:00 PM SCOTT BARRETT and KATHRYN GRADDY, London Business School
Freedom, Growth, and the Environment
- 4:45 PM Adjourn
- 6:00 PM Group Dinner

TUESDAY, AUGUST 4:

- 8:00 AM Coffee and Doughnuts
- 8:30 AM **INTERNATIONAL POLICIES TO ADDRESS CLIMATE-CHANGE AND OTHER
ENVIRONMENTAL PROBLEMS**
- WARWICK McKIBBIN, Australian National University
ROBERT SHACKLETON, Environmental Protection Agency
PETER WILCOXEN, University of Texas
*What to Expect from an International System of Tradable Permits
for Carbon Emissions*
- ZILI YANG, MIT
*Incentive Compatible Coalitions in International Agreements on CO₂ Emission
Controls*
- STEF PROOST and DENISE VAN REGEMORTER, Catholic University, Leuven
Equitable and Efficient Allocation of Air Pollution in a Federation
- 10:45 AM Coffee Break
- 11:15 AM **PANEL DISCUSSION: FROM KYOTO TO BUENOS AIRES:
ECONOMIC PERSPECTIVES ON THE NEXT STEPS IN GLOBAL CLIMATE POLICY**
- Moderator:
ROBERT STAVINS, Harvard University
- Panelists:
JEFFREY FRANKEL, Council of Economic Advisers and NBER
JONATHAN GRUBER, Department of the Treasury and NBER
MARK MAZUR, Department of Energy
PETER ORSZAG, formerly National Economic Council, White House
- 12:15 PM Lunch

SI PEG Program

Page three

- 1:15 PM LANS BOVENBERG and GILBERT VAN HAGEN, Tilburg University
Environmental Cost-Benefit Analysis in a Second-Best World
- 2:00 PM EDUARDO LEY, FEDEA Madrid
MOLLY MACAULEY, Resources for the Future
STEPHEN SALANT, University of Michigan
Spatially and Intertemporally Efficient Waste Management: The Costs of Interstate Flow Control
- 2:45 PM Break
- 3:15 PM RAMANAN LAXMINARAYAN and GARDNER BROWN, University of Washington
The Economics of Antibiotic Resistance
- 4:00 PM JANUSZ MROZEK, Georgia Institute of Technology
LAURA OSBORNE TAYLOR, Georgia State University
Estimating Risk Premia in the Workplace: What Have We Learned?
- 4:45 PM Adjourn

6/16/98

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Royal Sonesta Hotel

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Ann Wolverton	University of Texas
Zili Yang	MIT
Gilbert van Hagen	Tilburg University

Timeline

5/91 Graduation

8/91 Pomona

5/95

Boulder



8/95

ICF

~~Paris~~

Paris

5/96

Boulder

~~Albuquerque~~

8/96

Boston



summer 97

DC

8/98

DC

✓ Ecuador
Brazil
El Salvador

**Draft Answers to March 13 Questions To CEA
from Representative McIntosh
Chair of the House Subcommittee
on National Economic Growth, Natural Resources, and Regulatory
Affairs**

**C. Dr. Yellen's Testimony before the House Commerce Committee on March 4,
1998**

15. Please provide any and all analyses that support the Administration's conclusion that impacts on the U.S. economy of complying with the terms of the Kyoto Protocol are likely to be "modest".

Response: Our testimony concluded that the net costs of our policies to reduce emissions are likely to be small, assuming those reductions are undertaken in an efficient manner and we are successful in securing meaningful developing country participation as well as effective international trading, and the Clean Development Mechanism in future negotiations. In The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis, July 1998, (hereafter, the AEA) the analyses supporting this conclusion are presented. (see pp. 39-68)

15. Continued. Also, explain fully how the Administration can make such a forecast responsibly when as Dr. Yellen stated, "it is not yet possible to provide a full authoritative analysis of the Kyoto Protocol." Among other things, Dr. Yellen noted that there is still "much that we do not know" because much has been left unresolved by this treaty (for example, implementation issues, the rules and procedures governing international emissions trading, joint implementation projects, and the Clean Development Mechanism, and future emissions reduction obligations). Moreover, Dr. Yellen asserted that to her knowledge, "no [economic] model --whether used inside the government or not --has yet been set up to analyze the implications of the Kyoto Protocol, since this agreement is only a few months old. ."

Response: Policy decisions and public statements often need to be made based on the best information available at the time, even though thorough economic analysis of the scholarly sort takes longer.

As previously stated in testimony, the Kyoto Protocol is a work in progress; it is incomplete. There remains uncertainty about the ultimate nature of international permit trading pursuant to the Kyoto Protocol, and the timing and nature of developing country participation. However, there should be no uncertainty about the Administration's firm commitment to achieve effective international permit

trading, and meaningful participation by key developing countries. The Administration's conclusion, and the supporting but illustrative numerical estimates, are based on our policies to implement the Kyoto Protocol cost-effectively as well as on the Protocol itself.

16. Please provide any and all analyses that support the following estimates:

a. U.S. electricity restructuring "will offer approximately \$20 billion in cost savings".

Response: The derivation of this estimate is explained in the AEA in the section entitled potential electricity restructuring cost-savings. (see Appendix C)

b. Emissions trading among the Annex I countries "can reduce the cost to the United States of achieving its targets for 2008-2012 emissions by about half."

Response: Please see the section on the effects of climate change policy on the U.S. in the AEA. (see pp. 27-32, 45, 48, 51-52)

c. Emissions trading among a subset of Annex I countries (for example, the United States, Australia, Canada, New Zealand, and Russia) "can reduce costs by an estimated 60-70 percent."

Response: This statement is based on the section on the effects of climate change policy on the U.S. in the AEA. (see pp.27-32, 45, 48, 51-52)

Also, based on the estimates presented in Janet Yellen's testimony, please explain and fully document how more limited trading among this subset of countries would produce greater cost reductions than from either trading among all Annex I countries or trading with the full participation of Non-Annex I countries

Response: The market clearing price for greenhouse gas permits in an international trading system results from the supply and demand for internationally traded permits. If a country that is expected to be a seller decides not to sell, then the actual supply falls, and the permit price and associated costs increase. If a country that is expected to be a buyer decides not to buy, then demand falls, and the permit price and associated costs fall. In the case of trading under the Kyoto Protocol, both the U.S. and the European Union are projected by many economic models to be buyers. If the European Union decides not to participate in international trading, then the demand for permits on the international market would decline, and the permit price and costs would fall, thereby benefiting countries that continue to buy permits internationally.

d. The Clean Development Mechanism "might shave costs by roughly another 20 to 25 percent".

Response: The Clean Development Mechanism is included in the Kyoto Protocol, although the details about how it would work have still to be negotiated by the parties to the Protocol. The Administration's policy is that the details of the CDM should ensure that it becomes a cost-effective way to allow developed country firms to give financing and technical assistance for projects to lower emissions and to receive credit for the reductions. Our best professional judgment, based on discussions with a variety of informed analysts, is that CDM could achieve at least 20 percent of the emissions reductions available under full global trading. The statement that costs would fall by roughly another 20 to 25 percent is based on the SGM results given an assumption of 20 percent "effectiveness", and is further explained in the AEA.
(see pp. 35, 48)

e. Overall costs "would reach roughly one-tenth of one percent of projected GDP in 2010" (resource costs of achieving Kyoto targets for emissions reductions were estimated to be \$7 to \$12 billion per year in 2008 to 2012).

Response: The forecasted changes in GDP were taken from the SGM model output. Please see the section on the effects of climate change policy on the U.S. in the attached AEA for a brief summary. (see pp. 51-53)

Also, please explain how it is possible that compliance with the Kyoto Protocol, which has been projected by independent economists to be the most expensive environmental undertaking ever, could cost less than compliance with the recently issued U.S. air quality rules for particulate matter and ozone (the final Regulatory Impact Analysis for those rules estimated costs of \$46 billion).

Response: As mentioned in the testimony, independent economists have generally not estimated costs taking into account the specific attributes of the Kyoto agreement and the Administration's policy to implement it. In particular they have omitted the cost savings likely to result from international permit trading, from the Clean Development Mechanism, meaningful participation by key developing countries, trading across six categories of greenhouse gases, and the flexibility provided by including carbon sinks. This omission raises their cost estimates.

There is no particular reason why the costs of the Kyoto Protocol should have any particular relation to the costs of the recently promulgated air quality standards. Climate change policy might, for example, have the side-benefit of improving our terms of trade vis-a-vis oil-exporting countries. We believe that careful estimates of the costs of the Kyoto Protocol and the Administration's Implementation policy will be substantially less than \$46 billion per year, and indeed close to the illustrative

numbers we have presented earlier.

f. The assumption that the rate of improvement in energy efficiency (AEEI) will be 1.0 percent per year (which is greater than that assumed by the EIA).

Response: This number is only very slightly higher than the AEEI estimate of the Energy Information Agency. The increment can be viewed as a modest allowance for the effects of intensified research and development, technology dissemination, and cooperative government-business partnerships. We also note that Battelle's SGM model is typically run with a default value for the AEEI of 1.0.

In particular, please reconcile this assumption with the statement of the CEA in its 1998 Annual Report that "[u]ntil an emissions cap and trading system are in place, however, the economic incentive to use [technologies supported by the Administration's budget] may be low."

Response: No reconciliation is needed. The comment from the 1998 ERP implies simply that in the absence of a cap and trade system that would lower the price of using carbon-lean technologies relative to carbon-rich technologies, the incentives to adopt such carbon-lean technologies will be less than in a world with the target and trade system in place. Moreover, the AEEI represents the autonomous rate of technological improvement, i.e., the rate that would occur in the absence of price changes that the target and trade system might lead to, due merely to the greater availability of new technologies. Thus its value is a comment on the extent of one's technological optimism, and not about optimism of private parties to respond to price incentives.

Is the Administration assuming that such a system will be put into place in the short-run?

Response: No, the Administration's position on the timing of a target and trade system has not changed since last fall. The Administration then maintained that the system would be established with the benefit of 10 years of additional experience with similar market based mechanisms.

g. The estimated effect on energy prices will range from \$14 to \$23 per ton of carbon equivalent.

Please see the section of the AEA that describes the effects of climate change policy on the U.S. (see pp. 54-58)

h. "In energy-intensive sectors some employment reduction could occur, although given the very small predicted change in energy prices, impacts in most such

sectors are apt to be minimal. Furthermore, a large number of jobs will be created in other sectors --many of them high-tech jobs paying high wages."

Response Very standard economic analysis says that in the long run, total employment is determined by the size of the labor force, incentives to work, and the productivity of labor. Changes in prices -- such as result from developments in technology, trade, energy markets, or many other areas -- tend to have their effects on the composition of employment across sectors, more than on total employment.

As explained in testimony and in the AEA, the energy price changes expected to result from the Kyoto protocol and the Administration's implementation policies under the assumptions elsewhere identified, are likely to be modest. In particular, these price changes over the next decade are less than the average of year-to-year absolute price changes observed since 1960. Thus there is little reason to believe there will be large changes in employment even in the energy-intensive sectors. In the less energy-intensive sectors, there is no reason to expect any decline in employment at all. Most economic models would not predict changes in the overall level of employment resulting from such small energy price changes 10 years in the future. (see pp. 54-62)

The U.S. has a strong competitive advantage in a variety of high-tech sectors. Recent innovations in battery technology, and in fuel cells were announced by U.S. companies. These innovations, and future ones expected from U.S. companies, will be in demand world-wide. The growth in associated production is likely to lead to growth in high-wage jobs in this country.

I. As to each analysis, please indicate who prepared the analysis and provide records of comments from other federal agencies.

Response: All of the analysis for our testimony on climate change was prepared by CEA staff under the direction of the Members of the Council, with the collaboration of staff at several other government agencies. The following CEA current and former staff members worked on climate change:

Joe Aldy
Zach Candelario
Daniel Chang
Keith Fuglie
Randall Lutter
Adele Morris

White House Counsel has not yet made a determination concerning the document requests we have received. Our documents reflect internal deliberations of the Executive Office of the President with regard to ongoing policies of the Administration. Moreover the documents include material that could influence

ongoing negotiations.

17. Please provide any and all analyses that support the Administration's estimate that benefits relating to traffic congestion, highway accidents, and air pollution unrelated to climate change "could offset approximately a quarter of the resource cost of the climate change policy."

Response This analysis is summarized in the section of the AEA describing ancillary benefits. (see pp. 66-68)

White House Counsel has not yet made a determination concerning the document requests we have received. Our documents reflect internal deliberations of the Executive Office of the President with regard to ongoing policies of the Administration. Moreover the documents include material that could influence ongoing negotiations.

As to each analysis, please indicate who prepared the analysis and provide all records of comments from other federal agencies.

Response Randall Lutter on our staff, with the assistance of Treasury's Office of Economic Policy, and EPA's Office of Policy Planning and Evaluation prepared the analysis.

18a. In her testimony, Dr. Yellen stated that, in evaluating the "likely net economic impact of the Kyoto Protocol," the Administration has "drawn upon a broad array of analytical tools", and a "wide range of models of the energy sector and economy over the next 25 years" to assess the various possible costs and non-climate benefits of the Administration's emissions reduction policy. Please specify all of the models and analytical tools that the Administration has used and describe in detail their strengths and weaknesses.

Response: As explained in the testimony, the existence of modeling difficulties means that we should treat any model results with the caution that is warranted -- not that we should abandon rigorous economic analysis. We have employed a broad set of economic tools to analyze the policy options. Such tools include models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, "meta-analyses" of existing models (such as that undertaken by Robert Repetto and Duncan Austin of Resources for the Future), historical and sectoral examples, univariate and multivariate regression analysis, simulations, Hotelling-type theoretical models, CEA staff econometric forecasts of emissions in developing countries, stylized models of perfect competition and monopoly, basic economic reasoning and the various other sorts of theoretical and empirical tools of

analysis that abound in the scholarly literature. Drawing on this broad array of analytical tools allowed an intelligent evaluation of the policy alternatives.

We have considered and evaluated the following specific large econometric and computable general equilibrium models of the economics of climate change mitigation: Second Generation Model, G-cubed, MERGE, and DICE. We have also been exposed to results from many other models, such as GREEN, DRI, Markal Macro, Megabare, EPPA, FUND, MiniCAM, CETA, RIVM, and CETM/MRT.

18b. According to the testimony, the Administration has relied particularly on the Second Generation Model of Battelle Laboratories for many of its estimates. However, the IAT report indicated that the SGM model "focusses on long-term transitions and measures the economy in 5 year intervals," so that it risks racing past short-term transition issues, such as GDP loss and impacts on specific industries.

Specify all of the Administration's estimates that were derived from this model.

Response The Administration used this model's estimates as one of several inputs in its calculations of likely permit prices and resource costs for the different trading scenarios. Refer to the methodology section in the AEA. (see pp. 42-49) Information of the marginal abatement cost curves of non carbon greenhouse gases was missing from the SGM output and added to reflect provisions in the Protocol. Numerical estimates of expenditure changes and ancillary benefits used estimates of likely permit prices or emissions reductions as inputs.

Also, indicate why many of the Administration's key estimates were derived from this model.

Response: Each model has strengths and weaknesses; each has questions which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

The SGM model, unlike many economic models of climate change, has an explicit

model of emissions reductions in other countries, and so is exceptionally well suited for estimating emissions permit prices given international trade in permits. In addition, it has modules reflecting several major developing countries and data on all other developing countries as a group. Thus it is well suited to address the effects of developing country participation on permit prices. Finally, the timely availability of sufficient information about a variety of SGM model runs made its use practical between the time the Kyoto protocol was developed in December 1997 and our first testimony in March 1998.

Finally, please identify the corresponding estimates derived from each model that the Administration has used in assessing the impacts of the Kyoto Protocol.

Response: The development of corresponding estimates is a complicated technical task that is beyond the abilities of our small staff to complete in timely manner. We expect that the Energy Modeling Forum will continue to produce comparisons of various climate change models' forecasts of the effects of the Kyoto Protocol. Although some of these models have not yet incorporated the 5 categories of non-CO2 gases directly into their models, these comparisons should provide a full comparison of the SGM predictions with those of other models.

19. What are the 1990 baseline, the Fiscal Year 1997, 1998 and 1999, data, and the annual outyear estimates until 2012 for the following outcome performance measures mentioned in Dr. Yellen's testimony: morbidity rates for some diseases, mortality rates for some causes, monetary damages from temperature increase, consequences from some catastrophes, traffic congestion, highway accidents, and air pollution unrelated to climate change.

The AEA provides baseline data for traffic congestion, highway accidents, and air pollution unrelated to climate change. These data are for 2010, or for 1995, if more recent data do not exist and no published 2010 forecasts were available. For these data we have no information on outcome performance measures for the Fiscal Years requested, or for year-by-year estimates through 2012. (see pp. 66-69)

20. Why does the Administration maintain that the U.S. acid rain program experience "clearly demonstrates how programs like international permit trading, joint implementation and the Clean Development Mechanism will lead firms to find cheaper ways of reducing emissions that can lead to unexpectedly low costs"?

Emissions trading programs, by providing continuous economic incentives to reduce emissions further, generally lead costs to be much lower than would be the case under a variety of more prescriptive regulatory approaches.

Why does the Administration believe that it is appropriate to extrapolate from that

experience to the global arena.

The basic principle that there are gains from the ability to trade is of quite wide applicability. Indeed the textbook theory of gains from trade is perhaps most familiar and well-established at the international level. Economic incentives generally have similar effects in different countries and cultures: people everywhere are interested in higher incomes. International permit markets will lower compliance costs in all participating countries, because they provide financial incentives for sources to reduce emissions. These incentives will have the effect of lowering the costs of emissions cuts relative to what would be the case without any trading of emissions permits.

Won't the effectiveness of the international system, joint implementation, and the Clean Development Mechanism depend on different factors, such as the rules and procedures governing these mechanisms, the extent of participation by other countries, including developing countries?

Yes. The importance of effective trading rules, and rules on joint implementation and the CDM is the reason the Administration is asking other parties to the Protocol to support regulations that will lead to effective and successful trading, JI and CDM.

21a. In her testimony, Dr. Yellen stated that part of doing it smart (i.e., lowering the costs of reducing greenhouse gas emissions) under the Kyoto Protocol means "taking serious and responsible steps in the short-run to prepare us to meet our obligations in the longer-term." She indicated that these steps include a \$6.3 billion program of tax cuts and R&D investments, industry-by-industry consultations to prepare emission reduction plans in key industrial sectors, and legislation to restructure the electrical industry. Under what authority is the Administration pursuing this unilateral executive branch course of action in furtherance of the treaty's emissions reductions targets and without Senate Ratification?

Response: The \$6.3 billion in tax cuts and R&D investments is a proposal made to Congress as part of the Administration's 1998 budget. The industry-by-industry consultations do not require express legislative authority because they concern only voluntary emissions cuts that industries might make. The industries in question are sufficiently concerned about their roles in fostering climate change that they believe they should take voluntary measures.

21b. If the Administration is delaying the submission of the treaty to the Senate until it obtains meaningful participation by developing countries, doesn't that decision also require the Administration to delay any unilateral executive branch

action to address global warming until that cooperation is forthcoming.

Response: The Administration is not embarking on unilateral Executive Branch action to implement the Kyoto Protocol without ratification. To the contrary, steps to ensure compliance with the Protocol's requirements will be undertaken only with the full advice and consent of the Senate. However, the Administration is pursuing a variety of policies that make good sense even independent of concerns about climate change and that have the additional desirable property of reducing greenhouse gas concentrations. Examples of such policies include the CCTI. These policies all reduce energy consumption, and thereby reduce dependence on foreign oil and emissions of air pollutants unrelated to climate change, policy goals that have enjoyed bipartisan support for many years. The fact that these policies reduce carbon emissions should also be a shared policy goal, because in 1992 the Rio Treaty adopted by the Bush Administration and ratified by the Senate required the U.S. to take unilateral voluntary steps to return its emissions levels to 1990 levels.

c. Given that the Kyoto Protocol seeks to address a global issue, isn't [it] harmful to U.S. interests to proceed without the full participation of developing countries.

Response: The President has said that he will not submit the treaty for Senate ratification without meaningful participation by developing countries. We do not believe that the other actions identified above are harmful to U.S. interests.

d. Besides being unconstitutional, isn't it also premature and harmful to U.S. interests to take such unilateral actions, without ratification, when the Administration has characterized the Protocol as a "work in progress" a Protocol that is not yet fully complete nor ready for the President's submission to the Senate?

Response: No. As explained above, these actions have independent policy merit apart from their implications for greenhouse gas emissions.

D. Cost/Benefit Analysis of the Kyoto Treaty

22a. Please provide any and all analyses that the Administration or any federal agency prepared (or had prepared) or is preparing (or is having prepared) of the costs and benefits of imposing on the U.S. the binding targets and timetables set forth in the Kyoto Protocol for reducing greenhouse gas emissions, taking into account the global implications of the way in which this agreement is structured.

Response: The AEA provides additional detailed information about the economic analysis of the Kyoto Protocol. (see pp. 39-72) A key area that we have not pursued in our analysis, however, is the climate benefits of the Protocol. These

benefits are exceptionally difficult to quantify because climate change raises the risk of large-scale irreversible catastrophic events like displacement of ocean currents, and the release of methane from the warming of Arctic permafrost. In addition, the quantification of climate change benefits is quite dependent on the choice of discount rate, which for periods as long as a century is the subject of ongoing professional debate. More importantly, however, the Kyoto Protocol is just a first step in addressing climate change. Further steps will entail additional cuts in emissions in years beyond 2012, and uncertainty about the magnitude of these precludes meaningful analysis about the effects of the Kyoto agreement itself on climate.

Also please analyze and document the following:

22b. Whether the benefits of implementing this Protocol are justified by the costs.

Response: We have not quantified the benefits of this Protocol because it is only the first step towards controlling carbon concentrations in the atmosphere; emissions limits in years beyond 2012 have not been proposed or negotiated. In addition, estimating the value of these benefits in monetary terms is exceptionally difficult because of their complexity and uncertainty. There is also disagreement within the economics profession about how to account in benefit-cost analyses for the fact that climate change damages will occur in the relatively distant future.

Notwithstanding these analytic difficulties it is apparent that climate change if left unchecked will pose a substantial threat to climate on our only planet. Therefore we believe that the benefits of this Protocol justify its costs, given that these will be modest as a result of the flexibility provisions that are included in the Protocol and those that form an integral part of the Administration's implementation policies.

22c. Evaluate the effectiveness of this agreement by comparing the marginal abatement costs of the most plausible alternative scenarios for meeting the Kyoto targets, given the way in which this agreement is structured, with the marginal costs of other reasonable alternative compliance schemes.

Response: The Kyoto Protocol is a work in progress, so that the most plausible alternative scenarios for meeting the Kyoto targets are different from those based on a reading of the Protocol alone. The Administration has said that it will not submit the treaty for ratification without meaningful participation by key developing countries. Such participation, along with effective international trading of permits among Annex I countries would lower costs substantially. The effect of such participation, and of trading among Annex I countries is outlined in testimony, and described in detail in the results section of the AEA. (see pp. 26-35, 51-53)

22d. With respect to each scenario that is analyzed, identify the assumptions used, explain any uncertainties concerning the assumptions, and examine the sensitivity of net effects to the different compliance strategies, using a range of plausible assumptions about future economic development and about fundamental climate processes.

Response: Please see the methodology section of the AEA. (see pp. 42-50)

22e. Evaluate the opportunity costs of pursuing the Administration's strategy for the abatement of greenhouse gas emissions under the terms of the treaty;

Response: As the Protocol is a work in progress its opportunity costs can not be evaluated without also considering the additional flexibility in its implementation that will be achieved as the result of continued U.S. efforts in ongoing diplomatic discussions. The opportunity costs of the Protocol and the Administration's policies to implement it are extensively discussed in prior testimony by Dr. Janet Yellen, and in the AEA. (see pp. 51-68)

22f. Evaluate how the benefits and burdens of complying with this treaty would be distributed on the national and household levels, describing, among other things, the disparate regional and industrial impacts, and the effects on different income levels.

Response: We do not have estimates of the distribution of impacts across regions or industries, with the exception of some information on coal sector production, which is discussed briefly in the AEA. (see p. 62)

23a. In evaluating alternative scenarios, please examine the following.

23b. Compare the economic and environmental effects of not including developing countries in the effort to reduce global emissions (with the potential for binding developed countries to even greater obligations, without limiting developing countries at all) against the effects of addressing greenhouse gas mitigation on a global scale by the international community.

Response: Climate change is a global problem, so policy approaches encompassing more countries will likely be both more effective and more cost-effective than approaches involving only a few countries. Including developing countries will lower costs and permit prices substantially because of the many low-cost abatement opportunities in these countries. Estimates from the Battelle Laboratory's Second Generation Model, which are in line with other models, suggest that developing country participation through the Clean Development Mechanism could lower costs by 20 to 25 percent, relative to scenarios in which permits are traded among all or a subset of Annex I countries. The model suggests

that developing country participation through adopting emissions targets and participating in international permit markets could lower costs by nearly 60 percent.

23c. Compare the economic and environmental effects of complying with the timeframes set forth in the Kyoto Protocol with the effects of complying over longer time periods.

Response: The Administration's economic analysis (see AEA) has focused on assessing the economic and environmental effects of complying with the Kyoto Protocol and the President's policies to address climate change. We have not assessed the economic and environmental effects of the Protocol and President's policies under the assumption of a longer time frame than the Protocol specifies.

23d. Compare the impacts of reducing greenhouse gas emissions using international emissions trading, joint implementation, and the Clean Development Mechanism with the impacts of relying upon domestic emissions permit trading. In this regard evaluate alternative international trading scenarios: trading only among Annex I countries, trading that extends to a number of key developing countries, and trading in which all countries are fully participating.

Response: Please see the results section of the AEA. (see pp. 51-68)

24. With respect to any analysis provided, please identify and explain the basis for assumptions used regarding such factors as the rate of improvement in energy efficiency, the effectiveness of market incentives in increasing the market share of fuels that emit less carbon, and economic and demographic growth. Also, explain fully any assumptions on how emissions reductions will be achieved as, for example, through the early retirement of coal plants or nuclear plant life extensions.

Response: In developing the illustrative estimates using the SGM model we have used an autonomous energy efficiency index of 1.0, and baseline assumptions of the SGM model. Within this analysis, we have no particular information on the early retirement of coal plants or nuclear plant life extensions although information about the use of energy from these sectors is summarized in the AEA. (see pp. 54-58, 64) Such use can change with differences in the intensity of use of existing capacity, as well as with retirement or life extensions of existing plants.

25. In considering the opportunity costs, evaluate the extent to which the Administration's climate change strategy will require the diversion of funds from savings and/or investments which would have provided other benefits, such as saving social security, or more funding for education, health care, etc.

Response: The resource costs that are described in Dr. Yellen's testimony reflect the opportunity cost as it is usually understood by economists. The apportionment

of these costs to foregone spending, whether on apples and oranges or social security or education, is an unconventional analysis that we have not undertaken.

26. In assessing the impacts on the U.S. of complying with the Kyoto targets and timetables, please explain in detail the potential effects on the following indicators of economic performance: gross domestic product (GDP), per capita GDP, unemployment, income and real wages, trade competitiveness, and energy prices.

Response: The percentage changes in GDP (and per capita GDP) are outlined in prior testimony, and discussed in the results section of the AEA.(see p. 59)

We believe that the employment effects of the Administration's policies to implement Kyoto will not have significant effects on aggregate employment. Over the next ten years, industry and workers will have ample time to adjust to the modest changes in energy prices that we anticipate under the conditions that we have outlined, and that in any event are small relative to the year-to-year changes in energy prices that have been observed since 1960.

We have not assessed the effect of Kyoto on income (except for GDP as a measure of income) and real wages.

Trade competitiveness, unlike the other listed indicators of economic performance, is not a measure that is easily quantified. The testimony, however, discusses the effects of Kyoto on U.S. trade competitiveness.

Percentage changes in energy prices are also discussed in prior testimony and in the AEA (see pp. 54-58).

27. In assessing the benefits of complying with the Kyoto treaty, please evaluate fully the potential offsetting negative effects of exempting developing countries and of "carbon leakage".

Response: Exempting developing countries would amount to a hypothetical departure from the President's policy. The Kyoto Protocol establishes a Clean Development Mechanism whereby firms in Annex I countries such as the United States may undertake projects that reduce emissions in developing countries and receive credit for such reductions. CDM is likely to provide a broad range of cost savings to the U.S., and this conclusion is consistent with our interpretation of SGM model results that suggest that CDM would reduce resource costs by about 20 to 25 percent relative to scenarios in which there is permit trading either among all or a subset of Annex I countries. Inclusion of developing countries in the CDM and in international emissions trading would mitigate carbon leakage.

28. President Clinton has suggested that the U.S. economy can continue to grow

under this agreement. Please indicate at what rate the Administration expects that the economy will continue to grow during the next 10 to 20 years if the treaty is ratified and at what rate it is expected to grow if the treaty is not ratified.

Response: As shown in a figure on GDP in 2010 in the results section of the AEA (see p. 59), the effect on the GDP growth rate of the Kyoto Protocol and the Administration's implementation policies, given the assumptions that we have elsewhere described, is minimal relative to the anticipated growth in GDP between now and 2010. Under business as usual, the Second Generation Model projects U.S. GDP to grow 2.0859% annually between 1995 and 2010. With a permit price of \$14/ton, SGM projects the annual growth rate to be 2.0851%, and under \$23/ton, the annual growth rate is projected to be 2.0822%. (see p. 59)

29. Have any of the cost-benefit analyses performed by the Administration or any agency been peer-reviewed?

Response: With the exception of the IAT report, and some of the studies by the National Labs, we are unaware of any peer-review of Administration estimates. It is not the policy of the CEA to submit its official analysis for peer review.

30. In connection with these cost-benefit analyses, fully explain how the baseline(s), against which costs and benefits were calculated, was determined.

Response: Please see the AEA. (see pp. 42-50)

31a. Please provide all records of written or oral comments from other agencies on each of the cost-benefit analyses that were performed.

Response: White House Counsel has not yet made a determination concerning the document requests we have received. Our documents reflect internal deliberations of the Executive Office of the President with regard to ongoing policies of the Administration. Moreover the documents include material that could influence ongoing negotiations.

31b. Please provide all records of comments submitted by federal agencies on Dr Yellen's draft testimony about the economics of Kyoto for the hearing before the House Commerce Committee on March 4, 1998.

Response: White House Counsel has not yet made a determination concerning the document requests we have received. Our documents reflect internal deliberations of the Executive Office of the President with regard to ongoing policies of the Administration. Moreover the documents include material that could influence ongoing negotiations.

32a. Given the significant economic costs projected by private sector studies, why did the Administration abandon a year and a half-long effort to develop cost estimates of the President's proposed policies to reduce greenhouse gas emissions?

Response: First, the significant costs projected by private sector studies do not derive from analyses of emissions reduction scenarios that include the whole range of flexible elements that comprise both the Kyoto Protocol and Administration policy. The Interagency Analytical Team work to which the question refers was a modeling effort that produced some useful lessons, but as we found from the peer reviewers' comments, it also suffered from some shortcomings. The Administration Economic Analysis (AEA) builds on the IAT exercise and also the insights of a wide range of models and other relevant literature to derive its conclusion that, with the flexibility mechanisms included in the treaty, and with sound domestic policies, the economic impacts of complying with the Kyoto Protocol are likely to be modest.

32b. Please identify any and all private parties that are currently performing economic analyses of the Kyoto treaty or any aspect of it for the Administration. Describe their work and provide all products of their work in draft or final form.

Response: CEA has no list of parties doing economic analysis of the Kyoto Protocol or any aspect of it for the Administration. Several modelers have contracts or cooperative agreements with various agencies, but we have no contract or agreement with any of them to undertake specific analyses for us.

E. International Emissions Trading

33a. Even assuming that effective rules and procedures can be developed for an international emissions trading system and for joint implementation projects and that key developing countries agree to participate, isn't there a real risk that these mechanisms could effect an enormous transfer of wealth and jobs out of this country overseas, especially to the countries of the former Soviet Union, China, India, South Korea, Brazil, and Mexico (i.e. that this system would be essentially a foreign aid program)? Some studies have estimated that more than 50% of our reductions would have to be purchased from other countries.

Response: The Administration is committed to achieving as many cost-effective emissions reductions domestically as possible, and for example has proposed the Climate Change Technology Initiative to stimulate carbon-lean technology development and deployment. At the same time, our analysis does suggest that for the 2008-2012 time frame it makes sense for the U.S. to pursue low-cost emissions reductions abroad, as would happen with the full implementation of an international emissions trading program. The key point is that trading will be economically beneficial to U.S. firms. We expect the Annex B parties of the former Soviet Union and key developing countries will provide significant investment opportunities for U.S. firms to capture gains from emissions trading as those

countries restructure and develop their economies. Developing countries will represent the greatest share of new energy, transportation, and building infrastructure investment worldwide in the coming decades, and U.S. firms can help provide clean technologies and financing that will build those economies and markets, help stave off disruptive climate effects, and allow U.S. firms to capitalize on their investments in environmentally superior products and processes.

Our analysis does not suggest that emissions trading will have a significant negative impact on U.S. employment. If anything, the lower costs associated with a comprehensive trading program will help protect American jobs.

33b. Please provide and document estimates of the percentage of U.S. emissions reductions that might have to be purchased from other countries to minimize the costs of reducing emissions and which countries likely would be the beneficiaries.

Response: Our analyses provide illustrative estimates of how emissions trading and other flexibility mechanisms can lower costs, but ascribing with precision the emissions reductions to any particular country is impossible. The trades and emissions reductions undertaken by U.S. firms will depend on a whole host of factors such as the costs (including transactions costs) of emissions reductions in participating countries, the extent to which emissions can be cost-effectively offset through sinks at home and abroad, the role of the six categories of gases, and the development and deployment of climate-friendly technology. Further, the "beneficiaries" of trading would include the United States, particularly U.S. firms, due to the greatly lowered costs of achieving our target.

34a. What real incentive do developing countries have to participate in the international emissions trading system, which would require them to commit to mandatory reductions, when they can transfer emissions reductions credits in connection with joint implementation projects and obtain financing through the Clean Development Mechanism?

Response: Developing countries would experience significant gains from trading in emissions permits. The economic and environmental rationales for a target and trade approach by developing countries include:

- Greater economic benefits to developing countries: With targets at or only slightly below BAU, emissions reductions in developing countries would produce many billions of dollars through the international sale of emission reductions achieved at lower cost than the world price.
- Target and trade yields greater benefits than CDM: While the Clean Development Mechanism will result in benefits for developing countries, an effective target and trade system can produce far greater benefits to

developing countries. In contrast to the CDM, which is project based, countries that agree to emissions targets can employ a wide variety of measures to reduce emissions, and need not rely exclusively on project-based reductions. Nor do they always need to establish a baseline against which projects generate reductions. Like other trading parties, developing countries that agree to target and trade would need to follow the rules and guidelines for trading, but are otherwise free to pursue emissions reductions and sequestration in any and all sectors in the way they see fit. The advantage of trading is that they can be compensated for those reductions in a way in which voluntary measures cannot be, and the opportunities are more comprehensive than with CDM alone.

- Environmental benefits: Reducing carbon dioxide emissions generates ancillary air quality benefits through lower particulate matter, sulfur dioxide, and nitrogen oxides emissions. Air quality is a key environmental concern in many developing countries

Domestic Trading Systems and International Competitiveness Concerns

Introduction

If a carbon emission trading system were implemented in the US, energy intensive industries in the U.S. could be faced with significant increases in production costs relative to competitors in developing countries. However, the specific impacts on an industry's competitive position and market share will be determined by a complex set of conditions. First, the actual scope of reductions that would be achieved by domestic sources could vary widely depending on the scope of international trading and other factors. The design of the allowance holding and allocation systems could also have an impact on the actual increases in production costs. Additionally, energy and carbon intensity, the capacity to improve energy efficiency or fuel switch will influence the impacts as well.

This paper will explore how the design of a domestic emission trading system affects the ability of the U.S. to make adjustments that offset competitiveness impacts. The choices of where to place the allowance requirements (fossil fuel producers vs. major emission sources) and how the allowances are to be distributed (auction vs. allocation) both affect the potential to mitigate competitiveness impacts.

Initial Observations

Covering imported fossil fuels vs. competitiveness adjustments

- Requiring emission allowances to cover the carbon content of imported fossil fuels under the trading system is relatively straightforward
- However, making adjustments to mitigate competitiveness impacts is more complicated
- Adjustments could be made either through import levies and export credits or allowance requirements on imports and exemptions on exports

Relationship to WTO Rules

- The use of any mechanism to offset competitiveness impacts from greenhouse emission reduction policies:
 - ⇒ Involves many issues that are still unresolved within the WTO framework
 - ⇒ Would probably require new WTO agreements to clarify

Under an upstream auction system

- Generally, auctioned allowances would make treatment of allowance costs as an "indirect tax" possible and therefore subject to adjustments through use of import levies and export credits
- However, this would still need to be negotiated through a WTO process

Under a downstream allocation system

- With a downstream allocation, emissions associated with exported goods could be exempted from allowance requirements,
- However, emission reductions would have to be taken out of the cap from other emissions sources
- Even with a downstream system, adjustments that involve energy intensive imports into the U.S. will present difficulties

General Principles

- The more directly linked export credits are to actual costs incurred, the easier it is to prove that they are not an unfair subsidy

- Imports must be given treatment equal to that of domestic products
- The characteristics of imported *products* can be subject to regulation (such as carbon content), however imposing standards related to the *process* by which imports are produced is unlikely to be permissible

Part 1: Adjustment Mechanisms and International Trade Rules

The mechanisms that might be used to compensate for negative impacts on the competitive position of U.S. energy intensive industries are:

- **Border Tax Adjustments (Export credits and import levies to adjust for domestic "taxes"¹)**
- **Exemptions from Allowance Holding Requirements for Exports**
- **Allowance Requirements for Imports**

The rules that currently guide the WTO provide some guidance on how these measures may and may not be used. For example, nations currently using carbon or energy taxes are able to provide export credits and levy taxes on imports to offset the impacts on some energy intensive producers.

If the U.S. system were based on tradable allowances it would be difficult, and in some cases not possible, to give rebates to energy intensive U.S. exports. Therefore, it is possible that energy intensive products from Europe and Japan receiving such credits would not only be compensated, but their U.S. competitors would be charged import levies. Such a "double burden" on U.S. energy intensive exports to certain markets could be a "worst case" outcome if the relationship between domestic trading systems and trade adjustments is not adequately addressed.

The rules that define unacceptable subsidies and unfair import restrictions would make it very difficult to use import levies and export rebates in the context of some trading systems. Any export rebates must be clearly justifiable as compensation to a producer to offset costs from *indirect taxes*. For import levies, the key criterion is equality in the treatment of imported and domestic products.

Relevant Rules and Agreements

There have been cases in the WTO dispute resolution process that provide some insights into what competitiveness adjustments would be acceptable within current rules and agreements governing international trade. However, the WTO does not operate under a system that considers such cases as precedents. Therefore, future disputes resolutions would only consider the agreements that have been established by WTO members. It is also important to note that amending the agreements requires support from two-thirds of WTO members. Therefore, any attempts to amend the agreements would require the support of a substantial number of developing country members of the WTO.

General Agreement on Tariffs and Trade

¹ It is unclear at this point whether or not allowances purchased in an auction or on an open trading market could be treated in the same manner as a tax.

- Article II: part 2 (a): Import levies
- Article III: part 4
- Article XX (paragraphs b, d, and g): exemptions "to protect health, conserve natural resources and secure compliance with law and regulations which are not inconsistent with GATT"

Agreement on Subsidies and Countervailing Measures

- Article I: Definition of a Subsidy
- Annex I: Illustrative List of Export Subsidies
- Annex II: Guidelines on Consumption of Inputs in the Production Process

Basic trading systems and adjustments

Auction Systems

Trading systems based on an auction of allowances are more compatible with the use of adjustment mechanisms. Additionally, a system that requires major end users to hold allowances makes the use of adjustment mechanisms easier than a system that places allowance requirements on fuel producers. Since allowances are paid for directly by the sources required to hold them, the use of import levies and export credits would be acceptable so long as WTO members agree that such allowances are in fact *indirect taxes*.

Under an upstream auction system adjustment mechanisms are somewhat more complicated. The imposition of levies and credits would be relatively straightforward for petroleum refineries, since they are directly paying for their allowances. For other energy intensive industries such as steel, bulk chemicals and pulp and paper industries such adjustments would be probably require more negotiation. The U.S. would need to ensure that the credits and levies were acceptable as indirect taxes and not *unfair subsidies* or *trade barriers*. There is precedent for similar energy tax adjustments within Annex II of the Agreement on Subsidies and Countervailing Measures. However, how these principles would be applied in the context of emissions trading is uncertain.

Allocation Systems

Under a trading system that allocates allowances, the use of adjustment mechanisms becomes much more complicated. Since allowance holders do not pay directly for the allowances it would be hard to argue that they are in fact paying an indirect tax, and therefore subject to relief through credits and levies on competing imports. This raises a difficult question as to the precise impact of downstream allocation systems on competitiveness. Although it is true that the allowances would have an economic value and their use constitutes an opportunity cost, if allocated to a major emitter, they would not represent a direct increase in operating costs. This assumes however, that the source has an allocation sufficient to cover their production needs. Otherwise they would need to purchase additional allowances, incurring direct costs that could be credited. However, any additional investments that they might choose to make in response to the policy, such as fuel switching, would probably not be eligible for adjustment credits.

Conclusion

Even in the simplest case it is likely that using adjustment mechanisms would require negotiation within existing trading regimes. Working out details sector by sector might be required. Therefore, it is important to examine the energy intensive industries that are most likely to be vulnerable. This will allow for the establishment of priority areas to work out the necessary details.

Part 2 : Identifying Key Industries

Quantifying the impact of reducing greenhouse gas emissions on U.S. industry's international competitiveness involves significant uncertainty. The amount of reductions that would be achieved domestically through any implemented policy, (versus reductions achieved through international trading or the clean development fund), is not known at this point. Even when the actual reductions needed are known, the impacts among energy intensive industries will be varied. For example, the impact of changes in energy costs on a firm's decision to relocate production or their loss of market share is not easy to quantify. Environmental compliance costs are only one of several factors that influence location decisions. Factors such as legal and institutional structures, capital costs, labor costs, labor productivity, and proximity to suppliers or markets all influence location choices by multinational companies and international market shares.

However, any significant increase in production costs will put pressure on the competitiveness of energy intensive industries if foreign competitors are not faced with similar increases. Allowance distribution formulas or border tax adjustments are mechanisms through which any increase in energy prices to industry could be mitigated. Ensuring that any such mechanisms are compatible with current trade agreements would require international negotiation to reach the detailed agreements that would be required.

Therefore, it is important to identify high priority industries for which such details would need to be worked out. A framework of factors is laid out below as criteria to identify the energy intensive industries that might be most vulnerable to competitiveness pressures. Working through this framework allows the identification of industries for which the development of mechanisms to mitigate competitiveness concerns would be the highest priority.

The following are a set of variables that influence individual industry's competitiveness:

- A. The impact of a trading system on costs of production
 - Energy consumption as a share of production costs
 - Carbon intensity of energy sources
 - The ability of the industry to switch to less carbon intensive fuels or improve energy efficiency
- B. The level of competition with producers in countries not required to make reductions
 - Share of U.S. consumption met by imports from countries not required to take emission reduction actions in the first budget period
 - Share of U.S. production exported to countries not required to take emission reduction actions in the first budget period
- C. The relative importance of shipping costs and vulnerability to foreign competitors
 - Shipping costs in relation to total product costs. Value per ton of product provides an indicator of shipping costs; (e.g. cement @ \$30-\$60/ton faces higher transportation costs dollar value of product than steel @ \$750-\$1000/ton). Therefore, increases in product prices have a more negative impact on market share for steel than increases for cement

- D. Additionally, the number of U.S. jobs in a particular industry or other measures of economic significance might also be considered in prioritizing focus industries.

The table below represents a ranking of direct measures or indicators for the 31 industries with higher than the average energy intensities.

	Industry	Energy / \$ Value Added	Carbon as % of Energy	Potential to Fuel Switch	Non- Annex I Imports	Non- Annex I Exports	Shipping Cost	Employment
		Rank	Rank	Rank	Rank	Rank	High Medium Low	Rank
2046	Wet Corn Milling	13	5	21	27	15	H	21
2063	Beet Sugar	10	3	13	7	16	H	27
2075	Soybean Oil Mills	20	10	24	16	4	H	26
2611	Pulp Mills	5	13	12	13	1	M	17
2621	Paper Mills	9	11	16	28	10	L	2
2631	Paperboard Mills	8	12	27	29	11	L	8
2812	Alkalies & Chlorine	4	23	15	3	6	M	23
2813	Industrial Gases	16	25	1	4	7	M	22
2819	Industrial Inorganic Chemicals nec	18	14	14	5	8	M	7
2821	Plastics Materials & Resins	25	16	26	24	21	M	6
2822	Synthetic Rubber	21	28	22	21	27	M	18
2823	Cellulosic Manmade Fibers	19	27	17	19	24	M	28
2824	Organic Fibers Noncellulosic	30	7	23	14	25	M	9
2865	Cyclic Crudes & Intermediates	23	20	19	15	26	M	13
2869	Industrial Organic Chemicals nec (not elsewhere classified)	12	15	18	6	9	M	3
2873	Nitrogenous Fertilizers	2	22	9	22	22	H	25
2874	Phosphatic Fertilizers	31	17	11	23	23	H	20
2911	Petroleum Refining	3	2	29	12	14	M	5
3211	Flat Glass	17	26	5	9	30	M	19
3221	Glass Containers	22	19	20	17	17	M	11
3229	Pressed & Blown Glass nec.	28	31	31	18	18	M	10
3241	Cement Hydraulic	6	4	25	20	12	H	16
3274	Lime	1	1	28	2	3	H	29
3296	Mineral Wool	26	18	7	25	5	H	14
3312	Blast Furnaces & Steel Mills	11	6	30	8	20	L	1
3313	Electrometallurgical Products	14	24	2	11	28	L	31
3321	Gray & Ductile Iron Foundries	29	8	6	31	31	L	4
3331	Primary Copper	27	30	3	26	29	L	30
3334	Primary Aluminum	7	21	4	10	2	L	15
3339	Primary Nonferrous Metals nec	15	9	8	1	19	L	24
3353	Aluminum Sheet Plate & Foil	24	29	10	30	13	L	12

Conclusion

When the 31 industries with above average energy intensities are evaluated with the set of indicators, (giving each factor an equal weight), ten high priority industries for developing mechanism to mitigate competitiveness impacts are:

- Petroleum Refining
- Primary Aluminum
- Pulp Mills
- Industrial Organic Chemicals
- Lime
- Industrial Inorganic Chemicals
- Alkalies and Chlorine
- Industrial Gases
- Blast Furnace Steel Mills
- Paper Mills

Appendix - Detailed Tables on Energy Intensive Industries

Examining industrial energy intensity broadly reveals that five industrial groups can be considered above average in their energy intensity.

U.S. Industry Energy Intensity (Broad Sectors)

SIC Code	Industry Category	(Thous. Btu/\$ Value Added)
20-39	ALL INDUSTRY GROUPS	10.6
29	PETROLEUM & COAL PRODUCTS	113.1
26	PAPER & ALLIED PRODUCTS	43.5
33	PRIMARY METAL INDUSTRIES	39.8
32	STONE CLAY & GLASS PRODUCTS	22.7
28	CHEMICALS & ALLIED PRODUCTS	19.1
24	LUMBER & WOOD PRODUCTS	10.1
22	TEXTILE MILL PRODUCTS	9.5
20	FOOD & KINDRED PRODUCTS	6.7
34	FABRICATED METAL PRODUCTS	4.0
37	TRANSPORTATION EQUIPMENT	2.4
25	FURNITURE & FIXTURES	2.2
39	MISC. MANUFACTURING INDUSTRIES	2.0
36	ELECTRONIC & OTHER ELECTRIC EQUIPMENT	1.7
35	INDUSTRIAL MACHINERY & EQUIPMENT	1.6
38	INSTRUMENTS & RELATED PRODUCTS	1.1
27	PRINTING & PUBLISHING	1.0
23	APPAREL & OTHER TEXTILE PRODUCTS	0.9

source: 1994 MECS

A more detailed look at the energy intensity of U.S. industry shows 31 industrial sectors with energy intensities above the manufacturing average. Among these sectors the carbon intensity of the energy used also varies.

U.S. Industry Energy Intensity (Detailed Sectors)

SIC Code	Industry Category	(Thous. Btu/\$ Value Added)	Electricity as a % of Energy Use	Natural Gas as a % of Energy Use	Oil as a % of Energy Use	Coal as a % of Energy Use
20-39	ALL INDUSTRY GROUPS	10.6	16%	38%	4%	12%
3274	Lime	185.6	4%	14%	2%	71%
2873	Nitrogenous Fertilizers	169.5	5%	93%	0%	0%
2911	Petroleum Refining	137.8	4%	1%	72%	0%
2812	Alkalies & Chlorine	135.5	36%	41%	0%	0%
2611	Pulp Mills**	135.4	3%	9%	9%	3%
3241	Cement Hydraulic**	124.4	11%	8%	2%	63%
3334	Primary Aluminum	113.2	91%	8%	0%	0%
2631	Paperboard Mills**	107	5%	21%	5%	11%
2621	Paper Mills**	85.7	9%	21%	8%	15%
2063	Beet Sugar	75.5	2%	30%	3%	64%
3312	Blast Furnaces & Steel Mills**	67.4	8%	26%	2%	38%
2869	Industrial Organic Chemicals nec (not elsewhere classified)**	58.1	5%	61%	1%	7%
2046	Wet Corn Milling	51.4	11%	39%	1%	45%
3313	Electrometallurgical Products	49	70%	13%	0%	0%
3339	Primary Nonferrous Metals nec	46.4	37%	32%	0%	29%
2813	Industrial Gases	42.7	81%	19%	0%	0%
3211	Flat Glass	36.4	70%	13%	0%	0%
2819	Industrial Inorganic Chemicals nec	34.1	42%	0%	1%	9%
2823	Cellulosic Manmade Fibers	31.1	4%	0%	0%	0%
2075	Soybean Oil Mills	30.1	11%	54%	2%	27%
2822	Synthetic Rubber**	28.1	13%	67%	0%	0%
3221	Glass Containers	27.7	18%	80%	2%	0%
2865	Cyclic Crudes & Intermediates**	27.6	10%	64%	1%	0%
3353	Aluminum Sheet Plate & Foil	27.5	22%	73%	0%	0%
2821	Plastics Materials & Resins**	25	18%	0%	1%	6%
3296	Mineral Wool	24.7	24%	73%	0%	4%
3331	Primary Copper	21.4	16%	69%	0%	0%
3229	Pressed & Blown Glass nec.	20.5	17%	79%	0%	0%
3321	Gray & Ductile Iron Foundries	17.6	33%	37%	1%	30%
2824	Organic Fibers Noncellulosic	17.4	21%	0%	9%	31%
2874	Phosphatic Fertilizers	13	22%	0%	6%	0%

** Categories contain significant share of "other"

For Paper Product Mills (Pulp 76%, Paper 47%, and Paperboard 57%) largely biomass woodwaste

For Petroleum Refineries (67% is other) largely combusted petroleum feedstock

Source: 1997 Manufacturing Energy Consumption Survey (1994 data).

Non-Annex I Shares of U.S. Imports and Exports

<u>Energy Intensive Industries</u>	Imports from non-Annex I Countries as a Share of U.S. Consumption	Exports to non-Annex I Countries as a Share of U.S. Output
Pulp Mills	4.2%	12.7%
Paper and Paperboard Mills	0.5%	4.4%
Industrial Organic and Inorganic Chemicals	6.7%	13.5%
Fertilizers	2.1%	0.4%
Pesticides and Agricultural Chemicals	1.2%	4.6%
Cement	2.7%	0.3%
Glass	5.5%	4.5%
Steel	6.3%	3.6%
Aluminum	4.7%	3.9%
<u>Other Key Industries</u>		
Lumber and Wood Products	3.3%	1.5%
Transportation Equipment	3.4%	7.7%
Fabricated Metal Products	4.0%	3.5%
Instruments and Related Equipment	6.7%	7.1%
Electronic and Other Electrical Equipment	23.1%	19.5%
Textile and Apparel Products	25.5%	5.4%
Leather Goods and Products	56.1%	9.9%

Source: DRI McGraw-Hill, Fall 1996 Forecast.

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1/24/97

“The Cost of Stabilizing Global CO₂ Emissions—A Probabilistic Analysis Based on Expert Judgments,” Manne and Richels, *The Energy Journal* (1994)—Comments on earlier draft of paper.

The Energy Modeling Forum from 1993 compared a diverse group of energy-economic models that employed different methodologies. While these models generated vastly different results concerning the future of economic growth and energy usage, all of them yielded remarkably similar results when standardized so as to employ common numerical inputs. This illustrates an important point. While it seems appropriate that different results are achieved through using different methodologies, it is somewhat disconcerting that the results are sensitive to even modest changes in the underlying factors that are inherently uncertain. As such, it appears that the choice of methodology is secondary to the choice of values for population growth, energy intensity, technical progress, etc. The authors proceed to elicit responses from a group of experts in the field to generate inputs for their Global 2100 model. The authors wanted to collect estimates of certain parameters to use in their Global 2100 model without relying on the literature. However, the question arises as to where the experts collect the information that is used to create their predictions (i.e. are they influenced by the figures that are generated in the literature?). The following question was one of five questions asked of the experts:

What will be the average global rate of AEEI over the next century?

The responses generated the data on page 11, providing a range of values for the AEEI. One item of note is that when energy costs are a small fraction of total output, ESUB is approximately equal to the absolute value of the price elasticity of demand.

Parry, I., 1997. "Revenue Recycling and the Costs of Reducing Carbon Emissions," RFF Climate Issues Brief No. 2.

Tax-interaction effect. Taxes on labor and capital income distort economic activity, imposing regulations to curb emissions of CO₂ is likely to further add to these distortions. Taking into account this distortionary tax-interaction effect raises the overall costs of reducing CO₂ emissions. Economic costs to the US of using freely issued tradable permits is 5 times greater when interactions with the tax system are taken into account.

Revenue-recycling effect Some policies can raise revenues for the government (carbon taxes, auctioned emissions permits) which can be used to cut other distorting taxes. Reducing these taxes increases the level of employment and investment, producing an economic gain. The gain from the revenue recycling effect can offset most, but typically not all, of the added costs from the tax-interaction effect. Environmental taxes have a relatively narrow base, so they might be more distortionary than broader-based taxes such as personal income taxes.

Some policy instruments do not raise revenues, and cannot produce a revenue-recycling effect to counteract the tax-interaction effect. They therefore have a higher economic cost than revenue-raising instruments.

US EPA, 1997. "Aggregate Economic Impacts of Climate Change in the United States," Climate Change White Paper, Draft (1/16).

Global warming may bring with it changes in precipitation, weather patterns, ecological habitats, water availability, severe weather events, and cause sea levels and mean temperatures to rise. As the economy adapts to these physical changes, there will be market and non-market impacts. These impacts are the costs of doing nothing to stop global warming or the benefits of action. This study looks at a subset of market impacts using an integrated general equilibrium model of the US economy and several scenarios of climate change and economic vulnerability. It looks at changes in the costs of producing agricultural, forest, and fisheries commodities, heating and cooling indoor spaces, protecting coasts against sea level rise, maintaining air quality, and repairing storm and flood damages.

While the possibility of beneficial market impacts exists under moderate rates of warming, there is a significant probability of adverse consequences, particularly when non-market and omitted market impacts are considered. (p.20)

	Impact through/by 2080
National Income	-2.0 percent to +1.2 percent
Household Welfare (present discounted value)	-\$12,500 to +\$8,000
Social Welfare (aggregate present discounted value)	-\$1 trillion to +\$600 billion.

Reservations:

These aggregate estimates hide significant variability in impacts across regions, economic sectors, and industries. Market and non-market impacts that are omitted from the analysis represent substantial risks that could prove to be even more important than the included impacts. Further, the analysis ignores the possibility of sudden climate changes or surprises, and the modeling does not fully capture transitional costs or costs that occur when markets do not smoothly and completely adapt.

June 17, 1997 draft of "Climate Allowances Protocol (CAP): Comparison of Alternative Global Tradable Emissions Regimes," by William D. Nordhaus.

Characteristics of a Successful Regime

Nordhaus identifies several criteria for a successful regime which current proposals do not meet. His CAP system includes:

- Moderate efficiency from an economic and administrative point of view.
- Positive incentives for countries to participate and to fulfill their obligations.
- A decision process which will induce countries to agree to efficient levels of greenhouse gas reduction.

An ideal regime would also meet the following three criteria, which the CAP system addressess only partly:

- Recognize that countries with inept or corrupt governments may subvert the process or use it for personal gain.
- The regime must not injure other international agreements (trade and other).
- The decision process should be simple and familiar to countries.

The CAP Regime

The basic philosophy of the CAP system is that it should balance the costs against the benefits, be economically efficient, and respect the fact that the agreement must be in the self-interest of participating nations.

Determining Global Target for Reductions The main difference between the CAP regime and the current US proposal is that the overall emissions target and individual nations' allocation of permits are based on a dynamic cost-benefit analysis. Integrated assessment models are used to calculate what the ideal abatement is at any given time with currently available technologies and a global willingness to pay. Countries will vote a given "value" of reducing climate change, and the global willingness to pay will be set to the median vote; each nation's expressed WTP is weighed by its share of reducible emissions.

National Allocation of Permits Emission baselines are rolling targets for each nation. Permits will be allocated according to a formula that reflects each country's uncontrolled emissions and its ability to pay. Therefore, countries with rapid growth would not be penalized, and historically inefficient nations would not have windfalls.

Trading, Budgets, & Banking In this regard, the CAP regime is essentially the current US proposal. Nations will be allowed to buy, sell, barter and borrow other countries'

allowances as long as the rules are obeyed (emissions = allowances + net purchases). To avoid costly mistakes, extra carbon allowances would be available at some premium (50 percent) above the estimated efficient price.

Evolution Countries are expected to make emissions reductions when their per capita incomes reach a certain “entry-level income” and fully participate when they reach “full-participation income.”

Incentives for Participation Sanctions against violations, and incentives to participate, will come from import duties on the carbon content of imports.

Simulations

The RICE model was used to simulate five policy proposals and one baseline:

- **Baseline** Market, or “no-control” case where no climate policies are in place.
- **“Optimal” policy** Complete participation with lump-sum redistribution
- **Three CAP Regimes** Middle progressive assumes an entry-level income of \$5,000 per capita and full-participation at \$15,000; regressive (\$0 and \$5,000) and progressive (\$10,000 and \$20,000).
- **“Rio w/out Trade”** Emissions capped at 1990 levels for OECD countries
- **“Rio w/Trade”** Rio limits with emissions trading among OECD countries; this is effectively the U.S. proposal.
- **“Berlin Mandate”** Rio treaty but has 20 percent cuts in emissions from 1990 levels starting in 2010 and no trading.

Results (see attached tables)

Emissions Reduced -- All proposals are very similar over the next century (though CAP achieves slightly more reduced emissions). In the long run, however, current proposals do not have a mechanism to bring in big developing countries. In CAP, important developing nations incur some reduction obligations in the next century.

Economic Costs -- the three current proposals on the international agenda have substantial negative net benefits. According to these simulations, they are worse than doing nothing, imposing more than \$100 billion of discounted costs (control costs and climate damages discounted at a rate of 5 percent annually) for the Rio approach and \$1 trillion of discounted costs for the Berlin approach.

Efficiency -- CAP would achieve between 40 and 75 percent of the potential economic benefit and more than 96 percent of the long-term environmental benefit (depending on the time frame and progressivity schedule).

Reservations

- Sanctions linked to punitive import duties for non-participants could be a dangerous and unwarranted distortion of international trade.
- Mechanism for determining country preferences is complicated.
- Treatment of corrupt countries is problematic -- can we put conditions on the use of monies raised from sale of emissions allowances?
- Countries will have an incentive to “ratchet” up their emissions in one period to increase their base in the next.

“Regrets or No Regrets--That is the Question: Is Conservation a Costless CO₂ Mitigation Strategy?” Adam Rose and Shih-Mo Lin, *The Energy Journal*, (1995)

This paper develops a CGE model that essentially demonstrates that conservation would have a slightly negative effects on the US economy overall, while also having substantial negative effects on most energy industries. The GE framework is able to address some issues that a partial equilibrium framework cannot. First, if energy conservation savings are passed on to other industrial customers, there may be the possibility of further rounds of price reductions. However, the reduction in energy use would likely lower production levels in the coal, oil, gas, refined petroleum, and electric and gas utility industries. This would have the impact of promoting energy conservation through reduction in economic growth instead of improving energy efficiency. Using a 20-sector CGE model, the authors assume simple conservation measures that would reduce baseline emissions in the US by 12.8% (optimal response to a call for 20% global emissions reduction and an equilibrium permit price of \$38.35). This would result in a reduction of real GDP in 2000 by 1.44%, while only cutting energy use by 3.32% (due to substitution effects) and cutting CO₂ emissions by 3.44%. Further, employment, investment, and welfare (as measured through compensating variation) all are adversely affected by the conservation measures. Similar results hold for a modified conservation program as well as cases of implementing a carbon tax or permit trading system. The latter two cases do, however, result in considerable reductions in energy use and in CO₂ emissions over the base conservation case. Sensitivity analysis also demonstrates negative impacts on real GDP and employment. The authors conclude that conservation should not be oversold as a costless CO₂ mitigation strategy while noting that these results pertain only to the short run.

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1/23/97

"The Costs of Reducing U.S. CO₂ Emissions—Further Sensitivity Analyses," Manne and Richels (1990)

The authors note that "clearly, the AEEI parameter is highly controversial." They doubt that an AEEI of 1.5 (annual rate of change) is sustainable over a long period. This would exceed the U.S. GDP growth for much of the 21st century while implying that a rising GDP would be accompanied by falling energy demands during many decades of stable energy prices. The question arises: What would cause energy demand to go down even though there are stable energy prices? Critics of an earlier paper by the authors claim that by only considering AEEI values as high as 1.0 may be overly pessimistic in addressing the prospects for energy efficiency improvements. *Note that a low AEEI value does not necessarily imply a low overall rate of energy efficiency improvements since in addition to the AEEI effect there is also the effect of rising energy prices on demands.* This means that we can have autonomous and/or price-induced efficiency improvements, and some focus should be given to determining the degrees of impacts that each have. Unlike autonomous improvements in energy efficiency, the contribution from price-induced conservation is not costless.

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1/23/97

“The Berlin Mandate: The Design of Cost-Effective Mitigation Strategies,” Richels *et al* (1996)

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 costs.” The authors address two ways to promote this objective. In the first, emissions reductions are allowed to take place *where* it is cheapest to do so. In the second, reductions take place *when* it is cheapest to do so. The paper only focuses on costs of emissions reduction and not on the benefits. The four energy-economy models that the authors examine are: CETA, EPPA, MERGE, and MiniCAM (refer to paper for further description). These models employ a GE formulation of the global energy and economic system. One point that comes forward is that the stabilization of global emissions will eventually require the participation of developing countries. Also, all four models differ in their estimate of the order of the magnitude of the economic impacts. This occurs in large part due to the differences in the baseline emission levels. As such, a main result of the paper suggests that the costs of mitigation can be substantially reduced through international cooperation (tradeable permits system) and the optimal timing of emission reductions. This flexibility can reduce costs by as much as 80% or more, which could lead to trillions of dollars of savings in mitigation costs. However, knowing this only brings to light some further questions: How should we divide up the savings achieved through international cooperation? How do we guarantee that all parties maintain a credible path toward fulfilling emission reduction requirements?

1/23/97

“Learning By Doing: Pulling the Benefits of Energy Efficiency Technologies into Climate Change Strategies,” Laitner (1997)

This paper offers several methods that appear to be successful at enhancing the diffusion of technology so that energy efficiency can be realized. These include (1) selling productivity benefits, (2) scaling down the costs, (3) learning by doing, (4) banking on R&D, (5) promoting new institutional arrangements, (6) informing the market, and (7) capturing nonmarket benefits. The author points out that there are numerous studies that demonstrate the benefits of accelerated investment in energy efficient technologies. Since there have been no studies done on quantifying the magnitude of the opportunity costs of implementing these technologies (i.e. a GE model), the author suggests that “a second best solution may be good enough.” There is nothing more explicit on the rate of technology diffusion. However, there are some interesting trends in the table on page 10 (Energy Modeling Comparisons). Effectively, it appears that large R&D expenditures are necessary and sufficient to develop new technologies in order to achieve an average annual change in energy usage of 0% (approximately) or below 0% and to achieve decreases in carbon emissions. What incentives will produce these results?

1/27/97

Summary of Energy Efficiency Literature (AEEI and ESUB)

Estimates of values of the AEEI have been an issue of much debate in recent years. The values vary over a rather large range. Laitner (1997) claims that estimates of AEEI over 2.0 will require large R&D expenditures. Further, Manne and Richels (1990) claim that an AEEI of 1.5 or above is unlikely to be sustainable over a long period. Some critics argue that assuming that the AEEI cannot exceed 1.0 is incorrect as it is too pessimistic in its implications about prospects for energy efficiency improvements. A report by the EMF (September 1996) indicates a range for declines in aggregate energy intensity for the economy of 0.6% to 1.0%. The estimates exceed 1.0% for several models that exclude the industrial sector and fall to about 0.4% for one model focusing on industry alone (p. 12). These results are comparable with assumptions about the AEEI found in other economic models. Forecasts from the AEO97 indicate a range of AEEI between -0.7% and -1.0% (see Table 1, p. 6, AEO97). Estimates of the cost of abating carbon dioxide emissions have been sensitive to the AEEI. Greater AEEI in the baseline contributes to lower baseline CO₂ emissions, thus making it easier and less costly to achieve a specific emissions level based on historical targets (p.11). Refer to John P. Weyant, *Journal of Economic Perspectives*, Fall 1993, 7(4): 27-46.

Manne and Richels (1994) determined that while various energy-economic models yield vastly different results, the models all generate comparable results when standardized so as to employ common numerical inputs. While it seems appropriate that different results are achieved from using different methodologies, it is somewhat disconcerting that the results are sensitive to modest changes in factor inputs that are inherently uncertain. This indicates that the choice of methodology is secondary to the choice of values for population growth, energy intensity, technical progress, etc. As such, the authors survey a number of experts in the field to elicit their predictions on what the global rate of AEEI will be over the next century. The responses are as follows:

<u>Percentile</u>	<u>Minimum</u>	<u>Maximum</u>	<u>Average</u>	<u>Median</u>
10	-0.50	0.75	0.20	0.23
30	-0.10	1.00	0.45	0.45
50	0.10	1.30	0.70	0.68
70	0.00	1.50	0.97	0.90
90	0.90	2.00	1.38	1.20

The authors further note that when energy costs are a small fraction of total output, ESUB (elasticity of price-induced substitution) is approximately equal to the absolute value of the price elasticity of demand. The EMF (1996) also reported that the models indicate that energy demand would fall by only 3 to 8% after 20 years with a 25% increase in delivered energy prices. A change in energy demand of 3% translates to an

elasticity of -0.12 while that of 8% relates to an elasticity of -0.32. The EMF compared some other energy demand models, where the long-run elasticity ranged from -0.3 to -0.7 when measured at the wholesale or refinery level (i.e. the secondary level). After adjusting for differences between secondary (industrial) and average delivered energy prices for all sectors, estimates range from -0.4 to -1.0 (see "Aggregate Elasticity of Energy Demand," EMF, *The Energy Journal*, April 1981, 2(2): 37-76).

Further studies indicate additional insights. Large R&D expenditures are necessary and sufficient to develop new technologies that will allow average annual energy usage and carbon emissions to decrease (Laitner 1997). In terms of reducing carbon emissions through CO₂ mitigation, Rose and Lin (1995) use a CGE model, indicating that conservation would have slightly negative effects on the overall U.S. economy and substantial negative effects on most energy industries. Richels *et al* (1996) determine that the costs of CO₂ mitigation can be reduced through cooperation (i.e. tradable permits system) and the optimal timing of emission reductions.

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“Limits on the Economic Effectiveness of a Carbon Tax,” Robert Kaufmann, 1991, *The Energy Journal*, 12(4):139-144.

This paper briefly examines the extent to which certain fuel prices are expected to increase relative to other fuels when a carbon tax is placed on them. A tax of \$30 per ton of carbon will have varying effects on the change in the price of natural gas relative to oil in different OECD countries. This ratio ranges from 0.90 (a 10% decrease in the price of natural gas relative to oil) to 4.01 (approximately a 300% increase in the price of natural gas relative to oil). The author offers two implications in this paper for research and policy. First, analysts must use end-user prices explicitly to accurately assess the effects of a carbon tax on CO₂ emissions. Wellhead prices are significantly lower than end-user prices and using these prices to drive energy demand equations probably overstates the ability of a carbon tax to reduce emissions of CO₂. Second, to increase the economic effectiveness of a carbon tax, it may be useful to levy the carbon tax as a rate that could be based on a rate determined for natural gas. This would have the benefit of not causing such a large negative impact on the coal industry due to the large increase in the price of coal relative to oil or gas.

“A biophysical analysis of the energy/real GDP ratio: implications for the substitution and technical change,” Robert K. Kaufmann (1992), Vol. 6, 35-56.

Biophysical economists focus on developing economic models where energy and matter are the only primary inputs; this is in a manner consistent with the laws of thermodynamics. Upon factoring in the effects of thermodynamics, two primary effects are realized. First, at the macro level, the E/GDP ratio overstates the reduction in energy use since it does not account for changes in the types of energy used and the types of goods and services produced. Second, at a less aggregated level, typical analyses of sectoral energy intensity will exclude the energy used to produce capital and support labor. This will tend to underestimate the amount of energy used by a sector to produce a good or a service, and will overstate the ability of substitution to reduce total energy use. One study (Pimentel *et al*, 1973) determined that the amount of energy used directly as energy to grow a bushel of corn in the U.S. dropped 14.6% between 1959 and 1970. However, upon factoring in the energy used to produce the pesticides, fertilizers, tractors, and other nonenergy inputs to corn production, the energy used to grow a bushel of corn increased by 3%. Estimates from this paper for elasticities of substitution for France, Germany, Japan, and the UK range from -0.045 to -0.389. This is well below those elasticities estimated in previous studies (which range from -0.2 to greater than -1.0). The author claims that the smaller elasticities determined in this paper are an indication that indirect energy costs of labor and capital comprise a significant amount of the energy that is saved directly through substitution.

“The Economics of Strategies to Reduce Greenhouse Gas Emissions,” Lisa J. Cameron, Harry L. Foster, W. David Montgomery, 1997.

In examining the literature concerning the costs of implementing climate change policies, the authors focus on the lack of attention given to market failures and market barriers in the literature. Policy intervention is not required when market barriers, which include hidden costs, difficulties, or disadvantages perceived by users, are present because there are profit incentives to reduce or eliminate these transaction costs. Policy intervention can be useful when market failure—a situation where conditions are in place that prevent the correct price signals from reaching decision makers—exists. Of course this is only helpful when the benefits of a policy outweigh the costs of its implementation. If adoption of energy-efficient technologies is not taking place due to the presence of market barriers, then “no regrets” strategies do not exist. Government intervention is unnecessary and likely to be counterproductive in this situation. However, if non-adoption of these energy-efficient technologies is due to market failure, then “no regrets” strategies have the potential to overcome the market failure and improve economic efficiency. The authors provide three energy market failures: (1) underprovision of information with public goods attributes; (2) moral hazard in landlord-tenant relationships; and (3) the divergence of energy prices from marginal costs. There are a number of market barriers that are cited: (1) costs of conservation incurred but not accounted for; (2) differences in qualitative attributes between alternative products; (3) reluctance to spend resources on determining how a particular technology will work on own premises; (4) rationally high consumer discount rates; and (5) heterogeneous energy usage patterns. The authors conclude by stating the need for future research to distinguish between the impact of market failures and market barriers on the diffusion of particular energy-efficient technologies.

1/30/97

"Overview of Greenhouse Gas Mitigation Options," EPA

The focus of this paper is to examine the various possible greenhouse gas mitigation options in order to begin to develop a domestic mitigation program that will be consistent with the outcome of the likely agreement in Kyoto in December 1997. There are four major mitigation options that EPA examines: (1) R&D, (2) market transformation programs, (3) standards and regulations, and (4) emissions trading. Since R&D can be "partially" characterized as a public good, government support should be provided for developing energy efficiency technologies as the market will not provide the optimal level of R&D. Further, there are large environmental benefits that are not captured by markets even though it is valued by society. This would indicate that government assistance with R&D expenditures is required since it is addressing a market failure. In addressing market transformation programs, EPA refers to three oft-cited studies—NAS, OTA, and National Council for an Energy-Efficient Economy—indicating that the technological potential already exists to achieve cuts in energy consumption levels by 20% or more at a net economic benefit (this, in part, refers to the AEEI). EPA claims that the economy cannot realize these levels since there are "institutional, organizational, and other barriers that work against the diffusion of energy efficient technologies." EPA further states that standards for appliances can expand markets for energy efficient technologies, thereby reducing "information barriers." One reason for EPA making this claim is that "many consumers do not consider energy efficiency when making purchases [of appliances]." This is an indication of bounded rationality, and therefore should be treated as a market barrier, requiring no intervention. Finally, EPA mentions that emissions trading programs would be an effective means of reducing emissions, in part because these programs offer correct incentives to conduct R&D for pollution abatement technologies.

**“The Diffusion of New Technologies: Evidence From the Electric Utility Industry,”
Joskow and Rose, Rand (1990)**

This paper examines technological innovations and their subsequent diffusion in the steam-electric generating industry. Hazard rate models, with special attention given to proportional and log-logistic models, are studied. A brief look at the data suggest that relative to IOUs (investor owned utilities), cooperative and government-owned utilities tend to be smaller, have slightly lower fuel costs, build fewer units, and adopt new technologies less frequently and later. Further, there is a marked difference in adoption rates by size of utility. Results for the 2400 psi technology model indicate that firm size has a positive significant influence on adoption probabilities, so larger firms are more likely to adopt the technology earlier than the small firm. Fuel prices (in particular 1972 prices) have a positive impact on adoption probabilities. Also, the hazard models suggest that, at least initially, adoption probabilities tend to increase over time. The model does not suggest that ownership structure has a significant influence on adoption probabilities. Evaluating the elasticities of the log-logistic model for the 2400 psi technology for an IOU at the sample midpoint of 1965 indicates that a 10% increase in utility size leads to a 13.6% increase in the hazard rate (see Figure 5 for elasticities of hazard rates, 2400 psi). Compare these results to 10.7% for the Weibull proportional hazard model and 7-8% for the double-censored model (sample means for 1970 size and 1972 fuel cost variables) for the same 10% increase in utility size. Results for the supercritical technology are somewhat noisier. The size of the utility again has a positive and significant impact on adoption probability. Time is also significant, as the supercritical hazard rate path looks like a “stretched out” version of the 2400 psi path. Nothing else of note was statistically significant in the model. The elasticities of the hazard rates are 1.08 for the double-censored model (10% increase in utility size yields a 10.8 % increase in hazard rate) and elasticities are 20-30% higher for the proportional hazard and the log-logistic models.

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1/21/97

"Modeling The Processes of Technological Innovation and Diffusion: An Overview of Issues," Greening and Khrushch, 1996

This paper takes a general look at modeling the process of innovation and diffusion. Of note, the authors suggest that the diffusion process has been described with the characteristic S-shaped or logistic type of path. This appears to be fairly consistent across the technologies studied. The authors make one conclusion that the processes of innovation and diffusion do not occur in a linear progression.

1/21/97

“Modeling Technological Change in Energy Demand Forecasting: A Generalized Approach,” DeCanio and Laitner

This paper supports the position that the current “investment” approach models (i.e. conventional models) of technology diffusion tend to yield substantially high implicit discount rates. This occurs since “accurate estimates of the implicit discount rate cannot be obtained from cross-sectional data if the diffusion process is dynamic.” Bias of the conventional forecasting methodology is pronounced for highly profitable, low-payback technologies in their early stages of adoption. Models such as this will tend to consistently underestimate the effect of new technologies being observed early in their life cycles. As such, the authors claim that this approach is not accurate, and offer a different approach where they assume that “the spread of new technology is conceived as the simplest possible type of diffusion process.” This is sometimes referred to as the Fisher-Pry (1971) model. Table 4 examines space heating technology and determines that even under pessimistic assumptions about diffusion, any of the technologies listed would show greater market penetration after five years than the maximum shares allowed by the conventional investment model. Under the conventional forecasting framework, superior technologies never achieve their long-run potential, and inferior technologies persist in the market long after they would typically be replaced.

Some policy implications:

- Conventional energy forecasting models are too conservative about the prospects for energy saving resulting from the diffusion of energy-efficient technologies.
- The “investment” model is biased against emerging technologies early in their diffusion cycle.
- These conventional models underestimate the potential of market-based or voluntary programs, while also making tax incentives appear less powerful than they really are.

An International Market in Credits for Early Greenhouse Gas Emissions Reductions

Introduction

Article 17 of the Kyoto Protocol provides industrialized countries with the flexibility to “participate in emissions trading for the purposes of fulfilling their [emissions limitation] commitments”. Such trading would allow for the transfer of assigned amounts (AAs, or emissions budgets) among Annex B countries. However, the Protocol does not define the rules and guidelines governing greenhouse gas (GHG) emissions trading, stating that these shall be developed later by the Conference of the Parties. This paper proposes a practical, concrete step that would facilitate the development of rules for international GHG emissions trading: *the establishment of an international market in early emissions reduction credits*.

An international early reductions trading program would provide countries interested in trading with a hands-on opportunity to engage the critical issues involved in the design and implementation of an international GHG emissions trading program. The early reductions program could be used to test the trading rules that the Conference of the Parties develops; alternatively, the program could develop and test its own set of rules and then use its experience to inform the UNFCCC process. Issues that the program could engage include the monitoring and verification of emissions; the pros and cons of serializing AAs by country/sector/source of origin; regulation of trades to protect against problems such as price manipulation and market power; the tracking of trades; and establishing liability in cases of non-delivery of promised reductions.

The development of an international early reductions market would not only jump start trading and give the international community a chance to develop trading rules; it would also stimulate GHG emissions reduction activities in advance of the first commitment period. Countries that can make low-cost emissions reductions will respond to foreign demand for credits by making additional reductions, while buyers will be able to bring down their Kyoto compliance costs by buying credits from abroad. An early reductions program would ease the aggregate pain of meeting first commitment period obligations by reducing the overall cost of compliance and would give countries an incentive to meet commitments by investing in clean technologies now rather than retiring and retrofitting high emissions technologies later.

Domestic Early Reductions Programs

Of the flexibility mechanisms established under the Kyoto Protocol,¹ only the Clean Development Mechanism (CDM) has been expressly designed to give credit to emissions reduction activities taken prior to 2008. However, while the Protocol does not explicitly recognize emissions reductions made in Annex I countries prior to the beginning of the first commitment period (2008 - 2012), some Annex I countries are now considering the establishment of programs to reward early emissions reductions activities. These programs would reward emissions allowances to projects or companies that make GHG emissions reductions prior to 2008. Domestic early reductions programs are best suited to countries that will meet their Kyoto obligations by assigning responsibility for emissions reductions to individual emissions sources, either through cap-and-trade programs or through measures such as sectoral emissions targets. Early reductions programs would not work as well in countries that seek to meet their commitments through measures such as taxes and standards, which do not require companies or sectors to meet emissions targets.

The allowances given out to companies under domestic early reductions programs would be taken from rather than added to the allowances given out by the country in the first commitment period. For instance, a country that had a first commitment period assigned amount (AA) of one billion tons of CO₂-equivalent emissions and planned to meet its obligation through a domestic cap-and-trade program could earmark 50 millions tons of first commitment period allowances to firms that took early emissions reduction activities, leaving 950 million tons to be allocated during the first commitment period. In effect, early reductions programs would distribute a portion of first commitment period emissions rights (here five percent) among domestic companies which have taken early action. This would leave fewer allowances for distribution post-2008 (95 percent of the AA in this example). Since the country would give out only 95 percent of its AA in the first commitment period, it would meet its obligation for this period. Thus domestic early reduction programs are not inconsistent with the Kyoto Protocol. In essence, because domestic early reductions would be accounted for differently than CDM emissions reduction units produced prior to 2008 (which can be added to first commitment period AAs), they can be accommodated under the Protocol.

The main reasons for establishing domestic early reductions programs are to: 1) reduce or reverse GHG emissions growth rates, so that it is easier to meet Kyoto commitments; 2) recognize and reward the companies that are helping countries to meet their emissions limitation obligations; 3) build political acceptance for GHG regulation; and 4) provide companies with emissions trading experience prior to the onset of the first commitment period.

¹ These include emissions "bubbling" (Article 4); Annex I joint implementation (Article 6); the Clean Development Mechanism (Article 12); and emissions trading (Article 17).

Many complex issues must be resolved in designing a program to reward early reductions activities. These include:

- *Quantifying reductions:* Emissions reductions can be quantified in a number of different ways; for instance, they can be measured against a “business as usual” baseline, a “Kyoto Protocol” baseline (where credits are earned when a project or company reduces its emissions by more than the host country’s Kyoto Protocol Annex B reduction commitment), or something in between. It is important that emissions reductions be measured consistently across activities. This means that the rules for determining emissions baselines should be simple, clearly specified and uniformly applied; companies should not be able to create their own baselines. The system should be simple and transparent and should require a minimum of bureaucracy and staffing.

We believe that companies should be given credit only if they take early actions that go beyond those needed to bring company emissions in line with Kyoto commitments. Figure 1 demonstrates this concept by presenting a straight line drawn between the company’s current (1998) emissions and the level of emissions that the company would have to reach in 2008 to do its share in helping the country to meet its Kyoto obligation (in this case, seven percent below 1990 levels). The firm would be rewarded credit for early reductions only if net actual emissions over the whole period were below the line.

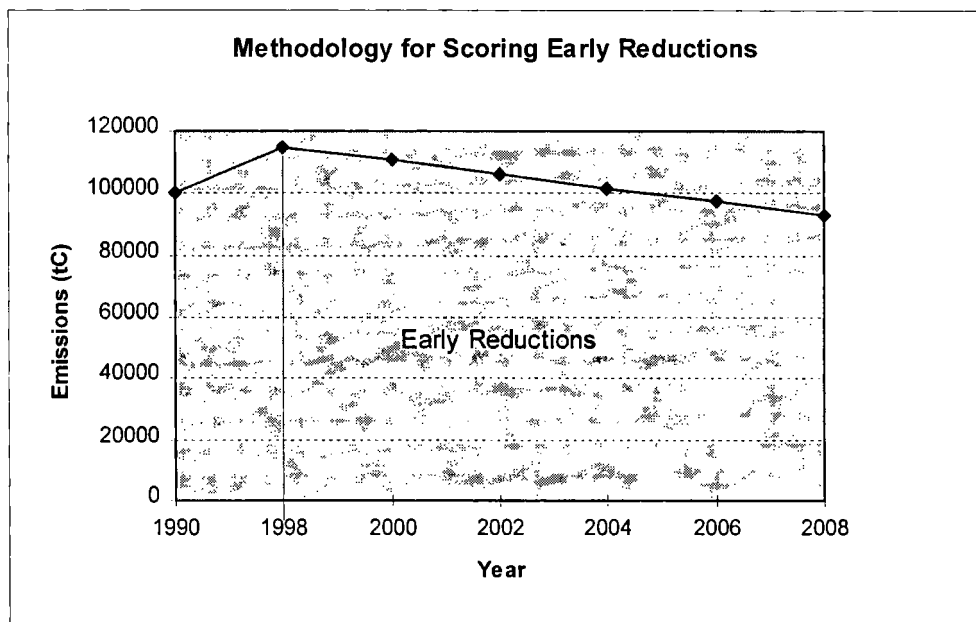


Figure 1

- *Participation:* Countries must decide whether their early reductions programs will involve (“upstream”) fuel producers or (“downstream”) fuel users (or both). An important issue here is double-counting: While it is feasible to design a system that includes both energy producers and users, there is a risk that two companies will be rewarded for the same emissions reduction. For instance, a fuel producer could be rewarded for developing a clean fuel while the company burning the fuel could take credit for reducing its emissions as well. We recommend that early reductions programs be established downstream rather than upstream. Under this approach, fuel producers would take credit only for reductions in carbon emissions in their own operations but not for the GHG benefits of clean fuels. Credits for these benefits would accrue to fuel users.
- *Reporting level:* In some cases companies undertake emissions reduction activities at some facilities even though their overall company-wide emissions increase. As they initiate early reductions programs, countries will have to decide whether they want to reward allowances to any company that undertakes a reduction activity, or reward only those companies that reduce their total emissions below the specified baseline. We recommend that the latter approach be taken. This would ensure that only companies that helped their countries to meet their Kyoto obligations received credit.
- *Eligible activities:* Early reductions programs can relate to activities that decrease emissions of CO₂ from fuel combustion only or can include other activities as well, such as those that produce gases other than CO₂ and forestry activities that create or sequester CO₂. The benefit of including other sources/gases may be the capture of low-cost mitigation opportunities; drawbacks can include the lack of certainty in measuring reductions. In general, emissions of CO₂ from energy combustion can be measured with greater certainty than other types of emissions. We advocate that at least initially, early reduction programs be limited to energy-related CO₂.

An International Early Reductions Market

An international early reductions trading system could be established by linking the domestic early reductions programs of various countries. Parties that wanted to participate would agree to reward emissions reductions made prior to 2008 by setting aside some portion of their first commitment period AAs. The international program most likely would include countries that planned to meet their Kyoto commitments by using domestic cap-and-trade programs or other regulatory approaches that assigned emissions limits to particular companies or sectors; in addition, the program would be appropriate for countries that plan to participate in Annex I joint implementation as sellers. By allocating AAs from the first commitment period to JI projects based on the emissions benefits that the projects provide prior to 2008, these countries would give developers an incentive to undertake projects early.

Establishing an international early reductions market would require participating countries to agree to a few general conditions, but they would not have to design and implement their domestic programs in identical fashion. All countries would have to specify upfront how much of their AAs they would make available for early reductions; in addition, to ensure that credits traded were backed by real reductions participating countries would be required to establish simple, transparent rules for setting emissions baselines and quantifying reductions. Next, for the sake of simplicity and to avoid emissions measurement and verification problems, at least initially all programs probably should be limited to including energy combustion activities only. Finally, countries would have to agree to use accepted methods for the measurement of emissions. Direct measurement of actual emissions would not be necessary or even desirable; instead, emissions would be estimated based on fuel use records and accepted fuel-specific default emissions factors.

Beyond these general requirements, harmonized rules would not be necessary. Ultimately it will not matter if some countries establish upstream early reductions programs and others downstream programs, or if some countries measure reductions against business as usual baselines while others measure against stricter standards, because regardless of program structure early reductions programs pose no environmental risk. Because the allowances given out through early reductions programs will come out of the allowances given out during the first commitment period, international early reductions trading will redistribute AAs among participating countries rather than producing new emissions rights. Total greenhouse gas emissions will not rise no matter how early reductions are quantified.

Compliance

Because participation in international early reductions trading will be voluntary, by definition there is no scope for sanctions on companies that do not reduce their emissions below baseline levels. However, one compliance issue does arise from the multi-year nature of early reductions programs. It is possible that a company could earn allowances and then sell them, and then subsequently increase its emissions such that by the end of the early reductions period its aggregate emissions for the period were above baseline levels. In this case the company would have sold allowances even though it had not made the requisite reductions. This issue could be resolved by requiring participating countries to agree to ensure that any allowances sold by their companies will be supported by real reductions. Countries could take any number of steps to honor such an agreement, including purchasing the needed reductions from other participating countries or the CDM, or imposing penalties on the selling companies and then using the proceeds to purchase reductions.

Implementation

Because international early reductions trading would effect a redistribution of first commitment period AAs among participating countries, the establishment of trading could be accomplished under the “bubble” provisions of Article 4. Countries participating in the international early reductions trading program could agree upfront that at the end of the early reductions period they will modify their obligations under Annex B based on the early reductions trades that have taken place. The rules and guidelines for emissions trading called for by Article 17 need not be defined as a prerequisite for an early reductions trading market; in fact, as noted earlier, the experience gained from the international early reductions program could inform the UNFCCC rulemaking process.

**NATIONAL BUREAU OF ECONOMIC RESEARCH, INC.
SUMMER INSTITUTE 1998**

**Workshop on Public Policy and the Environment
Don Fullerton and Lawrence Goulder, Organizers**

Royal Sonesta Hotel
5 Cambridge Parkway
Cambridge, Massachusetts

August 3-4, 1998

PROGRAM

MONDAY, AUGUST 3

8:00 AM Coffee and Doughnuts

8:20 AM Welcome and Introductions

8:30 AM **ENVIRONMENTAL REGULATION AND TECHNOLOGICAL CHANGE**

WINSTON HARRINGTON, RAY KOPP, RICHARD MORGENSTERN, WILLIAM
PIZER and JHIH-SHIANG SHIH, Resources for the Future
*The Diffusion of New Technologies: A Microeconomic Analysis of Firm
Decisionmaking at the Plant Level*

Discussant: WAYNE GRAY, Clark University and NBER

CAROLYN FISCHER, IAN PARRY, WILLIAM PIZER and MICHAEL TOMAN,
Resources for the Future
*Instrument Choice for Environmental Protection When Technological Change Is
Endogenous: Analytical and Empirical Results*

Discussant: RAYMOND PRINCE, U.S. Department of Energy

DAVID POPP, University of Kansas
The Effect of New Technology on Energy Consumption

Discussant: KEVIN HASSETT, American Enterprise Institute

10:45 AM Coffee Break

11:00 AM RESEARCH SKETCHES (2-5 minute presentations)

- 12:00 PM Lunch
- 1:00 PM ELENA IRWIN AND NANCY BOCKSTAEL, University of Maryland
Interacting Agents, Spatial Externalities, and the Endogenous Evolution of Land Use Patterns

Discussant: A. MYRICK FREEMAN, Bowdoin College
- 1:45 PM GEOFFREY HEAL, Columbia University and NBER
Environmental Degradation and the Measurement of National Income

Discussant: MARTIN WEITZMAN, Harvard University
- 2:30 PM Coffee Break
- 3:00 PM LISANDRO ABREGO, University of Warwick, and JOHN WHALLEY,
Universities of Western Ontario and Warwick and NBER
Labor Mobility and the Costs of Environmental Damage

Discussant: MATTHEW KAHN, Columbia University
- 3:45 PM SCOTT BARRETT and KATHRYN GRADDY, London Business School
Freedom, Growth, and the Environment

Discussant: DAVID KELLY, UC Santa Barbara
- 4:30 PM Coffee Break
- 4:45 PM JANUSZ MROZEK, Georgia Institute of Technology, and LAURA OSBORNE
TAYLOR, Georgia State University
Estimating Risk Premia in the Workplace: What Have We Learned?

Discussant: JAMES HAMMITT, Harvard University
- 5:30 PM Adjourn
- 6:00 PM Group Dinner

TUESDAY, AUGUST 4

- 8:30 AM INTERNATIONAL POLICIES TO ADDRESS CLIMATE-CHANGE AND OTHER
ENVIRONMENTAL PROBLEMS

WARWICK McKIBBIN, Australian National University and the Brookings
Institution, ROBERT SHACKLETON, U.S. EPA, and PETER WILCOXEN,

University of Texas and the Brookings Institution
What to Expect from an International System of Tradable Permits for Carbon Emissions

Discussant: RICHARD COOPER, Harvard University

ZILI YANG, MIT
Incentive Compatible Coalitions in International Agreements on CO₂ Emission Controls

Discussant: CHARLES KOLSTAD, UC Santa Barbara

STEF PROOST and DENISE VAN REGEMORTER, Catholic University, Leuven
Equitable and Efficient Allocation of Air Pollution in a Federation

Discussant: LAWRENCE H. GOULDER, Stanford University and NBER

10:45 AM Coffee Break

11:15 AM PANEL DISCUSSION: FROM KYOTO TO BUENOS AIRES — ECONOMIC PERSPECTIVES ON THE NEXT STEPS IN GLOBAL CLIMATE POLICY

Moderator: ROBERT STAVINS, Harvard University

Panelists: JEFFREY FRANKEL, President's Council of Economic Advisors;
JONATHAN GRUBER, U.S. Department of the Treasury; MARK MAZUR, U.S.
Department of Energy; VICTORIA GREENFIELD, U.S. Department of State

12:15 PM Lunch

1:15 PM LANS BOVENBERG AND GILBERT van HAGEN, Tilburg University
Environmental Cost-Benefit Analysis in a Second-Best World

Discussant: LOUIS KAPLOW, Harvard University and NBER

2:00 PM EDUARDO LEY, FEDEA Madrid, MOLLY MACAULEY, Resources for the
Future, and STEPHEN SALANT, University of Michigan
*Spatially and Intertemporally Efficient Waste Management: The Costs of
Interstate Flow Control*

Discussant: ARIK LEVINSON, University of Wisconsin and NBER

2:45 PM Coffee Break

3:15 PM RAMANAN LAXMINARAYAN and GARDNER BROWN, University of
Washington
The Economics of Antibiotic Resistance

Discussant: TALBOT PAGE, Brown University

4:00 PM MARTIN WEITZMAN, Harvard University
 Gamma Discounting for Global Warming

Discussant: MAUREEN CROPPER, University of Maryland and The World Bank

4:45 PM Adjourn

**White House Climate Change Task Force**

734 Jackson Place, N.W. • Washington, DC 20503

cc: JY
JA
SP
QF**FACSIMILE TRANSMISSION SHEET**

To	See Included List	From	Jim Rubin
Office		Date	8-26-98
Fax Number		Fax Number	395-2311
Office Number		Office Number	395-2310

Comments:

For your information, enclosed are drafts of 1) the revised options memorandum on allocations of risk and 2) a cover memorandum on strategy. These were provided to Todd Stern for preparation of an oversight meeting early next week.

Pages: 11, including this cover sheet.

IF TRANSMITTAL IS INCOMPLETE, PLEASE PHONE

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OMB	Jennifer Haverkamp	395-4579	395-7320
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USDA	Joe Glauber	720-6185	690-4915
	Margot Anderson	690-4915	720-6186
	Dan Reicher	586-9260	586-9220
DOE	Mark Mazur	586-9626	586-7700
	David Doniger	260-5155	260-2865
EPA	David Gardiner	260-0275	260-4332
	Bill White	260-4852	260-4724
	John Lieber	366-7127	366-4544
DOT	Pete Jordan	456-9500	456-9513
OVP	Dirk Forrister	395-2311	395-2310
CCTF	David Hales	216-3174	712-1750
USAID	Ed Montgomery	219-4902	219-5108
DOL	Sherri Goodman	703-693-7011	703-695-6639
DOD	David Weisman	703-614-1158	703-697-1887
	Bill Antholis	456-5334	456-2198
NEC	David Sandalow	456-2710	456-6224
CEQ/NSC			

Addressing the risk of overselling in international emissions trading

Issue for Decision: How to address the risk that a party may oversell emissions permits, and fail to retain enough assigned amount to cover its own emissions?

I. Background

In proposing trading rules, the US has attempted to strike a balance between economic efficiency and incentives for compliance. An efficient market in emissions permits will help keep costs down. Incentives for compliance are needed to achieve our environmental objectives. The agencies have come to agreement on most aspects of trading rules, but have not yet agreed on the proper allocation of the risk of overselling.

The US has several objectives in crafting rules for emission trading. Trading rules should create an economically efficient market. In addition, they should help achieve the Kyoto targets, should create an incentive for compliance, and should encourage participation by the FSU and prospective new entrants from the developing world.

The EU and environmental groups are concerned about overselling, especially by Russia and Ukraine. They fear that these countries will oversell their allotments early in the 5-year compliance period (2008-2012), and cite weak compliance and regulatory regimes in these countries. They believe that trading rules should contain additional incentives for compliance.

Others, including potential market participants, are concerned that some compliance incentives could hobble the nascent market in tradable permits. They believe that trading rules should focus, above all else, on facilitating development of the new market.

Recognizing that there are limited levers in traditional international law to compel Party compliance, the US has supported including positive incentives for compliance within the trading rules, where that can be done without significantly burdening efficient market function. Specifically, before Kyoto the US proposed including two compliance provisions in trading rules:

- A Party not complying with its measurement and reporting obligations would lose its eligibility to engage in further emissions trading, until it has remedied the problem.
- A Party that has run out of assigned amount during the 5-year commitment period would lose its eligibility to make further sales (although it would still be able to buy), so long as it remains in deficit.

The linkage between monitoring and reporting obligations and trading eligibility is broadly supported within the Umbrella Group, as well as by the EU. The "empty tank" rule, however, is not seen by the EU as an effective way to block large-scale over-selling early in the 5-year period. Concern over this possibility led the EU to propose buyer liability. Other than our previously

proposed compliance provisions (described above), the US has not yet announced a position on liability or advanced additional proposals to address the risk of over-selling.

II. Options

1) Seller bears the risk. If the selling party does not possess enough assigned amount to cover its emissions at the end of the period, the excess, with a penalty, would be deducted from its assigned amount for the next budget period. The party might also be subject to restrictions on sales in the second period. Buyers are responsible for ensuring that they obtain clear title to any permits purchased, but are not subject to the risk that permits will be recalled or devalued. Permits already sold remain the property of the buyer.

Benefits: Simplest and most efficient, because transaction costs are lowest. Buyers would be certain of the face value of any permits bought, and permits would be interchangeable. Buyers need not assess the risk of the selling Party's ultimate compliance. Loss of trading eligibility and repayment requirements provide incentive for compliance.

Downsides: Significant risk of overselling and excess emissions. Compliance incentives depend on Parties' commitment to participate in the global climate change treaty over the long haul. Loss of trading eligibility and repayment requirements alone may not be sufficient to prevent overselling by a government that seeks a short-term financial bonus. In this case, excess emissions may never be repaid.

2) Buyer bears the risk. If the selling Party does not possess enough assigned amount to cover its emissions at the end of the period, emissions permits that it had previously sold would be taken back from buyers and applied to cover the shortfall. The last permits sold would be the first ones returned (LIFO). Permits would differ in risk (and price) according to the original seller. Buyers, who would be on notice of these rules from the start, would have to assess the risks of a Party's non-compliance. Buyers might manage risks in several ways: by discounting prices paid, creating a portfolio of permits from different Parties and of different vintages; by making contracts contingent on compliance of the selling Party; or by buying options or taking other offsetting positions.

Benefits: Creates strongest protection against overselling. Uses market mechanisms to promote environmental objectives. A Party at risk of having excess emissions will receive lower prices for its permits; this creates a financial incentive to comply. Excess emissions are automatically covered, up to the extent of prior sales.

Downsides: Likely to increase costs. Likely to impede development of trading. Would require private sector buyers to assess and manage the likelihood of selling Parties' eventual non-compliance. Market tools for doing so efficiently could develop over time, but are not likely to exist at first; this could impose a significant burden on the nascent

emissions trading market. Concerns about market development could make US ratification more difficult.

Options (3), (4), and (5) are intended to offer more protection against overselling than "seller bears the risk," and less burden on the trading market than "buyer bears the risk."

(3) Seller bears the risk, cap on sales. To address large-scale overselling, a simple cap could be set on any Party's permit sales prior to the end of the budget period, based on the countries presenting the greatest concern. For example, the Administration's economic modelling suggests that Russia and the Ukraine will need approximately 70% of their assigned amounts to cover their own emissions. A Party could be limited to selling no more than 20% of its budget before the end of the budget period (the 10% difference representing a compliance reserve margin). Any portion of the remainder could be sold at or near the end of the five-year period if not needed to cover the Party's emissions.

A cap could be based on other formulations as well, such as percentage of allocation. For example, if a country had net sales greater than 1/5 of its allocation, then it could not sell any more, unless and until data showed that the country had cumulatively paid back this amount of overage (through any combination of emission reductions and permit purchases). At a given time, overage is defined as the difference: (net sales plus measured emissions) minus (the number of allocated permits, times the fraction of the budget period elapsed through the date to which the emissions data pertain).

Benefits: Trading takes place with low transaction costs because buyers do not bear the risks of sellers' non-compliance. Cap limits potential overselling, compared to option (1).

Downsides: Although caps limit overselling, they do not prevent it. Proposing a cap to address overselling may be inconsistent with our opposition to the EU-proposed caps on amounts parties may purchase or sell (supplementarity and "hot air" restrictions). (This drawback is addressed under option (5) below.) With respect to the second variation, it is unclear how these options would work where parties to the Protocol devolve emissions permits to firms, as an individual firm's right to sell would depend on whether prior sales by other firms had reached the national cap. This option requires detailed data on both spot and forward trades, as well as emissions, data that the central government may not have. Additional difficulty is introduced when a country is both a buyer and a seller. This option reintroduces some annualization into the multi-year budget format. The option is complicated to explain both in negotiations and in our domestic arenas.

(4) Seller bears the risk, with reserve account. To address smaller-scale overselling, sellers could be required to set aside a specified percentage (perhaps 10 percent or 20 percent) of the total sold. These permits could be sold at or near the end of the five-year period, if they were not needed to cover the selling Party's emissions. Until then, they would serve as a compliance reserve against possible excess emissions.

Benefits: Low transaction costs, as in option (3). Useful to address modest overselling (due to an unexpected surge in emissions, for example, intentional gross overselling). Compliance reserve grows with volume of permit sales. Reserve margin offers more protection against overselling than option (1).

Downsides: Protection against overselling is still incomplete for any percentage set aside less than 100%. Permit prices may rise in the early years because fewer permits would be available for sale, until they are released at the end when prices may drop. The higher the percentage set aside, the greater this effect.

(5) Seller/buyer hybrids. Options (3) and (4) can be reformulated to avoid caps. In the example in option (3), for example, sale of permits above the 20% level could be allowed under the condition of buyer liability. In other words, most permits would trade without any contingencies, but sales of the permits above the 20% level (in this example) would be subject to the risk of being recalled and returned to the seller Party to cover a shortfall at the end of the period. The same approach could be used in option (4), allowing sales of permits in the compliance reserve under buyer liability.

Benefits: Provides more protection against overselling than options (3) and (4), because sales above the cap are subject to recall against seller's excess emissions. All permits are allowed to go to market; most trade on basis of seller liability without contingencies, while buyer liability is focused where most pertinent to compliance risk. May provide selling parties with more incentives for compliance, since a price signal reflecting the party's compliance risk will be created for the permits in the compliance reserve. Avoids proposal at cross-purposes to our opposition to caps.

Downsides: Same as option (2), except that potential burdens on the market are limited to only those permits trading under buyer liability.

III. Positions of US interest groups and other parties

The following picture emerges from a series of stakeholder meetings coordinated by the White House Climate Change Task Force:

- Most private sector potential buyers and brokers expressed a strong preference for avoiding buyer liability. They generally agreed that the market could accommodate a buyer liability scheme, but at a significant cost.
- A minority of potential buyers and brokers said buyer liability would be workable.
- Environmental organizations generally prefer buyer liability, although several proposed hybrid options.

- All parties consulted agreed that the issue of overselling should be addressed.

Among the Parties:

- Other buyer members of the Umbrella Group generally favor "seller bears the risk."
- Russia and the Ukraine have endorsed Umbrella Group proposals to date. They are eager to get trading underway in order to begin realizing revenue. They have acknowledged the need to build up their monitoring and regulatory capacity and are looking to trading revenue as a source of funds for such efforts. They have not yet been engaged in detailed consideration on liability or the risk of overselling.
- The EU currently favors buyer liability but has recognized problems such as the potential domino effect on compliance. The EU probably supports the idea that excess emissions must be deducted from the second period, as in "seller bears the risk," but does not feel this is adequate to address overselling. Option (5) may also appeal to the EU as a means for both sides to get some of what they want.

Strategy for Addressing the Risk of Over-Selling (Liability) in International Emissions Trading

Issue for Decision: What strategy to follow in pre-Buenos Aires meetings on how to address the risk of over-selling (liability) in the rules for international emissions trading. A decision is needed by September 2.

Background

The attached paper concerns one issue related to international emissions trading on which the US has not yet taken a position: How should trading rules address the risk that a Party will "over-sell" emission permits and fail to retain a sufficient emissions budget ("assigned amount") to cover its emissions at the end of the five-year period? This issue is commonly framed as the question of "seller or buyer liability." A solution to this problem has to strike a balance between economic efficiency and incentives for compliance.

Concerns tend to focus on the potential for large-scale over-selling by Russia and the Ukraine, which currently have limited emissions monitoring and reporting capabilities and weak domestic regulatory regimes, and which many fear are most susceptible to trading off long-term compliance for short-term financial gain. However, the risk of over-selling is not exclusive to these countries, and potential solutions have implications for all Annex I countries.

The attached paper lists options which range from seller liability (with deduction of excess sales from the seller's second budget) to buyer liability. *There is an emerging consensus among the agencies that, as an end result, a middle ground option -- one that starts with seller liability and addresses over-selling either by stopping permit sales above a given level, or by shifting from seller to buyer liability when that level of permit sales has been reached -- may prove acceptable.*

If the oversight group agrees with this consensus, we face an immediate strategy decision, as described below.

Immediate Strategy Decision

The over-selling issue will be on the agenda of back-to-back meetings of the Umbrella Group in New Zealand (September 7-8) and the Annex I Experts Group in Paris (September 10-11). The issue for decision now is what strategy to follow in these talks and in subsequent meetings leading up to Buenos Aires. Broadly speaking, there are two options:

- (1) Advocate "seller liability" for now, reserving compromise on this issue as a bargaining chip to press the EU to drop its demands on complementarity and "hot air."
- (2) Initiate discussions on middle ground proposals with the Umbrella Group and the Annex I Experts Group, in order to promote more constructive dialogue on trading issues.

Discussion: In G-8 workgroup discussions in July, the Umbrella and EU sides agreed that even though they have deep differences on the highly-charged political issues of supplementarity and "hot air," both sides have a stake in showing some progress on trading and the other flexibility mechanisms at Buenos Aires. The G-8 workgroup agreed that a realistic goal for COP-4 at Buenos Aires is to reach Annex I-wide agreement on a number of mostly technical trading issues (e.g., emissions monitoring and reporting methods, systems for tracking transfers, procedures for participation by legal entities) and to obtain a COP decision on a work plan and schedule for resolving the remaining issues by COP-5.

Regarding the over-selling/liability issue, the question is whether this issue is best addressed early, or reserved for the end-game on supplementarity and hot air.

Options

(1) Advocate "seller liability" for now, reserving compromise on this issue as a bargaining chip to press the EU to drop its demands on supplementarity and "hot air."

Pros:

- While the Umbrella Group said in Bonn that it has no position on liability yet, "seller bears the risk" is implicit in prior papers and has been supported by some Umbrella countries.
- Tactically, "seller bears the risk" appears most consistent with our overall approach of no limits on trading.
- Position allows for future compromise when issues of supplementarity and hot air are joined in earnest.

Cons:

- Leaves us with a relatively weak answer to concerns of EU and environmentalists regarding risk of large-scale over-selling.
- Taking hard line now risks further politicizing this issue and hardening positions. Could make it harder to achieve progress at Buenos Aires on technical issues or to reach agreement on a schedule and work plan for adopting the rules.
- May make it hard to change our approach later. In particular, the Umbrella Group will need a credible answer on this issue if it should choose to initiate a trading group under its own trading rules.

(2) Initiate discussions on middle ground proposals with the Umbrella Group and the Annex I Experts Group, in order to promote more constructive dialogue on trading issues.

Pros:

- Allows us to work within the Umbrella Group towards a solution to this issue, rather than hardening Umbrella country views around a position that later will have to change.
- Similarly, allows us to work with EU and others (G-77, environmental NGOs) to meet a strongly held concern. Avoids politicizing another big issue and fueling broader feelings of opposition to trading. "Seller/buyer" hybrid (option 5) could appeal to EU and allow both sides the perception that they got what they wanted.
- Could help meet EU concerns over compliance that currently are manifesting themselves in the form of unacceptable demands to adopt Article 18 non-compliance rules before Article 17 trading may begin.¹
- Would allow movement towards Annex I-wide agreement at Buenos Aires on trading issues other than EU restrictions on supplementarity and "hot air." Would promote atmosphere for agreement by EU and G-77 to a concrete work plan and schedule for completing trading rules.

Cons:

- Resolving this issue at Buenos Aires would eliminate it as a bargaining chip over supplementarity and hot air restrictions.
- There is still some uncertainty among agencies over which option is best (although initial discussion of the middle ground options could be kept general enough to elicit reaction and allow more domestic discussion before a final choice must be made).
- "Seller liability with cap on sales" (option 3) could be seen as inconsistent with our opposition to EU-proposed caps on supplementarity and hot air.
- Would require getting consensus of Umbrella Group (both buyers and sellers). Some now favor seller liability. Others (Russia and Ukraine, in particular) may not have engaged deeply on this issue yet.

¹ The EU has argued for adopting binding compliance consequences under Article 18 before trading may commence under Article 17. Since Article 18 requires an amendment of the Protocol, this approach would introduce a major delay. The US and its Umbrella partners have sought instead to include important compliance provisions in the Article 17 trading rules themselves. Some progress in moving the EU towards our view was made at the G-8 discussion group in July. Since the EU is especially fearful of over-selling by Russia and the Ukraine, an effective response to that risk now could help get the EU off the Article 18 soap box.

Timing and Next Steps

Although we have conducted extensive discussions with stakeholders about the general seller and buyer options, we have not described middle ground options in great detail. If we are to seriously pursue one of these alternatives, it would be important to consult briefly with stakeholders to gauge their support or opposition. Such consultations would need to be done in advance of the Umbrella Group and Annex I Experts Group meetings, or sometime around September 3rd or 4th. Hence, we would need a decision on strategy by September 2.

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Note to Distribution

From David Doniger

August 27, 1998

Attached is a revised paper on national registry systems. As you will recall, this paper is based on the experience with the acid rain tracking system and on a number of interagency discussions earlier this year. The earlier paper was cleared in May for distribution to the Umbrella Group.

The recent consultations with stakeholders included discussion on the subject of accounting for the trade in GHG permits. We received generally positive reaction to a using the acid rain tracking system as the model for an international system.

I am sending this paper around for discussion and clearance at tomorrow's meeting at State (2-3PM) for two reasons. First, a clear understanding of the functioning of registries will help answer some questions raised in the context of the liability discussions. Second, registry issues will be on the agenda of the Annex I Experts Group meeting September 10-11. We indicated at the G-8 workgroup meeting that this was an area in which agreement was most readily reachable, and that we had ideas to bring forward. It will be extremely useful to be able to work on the basis of this paper at the AIXG meeting.

National Registries

Article 17 of the Kyoto Protocol provides that each Annex B Party may transfer any part of its assigned amount (its target) to any other Annex B Party. Under Article 3, such transfers are added to or subtracted from the Parties' original assigned amounts.

To assure transparency, promote compliance, and build confidence in emissions trading, trading rules under Article 17 should require each trading Party to maintain a *national registry* to record its international transactions and to report them periodically to the Secretariat. The Secretariat can then synthesize this information into an aggregate picture for several important purposes: (1) to compile and cross-check data on Parties' transfers and acquisitions; (2) to track trade-related changes in Parties' assigned amounts; and (3) to make the resulting balance (increased or decreased by international trading) available for compliance determinations and public disclosure at the end of the compliance period. Parties may also choose to consolidate their national registries for ease of administration.

This paper provides background on key design issues for national registries. It addresses how information in national registries can be reported to and synthesized by the Secretariat. On the basis of this background, simple rules for national registries and supplemental reporting can be developed for early agreement.

1. Q: Why require national registries?

A: National registries are needed for several important reasons. First, each of the Annex B Parties will need a registry to keep an official record of increases and decreases in its assigned amount due to emissions trading, and to report on such changes to the Secretariat. Second, registries can play a key role in facilitating emissions trading. National registries can be used by a Selling Party to prove that it or one of its legal entities actually possesses, and has the right to transfer, the part of an assigned amount (hereafter called a "tradeable unit") that it offers for sale. Likewise, registries can be used to record and confirm the transfer of tradeable units from a seller to a buyer. Third, national registries (together with monitoring and reporting pursuant to Articles 5 and 7) can provide compliance data at the end of the commitment period.

2. Q: What is traded?

A: Like the targets themselves, transfers or acquisitions under Article 17 should be counted in tonnes of carbon dioxide equivalent. The unit of trade could be defined as one tonne of carbon dioxide equivalent, or another agreed amount (100 or 1000 tonnes). Each tradeable unit should be identified by its nation of origin and the commitment period for which it was issued. Each tradeable unit should also carry a unique serial number (e.g., NZ1-001, US1-005, etc.).

3. Q: What ministry or agency should maintain each Party's national registry?

A: Each Party should identify a single government ministry or agency which is responsible for accounting for the Party's assigned amount. That ministry or agency would be

responsible for maintaining that Party's national registry containing, in a computer database, all of its tradeable units. The registry would show increases or decreases in the size of the Party's assigned amount as a result of trading. It would also record what tradeable units have been acquired from or transferred to other Parties as the result of trading.

4. Q: What information should national registries contain?

A: That depends on whether a Party retains possession of its assigned amount (and the authority to make international trades) at the national level, or whether it devolves possession and trading authority to legal entities (e.g., private sector firms). If the Party retains possession and trading authority at the national level, then its registry should identify the designated ministry or agency and the tradeable units that it holds. When an international sale is made between two such Parties, it would be carried out by moving tradeable units from the registry of the selling Party to the registry of the buying Party.

If a Party chooses to devolve possession and trading authority to legal entities, then its national registry should contain a separate account for each legal entity that holds tradeable units, identifying the units it holds. Prospective buyers would use registry account information to identify *bona fide* sellers (i.e., to verify that sellers actually hold the tradeable units they are offering to sell). When an international sale is made between legal entities of different Parties, it would be carried out by moving tradeable units from the account of the selling entity in the registry of one Party, to the account of the buying entity in the registry of the other Party.

Registries would also accommodate transfers between the government of one Party and a legal entity in another Party. Parties that choose to implement domestic emissions trading could use the same system to facilitate and keep track of transfers between domestic legal entities.

To promote provide transparency and efficient emissions trading, the rules should provide that account information (the number and serial identifier of tradeable units held in each account) shall be available to the public. Price information need not be reported in the registries for individual transactions; average prices will be revealed by private sector exchanges and brokerage services.

5. Q: Should registries be paper ledgers or computer databases?

A: Given the huge volume of data to be handled and the wide availability and low cost of modern computer technology, national registries should be kept in the form of electronic databases. In order to facilitate international reporting as well as an efficient marketplace, the electronic registries should be built on a compatible design. With compatible electronic registries, both domestic and international transfers can be carried out at low cost and almost instantaneously.

6. Q: Is there any need for paper certificates for tradeable units?

A: With electronic registries there would be no need for Parties to issue paper certificates for tradeable units. Paper certificates can be counterfeited, stolen, or lost, imposing costs on both

governmental bodies and entities to replace lost certificates, adjudicate conflicting claims, and insure against losses. Electronic account systems can give both the Parties and the private sector greater security and lower transaction costs. (The U.S. acid rain program uses an electronic registry system of this kind, with no paper certificates.)

7. Q: Should registries use serial numbers to identify individual tradeable units?

A: Identifying each tradable unit with a serial number would provide both governments and legal entities with increased certainty for transfers of tradeable units. Serial numbers could be used to prevent a given tradeable unit from being transferred by one seller to more than one buyer, whether by mistake or fraudulently.

8. Q: When should Party's registries be updated to reflect an international trade?

A: As explained earlier, transfers and acquisitions would be carried out by removing tradeable units from an account in one Party's registry and adding them to an account in another Party's registry. In order to facilitate an efficient, smoothly working market, it will be desirable to make such removals and additions on a near-real time basis. (The U.S. acid rain program makes such adjustments in registry accounts within two days.)

9. Q: Can Parties or other entities make private contracts for trades without changing their registries?

A: Buyers and sellers (including governments) could make a wide variety of contractual arrangements regarding future trades (e.g., agreements to transfer or acquire in the future). Rules under Article 17 would not need to address these contractual matters. International trades would be officially recognized and completed, however, only when tradeable units are removed from one Party's national registry and added to another's.

10. Q: Could a legal entity from one Party hold an account in the registry of another Party?

A: Parties may choose to allow foreign entities to maintain accounts in their registries. Thus, a multi-national company or a private broker might maintain holdings in the registries of several Parties. Likewise, a broker located in a non-Annex B country could have an account in the registry of an Annex B Party, at the Annex B Party's discretion.

11. Q: What information should be reported to the Secretariat, and how frequently?

A: Rules under Articles 7 and 17 should require each Party to report the results of its transfers and acquisitions of tradeable units at least on an annual basis, together with the Party's annual emissions inventory. Reports should indicate the amount, country of origin, commitment period, and serial numbers of tradeable units transferred to or acquired from each other Party. On the basis of these reports, the Secretariat can compile a synthesis report showing the trading activity among the Parties, keeping track of the location of all tradeable units, and showing the size of each Party's assigned amount, as adjusted by trading. The rules should provide that the contents of these syntheses reports are public information.

There may be advantages to more frequent reporting to the Secretariat. For example, any discrepancies between national registries would be identified earlier and could be resolved in a more timely manner.

Since Party-level information is all that is required to implement the Protocol, there would be no need for the Secretariat to receive information on the names of any private firms or other entities involved in transfers or acquisitions. Likewise, the details of trades between domestic entities within an Annex B Party would not need to be reported to the Secretariat. International reports also need not include price information, because average prices will be available through private sector exchanges and brokerage services.

12. Q: How can Parties use registry information for compliance purposes?

A: Each Annex B Party has the obligation to hold enough assigned amount at the end of the five-year commitment period to cover its net emissions during that period. As discussed under question 11, the rules should require each Party to report to the Secretariat annually on its holdings of assigned amount, as adjusted by emissions trading, in conjunction with its annual emissions reporting. Reports at the end of the fifth year of the commitment period would show Parties' five-year balances of emissions and assigned amount and would serve as the starting point for compliance determinations.

If a Party chooses to use emissions trading domestically, it will need to identify a set of legal entities who are required to hold enough tradeable units to cover their own emissions. These entities could be required to report on their emissions annually, and to surrender back to their government enough tradeable units each year to cover those emissions. The ministry or agency responsible for the national registry would then label those tradeable units as "used" or "consumed." (Those units would then be taken out of circulation and could not be used again, nor could they be transferred by either the legal entity or the government.) From these entity reports, the Party could determine and report to the Secretariat how much assigned amount it has used or consumed to that point. The registries would then contain information on tradeable units that remain available to be used against future emissions, or to be traded.

It should be noted that a Party that chooses to devolve tradeable units will not be able to know for certain whether the legal entities that hold those units intend to keep them to cover emissions in that country, or whether they intend to trade the units for use against emissions in another country. Thus, the balance remaining in a Party's registry can provide only an indication of how much assigned amount is left to be used. Parties have other means, however, to assure themselves that their entities will hold enough tradeable units at the end of the period to cover their emissions. The U.S. acid rain program, for instance, imposes an expensive penalty (10 to 20 times the market price of a tradeable unit) on any firm that does not have enough permits to cover its emissions at the end of the compliance period. Since the penalty is so much greater than the market price of the needed permits, firms choose to buy the permits rather than be in non-compliance. To date, not one U.S. firm has failed to hold the amount needed to cover its emissions.

13. Q: Could Parties choose to consolidate their national registries?

A: Some Parties may prefer to voluntarily consolidate their national registries with others in order to achieve cost savings and easier administration. The participating Parties' registries would then exist as distinct accounts in a single computer system, rather than as two or more separate systems. Making an international emissions trade then would require nothing more than moving tradeable units from one Party's account to another Party's account within the same electronic database. Parties might find this to be simpler than removing tradeable units from one country's computer system and entering them into another's. Such consolidation, however, would remain entirely voluntary.



United States Department of State

*Bureau of Oceans and International
Environmental and Scientific Affairs*

Washington, D.C. 20520

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August 26, 1998

TO: DISTRIBUTION

FROM: OES – Melinda Kimble *MLK*

SUBJECT: Meeting on Emissions Trading/Liability
FRIDAY, AUGUST 28, 2:00 P.M., MAIN STATE ROOM 7835

In preparation for the meetings in New Zealand (the Umbrella Group) and Paris (the Annex I Experts Group, AIXG), it is becoming important to more precisely resolve the US position on emissions trading "liability". Given the hectic travel schedules of all, the only time for such a session seems to be on Friday, August 28, from 2-3 p.m. We will hold the session in the OES conference Room (Main State Room 7835); the discussion will be based on the draft paper prepared by EPA and Treasury, and attached. Please call Lilly Roots Wiggins at 647-1554 for clearance into the building. I look forward to seeing you then.

Strategy for Addressing the Risk of Over-Selling (Liability) in International Emissions Trading

Issue for Decision: What strategy to follow in pre-Buenos Aires meetings on how to address the risk of over-selling (liability) in the rules for international emissions trading. A decision is needed by September 4.

Background

The attached paper concerns one issue related to international emissions trading on which the US has not yet taken a position: How should trading rules address the risk that a Party will "over-sell" emission permits and fail to retain a sufficient emissions budget ("assigned amount") to cover its emissions at the end of the five-year period? This issue is commonly framed as the question of "seller or buyer liability." A solution to this problem has to strike a balance between economic efficiency and incentives for compliance.

Concerns tend to focus on the potential for large-scale over-selling by Russia and the Ukraine, which currently have limited emissions monitoring and reporting capabilities and weak domestic regulatory regimes, and which many fear are most susceptible to trading off long-term compliance for short-term financial gain. However, the risk of over-selling is not exclusive to these countries, and potential solutions have implications for all Annex I countries.

The attached paper lists options which range from seller liability (with deduction of excess sales from the seller's second budget) to buyer liability. *There is an emerging consensus among the agencies that, as an end result, a middle ground option -- one that starts with seller liability and addresses over-selling either by stopping permit sales above a given level, or by shifting from seller to buyer liability when that level of permit sales has been reached -- may prove acceptable.*

If the oversight group agrees with this consensus, we face an immediate strategy decision, as described below.

Immediate Strategy Decision

The over-selling issue will be on the agenda of back-to-back meetings of the Umbrella Group in New Zealand (September 7-8) and the Annex I Experts Group in Paris (September 10-11). The issue for decision now is what strategy to follow in these talks and in subsequent meetings leading up to Buenos Aires. Broadly speaking, there are two options:

- (1) Advocate "seller liability" for now, reserving compromise on this issue as a bargaining chip to press the EU to drop its demands on supplementarity and "hot air."
- (2) Initiate discussions on middle ground proposals with the Umbrella Group and the Annex I Experts Group, in order to promote more constructive dialogue on trading issues.

Discussion: In G-8 workgroup discussions in July, the Umbrella and EU sides agreed that even though they have deep differences on the highly-charged political issues of supplementarity and "hot air," both sides have a stake in showing some progress on trading and the other flexibility mechanisms at Buenos Aires. The G-8 workgroup agreed that a realistic goal for COP-4 at Buenos Aires is to reach Annex I-wide agreement on a number of mostly technical trading issues (e.g., emissions monitoring and reporting methods, systems for tracking transfers, procedures for participation by legal entities) and to obtain a COP decision on a work plan and schedule for resolving the remaining issues by COP-5.

Regarding the over-selling/liability issue, the question is whether this issue is best addressed early, or reserved for the end-game on supplementarity and hot air.

Options

(1) Advocate "seller liability" for now, reserving compromise on this issue as a bargaining chip to press the EU to drop its demands on supplementarity and "hot air."

Pros:

- While the Umbrella Group said in Bonn that it has no position on liability yet, "seller bears the risk" is implicit in prior papers and has been supported by some Umbrella countries.
- Tactically, "seller bears the risk" appears most consistent with our overall approach of no limits on trading.
- Position allows for future compromise when issues of supplementarity and hot air are joined in earnest.

Cons:

- Leaves us with a relatively weak answer to concerns of EU and environmentalists regarding risk of large-scale over-selling.
- Taking hard line now risks further politicizing this issue and hardening positions. Could make it harder to achieve progress at Buenos Aires on technical issues or to reach agreement on a schedule and work plan for adopting the rules.
- May make it hard to change our approach later. In particular, the Umbrella Group will need a credible answer on this issue if it should choose to initiate a trading group under its own trading rules.

(2) Initiate discussions on middle ground proposals with the Umbrella Group and the Annex I Experts Group, in order to promote more constructive dialogue on trading issues.

Pros:

- Allows us to work within the Umbrella Group towards a solution to this issue, rather than hardening Umbrella country views around a position that later will have to change.
- Similarly, allows us to work with EU and others (G-77, environmental NGOs) to meet a strongly held concern. Avoids politicizing another big issue and fueling broader feelings of opposition to trading. "Seller/buyer" hybrid (option 5) could appeal to EU and allow both sides the perception that they got what they wanted.
- Could help meet EU concerns over compliance that currently are manifesting themselves in the form of unacceptable demands to adopt Article 18 non-compliance rules before Article 17 trading may begin.¹
- Would allow movement towards Annex I-wide agreement at Buenos Aires on trading issues other than EU restrictions on supplementarity and "hot air." Would promote atmosphere for agreement by EU and G-77 to a concrete work plan and schedule for completing trading rules.

Cons:

- Resolving this issue at Buenos Aires would eliminate it as a bargaining chip over supplementarity and hot air restrictions.
- There is still some uncertainty among agencies over which option is best (although initial discussion of the middle ground options could be kept general enough to elicit reaction and allow more domestic discussion before a final choice must be made).
- "Seller liability with cap on sales" (option 3) could be seen as inconsistent with our opposition to EU-proposed caps on supplementarity and hot air.
- Would require getting consensus of Umbrella Group (both buyers and sellers). Some now favor seller liability. Others (Russia and Ukraine, in particular) may not have engaged deeply on this issue yet.

¹ The EU has argued for adopting binding compliance consequences under Article 18 before trading may commence under Article 17. Since Article 18 requires an amendment of the Protocol, this approach would introduce a major delay. The US and its Umbrella partners have sought instead to include important compliance provisions in the Article 17 trading rules themselves. Some progress in moving the EU towards our view was made at the G-8 discussion group in July. Since the EU is especially fearful of over-selling by Russia and the Ukraine, an effective response to that risk now could help get the EU off the Article 18 soap box.

Addressing the risk of overselling in international emissions trading

Issue for Decision: How to address the risk that a party may oversell emissions permits, and fail to retain enough assigned amount to cover its own emissions?

I. Background

In proposing trading rules, the US has attempted to strike a balance between economic efficiency and incentives for compliance. An efficient market in emissions permits will help keep costs down. Incentives for compliance are needed to achieve our environmental objectives. The agencies have come to agreement on most aspects of trading rules, but have not yet agreed on the proper allocation of the risk of overselling.

The US has several objectives in crafting rules for emission trading. Trading rules should create an economically efficient market. In addition, they should help achieve the Kyoto targets, should create an incentive for compliance, and should encourage participation by the FSU and prospective new entrants from the developing world.

The EU and environmental groups are concerned about overselling, especially by Russia and Ukraine. They fear that these countries will oversell their allotments early in the 5-year compliance period (2008-2012), and cite weak compliance and regulatory regimes in these countries. They believe that trading rules should contain additional incentives for compliance.

Others, including potential market participants, are concerned that some compliance incentives could hobble the nascent market in tradable permits. They believe that trading rules should focus, above all else, on facilitating development of the new market.

Recognizing that there are limited levers in traditional international law to compel Party compliance, the US has supported including positive incentives for compliance within the trading rules, where that can be done without significantly burdening efficient market function. Specifically, before Kyoto the US proposed including two compliance provisions in trading rules:

- A Party not complying with its measurement and reporting obligations would lose its eligibility to engage in further emissions trading, until it has remedied the problem.
- A Party that has run out of assigned amount during the 5-year commitment period would lose its eligibility to make further sales (although it would still be able to buy), so long as it remains in deficit.

The linkage between monitoring and reporting obligations and trading eligibility is broadly supported within the Umbrella Group, as well as by the EU. The "empty tank" rule, however, is not seen by the EU as an effective way to block large-scale over-selling early in the 5-year

period. Concern over this possibility led the EU to propose buyer liability. The US has not yet taken a position on liability or advanced other proposals to address the risk of over-selling.

II. Options

1) Seller bears the risk. If the selling party does not possess enough assigned amount to cover its emissions at the end of the period, the excess, with a penalty, would be deducted from its assigned amount for the next budget period. The party might also be subject to restrictions on sales in the second period. Buyers are responsible for ensuring that they obtain clear title to any permits purchased, but are not subject to the risk that permits will be recalled or devalued. Permits already sold remain the property of the buyer.

Benefits: Simplest and most efficient, because transaction costs are lowest. Buyers would be certain of the face value of any permits bought, and permits would be interchangeable. Buyers need not assess the risk of the selling Party's ultimate compliance. Loss of trading eligibility and repayment requirements provide incentive for compliance.

Downsides: Significant risk of overselling and unremedied excess emissions. Compliance incentives depend on Parties' commitment to participate in the global climate change treaty over the long haul. Loss of trading eligibility and repayment requirements alone may not be sufficient to prevent overselling by a government that seeks a short-term financial bonus.

2) Buyer bears the risk. If the selling Party does not possess enough assigned amount to cover its emissions at the end of the period, emissions permits that it had previously sold would be taken back from buyers and applied to cover the shortfall. The last permits sold would be the first ones returned (LIFO). Permits would differ in risk (and price) according to the original seller. Buyers, who would be on notice of these rules from the start, would have to assess the risks of a Party's non-compliance. Buyers might manage risks in several ways: by discounting prices paid, creating a portfolio of permits from different Parties and of different vintages; by making contracts contingent on compliance of the selling Party; or by buying options or taking other offsetting positions.

Benefits: Creates strongest protection against overselling. Uses market mechanisms to promote environmental objectives. A Party at risk of having excess emissions will receive lower prices for its permits; this creates a financial incentive to comply. Excess emissions are automatically covered, up to the extent of prior sales.

Downsides: Likely to increase costs. Likely to impede development of trading. Would require private sector buyers to assess and manage the likelihood of selling Parties' eventual non-compliance. Market tools for doing so efficiently could develop over time, but are not likely to exist at first; this could impose a significant burden on the nascent

emissions trading market. Concerns about market development could make US ratification more difficult.

Options (3), (4), and (5) are intended to offer more protection against overselling than "seller bears the risk," and less burden on the trading market than "buyer bears the risk."

(3) Seller bears the risk, cap on sales. To address large-scale overselling, a simple cap could be set on any Party's permit sales prior to the end of the budget period, based on the countries presenting the greatest concern. The Administration's economic modelling suggests that Russia and the Ukraine will need approximately 70% of their assigned amounts to cover their own emissions. A Party could be limited to selling no more than 20% of its budget before the end of the budget period (the 10% difference representing a compliance reserve margin). Any portion of the remainder could be sold at or near the end of the five-year period if not needed to cover the Party's emissions.

A formula-based cap could give a similar outcome. For example, a country could be limited to sell no more than 20% of its total allotment. The country would be restricted from further sales until it had demonstrated that it had attained a "no deficit condition." The "no deficit condition" would be shown when total sales were less than the sum of purchases plus the difference between emissions and an even allocation of permits over time. For example, suppose a country were initially allocated 500 permits and would have total emissions of 350. Allocating permits evenly over time would yield 100 permits per year while emissions would be 70 per year, yielding a difference of 30 per year. Suppose the country sold 100 permits. Assuming it did not buy permits, the country would be restricted from further sales until into the fourth year of the budget period when the difference between an even allocation of permits and emissions would be equal to or greater than 100. Given a one-year lag on emissions reporting, it would be in the fifth year of the budget period that sales could again take place. Once the "no deficit condition" were shown, the country would again be free to sell permits up to 20% of its total allotment.

Benefits: Trading takes place with low transaction costs because buyers do not bear the risks of sellers' non-compliance. Cap limits potential overselling, compared to option (1).

Downsides: Although caps limit overselling, they do not prevent it. Proposing a cap to address overselling may be inconsistent with our opposition to the EU-proposed caps on amounts parties may purchase or sell (supplementarity and "hot air" restrictions). (This drawback is addressed under option (5) below.) With respect to the second variation, it is unclear how these options would work where parties to the Protocol devolve emissions permits to firms, as an individual firm's right to sell would depend on whether prior sales by other firms had reached the national cap. This option requires detailed data on both spot and forward trades, as well as emissions, data that the central government may not have. Additional difficulty is introduced when a country is both a buyer and a seller. This option reintroduces some annualization into the multi-year budget format.

(4) **Seller bears the risk, with reserve account.** To address smaller-scale overselling, sellers could be required to set aside a specified percentage (perhaps 10 percent or 20 percent) of the total sold. These permits could be sold at or near the end of the five-year period, if they were not needed to cover the selling Party's emissions. Until then, they would serve as a compliance reserve against possible excess emissions.

Benefits: Low transaction costs, as in option (3). Useful to address modest overselling (due to an unexpected surge in emissions, for example, intentional gross overselling). Compliance reserve grows with volume of permit sales. Reserve margin offers more protection against overselling than option (1).

Downsides: Protection against overselling is still incomplete for any percentage set aside less than 100%. Interim permit prices (prices during the five-year period) may rise because fewer permits would be available for sale, until they are released at the end. The higher the percentage set aside, the greater this effect.

(5) **Seller/buyer hybrids.** Options (3) and (4) can be reformulated to avoid caps. In the example in option (3), for example, sale of permits above the 20% level could be allowed under the condition of buyer liability. In other words, most permits would trade without any contingencies, but sales of the permits above the 20% level (in this example) would be subject to the risk of being recalled and returned to the seller Party to cover a shortfall at the end of the period. The same approach could be used in option (4), allowing sales of permits in the compliance reserve under buyer liability.

Benefits: Provides more protection against overselling than options (3) and (4), because sales above the cap are subject to recall against seller's excess emissions. All permits are allowed to go to market; most trade on basis of seller liability without contingencies, while buyer liability is focused where most pertinent to compliance risk. May provide selling parties with more incentives for compliance, since a price signal reflecting the party's compliance risk will be created for the permits in the compliance reserve. Avoids proposal at cross-purposes to our opposition to caps.

Downsides: Same as option (2), except that potential burdens on the market are limited to only those permits trading under buyer liability.

III. Positions of US interest groups and other parties

The following picture emerges from a series of stakeholder meetings coordinated by the White House Climate Change Task Force:

- Most private sector potential buyers and brokers expressed a strong preference for avoiding buyer liability, although they recognized that seller liability alone does not address the risk of overselling.

- A minority of potential buyers and brokers said buyer liability would be workable.
- Environmental organizations prefer buyer liability.

Among the Parties:

- Other buyer members of the Umbrella Group generally favor "seller bears the risk."
- Russia and the Ukraine have endorsed Umbrella Group proposals to date. They are eager to get trading underway in order to begin realizing revenue. They have acknowledged the need to build up their monitoring and regulatory capacity and are looking to trading revenue as a source of funds for such efforts. They have not yet been engaged in detailed consideration on liability or the risk of overselling.
- The EU currently favors buyer liability but has recognized problems such as the potential domino effect on compliance. The EU probably supports the idea that excess emissions must be deducted from the second period, as in "seller bears the risk," but does not feel this is adequate to address overselling. Option (5) may also appeal to the EU as a means for both sides to get some of what they want.

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Annex B Trading: A Report on Some Informal International Expert Discussions

Prepared by Michael Toman, RFF, Washington DC, and
Jean-Charles Hourcade, CNRS, Paris

Background

On 19-20 June 1998 a group of some 30 experts from the US, Canada, several European countries, and Japan met at Resources for the Future to discuss of a number of contentious unresolved issues related to Annex B trading of greenhouse gas emissions. This meeting came in the wake of inconclusive international meetings on trading in Bonn the week before to prepare for the upcoming 4th Conference of Parties to the Framework Convention on Climate Change (to be held this November in Buenos Aires).

The experts attending the RFF meeting came from academia, national governments, and the European Commission. Many of them had been active in the negotiations at Kyoto and Bonn. However, the meeting was entirely unofficial and followed conventional academic rules for nonattribution to encourage frank exchange of views. The goal was to foster an exchange of information and ideas that could help promote the shared goal of designing international climate policies that are efficient, credible, and reflective of national interests. There was no attempt to reconcile differences and achieve consensus on any issues. Nevertheless, all participants agreed that the discussions had helped considerably to clarify their understanding of the issues and disagreements, and some elements that might point the way toward reconciling differing views were identified.

Much of the discussion focused on the very controversial issue of "supplementarity." The idea behind this term, which is included in the Kyoto Protocol, is that the use of international emissions trading for complying with Protocol targets should be in addition to domestic policy measures. However, supplementarity is not precisely defined in the Protocol, and there is significant international disagreement about how it should be interpreted in practice. The discussion at the June meeting took as a point of departure the views expressed in the non-papers tabled at Bonn by the European Union and several Central & Eastern European countries, and the "JUSCANZ/Umbrella" group (the US, Canada, Japan, Australia, New Zealand, Norway, and Russia). However, the discussion also addressed a number of other issues related to how an Annex B trading system would be designed and operated. What follows is a summary by the organizers of some of the salient points in the workshop. While we have tried to faithfully reflect the discussions, the summary should be taken as reflecting the view of the organizers only and should not be attributed to any other participants.

General Points

The US and European countries have differing national circumstances and expectations with respect to GHG policy and different experiences with emissions trading. To succeed, international policy agreements must reflect and bridge these somewhat disparate national interests as well as broader disparities of view or understanding regarding sustainable development.

Policy toward Annex B trading must evolve with experience. To succeed, this policy institution must avoid being bogged down early with unnecessary constraints on its functioning at the time when it is still evolving, while also avoiding collapse due to political or economic distrust because of lack of care in implementation or false hopes about its performance.

Whatever steps the US, Europe, and other Annex B countries take to reconcile their positions on trading, they must also address the concerns of the G77+China on this and other flexibility mechanisms and find ways to make participation more attractive to those countries.

Supplementarity – Some European Concerns

US reliance on low-cost imported “assigned amounts” in the first commitment period, as a consequence of trading “hot air” from countries likely to be suppliers of assigned amount suppliers like Russia, raises concerns about the strength of US commitments to longer-term GHG reductions – if the US has done relatively little in the first period to alter its domestic energy use patterns and infrastructure, will it distance itself from costly continuation or strengthening of commitments thereafter?

Low international permit prices, in particular due to trading of “hot air,” also is seen as a threat to the pace of technical innovation needed to make lower future targets more affordable; the resulting “inertia” in the process of technical change and capital stock modification is seen as further elevating long-term abatement costs and slowing progress towards long-term emissions cuts.

European countries’ flexibility to follow their preferred courses of policies and measures is seen as being limited by low-cost international permit prices in the US. In particular, a low implicit price of carbon in the US relative to Europe because of a European interest in pursuing higher energy taxes as part of a larger fiscal policy restructuring (including lower labor taxes to stimulate employment) is seen as threatening industrial competitiveness in very energy intensive sectors exposed to international competition (though these are only a small part of the economy, on the order of 10 percent of the value added and 5 percent of employment, they are politically sensitive as well).

Trading in “hot air” is seen as a bad precedent in terms of future entry by other countries into Annex B of the Protocol (acceptance of national emission caps) – it is desirable to expand participation in Annex B to promote global GHG reductions and reduce leakage problems, but recurrent “hot air” is seen as potentially destabilizing permit trading and investment decisions over time.

Supplementarity – Some US Concerns

There is a tradeoff between flexibility of instruments and acceptability of targets – the US accepted its Kyoto target (and availability of the EU “bubble”) with an expectation about the availability to the US of flexibility mechanisms that would be compromised by a limit on use of imported permits.

Limiting the volume of trading is an inappropriate tool for responding to concerns either about the targets and goals that were negotiated in Kyoto or the credibility of national commitments to them. While concern about commitment to targets is fair, it is not useful to address that concern by restricting the means by which targets would be achieved. Moreover, the US legal system arguably makes its commitment to Kyoto targets once ratified at least as strong as the commitments to the targets (versus policies and measures) by European governments.

Limits on trading will not get rid of any existing “excess assigned amounts” that would be found in some countries. These amounts will only be banked and will lower permit prices later, thereby reducing incentives for technical change. Countries with excess assigned amounts might even gain in the short term, if the higher price of traded GHG emissions (since domestic abatement costs would be higher) more than offset the lower sales volume. Limits on Annex B trading could drive more trading to the CDM, which is more difficult to establish and monitor, while also reducing the incentive of developing countries to join Annex B.

US policymakers continue to find harmonization of domestic policies and measures not in the US interest, and resist the argument that the US should bear higher GHG control costs to accommodate European priorities such as the harmonization of fiscal policies, energy policies, R&D policies, or regulations in the transportation sector.

There is continued uncertainty about whether “inertia” is a handicap to longer-term technological evolution that can only be overcome if the implicit price of carbon emissions is made larger in the short term, though there is recognition that long-term technical change depends on the perceived credibility of long-term climate policy commitments.

There is finally some concern that limits on GHG trading are intended in part to shift more of the cost burden to the US versus the EU, enhancing the economic situation of the latter over the former.

Supplementarity – Some Points to Explore Toward Common Understanding

“Supplementarity” as expressed in the Kyoto Protocol is a complex concept reflecting a variety of political concerns. However, these concerns do not logically translate automatically into a quantitative limit on international emissions trading. Analysis and policy discussion could usefully focus on other tools that might also be used to address the concerns advocates of supplementarity requirements express.

There is a need for ongoing reassurance about long-term commitments to the goals of the Framework Convention on all sides. The US might consider ways it could demonstrate concrete domestic changes in energy use and investment. This could be done through concrete policies and measures, though targeting sectors or types of energy use would be contrary to current US policy to largely follow price-based strategies. An alternative strategy might then be early action to begin creating the necessary energy price signals in the US (e.g., through development of a domestic emissions trading infrastructure and its application prior to 2008, so that price expectations can start to affect investment decisions), as well as continued steps to promote R&D and reduce real market failures that limit use of energy-efficient technology. (Policies in this category require careful delineation to avoid "picking winners.") The emphasis would be on the process of developing and implementing policies, versus concrete numerical limits.

For their part, European governments could increase confidence by strengthening legal commitments to the targets, articulating early on their preferred baskets of policies and measures and how these will credibly produce the aims sought, and producing their own measure targeted toward stimulating R&D.

Long-term confidence could be enhanced by beginning discussion on targets for a second and subsequent commitment periods, though it will be hard to reach closure in this discussion with the first commitment period targets still so uncertain in practice. Finally, confidence could be enhanced by addressing the question of liability for noncompliance, which is discussed below.

There is a need for economic analysts to look at how legitimate EU interests in the exercise of fiscal policy and other domestic policies and measures can be made compatible with the interests of the US and other countries (including Europe) in a well-functioning, flexible and transparent international emissions market. One possibility could be to use domestic carbon-based energy taxes for emissions from the energy use in transportation and housing but provide opt-outs for the industry specifically for the exposed energy intensive sectors, who could comply through trading on the international permit market. Other options may also be available and should be explored. In this regard, it is worth examining to what extent, as the implicit price of carbon in the US rises through implementation of the Kyoto Protocol target with Annex B trading, it becomes easier for European economies to adopt higher energy taxes without creating or aggravating competitiveness concerns (indeed, shifting revenue generation to GHG emissions from other tax bases may increase competitiveness).

Whatever steps are taken, they must be made with an eye toward how credible and effective the policy mechanism seems to non-Annex B countries.

Structuring Annex B Trading – Points of Concern Among Various Participants

There was substantial discussion of how liability for “defective” credits should be assigned, especially under the assumption that trading evolves reasonably quickly to involve legal entities, not just Parties. Different participants expressed views about the virtues of increased attention to the integrity of credits under a “buyer beware” program, versus the high “transactions costs” such an approach likely would engender. It was pointed out in particular that buyers have no comparative advantage in monitoring seller behavior, and that an active market requires liquid, “anonymous” trading.

No closure was reached in this discussion. However, it was pointed out that there were various ways to strengthen a seller-liability approach (test compliance within the commitment period; require substantial domestic monitoring and enforcement before a country could be a seller; adopt rules that would put a noncompliant country into “buyer beware” status in the second commitment period, causing its credit value to be discounted; and having sellers (Parties and legal entities) provide insurance against risk of default by “bad apples”). Various strategies for reducing the burden of buyer liability also were discussed, e.g., focusing the provision on the last credits sold on the assumption that they are the most at risk of being defective.

Several other topics also were briefly discussed but not resolved. In the context of considering who trades, there was some discussion of the problem of non transparency and market power, especially if Parties trade. This issue is a real concern, but somewhat more in the EU and in Japan than in the US, where the prevailing assumption is that most trading will occur among private actors with limited market power. One idea advanced for dealing with this is an auction or some similarly transparent mechanism, to minimize political interference and protect the interests of smaller countries.

Some participants expressed concern that gratis allocation of domestic permits would offer unfair international competitiveness advantages through the transfer of wealth that would result; but other participants disputed the order of magnitude and the duration of this effect. And concerns again were expressed about how quickly it would be possible in practice to move to a fully comprehensive (multiple gas and sinks) approach.

The participants in the discussion have agreed to form a sort of informal network to foster continued exchanges on these and other issues related to Annex B trading. The hope is to follow the meeting with a similar workshop on the CDM.

**Draft Answers to Questions From Chairman Talent
to Dr. Yellen, Chair of the CEA**

1) In your written testimony, you referenced the increase in an average household's energy bill. What is your estimate of the impact of the Kyoto Protocol for the following cases:

a) Energy costs for an average household assuming that emissions trading is not allowed (approximately \$200/metric ton based on the SGM model). This data should include the components from oil (heating and gasoline), natural gas, and electricity.

This question does not apply to the Kyoto Protocol because Article 17 of the Protocol establishes the right to trade emissions among parties with emissions targets. However, our informal analyses of such a policy suggest that the effects on energy prices would be nearly 10 times greater than under the policy conditions that were identified in Dr. Yellen's testimony. The testimony indicated that effective international trading and meaningful developing country participation could result in permit prices of about \$14 to \$23/ton. We believe that this difference of nearly a factor of 10 underscores the importance of international permit trading and developing country participation, two cornerstones of the Administration's climate change policies.

This data should include a typical household in the following regions: Northeast, Southeast, South, Mid-West, Northwest and Southwest.

We have no data on spending by region and have not undertaken such analysis.

b) Direct energy costs for an average small business of 50 employees under the same conditions as listed in Item a above.

We have no data on spending on energy by small businesses and have not undertaken such analysis.

2) In addition to the direct energy costs, what is your estimate of the indirect costs of the policy for the cases described above?

We do not have quantitative estimates of indirect compliance costs.

[3)] Please provide the following:

1) At the time of the President's policy statement in October the reduction target for carbon stabilization at 1990 levels was approximately 375 million metric tons (Mmt). Since this announcement the EIA outlook has added another 80 Mmt to the target and the Kyoto reduction of 7 percent has added another 95 Mmt. The total reduction for energy alone is now 550 Mmt. If you add the other gases the Kyoto target for reduction is 650 Mmt. Since the total amount of emissions is critical to any economic analysis, please provide the assumptions used in your analysis for the amount of emissions to be traded. Also confirm which of the analyses you used

were performed after Kyoto.

As with any conventional economic model, our model assumed simply that the amount of emissions permits to be traded would be determined by the supply and demand for emissions permits among the trading countries. All of the quantitative analyses underlying Dr. Yellen's testimony were developed after Kyoto.

2) What are the Clinton Administration's assumed further emission reduction targets for the period 2013-2020?

We have made no assumptions about the emissions targets for the periods beyond 2012. The Administration has not proposed emissions targets for the second or subsequent commitment periods. Although Kyoto is a first step, and the President in October said that we must work toward further reductions in the years beyond 2012, the Administration is not prepared to propose an emissions target for these years.

3) What analysis of the total impact on the economy (both direct and indirect costs) of the U.S. has been performed using these assumptions?

The analysis that we have performed is summarized in Dr. Yellen's testimony to Congress and in the July 1998 report titled "The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis."

How are total costs reflected in your analysis since the SGM analysis you referenced in your testimony only treats direct costs, which is recognized to underestimate total costs by a factor of 2-4?

Our approach follows the practice of the researchers who have developed the SGM model and is consistent with other uses of this model. This same approach is also used by researchers at the Massachusetts Institute of Technology lead by Dr. Henry Jacoby. It reports costs as the sum of 1) the cost of emissions reductions achieved in the United States, calculated to reflect only the incremental cost of each reduction, i.e., the minimum compensation that a profit-oriented firm would need as compensation for such reductions, and 2) the total value of payments to firms outside of the United States for emission permits acquired through international trading.

Although we have followed a practice accepted by many modelers the measurement of total costs in the computable general equilibrium models used to assess the economic impacts of mitigating climate change is an area of ongoing study. For example, researchers within the Energy Modeling Forum recognize that modelers need a better understanding of why the costs are so different across models and some way to decompose the many components contributing to the overall cost of mitigation. Differences in cost have not yet been decomposed into distinct components in a manner that lets independent researchers evaluate the validity of such claims.

4) Estimates of the U.S. demand for emissions credits by year for the period 2008-2012 and the potential supply from Russia and the Ukraine based on

A) Projected demand relative to the Kyoto target.

B) Projected demand relative to the assumed additional reductions targets.

The Administration has no estimates of the demand for emission credits by year for the period 2008-2012. Demand will be sensitive to a variety of factors that are quite difficult to forecast 10 to 14 years in advance, especially the rate of technological innovation and the diffusion and adoption of current innovations and those placed on the market over the next ten years. For the same reason we have no estimates of the supply of emission credits.

In addition, as mentioned above, the Administration has not proposed additional reductions targets for periods beyond 2012.

[4]) Given this strong opposition by developing nations to even consider voluntary commitments and given the lack of progress on fleshing out the skeletal flexibility provisions (such as trading) in the protocol, isn't it unrealistic to expect savings from these areas and isn't the Kyoto Protocol likely to cost America substantially more? Please elaborate in your answer and supply details of your calculations.

Estimating the economic effects of international treaties is necessarily more complicated than in the case of domestic legislation because the effects are likely to depend in part on the actions of other countries over which the United States has no direct control. While there has been no recent news about breakthroughs concerning developing country participation it is important to keep the right perspective on this lack of news.

First, the breakthroughs at Kyoto were largely unanticipated given the reports about diplomatic standoffs during the months prior to December 1997. At Kyoto, the U.S. achieved provisions for trading (Article 17), coverage of six greenhouse gases (Article 3.1 and Annex A), the Clean Development Mechanism (Article 12), and credit for sinks (Article 3.3). The inclusion of these four provisions in the Kyoto Protocol, despite previous objections by some countries, adds flexibility in implementing the emission targets that will substantially lower costs.

Second, although the cost with full implementation of the Kyoto agreement itself would be greater than with the developing country participation outline in Dr. Yellen's testimony, it would be many times less than the estimated cost reflected in your question 1. For example, effective trading of permits among Annex I countries and participation of developing countries only through the Clean Development Mechanism --two provisions already included in the Kyoto Protocol, would yield permit prices comparable to \$23/ton estimate, provided that the European Union did not compete with the U.S. in buying inexpensive emission reductions from Eastern Europe. For details of this calculation see the discussion surrounding Table 4 (p. 52) in "The Kyoto Protocol and the

CLIMATE POLICY INSTRUMENTS UNDER UNCERTAINTY

Carolyn Fischer, Suzi Kerr, Michael Toman

Prepared for presentation/discussion at NBER /Yale Climate Change Policy Workshop,
Snowmass Colorado, August 13-14 1998
July 20 draft

INTRODUCTION

That issues related to climate policy instruments are receiving enormous attention is no surprise. However, much of that analysis examines the consequences of different policy designs in an essentially deterministic way. Since uncertainty is a crucial element of the climate policy debate, it seems useful to look a little more systematically at how uncertainty affects the design as well as the consequences of climate policy.

A great deal of attention has been paid to the nature of the “optimal” greenhouse gas reduction profile in the presence of uncertainties about damages, abatement costs, and discount factors (Manne and Richels 1992, Peck and Teisberg 1993, Weyant et al. 1996, Manne 1996, Pizer 1996, Kolstad 1996). This is an important part of the integrated assessment literature on climate change. Building on this work, studies also have followed the path blazed by Weitzman (1974) in considering how damage and cost uncertainty affect the choice of policy instrument, specifically the choice between price and quantity (tradable permits) policies (Pizer 1997, Newell and Pizer 1998; see also Hahn and Stavins 1995).

In this paper we focus mainly on a different set of questions related to the design and performance of emissions trading systems. The first concerns the allocation of various risks between private actors and the government in a domestic trading system. A key element of this part of the analysis is the recognition that there are different kinds of risks to be allocated. In particular, we distinguish between “exogenous” risks, those for example related to exogenous changes in abatement technology or scientific discoveries about climate change risks that alter regulatory targets, and “endogenous” risks, those principally related to “regulatory opportunism” on the part of the government or the regulated actors that affect the intertemporal credibility of the regulatory bargain.

The second set of issues we address continues this theme of credibility, but in the context of international actions to reduce emissions. This discussion is in two parts. We first consider the design of a credible international trading system for Annex I countries, focusing on the assignment of liability for “bad” emission permits (i.e., when the seller country is not in compliance with its Kyoto targets). The second part of the discussion addresses issues of credibility and liability in the context of Clean Development

Mechanism joint ventures in the presence of information asymmetries and incomplete enforcement mechanisms.

The third set of issues we address picks up some elements of the prices versus quantities debate. Here we note that the differences between the two kinds of instruments depends on how they are structured. In particular, when policies can adjust over time the distinctions between the two types of instrument may be less sharp. We also examine the dynamic incentives for technical progress in emissions reduction. We note that the strength of these incentives, and the performance of trading relative to other policies in inducing innovation, depend on a number of uncertain factors in addition to the instrument choice. The paper ends as usual with a summary and an identification of some research needs.

ALLOCATING RISKS IN A DOMESTIC GHG TRADING SYSTEM

Exogenous Shocks

In this section we take the abatement targets as given and focus on risks within a tradable permit market designed to achieve those targets. We begin this discussion by assuming that the government can commit irrevocably, now and in the future, to a particular policy.¹ This assumption is obviously artificial, and we relax it below; we make it here to focus attention on the impacts of exogenous uncertainties on socially optimal abatement investment responses, and the optimal allocation of the exogenous risks between government and the private sector.

While the lines separating exogenous and endogenous risks is somewhat blurry, we can identify several factors that are largely external to the operation of a GHG trading system. These include natural events, e.g., cold winters that increase fossil fuel demands or natural disasters that reduce economic activity and damage infrastructure; changes in scientific knowledge or social preferences about the severity of climate change risks; macroeconomic fluctuations and trends; and technical progress in GHG abatement. The form and stringency of GHG policy will affect these last two factors, but uncertainties about them are largely exogenous to GHG trading. Note that some of these factors are short-term or cyclical (business fluctuations or weather shocks), while others affect long-term trends in control cost or the desired level of GHG control (technical progress, improved climate risk assessment).

The socially optimal response to these risks consists of several kinds of activities. Information pertinent to these uncertainties should be collected and disseminated, and R&D to reduce uncertainties and increase options for GHG abatement should be

¹ Of course this does not mean the government commits to a fixed course of action, but rather to a decision rule that indicates how policy is to evolve over time in response to new events and the receipt of new information.

undertaken. Tangible investments also will be needed to efficiently meet the GHG emission targets. The irreversibility of investment will bias the socially optimal investment response toward slower and less capital-intensive actions.² In contrast, convex costs of investment with respect to time will bias toward faster investment, and investment that can be rapidly expanded, as protection against the potential need for more stringent targets.³ At the aggregate level, society needs to be able to respond quickly and at low cost to more and less stringent targets.

In a permit market, exogenous shocks play out in terms of the price of contracts (spot, forward, future, option) for GHG permits. The imposition of significant regulatory constraints on fossil fuel use and GHG emissions creates scarcity rents worth tens if not hundreds of billions of dollars. Public and private holders of permit assets will experience capital gains when permit prices rise, while permit buyers will experience increased costs for covering their residual emissions. These asset and price risks are negatively correlated. At the same time, changes in the price of permits are likely to be pro-cyclical with respect to the economy, in that factors which reduce (increase) economic activity and demand for fossil fuels also will reduce (increase) permit prices. These positively and negatively correlated risks can be efficiently spread throughout society through choices of private investment portfolios (including permit assets), derivatives in the permit market, and insurance.

Uncertainty will also affect technology choices. Investors will put a lower value on technology whose profitability is dependent on emissions targets being set at a certain level at a certain time. Firms also will see less value in technologies that might be made rapidly obsolete through innovation. Idiosyncratic technology cannot be efficiently shared through society. Private information about the choice of projects and the effort taken to implement them creates moral hazard problems and precludes efficient risk-sharing. Agents with little collateral will invest less than society would like, generating an efficiency loss, and agents with idiosyncratic investments will bear too much risk.

What is the appropriate role of government in implementing this portfolio of actions (again, abstracting for now from endogenous policy risks)? One of our key conclusions is that the government does not have a comparative advantage in bearing most of these risks, as opposed to having them borne by the private sector. Obviously the government does have a role in public goods provision, including the provision of information and activities to correct imperfections in the R&D market, such as support for basic research that reduces uncertainty. Government also has a role in mitigating macroeconomic risks through the implementation of appropriate fiscal and monetary policies.

From the perspective of GHG policy, however, government cannot reduce the exogenous risks of shifts in climate change knowledge, social preferences, technical innovation, or

² For the seminal articles on investment under uncertainty and responses to irreversibility see Henry (1974), Arrow and Fisher (1974), Freixas and Laffont (1984), and Dixit and Pindyck (1994).

³ See Lucas (1965 and 1967) and Treadway (1971) for seminal optimal adjustment path models.

international macroeconomic fluctuations. These risks also are correlated across the economy and are not “small” in relation to the overall scale of the economy, so the Arrow-Lind (1970) risk pooling argument for government assumption of risk does not apply. Any large or permanent shock borne by government will ultimately be returned to the private sector through higher taxation, with taxation’s additional costly distortion. Nor is it apparent that government has a comparative advantage in providing insurance; the private sector can effectively establish a variety of risk-allocation mechanisms, including derivative transactions associated with GHG permit trading. The government has no comparative advantage in addressing moral hazard problems.

One role the government could play is distributional. Some groups have limited access to risk markets and potentially disproportionate exposure to climate change policy risks. These groups include workers who have technology specific human capital, e.g., coal miners, and low-income groups in general. But, other than supporting basic R&D, and possibly providing a safety net, the government does not have a comparative advantage in addressing exogenous risk.⁴

What implications does this discussion have for the design of a GHG trading system? It seems to us that the following points are germane.

- In concert with a trading policy, the government should support basic R&D, and dissemination of information. The government also faces the difficult task of providing protection for more vulnerable parties in the economy, responding to distributional concerns. A variety of measures could be used, including increases in earned income tax credits and job retraining programs. One of several arguments for auctioning GHG permits rather than issuing them gratis is that it provides a less distortionary way of financing such activities (Parry et al. 1997; see also Fischer, Kerr, and Toman 1998).
- One of the strengths of a permit trading system is that it provides a number of excellent means for the private sector to respond to short-term and cyclical risks. These include the accumulation and use of banked permits, as well as the establishment of derivatives markets. Government should do nothing to discourage these developments, directly or indirectly (e.g., reducing the liquidity of the “spot” permit markets will reduce the capacity for derivatives like futures to take hold).
- Allocating permits denominated in fixed numbers of tons puts on the government the risk of exogenous changes in future targets, e.g., the government must buy back excess permits if changes in knowledge or social preferences (as well as drops in abatement cost) lower the desired aggregate emissions target. To allocate more of

⁴ These conclusions about the limited role for government would not apply in the same way to developing countries, where market and other institutional failures are more rife.

this risk to the private sector, the government could allocate permits denominated as percentages of uncertain future targets to be determined subsequently.⁵

- While permit auctions have a number of virtues, if the government auctions permits year-by-year or for only a few years into the future, it bears more of the asset risk associated with future changes in the prices of permits. To reduce the bearing of this risk, the government could pursue longer-term allocation of permits. This would not violate the given short term targets; as in the Acid Rain program, these allocated permits could not be used before particular dates. The government also could take positions in risk and insurance markets to reduce the variability of its returns, but allocating the asset risk to the private sector directly through longer-term permit allocations is more straightforward.⁶

Endogenous Uncertainties

In real life, contracts can never be complete. In the context of GHG policy, this creates uncertainty about future policy and opens up the possibility of post-contractual opportunistic behavior on the part of regulated entities or the government. These possibilities are strengthened by the fact that a sovereign government cannot preclude opportunistic behavior by itself or its successors in the future.

Opportunistic behavior by the government amounts to unilateral modification of the regulatory contract, as distinct from Pareto improving renegotiation as a consequence to changes in circumstances. If the government changes the allocation of permits, or taxes or confiscates privately held permits, it burdens certain actors while benefiting others. These are clearly endogenous risks of opportunism in our characterization. Such changes would reflect shifts in the political balance of power regarding the stringency of GHG control or the allocation of scarcity rents resulting from GHG limits.

Strategic unilateral modification of GHG policy by the government is troublesome because it undermines the incentives for efficient investment by the private sector. If firms face increased uncertainty about climate policy objectives because of governmental capriciousness, their tendency to invest more slowly and in less capital-intensive actions in the face of exogenous risks will be unnecessarily magnified.⁷ Permit banking, and

⁵ For this approach to succeed, the private sector would have to have some confidence in the government's policy rule. We return to this point below in discussing endogenous risk. The government also would want to provide as much information as it could about the potential evolution of future targets in order for the private sector to rationally price these assets.

⁶ This idea comes with some important caveats. Reduced asset risk could come at a cost if the private sector has little confidence in the government's conduct of GHG policy and heavily discounts future permits for endogenous as well as exogenous risk. In addition, the sale of significant amounts of GHG permits ex ante and the use of the proceeds could give rise to intertemporal distributional issues.

⁷ Incentives to adopt new technology would similarly be weakened if the act of doing so triggered a capricious tightening of a sector's emissions obligations. This point must be handled with care, however,

thus opportunities for intertemporal smoothing of abatement costs, will be unnecessarily limited if the risk of permit confiscation is seen as significant. Aside from these direct efficiency costs, strategic regulatory action by government also opens up new opportunities for costly rent-seeking.

Private actors may behave opportunistically or strategically with respect to GHG policy. The most obvious strategy is under-investment (either in scale or pace over time), in the hope that relief from compliance could be negotiated later. The sought-for relief could be based on sectoral pleading (commonly observed in regulatory debates), or on the broader grounds that forcing costly compliance at the scale and pace stipulated in international GHG agreements would damage the economy as a whole. The latter puts future regulators in the position of choosing between noncompliance and recession.

Any single actor considering strategic under-investment must compare the costs of underinvestment with the probability of regulatory relief. If actors seek aggregate relaxation of targets they compare the higher long-term costs of abatement resulting from their underinvestment if future targets are not relaxed, with the probability of negotiating a future relaxation in the targets and its expected size. If they are seeking benefits for their firm or sector, such as a greater share of future grandfathered permits, they compare the higher long-term costs of abatement their underinvestment generates with their expected capital gain through larger permit allocations. The probability of changing government policy depends on the political economy of a sectoral pleading and the probability that many other actors in the economy also would strategically under-invest, thus heightening the regulator's ex post environment/economy dilemma.⁸

How can these problems of governmental or private-sector opportunism be addressed in the context of a permit trading system? Contract theory suggests three basic methods – make contracts more complete, make renegotiation more costly, and reduce pressure to renegotiate. In considering these prescriptions, we must also keep in mind the practical difficulty of governments binding their successors. We therefore propose the following points:

- Spell out as clearly as possible the way that different contingencies are to be addressed. If permits are to be grandfathered, for example, the means by which this is to be done – including dealing with entry and exit of firms – should be defined as

because a drop in abatement costs also is a legitimate rationale for the government to pursue tighter standards than it had previously (this is the point advanced, for example, by advocates of intertemporal flexibility in GHG abatement). The key question here is the capriciousness of government action in changing standards; what needs to be avoided is using the influx of a new technology to justify tougher standards whose benefits do not justify the costs, or actions that penalize specific sectors which signal lower costs through early adoption of new technology.

⁸ It would seem that strategically under-investing is not a dominant strategy. If one small set of actors did so but the bulk of the economy did not, this sector's pleading for special relief would be somewhat weakened and the prospects for economy-wide dislocation would be lower. This is especially true with permit trading, which affords them the chance to trade for lower-cost emission reductions elsewhere.

precisely as possible, along with provisions for the sanctity of banked permits. While it is impossible in practice to spell out precisely the factors that would lead to changes in aggregate US emissions targets, clarity in the rules for sectoral allocation will limit some key channels for ex post opportunism. This in turn will increase the longer-term credibility of the policy, enhancing the efficiency of investment and causing less discounting for uncertainty of future permit assets.

- Use an auction for allocating permits, not a gratis allocation formula. Many of the opportunities for governmental opportunism seem to arise in connection with defining or redefining permit allocations. Powerful private interest blocs can exercise influence to the exclusion of others in the negotiation over allocation formulas. These opportunities are precluded if an auction is used. To be sure, there still will be rent-seeking behavior in the use of auction revenues, but that is an established part of fiscal policy already; unlike gratis formula allocation, an auction does not create a new venue for rent-seeking.
- Making longer-term allocations of permits that are specified in terms of percentages of future targets creates a constituency that can oppose weakening of policy commitment.⁹ It also means that government cannot gain revenue by changing targets. Finally, establishing the design of the trading system in legislation will make it more difficult to make capricious changes in policy later.
- Establish the credibility of policy targets as well as policy measures ex ante. The latter can be fostered, for example, by establishing the trading mechanism before the beginning of the commitment period in 2008. The former requires enough social consensus about the goals of climate policy that large parts of the private sector will be deterred from strategic under-investment, because there is some assurance before the fact that society understands and is willing to bear the costs.

To conclude this section, we note that there are complementarities in measures needed to address exogenous and endogenous risks in a GHG trading system. In both cases, clarity in the permit mechanism and allocation process and use of long-term allocation with banking seems warranted. Using permits denominated in shares of total emissions can create incentives for governments to raise revenue by making targets more stringent if permits are not allocated in advance, but when combined with long term allocation this approach also seems to have merit. A bigger challenge may arise in reconciling the advantages of intertemporal flexibility in responding to long-term climate targets under uncertainty, and the problems of deterring strategic under-investment or governmental shirking. Here again, a long-term allocation creates some countervailing pressure to

⁹ If the demand for permits is price-inelastic (because of a steep marginal abatement cost schedule), then increasing total emissions with pro-rata emissions shares would give permit holders more absolute emissions but would drive down the price per unit of emissions by more. This approach would not make the government bear directly the costs of an emissions-target reduction, but it would not gain any revenue either and it would indirectly bear costs by responding to greater private sector burdens.

opportunistic future relaxation of standards (as does technical progress that reduced future control costs).

DESIGNING CREDIBLE INTERNATIONAL TRADING SYSTEMS

The challenges in establishing credible GHG trading multiply when transactions are international. Much of the literature on international GHG policy has been concerned with the fact that international agreements are inherently difficult if not impossible to enforce legally, and the resulting challenges of making national commitments credible (Barrett 1994, Wiener 1998). Here we examine instead some of the questions raised by the additional challenges and opportunities created by international trading. Ultimate responsibility for obligations rests with the national governments of Annex 1 countries. They can, however, delegate trading privileges to sub-national parties (“legal entities” in the parlance of the Kyoto Protocol). Trading can occur among any combination of sub-national parties and national governments.

The Kyoto Protocol envisages at least two different kinds of international emissions transactions. One type involves exchange among actors in Annex I countries, those countries that have accepted binding limits on their aggregate emissions by the 2008-2012 period. These transactions could involve international trade in homogeneous domestic emission permits of different countries, or the exchange of heterogeneous project-specific emission reduction credits. In either case, national governments are responsible for aggregate compliance, presumably by limiting the emitters of those entities under their jurisdiction. Where permits are project-specific, national governments could hold sub-national actors responsible for specific permits. Sanctions are difficult to apply internationally but could be adopted by mutual consent to apply when aggregate compliance falls short. These could include having a lower national emission quota in subsequent commitment periods (to “make up its environmental debt”), and strictures on future trading opportunities (future permits or credits might be sold at a previously agreed discount, or subject to a caveat emptor test).

CDM Trades { The second type of transactions involves specific joint ventures between actors in Annex I countries and actors in non-Annex I developing countries, wherein the former invest in the latter to obtain emission reduction credits. These projects were referred to previously as joint implementation, but the Kyoto Protocol articulated a new name and potentially a new set of international institutional arrangements, the Clean Development Mechanism (CDM). For the CDM, seller countries do not have emission obligations so do not have national baselines to measure reductions against. Project level reductions are measured by assessing the additional reduction achieved, i.e., relative to business as usual. This is a controversial and costly process.

Parties to the Kyoto Protocol could minimize these costs and reduce manipulation of baselines by determining a set of generic criteria for evaluating the additional GHG

reductions associated with different classes of investments (e.g., enhancements in the power sector, improvements in end-use efficiency, use of low-GHG renewables). These criteria would be to a significant extent judgmental and would require revision periodically with experience, but they would provide a way to avoid the arduous and equally arbitrary project-specific determination of additionality. The criteria for ex ante assessment of project results would be based on measurable efforts and outcomes, e.g., the installation of particular kinds of equipment, rates of utilization, and so forth. Non-compliance in the specific project would be defined as any shortfall in project performance relative to the predetermined standard. Compliance would be assessed through spot-checking of projects to see if they meet or exceed the a priori performance estimates. If not, credits would be forfeited and additional penalties for noncompliance would be levied.

Even where non-compliance is clearly defined and measurable, and sanctions are used, parties may misreport reductions or claim inability to meet targets. One major instrument for controlling these behaviors in a permit market is the assignment of ex post liability for validity of traded permits. The question we address is, "Which country should bear liability for the validity of traded credits, the buyer, the seller, or both?" The fact that the two types of transactions involve different actors and operate under different domestic regulatory structures leads us to different conclusions about how responsibility for the integrity of the trading system should be imposed.

Performance Risks and Remedies in Annex I Trading

As already noted, Annex I trading involves either international trade in domestic emission permits or bilateral contracts for the creation and exchange of emission reduction credits. In either case, the fact that the actors trading all are in Annex I means that their respective governments are ultimately responsible for their actions and all trading entities should be governed by their domestic compliance mechanisms. The Kyoto Protocol requires each Annex I country to develop an operational capacity to keep track of their aggregate net emissions, and a capacity to develop and implement policies and measures to ensure that those emissions remain within the negotiated targets.

If these mechanisms worked as they were supposed to, then effectuating international GHG trading would require only a relatively minor increase in bookkeeping capacity. If domestically created permits are traded internationally, then regulators in the buyer and seller countries need to keep track of the volumes of the international flows and adjust domestic permit balances accordingly for the purpose of evaluating domestic compliance.¹⁰ If the national government decides to allow project-based credits, the

¹⁰ Note that while it may be useful to keep track of where the permits flow, there is no need to keep detailed regulatory records of individual buyer and seller transactions in this case. If, for example, a US permit holder sold some US permits to a Japanese entity, it would suffice for the seller's permit balance to be

accounting may become more complex, since there are no homogeneous emission permits involved to provide a unit of account. Nevertheless, since regulators in both buyer and seller countries must have the capacity to track or accurately estimate fossil fuel use and GHG emissions in order to credibly enforce their domestic targets, the same kind of parallel accounting as described above is sufficient for international purposes.¹¹

In practice, things could go wrong. Buyers and sellers could misrepresent their emissions to their national regulators. The national regulators could strategically misrepresent their total emissions and permit/credit balances to the international bodies charged with overseeing compliance under the Framework Convention and Kyoto Protocol. They also could simply not achieve their target net of trading and claim that conditions, possibly including the behavior of sub-national actors, were beyond their control.

In response to concerns about this potential threat to the credibility of Annex I trading, a number of proposals have been offered for assigning liability for “bad” permits or credits, those coming from a non-compliant seller country. Within Annex I, seller countries are always liable for net emissions minus permit sales. The question is whether the buying side should also be liable. Under this approach, if a government found that some of its regulated entities met their obligations with purchased permits or credits from a country determined to be non-compliant, that government would be responsible for covering their ex post “carbon deficits”. It could purchase additional “secured” permits or credits from other sources, as well as possibly being sanctioned in some fashion. The government would probably make their domestic entities liable under domestic law, but it cannot delegate aggregate national compliance responsibility. In all likelihood, the finding of noncompliance in the seller country would be based primarily on an accounting of aggregate emissions versus emission reduction obligations, though it is possible that some spot checking of individual transactions also could occur. Buyer liability could put all transactions with that country at risk. Alternatively, only project-based credits, or those permit or credit sales beyond some target level of seller country emissions might be subjected to this caveat emptor test.¹²

If buyer countries were liable for seller non-compliance, buyer countries and their sub-national actors, to whom they pass the liability, would undertake a variety of risk management measures. Expert assessments of noncompliance risk would be developed to help buyers gauge the probabilities of having their permits or credits devalued ex post, and these probabilities would be used by buyers to discount the price of purchased credits from less secure sources accordingly. To the extent that noncompliance was based on the

debited by US regulators and for Japanese regulators to note that the buyer has obtained a greater capacity to emit.

¹¹ The fact that transactions costs and oversight costs would be higher under bilateral contracting for emission reduction credits is one of the important advantages of establishing domestic trading programs and allowing domestic permits to be internationally tradable.

¹² For example, Russia could sell credits equal to the difference between its emission quota under the Kyoto Protocol and its 1998 emissions or some other target level – the so-called hot air – without triggering buyer liability, but sales beyond that mark would be caveat emptor.

nonperformance of a specific seller, rather than aggregate national emissions by the selling country, buyers would use the discounting mechanism as leverage to shift some of the burden of compliance back to sellers by offering higher prices for more secure emission reductions. Buyers would refuse to trade with especially risky sellers. These actions impose monitoring and risk-assessment costs on the buyer, encourage sellers to provide transparent information on their compliance, and punish unreliable sellers by limiting their gains from trading.

Introducing buyer liability, in addition to seller liability, will increase compliance, but may do so at high cost relative to the gains and relative to the costs of increasing compliance pressure on sellers. Buyers can affect seller behavior by observing seller conduct and then responding to it either by changing their trading behavior, offering less for risky credits, or by sanctioning non-complying sellers directly. For buyer liability to be beneficial, buyers must have a comparative advantage relative to the international community either in monitoring or responding to seller non-compliance, and they must not be so risk averse that bearing the risk of penalties for noncompliance would drive them from the market. Both buyer and seller must be able to be fully sanctioned. If these conditions hold it could be efficient for the international community to “sub-contract” with the buyer, with the threat of sanctions as the incentive, rather than increasing (or as a replacement for) their own effort.

Neither buyers nor intermediaries are likely to have a strong comparative advantage in assessing the prospective conduct of sellers, at least early on in the advent of international GHG trading. Any individual buyer country is in a very similar situation to the international agency when trying to monitor another country’s GHG production. If they subcontract monitoring to specialists, the international agency could do likewise. Buyers may duplicate each other’s efforts. Market reputations about seller conduct will take some time to develop.

Buyers’ options for policing seller behavior are inherently limited if defectiveness of credits is based solely on national aggregate emissions of the seller country versus transaction-specific findings. In particular, buyer liability is a form of joint and several liability that imposes the burden of non-compliant conduct by some buyers on all buyers. No buyer, and no sub-national seller, can control the risk of national non-compliance.

It follows that under buyer liability, buyers will face potentially high transaction costs in assessing the reliability of permits or credits offered on the international market. This will reduce trading and raise global abatement costs. Despite careful choice of sellers, buyers will still face uncontrollable risk that they will attempt to insure against by holding additional credits as a reserve margin or buying insurance from a broker. They will face high costs from the uncontrollable risk they are required to bear. Buyers are unlikely to satisfy the conditions for being a good monitoring and enforcement agent on the international community’s behalf.

We believe that on balance an appropriately defined seller liability program is the best way to allocate liability for performance failures in Annex I trades. To implement this program we would couple ex post sanctions on non-compliant Annex I countries with qualifying requirements for Annex I countries to participate in this trading market. The sanctions would have to be serious enough to motivate seller country governments to deter cheating by their private actors (e.g., forfeiture of future quota, limits on future access to the market), *given* that these countries are prepared to meet their international obligations. The national qualification process would look at countries' domestic monitoring and enforcement capabilities (including the general strengths of the legal systems for regulatory and contract enforcement), and perhaps at other factors that bear on their commitment and capacity to meet their obligations. Countries that fail to meet the qualifications would still be able to participate in trading, but only through the project-level CDM mechanism described below, with buyer liability. Determining a more fully articulated set of qualification criteria and applying them in practice would be inherently subjective, but no more so than determining countries' eligibility to participate in the IMF or WTO.¹³

Ultimately, for this approach to work the threat of future sanctions must deter cheating. This may not work; countries may simply walk away from their Framework Convention obligations. But the same risk exists in the absence of trading; in fact the risk arguably is bigger since compliance costs are higher (perhaps significantly) in that event. What is important, especially in the early stages, is to do as much as possible to develop a liquid and flourishing international trading system among Annex I countries subject to some basic credibility tests. We do not want to create a system, that we will live with for the indefinite future, which has high transactions costs, few trades, high national compliance costs, and consequently little national interest in meeting Kyoto goals.

Performance Risks and Remedies in CDM Trading

The situation with the CDM is fundamentally different from Annex I trading in at least three important respects. First, developing country hosts of JI/CDM projects are not currently obligated to cap aggregate emissions. These governments thus do not have the same obligations for policing the performance of domestic GHG abatement as their Annex I counterparts. Second, it is clear that a number of non-Annex I countries have less technical and institutional infrastructure for overseeing JI/CDM project results and enforcing contractual performance obligations than their counterparts in Annex I. Third,

¹³ The proposal in the text involves a single bright-line determination of eligibility to participate in Annex I permit/credit trading. More complex approaches are possible. For example, selling countries could be allowed to participate if they fail to meet all the criteria satisfactorily but with an automatic discount applied to their permits/credits. This would provide some inducement for improved performance in implementing monitoring and oversight. Again, the size and application of the discounts would be subjective, at least for some time until performance data and reputations become better established. If more complex qualification approaches such as this are used, we still believe there should be some threshold level of prospective performance to qualify for entry into the Annex I trading system.

Annex I actors obtaining the emissions credits also have a direct involvement in financing and possibly managing the investment project producing the credits. Their comparative advantage in monitoring and enforcement, and the prospects for two-sided strategic collusion to misrepresent project results, exist in a way that does not arise with more arms-length permit or credit transactions.

Consider first the problem of strategic collusion by credit buyer and seller to inflate the results of a CDM project, thereby increasing the payment to the seller while reducing the compliance burden of the buyer. Contract theory (see, e.g., Holmstrom and Milgrom 1990) suggests in this case, that as long as both actors can observe and control the behavior, the best way to deter such behavior is to assign liability for misrepresentation, once detected, to that actor with the greatest vulnerability to punishment. As partners in joint ventures, Annex I buyers have the ability to observe the number of credits created. They could refuse to pay for invalid credits. Annex I buyer countries are potentially more subject to reputational damage than non-Annex I, so they have stronger incentives to enforce domestic regulation. Combining this strong incentive with regulatory capability, Annex 1 sub-national buyers will face a wider array of credible domestic sanctions for noncompliance (including the possibility of citizen suits as well as formal regulatory punishments). The buyer would seem to be most vulnerable and hence should be held liable for correct reporting. This conclusion is strengthened by the observation that the buyer is better able than the seller to bear the increased economic risk implied by this penalty system.

A different set of problems arises when considering problems associated with failure of the project to deliver the promised emission reductions. This could arise either because of some unanticipated shock or because of insufficient effort. It may not be optimal to hold non-Annex I countries liable for the effects of unanticipated shocks. However these cannot generally be distinguished from lack of effort. Moral hazard is created by the inability to perfectly monitor effort in the project. Moral hazard problems are amplified by pre-certification of CDM projects. Pre-certification involves a predetermination of expected project outputs early on for purposes of valuing the project's contribution to compliance. The alternative would be waiting until the project reaches fruition and then monitoring the resulting emission reductions in an ongoing fashion. Such pre-certification is a powerful way to reduce the transactions costs associated with extensive, ongoing project-level monitoring, and thus make more of the gains from trade through CDM available to participants. However, by reducing the link between project payoff and effort, it invites less commitment to achieving the aims of the project. If pre-certification instead means that ex post, credit creation is measured only in a very noisy way, sanctions based on the noisy measure will increase the level of uncontrollable risk in the project.

The optimal assignment of responsibility for performance risks depends on the actors' information about each other's effort, the options for buyer and seller to alter each other's behavior, the options available to their respective governments for enforcement of sanctions, and their capacity to bear risk. As both financiers and co-developers of

projects, GHG credit buyers have the capacity to learn a fair amount about their host country partners' efforts as well as monitoring their own efforts. They can exert leverage over host country partners' performance by withholding payment in the event of non-performance, and they have a reasonable capacity to measure project outcomes. To the extent they are less risk-averse than sellers (for whom the marginal utility of income is higher and project income is a greater share of total income), buyers also are in a stronger position to bear unanticipated shocks by absorbing the residual liability for project shortcomings. By holding liable buyer countries, and through them the domestic actors engaged in CDM transactions, the incentives for achieving targets are increased and the tradeoff between providing strong incentives and sharing uncontrollable risk is lessened. We thus conclude that unlike Annex I trading, a buyer-beware approach is appropriate for project-specific joint implementation transactions through the CDM.

PRICES, QUANTITIES, AND INNOVATIONS

Although specific quantity targets have been selected for the first phase of greenhouse gas control, a great deal of uncertainty surrounds both the costs and the benefits of these goals. As more information is revealed, current policy is likely to be found to be off the mark. Price and quantity mechanisms can have different impacts on costs, abatement, and innovation under uncertainty. The differences are important when considering adjustment of policy targets, the method of implementing reductions, or the punishment function for undercompliance (or reward function for overcompliance).

Weitzman's (1974) original argument that price and quantity policy outcomes are not equivalent considered uncertainty in costs and benefits in a simple static setting. His seminal result finds a comparative advantage for price policies when marginal costs are more steeply sloped, while more steeply sloped marginal benefits favor quantity controls.¹⁴ Recent research by Newell and Pizer (1998) extends this analysis to a stock pollutant when costs are uncertain. The main Weitzman results still hold, but several other factors become important in the dynamic setting, as changes in current emissions affect future pollution stocks and shocks to current costs may also affect future costs. These factors include the depreciation rate of the stock, the discount rate for evaluating future benefits, and the correlation of costs over time.

Lower stock depreciation rates cause shocks to the flow of the pollutant to persist longer, causing greater variability in the stream of benefits to pollution reduction. Since benefits are concave (or damages from pollution are convex), this variation lowers the expected value of that stream. Since taxes allow for variation in the pollution flow, quantity controls become relatively more attractive. Similarly, lower discount rates favor quantity controls,

¹⁴ Essentially, taxes limit variation in costs, particularly when marginal costs are sensitive to small changes in abatement levels, by allowing the amount of emissions to adjust to cost shocks. Permits, on the other hand, allow marginal costs to vary, but they prevent change in the level of emissions, which is more important when marginal benefits are very sensitive to small changes in pollution levels.

since they raise the importance of future benefits. As Weitzman (1998) has recently pointed out, uncertainty in discount rates lowers the expected effective discount rate, since high rates imply insignificant weights on those future scenarios; extended to this case, discount rate uncertainty tends to favor quantity controls. Finally, positive correlation in costs across time causes shocks in costs to persist in abatement decisions into the future. Thus, cost correlation also exacerbates variation in the stock level, which tends to favor quantity controls. Still, Newell and Pizer find that price controls tend to be preferred to quantity measures when the pollutant stock is large relative to the flow. Essentially, taxes allow for more emissions when abatement costs are high and more abatement when costs are low, and these cost savings are more important than the impacts on damages when the annual flow is a small portion of the stock.

In these analyses, technology is taken as fixed (subject to random cost shocks). If technological change is endogenous, and not just fixed or subject to exogenous shocks, the relative attractiveness of policies may change. The relative ranking then depends not only on the aforementioned factors from the exogenous shocks model, but also on the innovating firm's ability to appropriate the resulting gains to other firms.

Fischer, Parry and Pizer (1998) decompose the rents an innovator can appropriate into four parts.¹⁵ The “abatement cost effect” is the increased willingness to pay for the new technology across all firms due to the impact of innovation on reducing firm abatement costs. From a social planner's perspective, this effect is all that matters, as it represents the true cost savings to society (assuming marginal costs and benefits or abatement were equalized ex post). The “imitation effect” is the leakage in willingness of non-innovators to pay for the new technology when there is the possibility of imitation to reduce abatement costs. This effect captures a market failure in R&D which transcends climate policy.

Two other pecuniary effects related to emissions trading can be defined. The “emissions payment effect” is the reduction in the innovator's payments for permits due to the effect of innovation on reducing the permit price. This effect is strongest under auctioned permits, when the innovator is liable for all its residual emissions. If the innovator owns permits, the loss in their value will offset some of the gain from the lower emissions liability. Finally, under gratis or auctioned permits, if a non-innovator were to use the imitation instead of the patented technology, it would have higher emissions and would pay for the additional permits. By reducing the permit price, innovation reduces these extra payments. This “adoption price effect” represents the corresponding reduction in royalty that non-innovators will pay for the new technology.

¹⁵ They employ a three-stage model wherein a single innovator develops a new technology, the other firms then decide whether to adopt or imitate that technology, and in the final stage abatement occurs. The tax or permit policy that induces the abatement (and thereby the innovation) is set at Pigouvian levels before innovation occurs and regulators do not anticipate innovation. In equilibrium, all firms adopt the technology; however, the options to imitate and to free ride on any drop in the equilibrium emissions permit price limit the innovator's ability to capture all the benefits to the industry of its invention.

The combination of these effects determines the incentives for innovation. In different situations, these incentives may be stronger with taxes or with permits. The abatement cost effect, net of the imitation effect, is stronger under taxes, because more abatement is performed post-innovation compared to a permit trading policy with fixed total emissions. When technological spillovers are large or the number of adopting firms is small, the innovator's direct incentives to reduce abatement costs increase relative to potential royalties from other potential adopters; thus, the emissions payment effect is more likely to dominate the adoption price effect. In this case an auctioned permit system can induce more innovation than a tax because the innovator experiences a larger drop in payment to the government.

Incentives for innovation are only part of what determines the welfare impacts of different abatement policies. In cases where the market for research and development functions relatively well and the ability to appropriate rents from innovation is high, what matters most is inducing the optimal level of emissions abatement over time. Innovation incentives tend to reinforce the results from the standard prices-versus-quantities literature. Taxes are relatively efficient when marginal benefits are flat, but they can induce too much innovation and abatement when marginal benefits are steep since the tax price does not adjust to reflect the lower marginal benefits when post-innovation abatement increases. When appropriation is more limited (for example, because the patent system is ineffective), auctioned emissions permits may induce the highest welfare gain, as the emissions payment effect becomes relatively more important. However, there is a danger of the emissions payment effect being too strong and inducing excessive innovation when the number of emitters is small (so that imitation threatens little loss of rent appropriability) or the initial abatement level is small (so that the baseline payment to the government that can be reduced by innovation is large).

The welfare discrepancies between policies are generally less important in situations where less innovation is performed during whatever period policies remain fixed, for example because the marginal cost of innovation is high. Conversely, if innovation is relatively easy, this will magnify the difference in outcomes between tax and permit policies. Similarly, if the tax rate or the quantity of permits can be reduced at regular intervals over time in response to cost-reducing innovation, the choice of specific policy tool will matter less. However, while regular adjustment will ensure greater ex-post efficiency, anticipation of these adjustments will compromise some incentives for innovation, as falling prices lead to a shrinking abatement cost effect and an adoption price effect which can outweigh the implied emissions payment effect (i.e., the adjusted tax policy adopts characteristics of a permit policy)

Cost uncertainty has different effects on the innovation incentives of the different policies. A tax caps the marginal cost of abatement and allows emissions to adjust to cost variations. Uncertainty then lowers expected abatement costs and, thus, the expected benefits of innovation under a tax. On the other hand, uncertainty raises the expected benefits the innovator appropriates under a permit system. This impact occurs through

the adoption price effect: marginal cost shocks do not affect actual abatement levels, but they do affect the amount of abatement a firm would perform if it chose to imitate rather than adopt the innovation, both directly and indirectly through the equilibrium permit price. Uncertainty raises expected royalty payments and thus reduces the expected adoption price effect; this occurs because cost uncertainty raises expected emissions permit payments when other emitters imitate rather than adopting the innovation.

The lesson from the recent contributions to the prices versus quantities literature is that the different policies can have very different welfare impacts, depending not just on the slopes of the marginal benefits and cost curves but also on pollution stock depreciation rates, discount rates, the correlation of costs over time, externalities in the market for research and development, cost of development and the scope for adoption of new technologies. Taxes tend to be preferred when marginal benefits are flat relative to marginal costs, pollution flows are small relative to the stock, costs are uncorrelated, and R&D spillovers are low. Annual quantity controls have an advantage when marginal abatement costs are flat relative to benefits, depreciation and discount rates are low or uncertain, costs are correlated over time, and innovations have widespread effects, much of which are nonappropriable spillovers, but innovators tend to be significant net buyers of permits. Unfortunately, many of these variables are still unknown.

Furthermore, policy choices encompass a broader spectrum than fixed taxes and fixed annual emissions flows, and other realistic policy designs lead to less of a discrepancy between the two types. Taxes, for example, can be nonlinear to reflect increasing marginal damages from pollution (Koplow and Shavell, 1997). Policy hybrids can be employed: for example, to put a ceiling on marginal costs, a permit policy could have a "safety valve" price at which the government sells extra permits (Pizer, 1996). To the extent that permits can be borrowed and banked over time, the expected price path will be constant in present value terms (and equivalent to an emissions tax indexed to the interest rate). Finally, both types of policies can be adjusted over time, either through rate changes or equivalent permit quantity changes.

In previous sections of the paper we have argued that denominating permits as shares of total allowed emissions without predetermining the totals, and allocating them several years in the future, has attractive features from the perspective of optimal risk allocation. This approach provides a means for adjusting to new information about benefits and costs. At the same time, if the government is concerned about threshold effects from growth in cumulative emissions it can limit their growth, while intertemporal flexibility in the reallocation of permits provides some of the same intertemporal cost smoothing as with an emissions tax.

Auctioning permits defined as a percentage of the target in advance also has implications for innovation incentives. The returns from innovation are initially captured within the private sector, but not necessarily by the innovator. The innovator can capture the "emissions payment" effect, which arises from the fall in permit price he induces, by holding permits short. If the target is made more stringent in response to the lower costs

the private sector receives any benefits from this through higher asset prices as well as bearing the higher abatement costs, in the same way that exogenous shocks are borne.

Thus this policy appears to have a number of attractive features. The message of the previous paragraph, however, is that it is difficult to determine a priori what policy design might be most efficient without a more detailed examination of the circumstances.

SUMMARY

Consideration of both exogenous risk (uncontrollable) and endogenous risk (concerns about policy credibility) suggest that permits should be auctioned several years in advance, and each permit should be defined as a percentage of a possibly varying target. For exogenous risks, this allows all risk to be pooled and managed as efficiently as possible within the private sector. For endogenous risk, it creates a vested interest which will pressure government to maintain or strengthen targets to offset the obvious pressures to weaken regulation. It also removes the ability of government to reallocate rents costlessly, or gain revenue by altering targets. Beyond the form of permit allocation, policy should be made as complete and transparent as possible, and its key elements should be established in legislation to limit prospects for capricious changes.

Another form of credibility problem is key in international emission permits markets, the credibility of traded permits. Permit markets can exacerbate or alleviate international compliance problems. We conclude that in trading among Annex I countries, the potential compliance benefits from adding buyer liability to seller liability are outweighed by the high transaction costs created and the level of uncontrollable risk buyers would have to bear. In contrast for trading with non-Annex I countries through the Clean Development Mechanism we conclude that the primary form of liability should be buyer liability. Buyers have considerably stronger incentives to comply than sellers both because they are more vulnerable to punishment and because their government's are able to enforce domestic regulation. Because trades are project based, buyers are able to observe and control accurate reporting. Because buyers have strong technical capabilities and can bear risk, they can be required to take full responsibility for achieving precertified credits even when there are large uncontrollable risks.

Finally, we note that while recent developments in the prices versus quantities literature provide several reasons for preferring price over quantity instruments, the actual performance of the two alternatives depends on a number of factors in addition to the relative slopes of marginal damage and abatement costs. Another important dimension of the tradeoff is the effects of the different policy types on innovation, and the extent to which innovation is suboptimal because of imperfect rent appropriability. More research is needed on these tradeoffs as well as on price versus quantity comparisons with different specifications of the two policies (differing degrees of dynamic adjustment, hybrids, and so forth).

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Incentive Compatible Coalitions in International Agreements on CO₂ Emission Controls

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ABSTRACT: Forming incentive-compatible coalitions is one of possible policy responses to deal with climate change. International environmental coalition issues have been extensively studied from the game theoretic approach. However, the game theoretic methodology had not been incorporated into empirical modeling works to study coalition problems until now. This paper is the first to integrate game theoretic treatment of coalition issues with large-scale, climate-economy modeling. An algorithm is developed to solve for “hybrid” coalitions in the RICE model (Nordhaus and Yang [1996]), relations between the incentive compatibility of coalitions and mitigation cost or climate damage structure are investigated, and policy implications of hybrid coalition solutions are indicated.

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Incentive Compatible Coalitions in International Agreements on CO₂ Emission Controls

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1. Introduction

Potential global climate change caused by anthropogenic greenhouse gas (GHG) emissions is one of the most serious international environmental concerns. From the Rio environmental summit in 1992 to the New York earth summit in 1997, calls for international cooperation have been assigned high priority as policy responses to global warming problems. While a binding international agreement on GHG emission control seems unlikely in the foreseeable future, as the painful negotiation process at the Third Conference of the Parties in Kyoto indicated, policy designers and environmentalists had lively discussions and debates on the formation and mechanism of such an agreement. Given the difficulties of forming a global coalition to cope with climate change, suggestions for forming various regional and local cooperative ventures have been proposed, such as Joint implementation (JI) and carbon emission permits trading.¹

One important, currently active branch of research relating to coalition issues focuses on

¹ For studies on joint implementation, see Bohm [1994].

game-theoretic approach. Game-theoretic approach has long been used to characterize some global environmental problems. More recently, economists employed game theoretic approach to examine conditions and agents' strategic behavior in negotiating and forming international coalitions to deal with global environmental problems, such as climate change. Relevant literature includes: Barrett [1994], Carraro [1997], Chen [1997], Heal [1994], Hoel and Schneider [1997], Kaitala and Pohjola [1995], and Karp and Sacheti [1997]. Game-theoretic approach provides insights in various aspects of forming international coalitions to deal with environmental issues. The highly stylized formulations in the above studies (sometimes accompanied by simple numerical examples), however, are not very helpful for the development of concrete policy recommendations. In addition, strategic behaviors of real parties (as opposed to abstract economic agents) in forming international environmental agreements are not captured by highly stylized theoretic models. On the other hand, many large-scale models integrating climate and economic issues have been developed to evaluate various CO₂ emission-control policies (see Weyant *et al.* [1996] for a summary), though most are not suitable for tackling coalition issues from game-theoretic viewpoints.

In this paper, game-theoretic approach is integrated with large-scale empirical modeling approach to examine possibilities of forming incentive compatible coalitions to cope with potential climate change. For this purpose, the concept of "hybrid coalition solution" is introduced, and an algorithm for solving hybrid coalitions developed. Hybrid coalition solutions are then sought in the RICE model (Nordhaus and Yang [1996]), a large-scale dynamic model of climate and economies. This paper examines strategic interactions between regions that join a coalition and those that do not. Relationships between willingness to participate in the coalition and mitigation

costs or climate change damages are also investigated.

The remainder of this paper is organized as follows: Section 2 describes conditions for forming international coalitions to control carbon emission and how these are incorporated into economic-environmental modeling. Section 3 introduces the “hybrid” coalition solution concept and the algorithm in the RICE model, and outlines the simulation designs. Section 4 analyzes the simulation results and economic implications. Section 5 offers concluding remarks.

2. Modeling Incentive-Compatible Carbon Emission Coalitions.

Climate change caused by anthropogenic CO₂ and other GHG emissions might have ominous consequences lasting for generations. Industrial activities that result CO₂ emissions bear the characteristics of joint production of stock externalities. Unlike stock externalities relating to other global environmental issues (such as ozone-layer depletion) that resulting in imminent adverse impacts, however, most of the damage attributable to climate change has yet to appear. Because of time lags between CO₂ emissions and the impact of climate change, incentives for coalition-forming are weak. In addition, the usual market failures associated with externalities make forming coalitions difficult. Because of these reasons, a Montreal Protocol-type international agreement on CO₂ emission control will not come smoothly. Even should such an agreement be reached, its enforcement would be difficult: Once any region's economic interests are hurt by the agreement, free-riding from the coalition will be unavoidable.

Because the nature of coalitions to control CO₂ emissions is so elusive, analysis of incentive-compatible coalitions is an imperative research agenda for both policy and theoretical interests. Only when the terms of a coalition are incentive compatible, can a rational region be

expected to join. To simultaneously capture the essence of coalition issues in CO₂ emissions control and to maintain the issues' tractability, the following assumptions and conditions are made for the subsequent discussion:

First, intertemporal dynamics is introduced explicitly into the framework. Climate change and CO₂ emissions control are long-lasting issues in a changing environment and strategic interactions among regions evolve over time, so static treatment is improper. Repeated game approach is also inadequate to deal with stock externality issues, because the decision spaces of agents change over time. This research project has therefore employed a differential game model with stock externalities.

Second, the model in this paper includes multiple, heterogeneous regions as decision-makers. Many previous game-theoretic studies on global environmental issues have either two agents (conveniently labeled "North-South" or "rich-poor") or identical multiple-agents. To examine coalition problems, a two-agent model is a degenerated special case in which either the non-cooperative Nash equilibrium or global cooperation prevails. No regional coalition exists in a two-agent model. For the identical multiple-agent case, an incentive compatible regional coalition is a contradiction in terms. Assumption of different mitigation costs, different climate-change impacts, and different scales of economies are crucial for modeling coalitions.

Third, all economic relationships in the model are assumed to be deterministic, to expose important strategic behavior among regions while eliminating the issues of model sensitivity and system uncertainty.²

² Computation for the deterministic case is still complex, as the next section of this paper shows. Hence, the assumption is also a computational necessity at this stage.

Based on the above assumptions, we further assume that a global economy consists of R regions. Region r emits $E_r(t)$ amount of CO_2 at time t ($t_0 \leq t \leq T$) into the atmosphere (the flow of stock externalities). Regional CO_2 emissions accumulate in the atmosphere. Collectively, atmospheric CO_2 concentrations cause the global mean temperature, $Te(t)$, increasing over time (the stock of stock externalities). $Te(t)$ adversely affects region r 's intertemporal payoff function, V_r , through a damage function $D_r(Te(t))$. However, by incurring certain mitigation costs, $C_r(t)$, over time, region r can reduce its own CO_2 emissions. By such mitigating efforts, a region can reduce its damage from temperature increases and reduce other regions' damage as well. Hence, region r 's payoff function can be expressed as an integral of regional mitigation costs over time:

$$V_r(C_1(t), \dots, C_r(t), \dots, C_R(t)) = \int_{t_0}^{\infty} F(C_1(t), \dots, C_r(t), \dots, C_R(t)) dt, \quad \forall r$$

Many solution concepts can be sought in the economic-climate processes mentioned above. Our study of regional coalition issues requires the following definitions:

Definition 1 (the Nash Equilibrium):

A triplet $(V_r^N, C_r^N(t), D_r^N(t))$ is a Nash equilibrium, if

$$V_r^N(C_1^N, \dots, C_r^N, \dots, C_R^N) \geq V_r(C_1^N, \dots, C_r, \dots, C_R^N), \quad \forall r, C_i \in C \quad \forall i.$$

Here, C is the space of mitigation decisions.

Definition 2 (the Pareto Optimal Allocations):

A triplet $(V_r^E, C_r^E(t), D_r^E(t))$ represents a Pareto optimal path if, for a region r , such that

$$V_r(C_1^E, \dots, C_r, \dots, C_R^E) > V_r^E(C_1^E, \dots, C_r^E, \dots, C_R^E),$$

then, for at least one region s :

$$V_s(C_1^E, \dots, C_r^E, \dots, C_s^E, \dots, C_R^E) < V_s^E(C_1^E, \dots, C_r^E, \dots, C_s^E, \dots, C_R^E).$$

To achieve a Pareto optimal path for CO₂ emissions, full-scale cooperation among all regions is needed. A cooperative outcome is equivalent to a solution from a global social planner's problem with a given distributional rule. In such a scheme, external effects of regional CO₂ emissions are fully internalized. The CO₂ emission path in the Nash equilibrium outcome, on the other hand, is inefficient. The Nash equilibrium does not coincide with any Pareto optimal allocation when stock externalities present.

Full-scale cooperation for internalizing global environmental externalities is extremely difficult. Local coalitions, as the second-best alternatives, are options for partially correcting global environmental externalities.

Definition 3 (Incentive-Compatible Coalitions):

K ($K < R$) regions form a coalition to interact strategically with the remaining R-K regions. Inside the coalition, members seek a Pareto optimal CO₂ emission path based on a distributional rule.³ If for all members in the coalition, that

$$V_k^E > V_k^N,$$

the coalition is called strongly incentive compatible; If by further redistribution inside the coalition, the above inequality holds for all members of the coalition, the coalition is called weakly incentive compatible.

Even the weakly incentive compatible coalition does not necessarily exist. For example, region A and region B form a coalition while region C stays outside the coalition. The efficient

³ The distribution rule here can be broadly interpreted as the social welfare weights assigned to each coalition member.

outcome reduces CO₂ emissions inside the coalition and entices region C to free-ride. One region in the coalition might be worse off by staying in the coalition due to high mitigation cost and compromised emission reductions. If the other region is too poor to compensate the “worse-off” region, the coalition cannot contrive. Intuitively, the larger the coalition, the more efficiency gains inside the coalition and the less inefficiencies outside the coalition (assuming a fixed-size global economy). A large coalition is therefore more likely to be incentive compatible.⁴

While conceptual distinctions between these three definitions are clear, a characterization of these definitions in empirical context is even more interesting. The next section solves the three solution concepts defined above in the RICE model.

3. “Hybrid” Coalition Solutions of the RICE Model

The RICE model is a multi-region optimal growth model treating climate change as stock externalities. The Appendix to this paper provides complete model description and parametric values and Nordhaus and Yang [1996] offers further details about the RICE model. For background of specifications for climate equations in the RICE model, see Nordhaus [1994]. The Pareto optimal allocation is the solution of a global social planner’s optimal control problem, as defined by system (A1) in the Appendix. The Nash equilibrium outcome is the solution of a differential game problem of n regions, as defined by system (A1') in the Appendix. The game is played out in the following way. Given its own mitigation cost and climate damage structure, as well as other regions’ CO₂ emissions patterns, each region determines its own CO₂ emission

⁴ Heal [1994] noted the effect of coalition size from a different angle by introducing the “minimum critical coalition” concept.

control strategies to maximize its intertemporal welfare function. Regions settle at an equilibrium state in which no region has incentive to deviate from its own CO₂ emissions path. Since each region has perfect foresight over time and all decisions are made during the initial period, the solution is an open-loop equilibrium.

Solution of the Pareto optimal allocation, defined as an optimal control problem, is straightforward. The solution of the Nash equilibrium has been resolved in Nordhaus and Yang [1996] by a special algorithm.⁵ An algorithm is proposed here to find coalition solutions in the RICE model.

Given the dimension of the model (six regions), there are $2^6 = 64$ ways to form a single coalition that strategically interacts with other regions.⁶ The Nash equilibrium and the cooperative outcome represent two special cases among these 64 possible combinations (with 0 and 6 regions in the coalition, respectively). With “1” representing “in the coalition” and “0” representing “out of the coalition,” a design matrix (displayed in Table 1) can reflect the full range of coalition scenarios. The Pareto optimal allocation scenario is depicted in the 1st row and the Nash equilibrium scenario is depicted in the 64th row.

To solve for coalition solutions, a new algorithm is developed to combine the optimal control problem and the differential game problem of the RICE model. A δ function, based on the design matrix, is attached to the objective functions of both the optimal control problem and the

⁵ Fankhauser and Kverndokk [1996] also solved the Nash equilibrium and the Pareto optimality in an empirical context.

⁶ For simplicity and without loss of generality, multiple-coalition scenarios, such as two 3-region coalitions, are not considered.

differential game problem.⁷ By doing so, if a region is in the optimal control problem, it is not in the differential game problem, and vice versa. The regional coalition, acting as one region, then enters the differential game with other single regions. Inside the coalition, the efficient allocation is determined simultaneously with the Nash equilibrium outside the coalition. Computationally, two solution routines in the original RICE model are combined, information from one routine being fed into the other during iterations. Because this algorithm involves both an optimal control problem and a differential game problem, it is called the “hybrid” coalition algorithm.

The hybrid coalition algorithm proved to be robust in the following test: Of 64 coalition scenarios, six scenarios (indicated by these shaded rows in Table 1) have five regions outside the coalition and only one within the coalition. Conceptually, these six scenarios are identical to the Nash equilibrium but they are kept in the calculation. In the algorithm, they are calculated in a different way from the Nash equilibrium (the case represented by the last row of Table 1). If the algorithm is robust, the seven scenarios should have identical solutions. The hypothesis is confirmed by the simulation results.⁸

Complete information about all state and control variables in the 64 coalition scenarios from the RICE model are voluminous. It needs to be parsimonious in digesting results. For purposes of analyzing the incentive compatibility of different coalitions, we are concerned with changes in the values of welfare functions (i.e., payoff functions in game theory terminology).

⁷ A δ function is defined as follows:

$\delta(x) = 1$, if $x \in X$, and $\delta(x) = 0$, if $x \notin X$. Here X is a criterion set.

⁸Source code is available upon request.

The algorithm is programmed in the GAMS language (Brook *et al.* [1992]). It takes about 4.5 hours on a Pentium Pro 200 MHz computer to finish one simulation consisting of 64 coalition scenarios.

Welfare levels of regions in each coalition scenario are compared with their counterparts in the Nash equilibrium and the Pareto optimal allocation. The outcomes of comparisons are listed in a tabular format like Table 2. Table 2 summarizes welfare changes from the Nash equilibrium position in 64 coalition scenarios when a region is in the coalition, based on default parametric assumptions of the RICE model. If a region is better off by joining the coalition, it is designated by a plus (+) sign in the relevant block; if a region is worse off, it is a minus (-) sign; if the region is outside the coalition, the block is left blank.⁹ Similarly, Table 3 contains welfare changes from the Pareto optimal allocation when a region is in the coalition. Note that Table 3 is not a mirror image of Table 2. A region can be better off or worse off in a coalition, compared to both its Nash and Pareto positions.

The simulations in this paper consist of one default run and several perturbation runs for coalition solutions. To avoid indexing inconsistencies, a single set of social welfare weights is used throughout simulations (the values of social welfare weights are given in the Appendix). The set is the intertemporal averages of time-dependent Negishi weights defined in Nordhaus and Yang [1996]. As mentioned before, social welfare weight in a social planner's optimal control problem is a distribution rule. In fact, the welfare weight ϕ_i and CO₂ control rate $\mu_i(t)$ of a region, *ceteris paribus*, have the following relationship:

$$\frac{\partial \mu_i(t)}{\partial \phi_i} < 0.$$

⁹ Because the welfare function here is a nonlinear transformation of per capita consumption over time, the numerical levels of welfare are not relevant. Only the cardinal properties of welfare matter here.

If a region is assigned a very small share of weights, it bears high mitigation costs than it would be for a larger share of weights. Because the region is less important in the eyes of the social planner, the cost-benefit evaluation regarding the region is less favorable. The set of average weights used in this paper is a relatively equitable starting point.

4. Results Analysis and Policy Implications

4.1. The Reference Simulation

Table 2 displays the results from the coalition simulation based on the default parametric assumptions of the RICE model. Two regions have unique sign in the table. The former Soviet Union (FSU) is always worse off and the rest of the world (ROW) is always better off by joining any coalition. The other four regions' signs are mixed.

In the RICE model, FSU has moderate CO₂ emission intensity due to its rich fossil resources and moderate economic growth. The mitigation cost structure is in line with that for other regions. Climate damage to FSU is lower than for other regions, however, mainly because of its geographic location: warming is a good thing for residents of Siberia so long as their homes are not inundated by sea-level rise. Due to the above specifications, FSU does not have strong incentives to reduce CO₂ emissions. In the social planner's scheme of coalitions, FSU is asked to contribute more for mitigation in all coalitions than it desired under the distribution rule. The light damage from climate change to FSU is not fully accounted for and external effects of FSU's CO₂ emissions to other regions in the coalition are considered in the coalition. Therefore, FSU is required to control more CO₂ emissions despite the fact that costs of these additional emission reductions cannot be compensated for by the benefits to FSU.

The case for the rest of the world (ROW) is the reverse. ROW is a heavy CO₂ emitter that will contribute about 60% of cumulative CO₂ emissions over the next century according to the RICE projection. ROW also has a fast-growing population and the lowest GDP per capita among all six regions. Such a pattern of economic growth ensures ROW a relatively small share in the social welfare weights. In a coalition for combating externalities, a region with a small share of social welfare weights takes less responsibility for emission control yet derives full benefits from the control efforts of heavily weighted regions. Therefore, ROW gains in all coalitions under our particular distribution rule.¹⁰

Table 2 indicates that the full-scale cooperation (Row # 1) is not a strong incentive compatible coalition under the distribution rule given by the intertemporal average Negishi weights. USA, CHN and FSU are worse off than their Nash equilibrium positions. Nevertheless, full cooperation under any distribution rule is a definitive Pareto improvement over the Nash equilibrium. The full cooperation here is a weak incentive compatible coalition. The losses of USA, CHN, and FSU in full cooperation can be compensated completely by three other regions. Although the losses by the three regions are not quantified here, they are small relative to gains made by other three regions. The compensation mechanism can be resetting the distribution rule or trading emission rights -- the latter being especially widely discussed by policy designers. In general, distribution rules exist under which every region is better off in full cooperation compared with the Nash equilibrium.

Several other phenomena revealed by Table 2 are worth noting. First, strong incentive-

¹⁰ For consistency, ROW is treated as one entity. Possible external effects inside ROW are ignored for the time being but are reconsidered in the perturbation simulations.

compatible coalitions (Simulations # 4, 12, 16, 28 and 44) are either OECD countries uniting with China, or OECD countries forming a block within (Simulation # 16). In fact, all coalitions within OECD are viable candidates at least for weak incentive compatible coalitions. Intuitively, less diversified agents form a coalition more easily. OECD situation is a case in point. Second, every two-region coalition involving ROW and another region has one winner, i.e., ROW, and a loser: given ROW's economic development level, it is unlikely ROW could compensate other region's losses. Therefore, such kinds of coalitions are not incentive-compatible and unsustainable. The phenomenon lends some rationale for Heal's [1992] "minimum critical coalition" concept. Third, there are no "lose-lose" coalitions. At least one net gainer exists in any coalition under the particular distribution rule defined by social welfare weights. Forming coalitions is always a good thing for at least some regions.

Table 3 displays welfare changes in coalitions relative to full cooperation. Three regions (JPN, EEC, and ROW) are consistently worse off departing from full cooperation to settle in a local coalition. These three have the most to gain from full cooperation, and thus more potential to compensate losers in the coalition. This pattern supports the claim that full cooperation is a weak incentive-compatible coalition. FSU is the only region that consistently prefers local coalitions (though it does not like these, either) to full cooperation.

Table 4 displays welfare changes when regions stay out of the coalition, relative to their Nash equilibrium positions. Without exception, all regions are better off. The situation shows that regions have windfall gains from other regions' coalition. Forming a coalition by some regions is not sufficient to encourage a third party following suit. Although Table 4 does not reveal whether an outsider region is a free-rider (its CO₂ emissions can be higher or lower than its Nash emission

level, depending on its strategic cost-benefit evaluation), a region can gain from others' coalition by acting strategically from the outside.

4.2 Perturbation Simulations

As mentioned earlier, incentives for joining a coalition are closely linked to a region's mitigation cost and climate damage structures. In other word, the elements comprising the triplets in Definitions 1 and 2 affect coalition outcomes. For a large model like RICE, it is impossible to investigate the whole spectrum of strategic sensitivities. To highlight the significance of the parametric specifications of cost and damage functions, we perturb only a few of these, one at a time.

Our perturbation simulations consist of 16 runs in which coefficient b_1 in the cost function (Equation A12) of USA as well as coefficient a_1 in the damage functions of FSU and ROW are allowed to vary. The cost function of USA has four "test high" and four "test low" scenarios; the damage function of FSU has four "test high" scenarios; the damage function of ROW has four "test low" scenarios. These alternative coefficient values are listed in Table 5. The social welfare weights, i.e., the distribution rule of the coalitions, are the same as those in the default run.

As will be seen shortly, changes to the USA cost function show how low and high mitigation costs affect coalition forming. Since the estimations on mitigation costs are uncertain, such sensitivity tests can and should be imposed on other regions also. The alternations of the FSU and ROW damage functions are more pointed: FSU is an outlier in damage structure (much lower than other regions). By increasing its benchmark damage incrementally, we can see how reduced diversities on the impacts side affect the forming of coalitions. Treating ROW as a single

agent is a very strong assumption. In reality, free-riding, non cooperative attitudes and other inefficiencies might be rampant inside the ROW bloc. Reducing benchmark damage is an indirect way to model internal multi-agent inefficiencies in the joint production of externalities.¹¹

Because the output from perturbation runs is too voluminous to be presented effectively in the format of tables 2 through 4, statistical presentations are provided instead. Table 6 records the number of plus signs for regions in each perturbation simulation as they would occur in a table like Table 2. In addition, total numbers of strongly incentive compatible coalitions are also reported here.

In Table 6, as mitigation costs of USA change from low to high, the signs of welfare changes of FSU and ROW when they are in the coalition relative to their Nash positions are not affected, while the signs of JPN, EEC, and CHN are marginally affected. However, the changes in mitigation cost significantly affect the USA's incentive to stay in the coalition: In any coalition, the social planner would put more CO₂ reduction responsibilities on those bearing low mitigation costs, *ceteris paribus*. If its mitigation costs are higher, the USA is more inclined to join a coalition because its responsibilities would be lighter than they would be in the default scenario -- and vice versa.

As shown in Table 6, the pattern relating to the signs of welfare change is not affected by the first two incremental increases of FSU's benchmark damages. Plus signs appear under FSU only when its benchmark damage approaches other regions' benchmark damage specifications. The simulation thus shows that less diversified damage structure across regions helps coalition forming.

¹¹ This method is used in the original RICE model (see Nordhaus and Yang [1996]).

When the benchmark damage of ROW is decreasing, the willingness to form a coalition from USA, JPN, EEC and CHN increase; FSU is still not attracted to any coalitions; ROW itself is almost totally uninterested in any coalition when the perturbed parameter is 1/10 of the default (see the last row in Table 6). A conclusion from this set of simulations is that a free-rider does not necessarily discourage other regions' desire to form a coalition.

The number of strongly incentive coalitions is correlated with the number of plus signs in all regions but has no definitive pattern. The number of possible candidates for weakly incentive compatible coalitions (not shown) is also related the number of positive signs among the regions.

For brevity, a summary table relating to Table 3 is not presented. The signs of all 16 perturbation simulations corresponding to Table 4 are the same as in the default run. This striking yet intuitive outcome can be explained easily by the fact that every outsider benefits from any coalition's enhanced efficiencies in providing externalities.

The last perturbation simulation considers an insightful special case. We set $a_1(\text{ROW}) = 0$ and see coalition outcomes. By setting a region's climate damage at zero, we captured one of the following two phenomena: First, the scenario represents the totally non-cooperative attitude toward CO₂ reduction coalitions by a block consists of large number of countries. When a large number of regions provide stock externalities, they tend to free-ride severely. Inefficiencies are so strong that regions are blinded to the potential impact. The damage while not zero, is perceived by those regions to be zero. The situation reflects the prevailing pessimistic views about the chances of forming international agreements for CO₂ reductions. Second, climate change might actually have no impact, or even a positive impact, on some regions. Therefore, imposing zero damage function is not a purely hypothetical experiment.

Tables 7, 8 and 9 display results from this case--total departures from all previous simulations. First, ROW is worse off in all coalitions compared with its Nash position (see Table 7). In addition, full cooperation is the worst position for ROW among all coalitions (see Table 8). This result is not surprising, since ROW is required to bear some CO₂ reduction responsibilities in a coalition and does not reap any benefits. Evidently, global full cooperation results in the lowest aggregate CO₂ emission, thus requiring ROW to reduce more CO₂ than any other coalition.

Second, USA, JPN, EEC, and CHN are strongly bounded to almost all coalitions (with a total of only five minus signs in Table 7) and full cooperation is their best position (all minus signs in Table 8). This outcome is less intuitive, but rational. The Nash equilibrium in this case differs from those in other simulations. Because the CO₂ control rate, $\mu(t)$, of ROW is zero, other regions' control rates need to be higher in the Nash equilibrium in order to compensate increased damage due to ROW's emissions. Therefore, every coalition included ROW (with no further redistribution) is a welfare improvement for the four regions. Even for FSU, which has a very low benchmark damage function, coalitions become more appealing (13 plus signs in Table 7). This phenomenon has strong policy implications.

Finally, ROW is totally indifferent outside of any coalition. As Table 9 shows, ROW's welfare levels remain unchanged in all coalition combinations. ROW is completely isolated from the external effects caused by CO₂ emissions.¹² It is easy to see that if all regions' damage functions are zero, the external effects disappear completely and no region has any incentive to form a CO₂ reduction coalition.

¹² This result is actually another proof of the robustness of the algorithm employed in this paper.

4.3. Policy Implication of the Hybrid Coalition Solutions

These simulations of the hybrid coalition solution in the RICE model provide several useful lessons for policy makers. First, both mitigation cost and climate damage structures of regions are vitally important to coalition forming. Although these relationships are well established in the game theoretic approach, they seem not fully appreciated by policy designers for international agreements on CO₂ reduction. CO₂ emission control is not altruistic heroism, so no region would willingly join a coalition that would hurt its welfare. In an international setting, willingness to pay is more crucial than ability to pay as a precondition for forming coalitions. The exercises in this paper provide a method for evaluating the willingness to join coalitions.

Second, the presence of free-riders in providing externalities does not necessarily discourage other regions from forming their own coalitions. In other words, if region C is determined to stay outside, regions A and B might still find ground for a coalition. Tables 7 through 9 reflect exactly this situation. Rational regions do not chase inefficient, Draconian emission reduction targets in an incentive-compatible coalition. Instead, they optimize CO₂ emission levels based on available information. If policy designers aim for such coalitions, advocates for “a global agreement or no agreement at all” are fallacious: a coalition needs not be global to work. Nevertheless, it is easier to find incentive-compatible distribution rules in a larger coalition than in a smaller one; certain small coalitions are not incentive-compatible.

Third, the distribution rule for a coalition is very important for its sustainment. Throughout the simulations, we used one set of social welfare weights as the distribution criterion for all coalitions so scenarios would be comparable. As we have already indicated, the selection is

reasonable: all regions' attitudes toward coalitions under this set are consistent with their perceivable behavior in reality. An infinite number of welfare weights are available from which to choose and endless arguments can be made about preferences of one over the other, based on decision makers' moral standpoint on coalitions' fairness. Different distribution rules can make a weakly incentive-compatible coalition into a strongly incentive-compatible coalition, and vice versa. However, distribution rules cannot change fundamental incentive compatibility, i.e., one cannot convert an incentive-incompatible coalition to an incentive compatible one simply by redistribution.

Fourth, while this paper has discussed the incentive compatibility of all coalitions under different mitigation cost and climate damage assumptions, the issue of how to form coalitions is not touched. The mechanism design approach to externality problems has resulted in some elegant products (for example the Clarke [1971] and Groves [1973] mechanisms), the ingenuity of such mechanism designs is yet made feasible in reality. For global environmental issues like climate change that are highly uncertain and long-lived, stimuli for forming coalitions are hard to find. While draconian CO₂ reduction proposals might keep negotiators busy for some time, they are not blueprints for collective actions. The simulation results reported in this paper indicate that regional coalitions, based on current knowledge of mitigation cost and climate damage structures, offers a prudent, "no-regrets" approach to dealing with the challenge of climate change.

5. Conclusions

This paper pioneers one approach of solving incentive-compatible coalition outcomes in a large-scale economy-climate model. Such an approach bridges the gap between highly stylized

game-theoretic methodology and empirical modeling endeavors in the research on global environmental issues. Efficient policy responses to global climate change rely on willing regional participation of international cooperation. The exercises in this paper shed light on how regions behave once they are in or out of a coalition. Judging from simulation results of the RICE model, regions' incentives to join a coalition are affected by their mitigation cost and climate damage structures and the distribution rule governing the coalition.

Uncertainties in all aspects of climate change give rise to scepticism about immediate policy actions based on modeling analysis. In light of these concerns, the principles established in this paper are independent of any particular model parameter specifications. Studies on the incentive compatibility of coalitions, such as the approach developed by this paper, are helpful for policy makers in negotiating international CO₂ emission reduction agreements, regional or global. Once we better understand mitigation cost and climate damage structures, the methodology in this paper can indicate likely outcomes of CO₂ reduction coalitions.

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Appendix

1. RICE Model for Pareto optimal allocations (an optimal control problem):

$$\underset{I_i(t), \mu_i(t)}{\text{Max}} \int_{t_0}^{\infty} \sum_{i=1}^n \phi_i(t) P_i(t) \ln(c_i(t)) e^{-\delta t} dt \quad (A1)$$

$$s.t. \quad Q_i(t) = A_i(t) K_i(t)^\gamma P_i(t)^{1-\gamma} \quad (A2)$$

$$Y_i(t) = \Omega_i(t) Q_i(t) \quad (A3)$$

$$C_i(t) = Y_i(t) - I_i(t) \quad (A4)$$

$$c_i(t) = \frac{C_i(t)}{P_i(t)} \quad (A5)$$

$$\dot{K}_i(t) = I_i(t) - \delta_K K_i(t) \quad (A6)$$

$$E_i(t) = (1 - \mu_i(t)) g_i(t) Q_i(t) \quad 0 \leq \mu_i(t) \leq 1 \quad (A7)$$

$$\dot{M}(t) = \beta \sum_{i=1}^n E_i(t) - \sigma M(t) \quad (A8)$$

$$\dot{T}_1(t) = F(t) - T_1(t) - \frac{\lambda_2}{\lambda_1}(T_1(t) - T_2(t)) \quad (A9)$$

$$\dot{T}_2(t) = \frac{T_1(t) - T_2(t)}{\lambda_1} \quad (A10)$$

$$F(t) = \frac{4.1 * \log(M(t)/M(t_0))}{\log(2)} + O(t) \quad (A11)$$

$$\Omega_i(t) = \frac{1 - b_{1,i} \mu_i(t)^{b_{2,i}}}{1 + a_{1,i} T_1(t)^{a_{2,i}}} \quad (A12)$$

2. RICE model for the Nash equilibrium (a differential game problem):

$$\underset{I_i(t), \mu_i(t)}{\text{Max}} \int_{t_0}^{\infty} \phi_i(t) P_i(t) \ln(c_i(t)) e^{-\delta t} dt \quad i = 1, 2, \dots, n. \quad (A13)$$

s. t. (A2) to (A7), (A9) to (A12), and

$$\dot{M}(t) = \beta[E_i(t) + \sum_{j \neq i}^n \tilde{E}_j(t)] - \sigma M(t) \quad i = 1, 2, \dots, n. \quad (A8')$$

Here $\tilde{E}_j(t)$ is exogenous, from region i' s perspective.

3. Definitions of variables and parameters in the RICE model (A1 to A12):

State variables:

$Q_i(t)$:	Production function
$K_i(t)$:	Capital stock
$C_i(t)$:	Consumption function
$c_i(t)$:	Per capita consumption
$E_i(t)$:	CO ₂ emissions
$M(t)$:	CO ₂ concentrations
$T_1(t)$:	Global average atmospheric temperature change
$T_2(t)$:	Average oceanic temperature change
$F(t)$:	Radiative forcing
$\Omega_i(t)$:	Adjustment function of cost and damage;

Control variables:

$I_i(t)$:	Investment function
$\mu_i(t)$:	CO ₂ emission control rate;

Parameters:

$\phi_i(t)$:	Negishi social welfare weights
$P_i(t)$:	Population
$A_i(t)$:	Productivity trend
$g_i(t)$:	Exogenous CO ₂ / output ratio trend
$O(t)$:	Exogenous radiative forcing;

Model dimension:

Region i :	USA, Japan (JPN), the European Union (EEC), China (CHN), the former Soviet Union (FSU) and the rest of the world (ROW);
Time t :	1990 - 2150 in 10-year steps.

4. Crucial Parameter Values:

	USA	JPN	EEC	CHN	FSU	ROW
Welfare weight ϕ	1.59	1.95	1.45	0.26	0.45	0.30
Damage coefficient a_1	0.01102	0.01174	0.01174	0.01523	0.00857	0.02093
Damage coefficient a_2	1.5	1.5	1.5	1.5	1.5	1.5
Cost coefficient b_1	0.07	0.05	0.05	0.15	0.15	0.10
Cost coefficient b_2	2.887	2.887	2.887	2.887	2.887	2.887

Table 1

Design Matrix

1 = in coalition: 0 = out of coalition

Simulation #	USA	JPN	EEC	CHN	FSU	ROW
1	1	1	1	1	1	1
2	1	1	1	1	1	0
3	1	1	1	1	0	1
4	1	1	1	1	0	0
5	1	1	1	0	1	1
6	1	1	1	0	1	0
7	1	1	1	0	0	1
8	1	1	1	0	0	0
9	1	1	0	1	1	1
10	1	1	0	1	1	0
11	1	1	0	1	0	1
12	1	1	0	1	0	0
13	1	1	0	0	1	1
14	1	1	0	0	1	0
15	1	1	0	0	0	1
16	1	1	0	0	0	0
17	1	0	1	1	1	1
18	1	0	1	1	1	0
19	1	0	1	1	0	1
20	1	0	1	1	0	0
21	1	0	1	0	1	1
22	1	0	1	0	1	0
23	1	0	1	0	0	1
24	1	0	1	0	0	0
25	1	0	0	1	1	1
26	1	0	0	1	1	0
27	1	0	0	1	0	1
28	1	0	0	1	0	0
29	1	0	0	0	1	1
30	1	0	0	0	1	0
31	1	0	0	0	0	1
32	1	0	0	0	0	0
33	0	1	1	1	1	1
34	0	1	1	1	1	0
35	0	1	1	1	0	1
36	0	1	1	1	0	0
37	0	1	1	0	1	1
38	0	1	1	0	1	0
39	0	1	1	0	0	1
40	0	1	1	0	0	0
41	0	1	0	1	1	1
42	0	1	0	1	1	0
43	0	1	0	1	0	1
44	0	1	0	1	0	0
45	0	1	0	0	1	1
46	0	1	0	0	1	0
47	0	1	0	0	0	1
48	0	1	0	0	0	0
49	0	0	1	1	1	1
50	0	0	1	1	1	0
51	0	0	1	1	0	1
52	0	0	1	1	0	0
53	0	0	1	0	1	1
54	0	0	1	0	1	0
55	0	0	1	0	0	1
56	0	0	1	0	0	0
57	0	0	0	1	1	1
58	0	0	0	1	1	0
59	0	0	0	1	0	1
60	0	0	0	1	0	0
61	0	0	0	0	1	1
62	0	0	0	0	1	0
63	0	0	0	0	0	1
64	0	0	0	0	0	0

Table 2 Welfare Changes when in Coalition (from the Nash Position)

Reference Scenario

Simulation #	USA	JPN	EEC	CHN	FSU	ROW
1	-	+	+	-	-	+
2	+	+	+	+	-	
3	-	+	+	-		+
4	+	+	+	+		
5	-	+	+		-	+
6	+	+	+		-	
7	-	+	+			+
8	-	+	+			
9	-	+		-	-	+
10	+	+		+	-	
11	-	+		-		+
12	+	+		+		
13	-	+			-	+
14	+	+			-	
15	-	-				+
16	+	+				
17	-		+	-	-	+
18	+		+	+	-	
19	-		+	-		+
20	+		+	+		
21	-		+		-	+
22	+		+		-	
23	-		-			+
24	-		+			
25	-			-	-	+
26	+			+	-	
27	-			-		+
28	+			+		
29	-				-	+
30	+				-	
31	-					+
32						
33		+	+	-	-	+
34		+	+	+	-	
35		+	+	-		+
36		+	+	-		
37		+	+		-	+
38		+	+		-	
39		-	-			+
40		-	+			
41		+		-	-	+
42		+		+	-	
43		+		-		+
44		+		+		
45		-			-	+
46		+			-	
47		-				+
48						
49			+	-	-	+
50			+	+	-	
51			+	-		+
52			+	-		
53			+		-	+
54			+		-	
55			-			+
56						
57				-	-	+
58				+	-	
59				-		+
60						
61					-	+
62						
63						
64						

Table 3 Welfare Changes when in Coalition (from the Full Cooperation Position)

Reference Scenario

Simulation #	USA	JPN	EEC	CHN	FSU	ROW
1						
2	+	-	-	+	+	
3	-	-	-	-		-
4	+	-	-	+		
5	-	-	-		+	-
6	+	-	-		+	
7	-	-	-			-
8	+	-	-			
9	-	-		+	+	-
10	+	-		+	+	
11	-	-		-		-
12	+	-		+		
13	-	-			+	-
14	+	-			+	
15	-	-				-
16	+	-				
17	-		-	+	+	-
18	+		-	+	+	
19	-		-	-		-
20	+		-	+		
21	-		-		+	-
22	+		-		+	
23	-		-			-
24	+		-			
25	-			+	+	-
26	+			+	+	
27	-			-		-
28	+			+		
29	-				+	-
30	+				+	
31	-					-
32						
33		-	-	-	+	-
34		-	-	+	+	
35		-	-	-		-
36		-	-	+		
37		-	-		+	-
38		-	-		+	
39		-	-			-
40		-	-			
41		-		-	+	-
42		-		+	+	
43		-		-		-
44		-		+		
45		-			+	-
46		-			+	
47		-				-
48						
49			-	-	+	-
50			-	+	+	
51			-	-		-
52			-	+		
53			-		+	-
54			-		+	
55			-			-
56						
57				-	+	-
58				+	+	
59				-		-
60						
61					+	-
62						
63						
64						

Table 4 Welfare Changes when out of Coalition (from the Nash Position)

Reference Scenario

Simulation #	USA	JPN	EEC	CHN	FSU	ROW
1						
2						+
3					+	
4					+	+
5				+		
6				+		+
7				+	+	
8				+	+	+
9			+			
10			+			+
11			+		+	
12			+		+	+
13			+	+		
14			+	+		+
15			+	+	+	
16			+	+	+	+
17		+				
18		+				+
19		+			+	
20		+			+	+
21		+		+		
22		+		+		+
23		+		+	+	
24		+		+	+	+
25		+	+			
26		+	+			+
27		+	+		+	
28		+	+		+	+
29		+	+	+		
30		+	+	+		+
31		+	+	+	+	
32						
33	+					
34	+					+
35	+				+	
36	+				+	+
37	+			+		
38	+			+		+
39	+			+	+	
40	+			+	+	+
41	+		+			
42	+		+			+
43	+		+		+	
44	+		+		+	+
45	+		+	+		
46	+		+	+		+
47	+		+	+	+	
48						
49	+	+				
50	+	+				+
51	+	+			+	
52	+	+			+	+
53	+	+		+		
54	+	+		+		+
55	+	+		+	+	
56						
57	+	+	+			
58	+	+	+			+
59	+	+	+		+	
60						
61	+	+	+	+		
62						
63						
64						

Table 5 Values of Perturbed Parameters

	b1(USA)	a1(FSU)	a1(ROW)
Test High	0.200	0.02057	
	0.150	0.01857	
	0.120	0.01557	
	0.100	0.01257	
Default	0.070	0.00857	0.020930
Test Low	0.030		0.010930
	0.020		0.005930
	0.010		0.004186
	0.007		0.002093

Table 6 Number of Positive Welfare Changes from the Nash Position

	USA	JPN	EEC	CHN	FSU	ROW	Strong Coalitions
Default	13	26	28	13	0	31	6
Cost High 4	23	26	27	11	0	31	6
Cost High 3	18	26	27	13	0	31	7
Cost High 2	18	26	27	13	0	31	6
Cost High 1	15	26	28	13	0	31	6
Cost Low 1	13	27	29	13	0	31	6
Cost Low 2	8	27	29	13	0	31	1
Cost Low 3	4	27	29	13	0	31	1
Cost Low 4	3	27	29	17	0	31	1
Damage High 4	13	26	27	13	4	31	9
Damage High 3	13	26	28	13	2	31	8
Damage High 2	13	26	28	13	0	31	5
Damage High 1	13	26	28	13	0	31	6
Damage Low 1	23	29	30	17	0	31	7
Damage Low 2	28	30	31	28	0	31	19
Damage Low 3	29	30	31	29	0	29	19
Damage Low 4	29	30	31	29	0	4	6

Note:

1. Scenario # 1 is the closest to and #4 is the furthest from the default
2. "Cost Low" and "Cost High" are related to USA, "Damage High" is related to FSU and "Damage Low" is related to ROW.
3. See Table 5 for the values of parameter perturbations used.

Table 7 Welfare Changes when in Coalition (from the Nash Position)

Extreme Scenario: A1(ROW) = 0

Simulation #	USA	JPN	EEC	CHN	FSU	ROW
1	+	+	+	+	-	-
2	+	+	+	+	-	-
3	+	+	+	+		-
4	+	+	+	+		-
5	+	+	+		+	-
6	+	+	+		-	-
7	+	+	+			-
8	-	+	+			-
9	+	+		+	+	-
10	+	+		+	-	-
11	+	+		+		-
12	+	+		+		-
13	+	+			+	-
14	+	+			-	-
15	+	+				-
16	+	+				-
17	+		+	+	-	-
18	+		+	+	-	-
19	+		+	+		-
20	+		+	+		-
21	+		+		+	-
22	+		+		-	-
23	+		+			-
24	-		+			-
25	+			+	+	-
26	+			+	-	-
27	+			+		-
28	+			+		-
29	+				+	-
30	+				-	-
31	+					-
32						-
33		+	+	+	-	-
34		+	+	+	-	-
35		+	+	+		-
36		+	+	-		-
37		+	+		+	-
38		+	+		-	-
39		+	+			-
40		-	+			-
41		+		+	+	-
42		+		+	-	-
43		+		+		-
44		+		+		-
45		+			+	-
46		+			-	-
47		+				-
48						-
49			+	+	+	-
50			+	+	-	-
51			+	+		-
52			+	-		-
53			+		+	-
54			+		-	-
55			+			-
56						-
57				+	+	-
58				+	-	-
59				+		-
60						-
61					+	-
62						-
63						-
64						-

Table 8 Welfare Changes when in Coalition (from the Full Cooperation Position)

Extreme Scenano: A1(ROW) = 0

Simulation #	USA	JPN	EEC	CHN	FSU	ROW
1						
2	-	-	-	-	-	
3	-	-	-	-		+
4	-	-	-	-		
5	-	-	-		+	+
6	-	-	-		-	
7	-	-	-			+
8	-	-	-			
9	-	-		-	+	+
10	-	-		-	-	
11	-	-		-		+
12	-	-		-		
13	-	-			+	+
14	-	-			-	
15	-	-				+
16	-	-				
17	-		-	-	+	+
18	-		-	-	-	
19	-		-	-		+
20	-		-	-		
21	-		-		+	+
22	-		-		-	
23	-		-			+
24	-		-			
25	-			-	+	+
26	-			-	-	
27	-			-		+
28	-			-		
29	-				+	+
30	-				+	
31	-					+
32						
33		-	-	-	+	+
34		-	-	-	-	
35		-	-	-		+
36		-	-	-		
37		-	-		+	+
38		-	-		-	
39		-	-			+
40		-	-			
41		-		-	+	+
42		-		-	-	
43		-		-		+
44		-		-		
45		-			+	+
46		-			+	
47		-				+
48						
49			-	-	+	+
50			-	-	-	
51			-	-		+
52			-	-		
53			-		+	+
54			-		-	
55			-			+
56						
57				-	+	+
58				-	-	
59				-		+
60						
61					+	+
62						
63						
64						

Table 9 Welfare Changes when out of Coalition (from the Nash Position)

Extreme Scenario: A1(ROW) = 0

Simulation #	USA	JPN	EEC	CHN	FSU	ROW
1						
2						
3					+	
4					+	
5				+		
6				+		
7				+	+	
8				+	+	
9			+			
10			+			
11			+		+	
12			+		+	
13			+	+		
14			+	+		
15			+	+	+	
16			+	+	+	
17		+				
18		+				
19		+			+	
20		+			+	
21		+		+		
22		+		+		
23		+		+	+	
24		+		+	+	
25		+	+			
26		+	+			
27		+	+		+	
28		+	+		+	
29		+	+	+		
30		+	+	+		
31		+	+	+	+	
32						
33	+					
34	+					
35	+				+	
36	+				+	
37	+			+		
38	+			+		
39	+			+	+	
40	+			+	+	
41	+		+			
42	+		+			
43	+		+		+	
44	+		+		+	
45	+		+	+		
46	+		+	+		
47	+		+	+	+	
48						
49	+	+				
50	+	+				
51	+	+			+	
52	+	+			+	
53	+	+		+		
54	+	+		+		
55	+	+		+	+	
56						
57	+	+	+			
58	+	+	+			
59	+	+	+		+	
60						
61	+	+	+	+		
62						
63						
64						