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Clinton Presidential Records
Council of Economic Advisers
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Environment: Climate Change Vol. II [2]

2017-1095-F

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RESTRICTION CODES

Presidential Records Act - [44 U.S.C. 2204(a)]

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RR. Document will be reviewed upon request.

11/4/96
Alice
For 1Pm
mtg

CLIMATE CHANGE CHEAT SHEET

Scientific

The four most important greenhouse gases (GHG), which account for 99.5% of anthropogenic sources, in descending order are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O)

Concentrations of these gases:

Gas	Preindustrial	1993	2100 (upper bound, business-as-usual)
CO ₂	280 ppm	358 ppm	650 ppm
CH ₄	0.7 ppm	1.72 ppm	3.12 ppm
N ₂ O	0.275 ppm	0.312 ppm	0.400 ppm
Fluorocarbons (HFC, PFC)	0	0.0003 ppm	0.0012 ppm

Greenhouse warming potential (GWP) Year 2100 CO₂ equivalent concentrations (business as usual)

1 ton CO ₂ = 0.27 tons of carbon (C)	650 ppm
1 ton CH ₄ = 6.69 tons of C	76.6 ppm
1 ton N ₂ O = 80 tons of C	32 ppm
1 ton fluorocarbons = 40 tons of C	.048 ppm

U.S. Situation

1993 emissions of GHG based on carbon equivalent

CO ₂	1406 million metric tons (1372 from energy consumption)
CH ₄	178 million metric tons
N ₂ O	40 million metric tons
fluorocarbons	20 million metric tons

Utilities responsible for 30% of U.S. GHG emissions

Transportation responsible for 27% of U.S. GHG emissions (fastest growing source)

In 1993, U.S. was responsible for 25% of world-wide emissions of CO₂ from burning fossil fuels, is projected to emit 13% by 2050

In 1993, U.S. was responsible for 21% of GHGs.

Economic

\$100 carbon tax would increase, in short run

gasoline prices by \$0.37/gal.

coal by \$75 per ton (current price \$28/ton)

petroleum by \$12/bbl (current price \$23/bbl)

natural gas by \$0.15 per 1000 cf (current price is \$1.65)

electricity from coal-fired plants by \$0.10/kwh (currently \$0.03/kwh)

electricity from natural gas combined cycle (NGCC) plants (the most energy efficient technology) by \$0.035/kwh (currently \$0.04-0.045/kwh)

Coal fired generating capacity in 1993 was 302,000,000 kw

Current capital costs for NGCC plants is \$500/kw, for coal fired plants is \$1421/kwh

(Back of the envelope estimate: Replacing 10% of coal fired plants with NGCC plants would require \$15 billion; 20%, \$ 30 billion, etc. Note: natural gas prices will increase as a result of fuel switching and switching may require some expansion of gas line capacity).

The industry expected to be most affected by reducing CO₂ are coal mining, gas and oil producers, petro-chemicals, steel, utilities, aluminum, agriculture, auto industry and cement industry

Just CO2 - Nick all other
greenhouse gases -

DRAFT**DRAFT**DRAFT

10/31/96

Stabilizing 2010 Carbon Emissions at the 1995/1996 Average Level: A Quick Turnaround Analysis

This note responds for your request for a quick-turnaround analysis of reducing carbon emissions in 2010 at the current emissions level. For purposes of this analysis the target emissions level for 2010 was assumed to be 1425 million metric tons (MMT), approximately the average of 1995 and 1996 emissions of carbon from the energy sector. The 1996 Annual Energy Outlook reference case projects an emissions level of 1660 MMT in 2010 absent new policies directed at reducing emissions.

Two models (MARKAL-MACRO and IDEAS) were used to develop some preliminary insights into the imputed carbon value required to reach the assumed goal. Table 1a reports the imputed carbon tax values from the MARKAL-MACRO and IDEAS models. The required implicit or explicit carbon value would increase delivered (including imputed carbon values) fossil fuel prices significantly from the reference case projections for the year 2010, which are reported in Table 1b. Note that prices paid to suppliers would fall for coal and oil, but increase for natural gas due to rising demand.

Table 1a Imputed Carbon Values in 2010

	MARKAL-MACRO	IDEAS
Imputed Carbon Value (\$94/ton)	66.00	140.00
Increment to Demand-Side Fossil Fuel Prices		
Coal (\$94/short ton)	35.71	75.56
Petroleum (\$94/barrel)	7.87	16.65
Natural Gas (\$94/mcf)	0.96	2.09

Table 1b: Reference Case Fuel price projections

Base Case Fossil Fuel Prices

Coal (\$94/short ton)	
at Minemouth	17.43
Delivered to Utilities	25.88
Petroleum: World Crude (\$94/barrel)	23.70
Natural Gas (\$94/mcf)	
Wellhead	2.15
Residential	6.08
Industrial	2.84
Electric	2.49

DRAFT**DRAFT**DRAFT

10/31/96

The different approaches of the two models used should be recognized. The MARKAL-MACRO model assumes perfect foresight and full knowledge of cost information on fuel and technologies. The whole energy system is optimized simultaneously, considering technologies on both the demand and supply sides to meet energy service needs. Energy savings and carbon emission reductions opportunities are evaluated within each sector, across sectors, and over the whole time horizon under consideration.

The IDEAS model relies on behavioral relationships between energy savings from energy conservation investment, fuel prices, and technology choices. IDEAS treats each sector independently, with decisions in most sectors based on economic information available for the current time period only. For the electricity sector, the model has the capability to look ahead and optimize based on assumptions on future technology and fuel prices.

In the time available for this quick turnaround analysis, only the DRI macroeconomic model was used to simulate effects of higher demand-side energy prices on the US economy. This model was used as the primary basis of the Administration presentation at the June Analysis Workshop, notwithstanding the concerns of the Department that results from a broader variety of models should be presented. We continue to believe that other types of models may provide additional relevant insights.

Table 2 summarizes the GDP losses for three scenarios -- stabilization at the 1990 level.

Table 2 GDP Losses (Billions in \$1994) Resulted from Carbon Taxes

	NPV 7%, 2000-2015	2010 Loss	
Stabilization to 1990 Level (using IDEAS Tax Level)	\$517 ^b	\$98	1% GDP IN 2010
Stabilization to 1995/1996 Average Level (using IDEAS Tax Level)	\$417 ^b	\$69	
Stabilization to 1995/1996 Average Level (using MARKAL-MACRO Tax Level)	\$196 ^b	\$33	1/3 of 1% of GDP IN 2010

We would close by reemphasizing the preliminary nature of the results presented above, which are outlined here only in response to your urgent request. We could provide additional sectoral detail upon request if you let us know what you need.

taxes - lump
sum

• Reduction in costs of clean environmental programs -

• Lowers health benefits - savings in health care expenses

100	1 ton coal	2 CO ₂	80
100	1 oil	1 CO ₂	60

Green GDP:

Alice Thurs, 11/7/86
for Bob

Naturally Optimal Climate Response Action Partnership (NOCRAP)

Introduction

NOCRAP, a group dedicated to advancing common rather than special interests, is increasingly dismayed by the disconnect between remedies proposed to address the threat of climate change and the actual nature of that threat.

To help stimulate new thinking, NOCRAP offers a modest proposal (outlined below) based on the simple analytics of fossil-fuel carbon stocks and flows. The analytics are "back of the envelope," and would need to be carefully vetted by domestic and international groups in possession of the requisite tools (and toolboxes, of course).

The analysis and strawman proposals outlined below are directly based on relevant academic and policy literature, including reports of the Intergovernmental Panel on Climate Change (IPCC). While some implementation details of the strawman proposal are new, it should be emphasized that the basic insights are not original to NOCRAP. The latter, not the former, are most important, since other implementation packages could easily be built around the same insights.

This brief paper is divided into three sections:

- Analytic Foundations of NOCRAP Proposal
- NOCRAP Strawman Proposal
- Domestic and International Equity Considerations Surrounding NOCRAP Proposal

A. Analytic Foundations of NOCRAP Proposal

1. Future coal use trends are the key determinant of future atmospheric carbon dioxide (CO₂) concentrations. Other fossil fuels are relatively unimportant. For example, by 2100, coal combustion accounts for more than 88 percent of total energy-related CO₂ emissions in the IPCC's midrange IS92a emissions scenario. Total emissions from other fuels, which are on a downward path after the middle of the next century, are only about 1/3 of today's level of total CO₂ emissions from the energy sector in 2100, a level that will not interfere with efforts to stabilize atmospheric concentrations of greenhouse gases.
2. Regardless of what mitigation policies are adopted, we are likely to use a large fraction of whatever natural gas and oil can be recovered at costs within low multiples of current recovery costs. However, using all available oil and natural gas does not interfere with the objective of keeping carbon well below an atmospheric doubling of pre-industrial CO₂ concentrations – equivalent to about a 55 percent increase from the current CO₂ concentration of 355 parts per million.
3. Coal has two primary uses: as a fuel for electricity generation (current use) and as a feedstock for coal-derived synthetic fuels (CDF's) to replace petroleum-based fuels (anticipated use), especially in the transportation sector. Together, synfuels and electricity generation account for over 80 percent of projected coal use in the year 2100 in the IPCC

IS92a "mid range" scenario. NOCRAP believes that the actual value probably exceeds 90 percent, because it is implausible that residential heating in Asia would remain as a significant use of coal by 2100 given projected income growth.

4. If agreement could be reached to prevent the use of coal for electricity generation and synfuels production over the long-term on a global basis, we would have implicitly limited concentrations of carbon dioxide to less than a doubling over preindustrial levels (about 280 parts per million) and less than a 55 percent increase over current atmospheric concentrations (about 358 parts per million).

5. It might be relatively easy to curtail the use of coal for electricity and synfuels production through the adoption of binding international commitments.

- Because synfuels production is not a significant economic activity now or on the immediate horizon, there are no strong vested interests (other than the economic interests of future generations we are trying to protect by limiting greenhouse gas concentrations)
- Coal-based electricity generation is currently an important economic activity and is expected to remain important in some scenarios where limitation of carbon emissions is not a constraint. However, with steadily improving renewable energy technology and the prospects of continued progress, as well as the possibility of revisiting nuclear fission as a source of electricity, the economic value of coal-based electricity generation is not likely to be a deal-breaker, particularly if the switch to non-coal fuels takes place over an extended period. Note that it would probably be important for climate negotiators to avoid any foray into what the substitute fuels should be -- the climate policy interest extends only to assuring the eventual phaseout of coal use.
- Enforcement of an agreement to limit the primary uses of coal should not be difficult. Both of uses in question are capital-intensive and very easy to monitor by non-intrusive means.
- A focus on long-term coal use in structuring new commitments could help to unblock current negotiations by relieving the anxieties of oil-exporting countries. While it may be possible to "roll" these parties, it does not appear to be necessary to do so and may therefore not be worth the effort.

With the points as the analytic backbone, the next section briefly describes the outlines of one possible set of institutional arrangements.

B. The NOCRAP Strawman Proposal

The NOCRAP strawman sees the contrast between "delay in undertaking commitments" and "immediate abatement" as a false dichotomy. Its emphasis is on an immediate commitment to phased action on a global scale, which constitutes a third, and highly attractive, path.

1. Developed country (Annex 1 parties) commitments.

- Annex 1 parties agree not to pursue development of coal-derived fuels (CDI's). The regime would provide an exception allowing for the manufacture of hydrogen and other CDI's with no carbon content, provided that all carbon generated in the fuel manufacturing process was removed and sequestered. CDI's manufactured under this exception would be indistinguishable from other no-carbon fuels such as renewables and nuclear from a greenhouse perspective.
- Annex 1 parties agree to stop building new coal-fired generation capacity after a specified year -- for example, 2020. These parties further agree that coal-fired plants built between the date of the agreement and the specified date would have a maximum lifetime of 50 years burning coal, and that all existing coal fired plants as of the date of the agreement would have a maximum lifetime of 50 years from the date of the agreement.
- Annex 1 parties agree not to export coal to non-Annex 1 parties for uses prohibited to Annex 1 countries, with the exception that exports of coal to fuel coal-fired generating stations built after the Annex 1 cutoff date would be allowed if a later cutoff date for developing countries is established.
- Annex 1 parties (and possibly others) fund an incentive payment/loan program to win the voluntary acquiescence of key developing countries with large coal reserves to the commitments outlined in the next section.

2. Developing Countries (non-Annex 1 party) commitments.

Developing countries with significant coal reserves, such as India, China, and South Africa would be offered a significant up-front incentive payment/loan (details below) for their acquiescence to the following developing country commitments.

- Agreement to forgo future development of coal-derived fuels
- Agreement to stop building new coal-fired electric generating stations after a specified date. The date would follow by approximately 20 years the end of new coal plant construction in the Annex 1 area. The restrictions on the lifetime of coal-fired plants outlined for Annex 1 parties would also apply.
- Agreement not to export coal to any developed or developing country for uses inconsistent with either these commitments (for all potential exports to developing countries) or the commitments undertaken by Annex 1 countries (for potential exports to developed countries).

3. Structure of the incentive payment to developing countries.

The incentive payment would be structured as a loan that would never have to be repaid if attached covenants incorporating the commitments outlined in the preceding section were honored. In the event these commitments, as codified in the loan covenants, were not honored, the loan, with accrued interest, would immediately become payable.

- The accrual of interest could make a decision to renege on their fuel use commitments very costly for recipients of the incentive payments. For example, an incentive "loan" of \$100 billion in the year 2000 would accrue to an aggregate repayment value of over \$4.5 trillion by 2040 assuming a 10 percent interest rate. This amount, about 2/3 of current annual U.S. Gross Domestic Product, is not exactly chump change, even accounting for expected growth in developing economies.

4. Financing the incentive payments to developing countries

Payments to buy the coal birthright from China, India, and South Africa would not be trivial -- it will definitely cost more than the equivalent of the Old Testament bowl of soup. However, several options are available.

- United Nations Formula: Least-creative and least-relevant, but its there.
- Inverse Coal Reserves Formula: Under the NOCRAP proposal, Annex 1 countries with large coal reserves would be called upon to sign away long-term rights to exploit their domestic resources without receiving any compensation. The inverse coal reserves formula would take account of this sacrifice-in-kind by allocating the lions' share of the burden of buying off coal-rich developing countries to Annex 1 parties that have made no sacrifice, or only a small sacrifice, in terms of their domestic resources.
- OPEC Sigh-of-Relief Formula: The NOCRAP proposal effectively takes oil and gas off the table, relieving key concerns of OPEC countries. A large contribution to underwriting the incentive loan to developing countries would be a thoughtful way for oil-exporting countries to thank the international community for targeting greenhouse mitigation efforts away from their economies.
- Sanctimoniousness Quotient (SQ) Formula. The sanctimoniousness quotient would be computed by impartial observers to the negotiations based on careful observation of the sessions. There are two variants: retrospective and prospective.

In the retrospective variant, Germany is required to raise the lion's share of the incentive payment, with some help from other Europeans.

The prospective variant would allocate responsibility for incentive payments based on future negotiating behavior. Hopefully, this mechanism would provide an incentive for better behavior by Europeans in the negotiating process.

Unfortunately, we see no effective way to apply either SQ variant directly to business and environmental non-governmental organizations (NGOs) -- if this could be done, the burden on governments might be substantially reduced.

5. Periodic Review of Commitments and Other Gases.

The program described above, which would hold atmospheric concentration of carbon dioxide below 550 ppm and put them on a slowly declining path by the turn of the century, would not necessarily meet the objective of avoiding “dangerous anthropogenic interference with the climate system.” Periodic reviews would be necessary to evaluate the possible identification of convincing evidence of a threshold concentration value below 550 ppm. Given the pace of scientific progress, such regularly scheduled reviews should be relatively infrequent – once a decade at most. Special reviews could be scheduled by a supermajority of the parties in the event that startling new findings become available.

Given concerns related to the near-term rate of potential climate change, parties may also wish to focus additional efforts on methane and other greenhouse gases that have a relatively short atmospheric lifetimes and large near-term impacts on radiative forcing. Such actions are beyond the scope of this paper, but could be included in any agreement.

6. Enforcement

Enforcement should not be problematical. Coal power plants or synfuels plants are large, discrete, industrial facilities that cannot be built, maintained, or operated without attracting attention. Parties would need to agree to monitoring of carbon removal and sequestration activities should they elect to build CDF facilities under the exception provision.

C. Domestic and International Equity Considerations

1. Employment and Competitiveness:

Coal Labor: Representatives of coal labor might welcome this approach, since adverse impacts on coal mining are limited to the very distant future. Existing coal miners would be effectively held harmless, and there would probably still be room for the sons and daughters of today’s coal miners to enter the industry. Anyone who wants to protect the rights of their grandchildren to work in coal mining doesn’t deserve to be taken seriously.

Labor in Energy-Intensive Industries. The timing of the NOCRAP proposal would virtually eliminate concerns about short-term swings in the location and operating rates of existing facilities in energy-intensive industries.

Climate Industry Labor: The NOCRAP approach is probably most threatening to workers in the industry surrounding climate policy. It would stall the current trend towards a rapid increase in the number of climate “professionals,” including diplomats, advocates, bureaucrats, analysts, scientists, and pseudo-scientists. In fact, without NOCRAP or something like it, employment in the climate industry would probably exceed employment in the U.S. coal mining industry sometime during the first quarter of the next century. Adoption of the NOCRAP approach would pose special adjustment challenges for aspiring “climate fuhrers” and “climate fuhrresses(?)” who would have to find an

alternative to their planned careers of dictating national and global energy use patterns to ordinary citizens.

2. Agenda Decoupling

Economic Agendas: Countries seeking to gain an economic advantage through the imposition of short-term emissions mitigation commitments that are relatively more onerous for their competitors than themselves would have to find alternative ways to boost their competitive positions.

Environmental and Energy Security Agendas: Advocates of steps to address issues such as tropospheric smog, particulate pollution, vehicle congestion, urban sprawl, oil import dependence, and other concerns who have jumped on the climate bandwagon would have to start walking. While there may be important social objectives worth pursuing in these and other areas, they are not closely coupled to a climate change policy patterned on the NOCRAP strawman.

3. Global Costs and Their Distribution

From a global perspective, the cost issue hinges on the potential economic value of the coal-derived synfuels whose development would be stifled. Simply put, it's almost impossible to tell from here what we might be giving up. We can be relatively confident that alternatives to coal for electricity generation will not be too costly, if indeed they are more costly than coal at all, by the time coal use is significantly restricted.

From a national perspective, developed countries with large coal reserves are probably the biggest losers, although they are likely to lose much less than they would under policy proposals with an inappropriate focus on near-term abatement. The major developing countries would clearly benefit, since they retain the option of rejecting the proposed up-front incentive payment if they feel that its value does not offset the cost of the proposed commitments.

4. Intergenerational Equity

The NOCRAP strawman is built on the premise that we can guarantee the climate future of future generations by seeking to constrain their economic options regarding future use of coal. As such, it builds directly on the principles (or lack of same) in recent international environmental agreements. For example, the permanent ban on Antarctic mining entered into earlier in the decade seeks to protect the interests of future generations by preventing them from making their own choice regarding this question based on the updated information regarding needs and technologies that will undoubtedly be at their disposal.

COMPARISON OF ESTIMATES OF US GDP AND WELFARE EFFECTS OF CARBON POLICIES

Policy	Carbon tax Lump sum recycling	Same	Same	Same	Same	Same	Same	Same	Same	Same	Auction Permits lump sum recycling to consumers starts in 2000
Target	Stabilize CO2 emissions at 1990 levels by 2020, tax starts in 2000	Same	Same	Same	Same	Same	\$15/ton starting in 1990, rises 5%/yr to \$39.80 in 2010	Same	Same	Same	Stabilize GHG at 1990 levels by 2010
Model(s)	CRTM	OECD, FOSSIL 12, ERM	MWC	DGEM	Goulder	GLOBAL 2100	DRI	LINK	Jorgenson Wilcoxon	Goulder	DRI paper
Source	Gaskins, AER, May 93, pp. 319, 321	Same	Same	Same	Same	Same	Shakelton, et.al. pp. 3, 15-6	Same	Same	Same	June 7 workshop pp, 3, 12

Effects=====											
Carbon Tax	\$150/ton (\$1990)	\$75/ton (\$1990)	\$75/ton (\$1990)	\$25/ton (\$1990)	\$25/ton (\$1990)	\$25/ton (\$1990)	\$39.80/ton (\$1990)	Same	Same	Same	\$125/ton by 2010 (\$1995)
Revenue	NA	NA	NA	NA	NA	NA	\$85 bil in 2010	Same	Same	Same	\$176.9 bil by 2010 (\$1995)
Change GDP	-0.50% in 2010	-0.25% in 2010	-0.50% in 2010	-0.60% in 2010	-0.30% in 2010	-0.75% in 2010	Chg.PV= -0.58% at 3% dr	Chg.PV= -0.46% at 3% dr	Chg.PV= -0.62% at 3% dr	Chg.PV= -0.24% at 3% dr	-0.75% in 2010
Change Welfare	NA	NA	NA	NA	NA	NA	NA	NA	Chg.PV= -0.83% at 7% dr*	Chg. PV= -0.44% at 7% dr*	NA
Notes									* social time pref.	social time pref.	

from Richels, Brander, Grunspach & Wisbey P. 6, P. 24
 AUGUST 1995 FOR CETA, FPPA, MERGE,
 MINIRAM models

Figure 7. OECD GDP Losses under Alternative Assumptions about Economic Efficiency
 (based on average of model results)

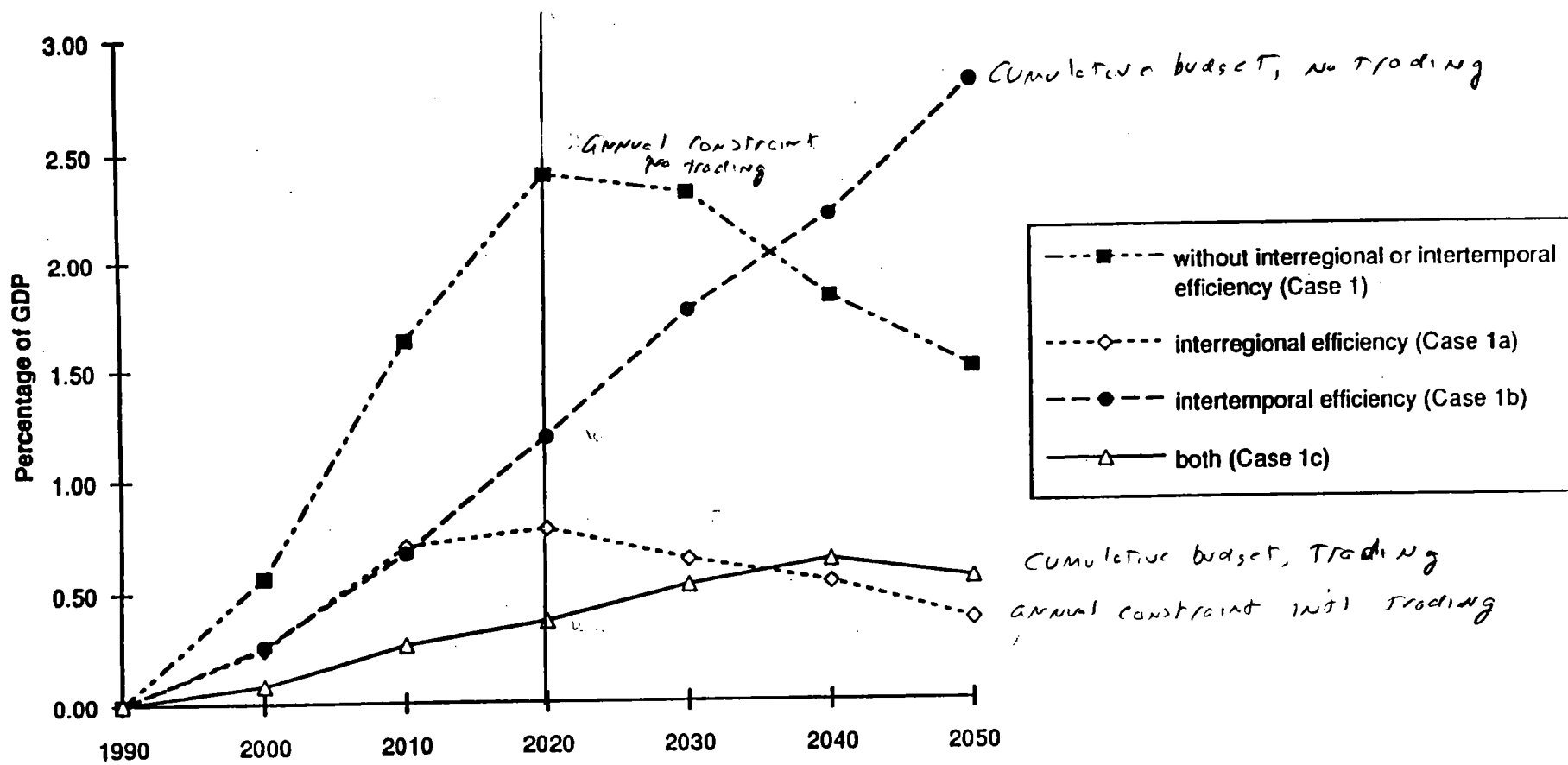


Table 6 Model classification and examples applied to CO₂ abatement costing

Sectoral division: Models/authors	Bottom-up		Top-down		Energy market/macro-economic	
	Equilibrium (resource allocation)		Growth			
	Partial	Linked	General	Partial	Linked	General
National	OTA NAS Mills (& many others)	MARKAL ETA-MACRO MARKAL- MACRO	DGEM (Jorgen- sen & Wil- coxon) Goulder Bergman Glomsrod Proost & Van Regemorter	e.g. electricity market models Ingham & Ulph	GDMEEM (N. Goto)	LINK MDM (Barker) ORANI (Marks)
Regional	EFOM	MIDAS			MIDAS- HERMES	QUEST HERMES G-CUBED (McKib- ben & Wilcoxon) DRJ—Europe
Global	Goldem- berg	ERB	GREEN Whalley & Wigle WEDGE	(Optimizing) DICE (Nord- haus) (Non-optimizing) Anderson & Bird	e.g. Inter- national oil market models	

mization and simulation. Table 6 classifies the major models discussed in this paper according to this scheme, which has a pragmatic focus on the factors of greatest importance to abatement costing. Other classification approaches by Boero et al (71), and Beaver (60, 61) have similar elements but differ in detail.

6. NUMERICAL ASSUMPTIONS AND SENSITIVITIES

Assumptions drive model results. Critical parameters can be usefully (though not exclusively) divided into those that govern the overall scale of the system and reference missions, and those that directly affect the relative cost of emissions reductions. GNP and population growth rates, income elasticities and the rate of "autonomous end-use energy-intensity improvement" ("AEEI") primarily affect the baseline scale; background fossil-fuel prices strongly affect both the baseline emissions and abatement costs; the cost of low-carbon technologies and price elasticities largely drive abatement costs though they also affect baseline emissions.

6.1 Population and GNP Growth Rates

The demand for energy is driven by population and per capita energy demand, and all economic models at least assume that the latter is driven by per capita GNP. It is consequently much more difficult to restrict the growth in emissions for a developing country with a high population and economic growth rate, such as India, than for a more slowly growing developed economy, for example, Germany, which has a static or declining population.

The uncertainties in future global population are reflected in abatement studies; estimates for the year 2025 for example include 9.5 billion for the NAS (47) and 8.2 billion for Edmonds & Barns (81). However, the latter study found that there was little impact from a reduction in population growth for approximately 15 years, that is until labor force and therefore GNP was affected. Projections suggest that the increase in global GNP will be much greater and more uncertain than population growth, and so differences in GNP projections account for a greater part of variation in baseline emissions.

Different baseline GNP and energy demand assumptions across studies complicate comparisons of the GNP loss associated with a target CO₂ reduction. In models that derive GNP from labor productivity, this is correspondingly critical. For example, in the United States in 2020, GNP baseline estimates range from \$7.5 to \$11.5 trillion [CSIS (91) and Edmonds & Barns (82), respectively]; the low costs of CO₂ stabilization in the

Memo. 11/4/96, 3:10 PM

THE WHITE HOUSE
WASHINGTON
October 29, 1996

*cc: JAF
RR*

MEMORANDUM FOR DISTRIBUTION

FROM: Michael Warren, Executive Director
National Economic Council

SUBJECT: Climate Change Deputies Meeting

There will be a joint NEC-CEA Deputies meeting on climate change on Monday, November 4 at 3 p.m. in room 231 OEOB. This meeting will be chaired by Dan Tarullo and Kathleen McGinty.

Deputies plus one are invited to attend. It is important that deputies personally attend.

An agenda will be sent to you later this week. Please call Kristen Panerali at the NEC at 456-5353 with your clearance information by COB Wednesday, October 30. Thanks.

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E X E C U T I V E O F F I C E O F T H E P R E S I D E N T

30-Oct-1996 04:26pm

TO: Alicia H. Munnell
TO: Jeffrey A. Frankel

FROM: Raymond Prince
 Council of Economic Advisers

CC: Lisa D. Branch

SUBJECT: Deputies meeting on Monday

There are no plans at this time to come to the December meetings with a specific proposal concerning targets and timetables. But you may want to argue in the meeting that it would be advisable to come with an understanding about what would not be acceptable in order to prevent the U.S. from being pushed into some tacit agreement that would not be in our interests. A similar situation was avoided in the July meetings when the U.S., which did not propose any specific targets, made it clear that it could not accept something like the AOSIS proposal to reduce emissions by 20% in 2005.

The back-of-the-envelope estimates which Joe requested could be a useful input for determining where the line should be drawn but I have a sense that we may not get those estimates by the Deputies meeting on Monday with further pressure on CEA's part.

E X E C U T I V E O F F I C E O F T H E P R E S I D E N T

30-Oct-1996 05:07pm

TO: Raymond Prince

FROM: Jeffrey A. Frankel
 Council of Economic Advisers

CC: Alicia H. Munnell

CC: Lisa D. Branch

SUBJECT: RE: Deputies meeting on Monday

We may or may not get the "back of the envelope" estimates by the end of the week. But it strikes me that, either way, we can probably get numbers that we would find as useful simply by looking through the results in the literature that we already have.

Ray,

Could you look through the articles and books and summaries we have, and collect estimates to fill in a table that gives the implications for the basic energy prices (and for deadweight losses and/or GNP) from as many models as are reported (be sure to note down the source, in addition to the name of the model) from the following experiments:

reduction of 2010 emissions to 1990 levels with market-based system, including optimal intertemporal and international trading

the same without intertemporal (I guess I mean no increase in emissions even in the short run, or something like that) and international trading

the same with intertemporal but without international trading

and so forth.

Exclude any recycling of tax revenue (except on a lump-sum basis, which is equivalent to giving away permits) for this purpose. Also, exclude any models that assume the automatic adoption (i.e., even without changes in energy prices) of technology that is currently not in use.

I am sure that you will not be able to fill in the whole table. But it would be useful to have some of it by Friday.

Thanks
JF

E X E C U T I V E O F F I C E O F T H E P R E S I D E N T

30-Oct-1996 07:28pm

TO: Jeffrey A. Frankel

FROM: Alicia H. Munnell
 Council of Economic Advisers

CC: Raymond Prince
CC: Lisa D. Branch

SUBJECT: RE: Deputies meeting on Monday

I agree that all those pieces of data would be very valuable. EPA and Energy have done a series of runs with those assumptions. But we still need a back of the envelope calculation so please keep the pressure on to produce that type of information by Thursday or Friday.

THE WHITE HOUSE

WASHINGTON

November 1, 1996

MEMORANDUM FOR DISTRIBUTION

FROM: Michael Warren, Executive Director
National Economic Council

SUBJECT: NEC/CEQ Climate Change Deputies Meeting

Attached are documents that may be useful in preparation for the NEC-CEQ deputies meeting scheduled for Monday, November 4th at 3 pm in room 231 OEOB:

1. Agenda
2. Outline of the major issues we will be discussing at the meeting: international emissions trading, joint implementation, and targets design. (Longer staff-level background papers on these subjects were recently circulated in draft form to your climate change policy staff. These longer papers may be helpful in preparing for the meeting as well.)

While this is not a decisionmaking meeting, we will be discussing some of the major issues that are to be the focus of an international meeting in early December, in which USG representatives will be participating. Accordingly, your attendance on Monday is strongly encouraged.

If you have not done so, please call Kristen Panerali at the NEC at 456-5353 with your clearance information. Thanks.

Distribution:

Charles Curtis, DoE
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Tim Wirth, State

DEPUTIES COMMITTEE MEETING
CLIMATE CHANGE NEGOTIATIONS
NOVEMBER 4, 1996

- I. Status of melding and how results will be integrated into policy process
- II. Target design options
- III. International emissions trading and joint implementation programs

DEFINING THE FORM OF THE TARGET

BACKGROUND

- * While rejecting proposals for short-term emissions reductions, at the second Meeting of the Parties in July, the United States called for a realistic, verifiable and binding medium-term emissions target.
- * Proposals by some other countries have defined a target in terms of a single level that would be reached in a given year (e.g., a 20% reduction by 2005).
- * Options exist for structuring a target which provides greater flexibility and potentially reduced compliance costs.
- * This discussion focuses only on the form of the target and not on the level of the target nor the timing for reaching the target which are being examined by the Interagency Analytical Team.

KEY ISSUES AND OPTIONS

- * **Form of Target:** The simplest option would be to follow existing proposals and call for a specific level of emissions reduction to be achieved by a specific year. A second option would be a multi-year average target (e.g., a specified target achieved over the average of 2010-2015). Thirdly, the target could take the form of a cumulative target over a much longer period of time (e.g., 20 or 30 years or longer). A fourth option would be to define a target in terms of each nation's contribution to atmospheric concentration of greenhouse gases (however, this type of target might be harder to implement and be more controversial).

These options must be evaluated in terms of their impacts on such factors as economic costs, capital stock turnover, the rate of technological change, and the rate of climate change.

- * **Baseline:** The current baseline under the Framework Convention's non-binding aim is to return to 1990 emissions levels for each developed country. The range of options for an alternative baseline include:

- o shifting to a more recent year (e.g., 1995 or 2000);
- o adjusting emissions levels to reflect weather, energy or economic anomalies;
- o averaging emissions over several years; or
- o focusing on changes from projected levels of future emissions.

These options must be evaluated in terms of the degree of flexibility and cost savings they offer and how they would impact the United States and other nations.

- * **Treatment of Gases:** The United States has supported and the Climate Convention covers all greenhouse gases (except those controlled under the Montreal Protocol's ozone treaty). These include: carbon dioxide, nitrous oxide, methane, and fluorinated compounds. While continuing to support a comprehensive approach to the issue, a number of options are possible:

- o define a target using a single basket approach and allow trading between gases;
- o define a target in terms of carbon dioxide from energy use alone (70 percent of emissions) and treat other gases separately; or
- o limit the target only to sources and sinks of gases that can readily be quantified.

- * **Other Issues:**

- * How do we define "medium-term" commitments?
- * How often should commitments be reviewed?
- * How will the form of the target impact emissions trading? Will the choice of targets hinder efforts to further engage developing countries?

JOINT IMPLEMENTATION

BACKGROUND

- * Joint implementation (JI) is a concept under which entities from different countries could work together to reduce, avoid or sequester greenhouse gas emissions.
- * The U.S. has been an advocate for allowing joint implementation for two reasons:
 - o It can reduce the costs of meeting any given target by achieving those reductions through some combination of actions at home and abroad.
 - o It provides a potentially powerful incentive for redirecting investment flows in developing countries and economies in transition toward more greenhouse friendly technologies.
- * A limited form of JI (trading rights for producing CFCs) was used under the Montreal Protocol to reduce the costs of the phase-out of ozone-depleting substances.
- * To date, joint implementation has received only limited support by Parties to the Convention with strong opposition from many developing countries. This opposition reflects an unwillingness to accept baselines and concerns over sovereignty.
- * A broad spectrum of U.S. industry has strongly supported JI. For example, electric utilities have developed and support their own voluntary JI program.
- * A pilot JI project has been initiated to improve understanding but without granting "credit" for such activities (the amount of "credit" is an open issue).

ISSUES AND OPTIONS

- * Stay the course: Continue supporting the existing pilot project and work toward building a foundation for shifting to a credit-based regime in the future.
- * Advance the process: Seek agreement now that JI would be allowed after some specified year (e.g., 2000) with credit given to the parties involved.
 - joint activities between developed countries could build on agreed baseline commitments.
 - joint activities with developing countries could be permitted if the developing nation "opted in" and agreed to a baseline or could be permitted on a project-by-project basis.
- * Some observers have expressed some concern that a large JI program could have negative job implications for developed countries by shifting investment to developing countries with lower costs of emissions control.

INTERNATIONAL EMISSIONS TRADING

BACKGROUND

- * International emissions trading is a more systematic form of joint implementation where national commitments to reduce greenhouse gas emissions can be achieved through some combination of activities at home and abroad.
- * Given the large differences in the marginal cost of controls among countries, the potential savings for meeting an agreed-upon target appear significant. For example, one modeling exercise showed a savings of roughly 70% for the United States if emissions trading were permitted on a global scale. This study assumed no transaction costs.
- * Establishing a robust emissions trading system represents a significant challenge given the complexities of any international climate regime.
- * A limited form of "international" trading has been used successfully under the Montreal Protocol. Emissions trading programs within the United States have been widely viewed as a success in reducing the costs of acid rain controls.
- * International emissions trading is widely supported by business and many environmental groups within the United States. Most developed countries have less experience with the regime but their interest appears to be increasing. Most developing countries have opposed any form of trading for reasons of national sovereignty and unwillingness to accept an emissions baseline.

ISSUES AND OPTIONS

- * Differences in domestic implementation: Countries are likely to employ a wide range of options in implementing domestically any internationally agreed upon emissions target. This will complicate the process of ensuring the integrity of international trades and potentially impact transaction costs.
- * Inclusiveness of trading regime: Trading between different greenhouse gases could be permitted, as could trades between sources and sinks. However, emissions from some sources are easier to quantify and verify than emissions from other sources.
- * Participants in trades: Trading must involve active private sector participation. At the same time, governments, not individual firms, are responsible for their treaty obligations. One option, to create a new entity that reviews or approves all trades, has little appeal.

- * Relationship to compliance: In defining measures related to compliance for the treaty, it will be important to take into consideration the need to support the integrity of trades without imposing undue transaction costs.
- * A country can attain its emissions reduction goals by either controlling domestic emissions or through trade of emissions rights. This points up the importance of the initial allocation of emission rights.
- * In the absence of a worldwide cap on emissions, international emissions trading by itself will not be sufficient to meet a global emissions target.

2/3/95

TO: AM
From: Ray S

cc: Rv

TO: KARL HAUSKER, ENVIRONMENTAL PROTECTION AGENCY

FROM: Ray Squitieri

SUBJECT: The Upside of Climate Change

I'm afraid I was too glib in responding to your follow up question on Wednesday. I agree that climate change could be a real problem. I also agree that going beyond no-regrets policies makes sense. As an economist, I would state my conclusion this way: in the presence of significant uncertainty, the asymmetric risks of climate change combined with the principle of risk aversion and the advantages of portfolio balancing provide the rationale for going beyond no regrets policies.

Moreover, I certainly agree that transition costs would accompany a shift to a warmer climate -- or to a colder climate, or to a wetter or dryer climate. We have historical evidence that climate shifts major disruptions in particular settlements, even if the effects might have been neutral for the world as a whole. The Central and Eastern Mediterranean were once much wetter than they are today. Ancient Phoenicia and its colony Carthage were well forested 2500 years ago, but no longer. Ancient Greece was clearly more forested and probably wetter in the age of Pericles than it is today. Mesopotamia was far more conducive to agriculture 5000 years ago than it is now, chiefly because it had more water (by the way, it was also warmer: the earth as a whole was perhaps 2° C. warmer then than it is now). The Mongol hordes probably left their central Asian grasslands, invading China, India, and Russia, in response to a decline in rainfall and therefore grass yields in their homeland. All these climatic changes brought social dislocation and cost. But I'm not convinced the net effect was negative worldwide effect.

At the same time, I do think there is a possible upside to climate change, which I think has been largely ignored in the debate so far. Moreover, I observe for the sectors I am familiar with, that damage estimates have been falling steadily (in fact, decreasing monotonically with time); if either Bill Cline or Bill Nordhaus were to redo his damage estimate from three years ago, he would certainly revise the earlier estimate downward.

Diurnal and seasonal variation. The GCMs show temperature increases concentrated in the high latitudes¹. This means milder winters and a longer growing season. Further, the consensus now seems to be that a warmer climate results in more evaporation (largely from the oceans), meaning more clouds. This in turn lowers the daytime highs (albedo effect), and raises nighttime lows (insulating effect). The result is almost certainly good for agriculture, as it decreases the number of very cold days at the edges of the growing season, and the number of very hot days at the peak. The IPCC 1994 Supplement says that

the post-war global climate record shows exactly this pattern.

Extreme effects. Many GCMs predict an increase in the number and intensity of hurricanes. The damage studies (Cline, Nordhaus, Tol, Fankhauser) all assume this would result in net costs worldwide. But consider the question of decrease in the number and intensity of hurricanes. Is this unambiguously good? Floridians, East Texans, Cubans, and Filipinos would say yes, but Mexicans and Chinese would say no -- they rely on hurricanes for essential rainfall, and would probably like to see hurricanes increase rather than decrease.

Feedback effects. Greenland ice core data tells us that the Earth has experience sharp swings in climate (about 3° C. within a few decades). This tells us first, that temperature swings are not immediately damped (that's the bad news) and second, that this did not lead to runaway feedback effects (methane release from permafrost thawing, shutting down of the North Atlantic cold-water current, etc.) as has been suggested (that's the good news).

Agriculture. In a recent study, John Reilly and others have estimated the effect of temperature increases on worldwide agriculture, concluding that worldwide production will increase for temperature increases up to 2° C (as I remember, they don't estimate effects much above that). Older agriculture studies often assumed that farmers do not make adjustments -- switching crops, adjusting land under cultivation, etc. -- in response to changes in climate. Worse, earlier studies often assumed no changes in agricultural trade. These assumptions will guarantee a fall in production for almost any change in climate (or indeed, any change at all). When trade and adaptation are taken into account, the picture suddenly looks good for warming.

This is consistent with geological evidence from earlier times, in which very warm eras (Cretaceous, Mesozoic, etc.) allowed an abundance of life (and therefore food) on land, sea, and air. One example: we know from dinosaur fossils that the Gobi Desert and the Great Basin of the Western US were once warm, with much more water than they have now. Today, these places cannot support the extensive food chain necessary to support large fierce predators like carnivorous dinosaurs, yet this was the picture before 65 million years ago. I am not saying I would prefer a climate in which the Gobi Desert was a warm swamp, just that even a great deal of warming may well be consistent with more food, not less.

As a corollary, a warmer world would in equilibrium probably contain more biodiversity (biodiversity might drop during the transition), for the same reason that the Gulf Coast of Louisiana is host to more bird species than the entire northern tier of states; and for the same reason that the Gobi Desert was host to many more species during the age of dinosaurs than it is now.

But even if all adaptation fails, how large could losses be? Published estimates for the U.S. for 2xCO₂ range from 9.5% of agricultural output (Cline) to 0.6% (Nordhaus), with Fankhauser, Titus, and Tol in between. These estimates do not

seem to include any increases in productivity. But agricultural productivity in fact has been growing at about 3% annually over the last century, which translates to a 20-fold increase over that time. Even if the pace of change slows by half, a 1% 10% or even 20% decrease in quantity would be trivial.

Other anthropological evidence. For most of the last 100,000 years, the Earth was significantly cooler than it is now. About 10,000 years ago, the climate turned warmer until, from about 7000 BC to 3000 BC, the Earth was 2° to 3° C. warmer than it is today. Historians refer to this period as the Climatic Optimum. The Earth's carrying capacity increased substantially during that time. Agriculture emerged in Europe during that time. In China, which was perhaps 5° warmer than today (the southeast region of today's China), and where agriculture was already established, rice was planted a month earlier than it is today, and bamboo grew much farther north than today.

Health, Utility. In the United States, migration has been, on balance, from the north to the south. This suggests that Americans, when they have a choice, prefer to live in a place that is, on average, warmer than their home now. Large cities have become several degrees warmer this century from the "heat island" effect; this does not seem to have slowed their growth. Very few will even notice a change, as any climate "migration" that occurs will be much slower than human migrations that go on all the time².

Energy consumption. Howard Gruenspecht and Don Rosenthal have shown that for the US, a 2xCO₂ warming would save more in heating energy than it could cost in air conditioning energy. No one has done this calculation yet for the world.

Other considerations: Back to the future. If we could look back on today's climate debate from the point of view of the year 2015 (when I will have reached the age of ... 39), I believe we would come to the following conclusions:

- Most analysis up to (at least) 1995 overemphasized negative effects. Most of these suppositions were later refuted or the accompanying estimates sharply reduced in magnitude.
- The net global effects of a 2xCO₂ warming will be small. A few locations will be much worse off; a few locations will be somewhat better off; most people in most countries will not notice anything.
- GCMs were a nice research idea, and perhaps a good zero-th order approximation of reality, but their main contribution was that they led to something better, not that they produced useful results.

I'd be interested to know your thoughts.

1. According to the criteria applied to any economic models, the GCMs are still woefully unreliable.

2. That having been said, I should also add that GCMs cannot represent discontinuities, and certainly not on a regional scale. So it is quite possible that the rate of change of temperature, rainfall, etc. for some regions will be much faster than the GCMs indicate.



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

MEMBER

October 15, 1996

MEMORANDUM FOR JOE STIGLITZ
JEFF FRANKEL
RAY PRINCE

FROM: ALICIA MUNNELL *am/ff*

SUBJECT: U.S. Submission on Elements of a New Legal
Instrument

The attached document will be sent to the Secretariat within the next day or so. This means that it will become a public document. If we have any disagreements, we need to alert the State Department by COB today, Tuesday, October 15.

I think we should have a brief meeting this afternoon.

Attachment

U.S. Submission on Elements of a New Legal Instrument (October 15, 1996)

General

In the U.S. view, the new legal instrument should respond effectively to the environmental challenge posed by climate change; should reflect outcomes that are real and achievable; should be consistent with economic prosperity; should allow for maximum flexibility and cost-effectiveness in its implementation; and should lay the foundation for continuing progress by all countries.

We believe that the following elements would serve as a useful basis for the consideration of topics that would need to be included in this instrument. Given the continuing uncertainties surrounding the form of such an instrument, we have noted particular aspects of these issues that may differ depending on whether the Parties choose a protocol or an amendment to the FCCC to codify their agreement.

Preamble

If the legal instrument takes the form of a protocol, it might include a preamble. If it takes the form of an amendment, it would not, although the decision adopting the amendment could.

Definitions

A protocol would need to incorporate some or all of the definitions in Article 1 of the Convention, include its own definitions, or some combination of the two. An amendment, to the extent it introduces new terms, might also require amendment of Article 1.

Objective

An amendment would, and a protocol should incorporate the objective in the Convention; we do not believe it is either necessary or desirable to develop a separate objective for this legal instrument.

Level and Structure of the Target

The Geneva Declaration calls for a legally-binding target and timetable. The Berlin Mandate calls for adoption of the protocol/other legal instrument at COP-3, making negotiation of differentiated commitments in this timeframe impracticable. Therefore, it will be important that the target/timetable be sufficiently specific (to facilitate compliance), flexible in terms of its implementation (to encourage broad participation) and straight-forward (to ensure negotiation and adoption by COP-3). As we noted at COP-2, the United States has serious reservations about efforts to develop harmonized policies and measures.

Ideas proposed thus far include:

- a flat target (measured against a fixed year or baseline trend)
- a cumulative or aggregate target (reducing total emissions over a particular time period by an agreed percentage)
- a target based on a rolling average
- a collective target (e.g., "Annex I", OECD, EU)
- individually pledged (binding) targets
- differentiated targets (possibly based on a formula)

numbus. Analysis of the effects of each of these ideas will depend not only on the level agreed upon but also on the extent of participation (number of Parties) in the process. The United States is currently developing a toolbox to facilitate analysis of these and other options. We anticipate that, by March 1997, the full array of choices would be tabled by Parties, and that the development of specific language for inclusion in the instrument could be considered.

Advancing Article 4.1 Commitments

In the U.S. view, next steps must involve actions by all Parties, recognizing their common but differentiated responsibilities and capabilities, and these must be reflected in the Kyoto agreement. There are a number of assumptions that underlie U.S. views on next steps:

- Article 4.1:
 - Applies to all Parties, not just to developing country Parties;
 - Speaks to issues ranging from inventorying emissions, to reporting, to adopting policies and measures;

- Speaks to the requirement to promote the development and transfer of technologies;
- The Convention anticipates that the status of countries will evolve over time (e.g., Article 4.2(f))
- Paragraph 2.b of the Berlin Mandate governs what will be included on this issue in the Kyoto agreement

Bearing in mind these assumptions, there are a number of approaches that can be taken through a new legal instrument. The Parties can agree to:

- continued and more systematic support for efforts to develop national action plans (particularly in developing countries) following the revised Annex I Guidelines for National Communications and the newly adopted Non-Annex I Guidelines for Initial Communications
- redoubled efforts to adopt and implement "no-regrets" measures
- expanded programs aimed at developing, diffusing and deploying climate-friendly technologies (including through systematic efforts to identify and remove barriers to technology transfer and to improve the performance of existing financial institutions)
- further consideration of thresholds at which the status of countries would change, and the process involved in such a change in status
- further consideration of future steps (post-Kyoto) toward the objective of the Convention

Emissions Trading/Joint Implementation

In the U.S. view, emissions trading/joint implementation will be an essential element of the Kyoto agreement; it will therefore be a priority task to establish the guidelines for a credible emissions trading/joint implementation regime by December 1997.

Various design questions will need to be resolved by the Kyoto Conference, including, for example, whether inter-gas trading will be allowed; how trades would most effectively be monitored and reviewed; what distinctions might be drawn with respect to participation in an emissions trading/joint implementation regime (e.g., absent national targets, could project-specific baselines be used?)

A number of principles must underlie an emissions trading/joint implementation regime. Such a regime must be efficient, transparent and verifiable and must produce real reductions. A preliminary elaboration of these principles should already be possible; in the U.S. view, the regime should:

- allow parties to trade or exchange credits toward and against national greenhouse gas reduction or limitation commitments;
- ensure that emissions reductions are created by actions that verifiably and reliably reduce accrued, net emissions;
- minimize costs, especially transaction and administrative costs;
- motivate parties to achieve and strengthen national commitments to reduce or limit greenhouse gas emissions;
- motivate economic actors to find and implement on a continuous basis cost-effective greenhouse gas emission reductions;
- be as flexible as possible to accommodate differing national approaches to achieving emissions commitments;
- promote compatibility among national approaches to facilitate trading/exchanging credits
- be as inclusive of Parties, sub-national entities, gases and sectors as possible;
- ensure transparency through stringent monitoring, record-keeping and reporting;
- provide incentives for compliance -- and mechanisms to limit the benefit accorded to non-compliant Parties, and to ensure that non-compliance does not adversely affect environmental progress under the agreement.

Institutions

For reasons of administrative efficiency and in light of budgetary constraints, a new legal instrument should utilize existing institutions to the maximum extent practicable.

A protocol would need to specify its institutions. In the case of an amendment, the institutions established under the Convention would apply. (Note: We do not believe it would be appropriate for non-Parties to a protocol to be officers of an institution serving the protocol.)

Compliance

The term "compliance" is used in this context to refer to the cluster of processes/mechanisms that provide incentives for the Parties to abide by their legal commitments.

Ensuring effective compliance will be critical for environmental as well as economic reasons. Unless parties comply, actions taken are likely to be inadequate and global warming will continue unabated. Uneven compliance will undermine confidence in the Convention and encourage "free-riding."

In addition to promoting compliance by including commitments that are realistic and verifiable (as noted above), the instrument should provide supplementary means, for example, with respect to ascertaining whether Parties are meeting their obligations and with respect to appropriate consequences for non-compliance.

An amendment to the Convention would be covered by the Convention's reporting requirements, as well as dispute settlement provisions and multilateral consultative process, once established. A protocol would need to specify whether any of these Convention mechanisms would apply, as well as any additional compliance-related provisions.

Decision-Making

Only the Parties to the protocol or amendment should have decision-making authority with respect to that instrument.

Final Clauses

A protocol would need to contain several final clauses, including, for example, provisions on entry into force and amendment. An amendment's final clauses are already set forth in the Convention.

Re: Climate Change



United States Department of State

*Bureau of Oceans and International
Environmental and Scientific Affairs*

Washington, D.C. 20520

October 21, 1996

UNCLASSIFIED
MEMORANDUM

TO: Please See Attached List *[Signature]*
FROM: OES/Acting -- Rafe Pomerance
SUBJECT: Copy of the U.S. Submission to FCCC Secretariat

I have attached to this memorandum a copy of the final version of the U.S. submission on "Elements of a New Legal Instrument" which was sent to the climate change secretariat in Bonn this afternoon. In redrafting this paper, we have taken into account all of the very many valuable suggestions and viewpoints submitted by a variety of government Departments and Agencies. We carefully edited those areas where conflicting suggestions were made to ensure that this submission is consistent with Under Secretary Wirth's July 17th statement in Geneva.

Your cooperation in this matter -- especially in view of the tight turn-around time involved -- is very much appreciated.

Attachments:
As stated.

UNCLASSIFIED

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DOCUMENT NO. AND TYPE	SUBJECT/TITLE	DATE	RESTRICTION
001. list	Group of Six Plus [PII] [partial] (1 page)	10/21/1996	b(6)

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FOLDER TITLE:

Environment: Climate Change Vol. II [2]

2017-1095-F
bg237

RESTRICTION CODES

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- P1 National Security Classified Information [(a)(1) of the PRA]
- P2 Relating to the appointment to Federal office [(a)(2) of the PRA]
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- P6 Release would constitute a clearly unwarranted invasion of personal privacy [(a)(6) of the PRA]

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RR. Document will be reviewed upon request.

Freedom of Information Act - [5 U.S.C. 552(b)]

- b(1) National security classified information [(b)(1) of the FOIA]
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- b(7) Release would disclose information compiled for law enforcement purposes [(b)(7) of the FOIA]
- b(8) Release would disclose information concerning the regulation of financial institutions [(b)(8) of the FOIA]
- b(9) Release would disclose geological or geophysical information concerning wells [(b)(9) of the FOIA]

GROUP OF SIX PLUS

OSTP	Rosina Birbaum	456-6202	FAX: 456-6025
CEA	Alicia Munnell (b)(6)	395-5036	FAX: 395-6947
NEC	Elgie Holstein	456-5365	FAX: 456-2223
OMB	T.J. Glauthier (b)(6)	395-4561	FAX: 395-4639
Justice	Lois Schiffer (b)(6)	514-2701	FAX: 514-0557
Commerce	Jeffrey Hunker (b)(6)	482-6055	FAX: 482-4636
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Treasury	Robert Gillingham (b)(6)	622-2220	FAX: 622-2633
Interior	Brooks Yeager DOB: SS#:	208-6182	FAX: 208-4561
USTR	Jennifer Haverkamp (b)(6)	395-7320	FAX: 395-4579
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EPA	Mary Nichols (b)(6) David Gardiner (b)(6)	260-7400 260-4332	FAX: 260-5155 FAX: 260-0275
DOT:	Frank Kruesi (b)(6)	366-2222	FAX: 366-3997

U.S. Submission on
Elements of a New Legal Instrument
(October 21, 1996)

General

In the U.S. view, the new legal instrument should respond effectively to the serious threat posed by global climate change; should reflect outcomes that are real and achievable; should be consistent with economic prosperity; should allow for maximum flexibility and cost-effectiveness in its implementation; and should lay the foundation for continuing progress by all countries.

Meeting the ultimate objective of the Convention will require concerted, long-term efforts by all Parties. While it is important for developed countries to take the lead, it is also essential that the Kyoto agreement recognize the growing contribution of developing country emissions and begin to plan for appropriate, cost-effective ways to address these emissions in a sustainable manner. In this connection, at COP-2 the United States called for continued work toward a longer-term concentration goal (e.g. for the next 50-100 years), recognizing that scientific understanding and technology will improve over time.

In putting forward these suggestions for a new legal instrument, the United States has rejected proposals by some countries calling for short-term targets that we believe are neither realistic nor achievable. We have also rejected the use of inflexible, internationally harmonized policies and measures. In the spirit of providing individual countries greater flexibility in meeting any agreed upon limitations, we believe that it is critical that flexibility in implementation be accorded all countries, including through emissions trading and joint implementation among nations.

We believe that the following elements would serve as a useful basis for the consideration of topics that would need to be included in a new legal instrument. Given the continuing uncertainties surrounding the form of such an instrument, we have noted particular aspects of these issues that may differ depending on whether the Parties choose a protocol or an amendment to the Convention to codify their agreement.

-2-

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If the legal instrument takes the form of a protocol, it might include a preamble. If it takes the form of an amendment, it would not, although the decision adopting the amendment could.

Definitions

A protocol would need to incorporate some or all of the definitions in Article 1 of the Convention, include its own definitions, or some combination of the two. An amendment, to the extent it introduces new terms, might also require amendment of Article 1.

Objective

We do not believe that it is either necessary or desirable to develop a separate objective for this legal instrument, whether an amendment or a protocol. The Convention's Article 2 would apply to an amendment. A protocol should incorporate Article 2 of the Convention.

Level and Structure of the Target

The Geneva Declaration calls for quantified, legally-binding objectives within specified timeframes. This is consistent with the U.S. call at COP-2 for a shift in the negotiations away from unrealistic, near-term proposals to legally-binding, medium-term targets that are both realistic and achievable.

A number of ideas and approaches regarding the structure of the target have been suggested thus far in the discussions within the Ad Hoc Group on the Berlin Mandate (AGBM). Many of these ideas and approaches have focused on a single-year target, but we believe it will be important to consider a broader range of possibilities (e.g., cumulative or aggregate targets covering a number of years, multiple-year rolling average targets, flexibility over time through banking and borrowing, etc.) We anticipate that more such ideas and approaches will be tabled and considered as we work toward a new legal instrument for adoption at COP-3.

The Berlin Mandate calls for adoption of the protocol/other legal instrument at COP-3, making calls to date for differentiated commitments in this timeframe impracticable.

-3-

In addition to being realistic and achievable, it will be important that the target/timetable be sufficiently specific (to facilitate compliance), flexible in terms of its implementation (to encourage cost-effectiveness and broad participation) and straight-forward (to ensure negotiation and adoption by COP-3). As we noted at COP-2, as a general proposition, the United States opposes mandatory, harmonized policies and measures. However, we are open to the possibility of exploring consensus on agreed procedural measures, for example, those that might be necessary to implement an international trading regime or ensure enhanced reporting.

The United States is continuing its domestic analysis and assessment efforts so as to contribute to this discussion in upcoming negotiating sessions.

Advancing Article 4.1 Commitments

"Continuing to advance the implementation of Article 4.1 commitments" will be a critical component of next steps and must be reflected in the Kyoto agreement. Given the global nature of this problem, we must work together toward a global solution, recognizing our common but differentiated responsibilities and capabilities. A number of assumptions underlie U.S. views on next steps:

- Article 4.1:
 - applies to all Parties;
 - speaks to commitments ranging from inventories of emissions, to reporting, to adopting measures to mitigate climate change;
 - speaks to the requirement to promote the development and diffusion of technologies;
- The Convention anticipates that the status of countries will evolve over time (e.g., Article 4.2(f))
- Paragraph 2.b of the Berlin Mandate governs what will be included on this issue in the Kyoto agreement

Bearing in mind these assumptions, there are a number of approaches that can be taken through a new legal instrument. For example, the Parties could agree to:

- continued and more systematic support for efforts to develop national action plans (particularly in developing countries) following the revised Annex I Guidelines for National Communications and the newly adopted Non-Annex I Guidelines for Initial Communications

-4-

- redoubled efforts to adopt and implement "no-regrets" measures
- expanded programs aimed at developing, diffusing and deploying climate-friendly technologies (including through systematic efforts to identify and remove barriers to technology diffusion and to enhance the role of international financial institutions in responding to the threat of global climate change)
- further consideration of thresholds at which the status of countries would change, and the process involved in such a change in status
- further consideration of future steps (post-Kyoto) toward the objective of the Convention

International Emissions Trading and Joint Implementation

In the U.S. view, flexibility will be an essential element of the Kyoto agreement, including international emissions trading and joint implementation; it will therefore be a priority task to establish the guidelines for a credible emissions trading and joint implementation regime by December 1997.

Properly designed emissions trading and joint implementation regimes will motivate parties to achieve and strengthen national commitments to limit or reduce greenhouse gas emissions, because the cost savings potential in these types of programs can achieve more environmental protection than less flexible, less cost-effective regimes.

A number of principles must underlie an emissions trading and joint implementation regime. At a minimum, such a regime must be credible, efficient, transparent and verifiable.

Various design questions need to be addressed, and we intend to present our further thinking in this regard in the near future.

Institutions

For reasons of administrative efficiency and in light of budgetary constraints, a new legal instrument should utilize existing institutions to the maximum extent practicable.

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A protocol would need to specify its institutions. In the case of an amendment, the institutions established under the Convention would apply. (Note: We do not believe it would be appropriate for non-Parties to a protocol to be officers of an institution serving the protocol.)

Compliance

The term "compliance" is used in this context to refer to the cluster of processes/mechanisms that provide incentives for the Parties to abide by their legal commitments.

Ensuring effective compliance will be critical for environmental as well as economic competitiveness reasons. Unless Parties comply, there will be little incentive for each Party to act and we will not achieve our environmental objectives. Uneven compliance will undermine confidence in the new legal instrument and encourage "free-riding."

A key means of promoting compliance will be to ensure that commitments are realistic and achievable (as noted above). In addition, it will be important to consider supplementary means for promoting compliance, including ways to ascertain whether Parties are meeting their obligations. In this context, we will need to consider elaborating existing reporting and review mechanisms.

Unless otherwise provided, an amendment to the Convention would be covered by the Convention's reporting requirements, as well as dispute settlement provisions and any multilateral consultative process that might be established. A protocol would need to specify whether any of these Convention mechanisms would apply, as well as any additional compliance-related provisions.

Decision-Making

Only the Parties to the protocol or amendment should have decision-making authority with respect to that instrument.

Final Clauses

A protocol would need to contain several final clauses, including, for example, provisions on entry into force and amendment. An amendment's final clauses are already set forth in the Convention.

-6-

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CEA - AMunnell
CEQ - SSeidel
NEC - EHolstein
NSC - DSandalow
OMB - TJGlauthier
OSTP - RBierbaum
DOC - JHunker
DOE - DForrister/MChupka
EPA - DGardiner/MNichols
DOI - BYeager
DOJ - LSchiffer
DOT - FKruesi
NOAA - DHall
Treasury - JGotbaum
USDA - CRawls
USTR - DShark

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SUMMARY

Climate change presents the decision maker with a set of formidable complications: large uncertainties, the potential for irreversible damages or costs, a very long planning horizon, long time lags between emissions and effects, a global scope, wide regional variation, and multiple greenhouse gases of concern. Irrespective of the possible consequences of climate change, policies that mitigate or assist adaptation to climate change and have zero or negative net costs (*no-regrets* policies) are clearly justified. If the evidence suggests that damages can be expected from climate change, then the expectation of damages provides a rationale for going beyond no-regrets policies to those that incur positive net costs. The principles of risk aversion and portfolio balancing provide a rationale for further steps.

The atmosphere is an international public good, in that all countries benefit from each country's reduction in greenhouse emissions; greenhouse gases are an international externality, in that emissions by one country affect all other countries to some extent.

Both public goods and externalities require a legal framework within which the problems they pose can be addressed. Mechanisms for control of international public goods may include the definition of property rights, the definition of limits to emissions, and a consensus for distributing the same in a fair and equitable manner. If, on the other hand, each agent acts in its individual interest, the result will be too little of the public good and too much of the externality.

A decision process for climate change should be sequential. It should also be able to respond to new information with midcourse corrections and to include insurance arrangements, hedging strategies, and the option value of alternative courses of action. The challenge today is to identify short-term strategies in the face of long-term uncertainty. The question is not, what is the best course over the next 100 years, but rather, what is the best course for the next few years, knowing that a prudent hedging strategy will allow time to learn and change course.

Policy measures to reduce risks to future generations include (1) immediate reductions in emissions; (2) research and development related to new supply and conservation technologies; (3) continued research on how much change is likely and what its effects will be; and (4) investments to assist in adaptation if significant global warming occurs. A well-

chosen portfolio of policies will yield greater benefits for a given cost than any one option undertaken by itself. Striking the appropriate balance requires taking into account costs, benefits, and risks.

In an interrelated global economic system, an attempt to reduce greenhouse gas emissions in one region or one sector of the economy may be offset by increases in other regions or sectors. This may occur through the loss of comparative advantage in the carbon-intensive sectors of the regions that limit emissions, through the relocation of industries, or through changes in world energy prices and the resulting shift in consumption. Any control strategy must account for these global effects.

For the purposes of analysis it is useful to separate efficiency from equity. The Framework Convention on Climate Change (FCCC) requires all parties to formulate and implement programmes to mitigate climate change and facilitate adaptation to climate change on the basis of their common but differentiated responsibilities, and taking into account their specific national and regional development priorities, objectives, and circumstances. Developing countries are more likely to be adversely affected economically than the developed countries; moreover, developing countries often lack the financial and technical resources to respond to these changes.

Efficiency requires that emission reductions occur where their cost is lowest, irrespective of who bears the financial responsibility. Efficiency calls for removing energy subsidies, reforming and clarifying property rights that affect energy use and carbon storage, and reducing nongreenhouse externalities that have the side benefit of reducing greenhouse emissions. Efficiency may also be promoted, and greenhouse emissions reduced, by better information dissemination and by addressing capital market imperfections that inhibit the adoption of energy-efficient technology. Dynamic analysis indicates large potential gains from flexibility in the timing of greenhouse reductions to allow for the economical turnover of capital stock and to allow time for the development of low-cost substitutes. Policies that promote efficiency by requiring nations to face the full costs of their actions will also address equity concerns. International mechanisms, such as joint implementation, coordinated economic instruments, carbon taxes, and tradable permits, if appropriately implemented, would promote efficiency.

1.1 Introduction

In recent decades, atmospheric emissions of greenhouse gases have risen significantly. Concentrations are currently about 25% greater than at the beginning of the Industrial Revolution. If current trends continue, concentrations will double from preindustrial levels before the end of the next century and, if unchecked, continue to rise thereafter (IPCC, 1990a).

The scientific community has noted the potentially serious effects of increased concentrations. These climatic effects could, in turn, have further effects on the biosphere, including an increase in mean global temperature, an increase in sea level, changes in agricultural yields, forest cover, and water resources, and a possible increase in storm damage.

Increased concentrations of greenhouse gases are the result of fossil fuel burning, deforestation, livestock raising, and other human activities. Concerted action on the part of individuals and governments will be required to slow the increase in concentrations. Changes in greenhouse gas concentrations and the analysis of the climatic and other physical consequences of those changes lie within the purview of the physical sciences. The role of human activity in generating greenhouse gases, the consequences of those changes for humans, and possible responses lie within the purview of the social sciences.

Climate change impacts are likely to vary dramatically from country to country. A warmer climate could benefit sectors of the economies of some mid- and high-latitude countries. It is possible that anthropogenic warming might heat the atmosphere enough to prevent or delay another ice age. On the other hand, even modest economic losses averaged over the globe could mask large regional losses: a rising sea level and the possibility of increased storm surges could threaten the survival of some small island states and coastal areas and could increase the risk of midcontinent drought and desertification for inland areas on the periphery of deserts. Such changes could promote human migration and major conflicts as well as famine, disease, and increased mortality.

Within the past decade, a consensus has emerged on some key issues in the economics of climate change. This report describes areas of consensus as well as areas of disagreement, the sources of disagreement, and further research that could narrow the range of disagreement. This chapter frames the issue of climate change largely from the point of view of economics but also from that of other social sciences, introducing the more detailed discussions in the chapters to follow.

At least two arguments have been offered to justify the commitment of resources to mitigate climate change. The first arises from fundamental values, the second from decision analysis. They may be summarized as follows:

- (1) We have only one planet. Some changes are largely irreversible and may occur rapidly. Prudence calls for avoiding a large-scale experiment with the planet. Thus, avoiding anthropogenic climate change lies beyond the scope of normal economic calculation.
- (2) The potential exists for the occurrence of sudden, largely irreversible, nonlinear changes in the global

ecosystem. These would have major economic effects, which would be particularly severe in some countries or regions.

Even if the first view is adopted, economics has much to contribute to the discussion, for the question of cost-effective emission reductions must still be addressed. If the second view is adopted, economics and cost-benefit analysis will clearly be relevant, both in deciding how much mitigation to undertake and in designing the measures.

This chapter, and others in this Assessment Report, draw on the findings of the IPCC's Working Groups I and II, and follow the guidelines provided by the Framework Convention on Climate Change (FCCC). The Convention leaves open a number of important questions that must be addressed at the political level through future negotiations, including reviewing the adequacy of commitments. It is hoped that the findings of this chapter, and the assessment report more broadly, will contribute to these future negotiations by providing an understanding of the costs and consequences of alternative actions and their scientific basis.

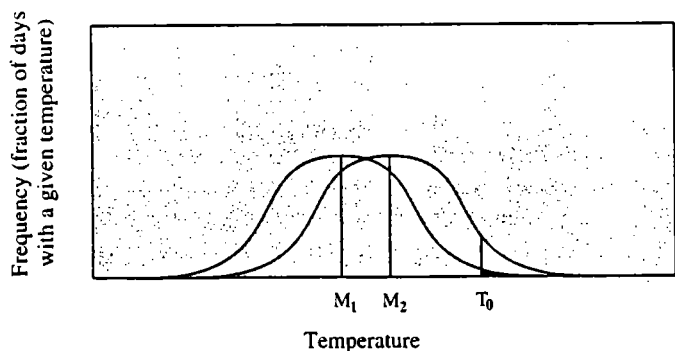
1.2 Features of Climate Change

Climate change could impose a variety of impacts on society. Volume 2 of this report analyzes these impacts in detail. They include effects on agriculture, forests, water resources, the costs of heating and cooling, the impact of sea level rise on small island states and low-lying coastal areas, and a possible increase in extreme events (e.g., storms). Although most attention to date has focussed on negative impacts, some impacts will be positive. Beyond these tangible impacts are a variety of intangible impacts,¹ including damages to existing ecosystems and the threat of species losses.²

Climate change presents the analyst with a set of formidable complications: large uncertainties, the potential for irreversible damages or costs, a very long planning horizon, long time lags between emissions and effects, a global scope, wide regional variations, and multiple greenhouse gases of concern.

Large uncertainties. Although natural scientists agree that greenhouse gas concentrations are rising, there remain major uncertainties about the impacts on temperature and climate. These are reflected in a wide range of estimates of future global mean temperature increases and in uncertainties about regional climate changes. Estimates of net economic losses for the most likely range of warming over the next century, and the great uncertainties associated with such estimates, are discussed in Chapter 6. Social scientists do not agree on the size of the behavioural responses or economic effects that would follow or on the effect of these changes on human well-being (Manne and Richels, 1992; Peck and Teisberg, 1993; Nordhaus, 1993).³

Nonlinearities and irreversibilities. Nonlinearities occur when changes in one variable cause a more than proportionate impact on another variable. Irreversibilities are changes that, once set in motion, cannot be reversed, at least on human timescales. For example, some have suggested that even a modest increase in atmospheric greenhouse gas concentra-



Note: As average temperature increases from M_1 to M_2 the number of days when the temperature exceeds T_0 increases significantly.

Figure 1.1: Effect of an increase in average temperature on the number of days that exceed a specified threshold.

tions could, beyond a certain point, trigger a substantial increase in temperature. Some have hypothesized that “runaway warming” could be triggered by a disruption of the North Atlantic thermohaline circulation or by methane release from thawing of permafrost.⁴ Alternatively, even a modest increase in average temperature might significantly increase weather-related agricultural losses because, for many crops, extra days of extreme heat severely limit yields. In Figure 1.1, if the threshold temperature for crop damage is T_0 , then even a small increase in the mean temperature, from M_1 to M_2 , may greatly increase the number of days above the threshold, represented by the area under the curves to the right of T_0 .⁵ On the other hand, spending large sums to reduce the risk of climate change may also have largely irreversible consequences, slowing development as it drains resources from other efforts to improve the human condition.

Long planning horizon. Greenhouse gas concentration changes occur over a long period of time; the full consequences of actions taken over the coming decades will be felt increasingly over the next century and in future centuries. The truly long-term nature of the problem is one of the distinctive aspects of greenhouse gas warming. Seldom has the world consciously faced a set of decisions likely to affect our descendants one, two, or three centuries from now.⁶ Because the costs of taking action today are borne by the current generation, whereas the benefits that accrue will be felt possibly hundreds of years in the future, the world community is now faced with issues of intergenerational equity on an unprecedented scale. Although society has addressed similar problems concerning trade-offs over periods of fifty or even a hundred years, the long planning horizon for climate change puts the analytic questions at issue in a new light. The length of time involved has one further implication: changes in technology, as well as population and consumption patterns, become of paramount importance.

Long life of capital stock. Every country has made large capital investments in its cities, farms, ports, and other assets. Some of this investment cannot be changed without large costs: low-lying port cities, for example, cannot easily be rebuilt. For other investments, the cost of change will be small.

For diversified agricultural economies, the cost of switching from one annual crop to another will be small if the temperature increase is modest; for less diversified economies, the costs may be larger. In short, both mankind and ecosystems have adjusted to the current climate, and adjustments to accommodate climate change may be costly.

Inertia in the climate system. Atmospheric concentrations, rather than emissions, determine the amount of warming projected by climate models. Concentrations change much more slowly than emissions, meaning that affected nations might not have enough time to prevent impacts from climate change, or to mitigate economic impacts after the effects of climate change become evident. In this respect, the risks of climate change are unlike those of earthquakes or floods. Long time lags and the difficulty of detecting climate change increase the difficulty of reliably determining the magnitude and timing of future effects before they begin to occur.

Global scope. Climate change is a global challenge, which cannot be answered by a single country acting by itself. Mitigation must be coordinated globally. In an interlinked world economy, not only are the actions of a single country, or group of countries, not likely to be sufficient to address the problem, they are likely to be largely offset by actions of other countries. If, for instance, one group of countries reduces timber cutting to increase carbon absorption, the price of lumber will rise, which may induce other countries to increase cutting in their forests.

Moreover, whereas economic analysis generally takes the point of view of a single decision maker or government, the important decisions on climate change will, of necessity, be made by many sovereign governments. Economic and decision sciences are not yet able to predict the outcome of bargaining problems of this type.⁷

Regional variation. Impacts are likely to vary greatly both within and among countries. Some countries and regions will suffer from warming; others will benefit, at least in some sectors. Some cold countries will benefit from a reduction in heating costs and an increase in the length of growing seasons; some warm countries will see a drop in yields from agriculture and forestry; low-lying states are likely to suffer from increased storm surges and flooding.

Aggregation. For the world as a whole, the net effect at any time will be the sum of local effects at many points on the globe, some positive and some negative. Analysts have no way to estimate this sum without detailed local calculations (summarized in Chapter 6).

Multiple gases of interest. The enhancement of the greenhouse effect depends on the concentration of all greenhouse gases, even though most economic modelling to date has limited itself to the implications of changes in CO_2 . Because greenhouse gases differ in radiative efficiency and atmospheric lifetime, analysts have devised measures of global warming potential (IPCC, 1990a, 1995) that seek to allow radiative forcing from changes in the concentration of all greenhouse gases to be measured in a commensurable fashion.⁸ Studies also demonstrate the important role of sulphur and other aerosols, which cause negative radiative forcing (i.e., cooling) by reflecting incoming solar radiation.⁹

Importance of net emissions. Because greenhouse gas concentrations depend on net rather than gross emissions, changes in forests and other greenhouse gas sinks must be taken into account.¹⁰

Efficiency vs. equity. From an economist's perspective, how much to reduce emissions is a matter of efficiency (because achieving the proper level of emissions raises net well-being), but who pays is a matter of equity. Economics has much to say about the former, but much less about the latter. Nonetheless, equity considerations will drive many of the policy decisions made under the Framework Convention on Climate Change.

1.3 Contribution of Economics

Economics and the social sciences offer perspectives on climate change not provided by the physical sciences. In the classic definition, economics is the study of the allocation of scarce resources that have alternative uses. Economics emphasizes the importance of trade-offs between different uses of resources, and the forgone value of other uses of a resource, called the opportunity cost. In the context of climate change, this means that (1) costs and benefits matter; (2) resources are not free; and (3) resources used for one purpose are no longer available for other purposes.

This chapter sets out the logic of cost-benefit analysis as applied to climate change. Standard cost-benefit analysis requires (1) a valuing of costs and benefits over time, using *willingness to pay* as a measure of value and (2) a criterion for accepting or rejecting proposals.¹¹ The standard criterion is the *compensation principle* (Kaldor, 1939; Hicks, 1939), which says that if the project yields positive net benefits, then those made better off could compensate those made worse off with something extra left over. As long as compensation is paid, the result is an unambiguous gain in welfare, without the necessity of weighing effects on different individuals.

Climate change raises difficulties with both requirements. Valuation is difficult because of the difficulty in valuing environmental amenities, which are generally not traded in the market. And the compensation principle will not apply if mechanisms for affecting transfers do not exist, either between countries or regions in one generation, or – especially – between generations. If transfers are not feasible, then the analysis must assign weights to different individuals (for example, the utilitarian welfare function gives equal weight to each person). Only then can conclusions be drawn about net benefits for society as a whole. This issue is addressed in the discussion of equity in Section 1.4.

Beyond these fundamental concepts are ideas, originally from other areas of economics, that may be applied directly to the study of climate change; these include work on risk, dynamics, sequential decision making, public goods and externalities, taxation, and general equilibrium.

1.3.1 Risk

In the past thirty years, much new economic research has focussed on rational responses to risk,¹² including three areas

important to a systematic examination of and rational response to climate change: portfolio theory, insurance, and decision analysis.

1.3.1.1 Portfolio theory

A portfolio manager attempts to get the best return for a given level of risk. One approach is to buy several types of assets whose returns are not correlated or are negatively correlated (that is, whose prices move either independently or in opposite directions). In this respect, climate change policy decisions can be compared to investment portfolio decisions.

When faced with a risk, an individual may (1) act to reduce the chance the unfavourable event will occur; (2) act to reduce the cost if the event does occur; or (3) spread part of the risk to others through insurance. In response to the threat of climate change, nations may (1) reduce the chance that warming will occur by reducing greenhouse emissions (mitigation); (2) adjust to climate change if it does occur (adaptation); or (3) spread part of the risk through insurance. A portfolio approach can be expected to include both mitigation and adaptation actions. These may include government policy reforms, such as reducing fossil fuel subsidies; increased carbon sequestration; reducing emissions of methane and other non-CO₂ greenhouse gases; research and development, which can promote emission reductions or make it easier to adapt to any changes that do occur; and international actions, including joint implementation (one country funding emission reductions in another country) and technology transfer.

A well-chosen portfolio of climate change investments will yield greater benefit for a given cost than any one option undertaken by itself. For an individual country, the issue is how to choose the portfolio of policy measures best suited to its circumstances and to adjust the portfolio over time in response to new developments. Governments will be making climate change decisions for several decades at least. This means that they will have many opportunities to adjust the size (total resources) and mix (choice of measures) of their portfolios of responses. Portfolios may differ from country to country.

1.3.1.2 Risk aversion

Individuals and societies are generally risk-averse when facing large risks; that is, they are willing to pay something to reduce the likelihood of a large risk. The amount they are willing to pay is called the *risk premium* (see Box 1.1).

That individuals and societies are *risk-averse* means that average utility (well-being) is increased by pooling risks, or, equivalently, that people are willing to pay to reduce the risks they face. If society as a whole is risk-averse, then some investments with a negative expected return, for example, a particular investment in climate change mitigation, should be undertaken if they reduce the probability of a loss or the costs of future adaptation.

The magnitude of those expenditures depends on society's degree of risk aversion and the magnitude of the risk. The *risk premium* – the extra amount that society is willing to pay to reduce a risk – is small if the stakes (say, the maximum loss) are small, and large if the stakes are large. An investment of a

BOX 1.1: RISK AND UNCERTAINTY

Uncertainty arises when a decision can lead to a range of outcomes.

Expected return or *expected value* of a decision is the mean of the distribution of returns, the amount a person would on average receive as a consequence of the decision.

Risk aversion measures an individual's unwillingness to take risks.

Risk premium is the amount an individual would pay to replace the uncertain distribution of outcomes with the expected value.

Certainty equivalent is the amount that makes an individual indifferent between it and a risky proposition; for a risk-averse person, the certainty equivalent is higher than the expected return; the difference is the risk premium.

dollar is justified if it reduces the loss of expected utility by more than a dollar, and not justified if it reduces the loss by less than a dollar. Thus, results reported below focussing on the expected loss of GDP from climate change do not directly address the risk premium. If a possible outcome is a loss of 10%, even though the expected loss is only 3%, then the *certainty equivalent* loss will exceed 3%. A dollar investment that reduces this certainty equivalent loss by more than a dollar should be undertaken. Such an investment could either reduce the average loss, for example, by reducing the probability of the loss occurring (through mitigation actions), or reduce the variance of the loss. For example, some actions that reduce extreme losses will have more than proportionate returns.

Ascertaining the magnitude of the risks, or how they are affected by any particular action, is often difficult in a dynamic setting. One key consideration is how the particular action affects the remaining options – the set of actions available in the future – along with their costs and benefits. Risk-reducing expenditures are referred to as *precautionary investments*. Making precautionary investments has the same effect as buying conventional insurance.

The insurance expenditures associated with mitigation actions and investments are, in a sense, only the differences between the actual expenditures and the *no-regrets* benefits (the benefits other than those associated with greenhouse gas emissions). Thus, investments in fuel-efficient cars may have a direct benefit in reducing the cost of running a car and in reducing its emissions of local air pollutants. The mitigation investment is only the additional investment for climate purposes.

Irrespective of the possible consequences of climate change, policies that mitigate against or assist adaptation to climate change and have zero or negative net costs (no-regrets policies) are clearly justified. If the evidence suggests that damages can be expected from climate change, then the expectation of damages provides a rationale for going beyond no-regrets policies to those that incur positive net costs. The principles of risk aversion and portfolio balancing provide a rationale for further steps. The costs of such policies might be

justified as a risk premium to be paid for the added security of reducing the likelihood of climate change.

Traditional insurance rests on two principles: pooling risks and transferring risks to those more willing or better able to bear them.¹³ Because the risks associated with climate change are correlated, pooling risks is less effective than it is in other situations. Nonetheless, differences in predicted regional impacts, implying less than perfect correlation in climate change risks, make possible some degree of risk pooling. This holds irrespective of who pays the cost, because wealthier individuals and countries are better able to bear risk.¹⁴ Many countries likely to be most adversely affected will be developing countries, whereas many of the countries least affected (or positively affected) will be the industrialized countries, which could provide insurance for effects of climate change that might fall harder on less developed economies.¹⁵

Insurance markets, however, face three problems in addressing climate change. First, they lack a mechanism to transfer some of the risk from those likely to bear it (future generations) to the current generation. Second, losses associated with climate change are likely to be both correlated and large, compared to losses absorbed in a single year by the commercial insurance industry (which itself has been hard pressed in recent years to handle natural disasters). Third, the long-term nature of climate change insurance raises the problem of contract enforcement: Will contracts signed today be enforceable tomorrow? Will the insurers be around to pay claims fifty or one hundred years from now? (Even in the industrialized countries, private markets may be inadequate to insure against losses from a major national disaster today.)

These considerations suggest that private markets will not be able to insure fully against climate change. One possible solution would include international action to establish insurance markets, perhaps with government reinsurance. Should such an insurance market be established, careful attention will have to be given to ensuring that the insured parties engage in appropriate adaptation actions, reducing the losses that might be associated with any greenhouse gas warming.¹⁶

1.3.1.3 Precautionary investments

A business makes precautionary investments to reduce the total risk of its portfolio. Numerous policy measures are available to reduce risks to future generations from climate change. Four have been most often discussed in recent years: (1) immediate reductions in emissions to slow climate change; (2) research and development focussing on new supply and conservation technology to reduce future abatement costs;¹⁷ (3) continued research to reduce uncertainties about how much change will occur and what effects it will have; and (4) investments in actions to assist human and natural systems to adapt to climate change if it occurs.

Precautionary investments may reduce the risk of climate change itself (mitigation), or they may enhance the ability of future generations to respond, in one of two ways. First, by analogy, an individual may set money aside in a "rainy day fund" when things are going well and allow it to grow over time in order to make it easier to adapt to difficulties that may occur later. Similarly, by increasing investment in productive

assets now, countries will have a richer economy to draw on should climate change damages occur later. A policy of precautionary investments means investing more than would otherwise have been invested. Second, investments can be made (including investment in research and development) that would enhance the economy's ability to adapt should climate change damages occur.

Precautionary investments may also enhance the ability of future generations to react. An important reason that people establish savings accounts is to reduce the impact of unfavourable events in the future. Similarly, a society may elect to accumulate capital against the possibility of a large loss from climate change. This is one thread of the debate over discount rates discussed in Chapter 4. Those who argue for a discount rate close to the opportunity cost of capital point out that society may choose between immediate greenhouse gas mitigation, at a cost, and delayed mitigation, with some of the money saved put aside as a savings account for our grandchildren in the event of large climate-induced damages.

1.3.2 Sequential decision making

As a policy question, global climate change is sometimes posed as a choice between (a) doing nothing at all or (b) committing to all-out effort. Given the large current uncertainties about the costs and benefits of greenhouse mitigation, this is the wrong way to frame the issue, as it obscures the choices that should be evaluated. Moreover, in part because option (b) may be perceived as too expensive to get political support, policy paralysis often results.

A more useful formulation is: "Given current knowledge and concerns, what actions should we take over the next one or two decades to position ourselves to act on new information that will become available?" (Lind, 1994). For example, decision makers would like to know if the possibility of irreversible damages, such as might be suffered by low-lying states, justifies undertaking an aggressive abatement programme immediately.¹⁸

Climate change demands a decision process that is sequential and can incorporate new information. Timing will be a key element, and the date of resolution of uncertainty an important element of the analysis. Figure 1.2 shows schematically the progression from a simple decision to a sequence of linked decisions. In this example, the simple decision might be whether to take aggressive abatement actions now. Let us assume that the uncertainties are resolved in 2005. In the case of sequential decisions, Decision 1 (in 1998) could be whether to take aggressive abatement actions now; Uncertainty 1 (resolved in 2005) might be the cost of mitigation; Decision 2 (in 2010) might be whether to tighten abatement programmes already in place; and Uncertainty 2 (resolved in 2020) might be the relation between greenhouse concentrations and temperature increase. Since both climate change and new knowledge (learning) are continuous processes, actions to address climate change should be adjusted continuously in the light of new information.

A sequential decision-making strategy aims to identify short-term strategies in the face of long-term uncertainty. The next several decades will offer opportunities for learning and

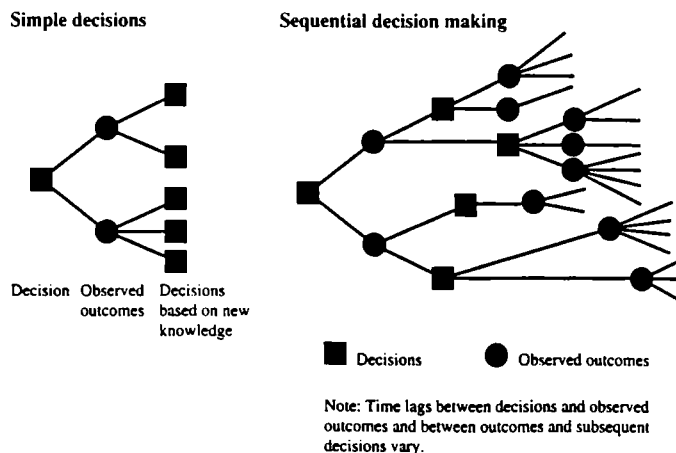


Figure 1.2: Sequential decision making.

making mid-course corrections. The relevant question is not "What is the best course for the next 100 years?" but rather, "What is the best course for the next few years?" because a prudent hedging strategy will allow time to learn and change course.

For example, the choices might be (1) immediate investment in new plant and equipment, (2) aggressive research and development on greenhouse abatement technology, or (3) deferring large investment for ten years, when the nature and size of the threat are better understood, when costs will presumably have dropped owing to the availability of improved technologies, and the job can be done more efficiently.

Inappropriate interim goals increase the total cost of addressing the problem (Richels and Edmonds, 1993). For example, a commitment to certain levels of emissions in certain years fails to take into account the effects of temporary economic disturbances on GDP, and thus on emissions and, hence, on the cost of controls.

Because of the high cost of being wrong in either direction, the *value of information* about climate change is likely to be great. In particular, the value of information about the sensitivity of temperature to CO₂ increases, the temperature damage function, the GDP growth rate, and the rate of energy efficiency improvement is likely to be high (Chao, 1992; Peck and Teisberg, 1992; Manne and Richels, 1992; Nordhaus, 1993).¹⁹

The presence of uncertainty along a dynamic path creates an *option value*, the value of preserving choices for the future. In climate change, the term has been used in two different ways. One stresses the irreversibilities of climate change: mitigation expenditures now preserve the option of avoiding adaptation expenditure later. The other stresses irreversibilities in investment and the cost of premature turnover of capital. Any action taken today changes the options available later or, more precisely, changes the consequences of any future action. Sequential decision making focusses on how those consequences are affected if one action is taken today rather than another, and on how these consequences are affected if actions are taken in parallel rather than serially.

1.3.3 Dynamics

The problem of greenhouse gas warming involves additions to concentrations resulting from net emissions over extended

periods of time. Thus the analysis must focus on dynamics. Dynamic analysis involves three stages: the dynamic processes involved, the trade-offs, and judgments concerning those trade-offs.

Dynamic analyses have led to important insights. For example, atmospheric concentrations of greenhouse gases and, therefore, their effect on temperatures depend on the total amount emitted over a period of years. A given concentration target can be achieved by a variety of emission timepaths. Timepaths that provide for the economical turnover of existing capital stock and time to develop low-cost substitutes are likely to be less costly. This suggests large potential gains from flexibility in the timing of emission reductions.²⁰

1.3.3.1 Kaya identity

The driving forces in emissions of any greenhouse gas can be seen in the following identity for carbon dioxide emissions (Kaya, 1989):

$$\begin{array}{ccccccc} \text{CO}_2 & = & \text{CO}_2/E & \times & E/Q & \times & Q/L & \times & L \\ \text{carbon} & & \text{carbon} & & \text{energy} & & \text{output} & & \text{popu-} \\ \text{dioxide} & & \text{dioxide} & & \text{per unit} & & \text{per} & & \text{lation} \\ \text{emissions} & & \text{emissions} & & \text{output} & & \text{capita} & & \\ & & \text{per unit} & & & & & & \\ & & \text{energy} & & & & & & \end{array}$$

or, expressed in rates of change:

$$d \ln \text{CO}_2 / dt = d \ln \text{CO}_2 / E / dt + d \ln E / Q / dt + d \ln Q / L / dt + d \ln L / dt$$

that is, the percentage rate of change in carbon dioxide emissions is equal to the rate of change in carbon dioxide emissions per unit energy plus the rate of change in energy requirements per unit output plus the rate of change in output per capita plus the rate of change in population.²¹

This identity clarifies different approaches to reducing emissions. For a developed country with a stable or slowly growing population, as long as the ratio of emissions to output declines at least as fast as productivity rises, CO₂ emissions will not increase. Because of the substantial potential for energy efficiency improvements, this seems feasible for most developed countries. Many opportunities exist for increasing end-use efficiency, represented by the second term on the right-hand side – for example, a shift from cars to public transportation and from less to more fuel-efficient cars and homes.²² (The same term may also reflect structural shifts in the economy, as in the case of a shift away from energy-intensive industries.) Fuel switching (for example, from coal-based electricity to oil, gas, hydroelectric, wind, or geothermal), represented by the first term, also offers the potential to limit CO₂ emissions in many countries.

For many developing countries, emissions will increase unless energy efficiency and greenhouse gas emissions per unit of energy change to offset growth in per capita output and population. For many developing countries with rapidly growing populations, pressures for economic development will make it difficult to direct capital from investments with higher greenhouse gas emissions to those with lower greenhouse gas emissions.²³

Evidence for two other essential issues is currently limited. First, to what extent will improvements in energy efficiency require net increases in investment beyond the resources saved from reduced energy usage; in other words, how much does aggressive emission reduction depress economic growth? Order-of-magnitude calculations suggest the presence of only limited trade-offs, at least for the near term. Second, do developing countries have the institutional capacity to achieve the desired increases in emission efficiency?

1.3.3.2 Nonrenewable resources, backstop technologies, and emission reduction strategies

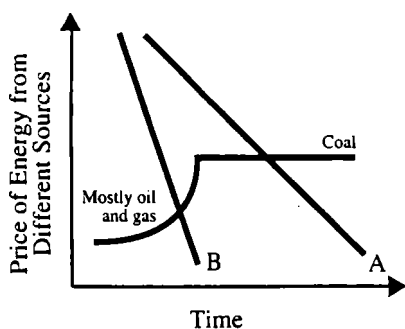
In principle the atmosphere is a renewable natural resource. However, the longevity of the greenhouse gases and the relationships between stocks and flows mean that, for practical purposes, it may be better treated as an exhaustible natural resource, although one in which welfare depends not just on the flow out of the stock but on the stock itself.²⁴

The central problem with natural resources, whether renewable or not, is timing. Many renewable resources possess a maximum sustainable rate of exploitation. Exploitation cannot long exceed this maximum rate without depleting the stock and ultimately reducing the harvest. Corresponding to the sustainable flow rate is a steady-state stock. If, initially, the actual stock exceeds the steady-state stock, then the flow can exceed the maximum sustainable flow for a while. The question is how to distribute this excess over time. In addition, even when the stock is at the sustainable level, it may be desirable in times of emergency to exceed the maximum sustainable flow. For a renewable resource, this can be done, though only at the expense of decreased flows later.²⁵

Timing of reductions in greenhouse gas emissions should reflect differences in costs, discounting (to evaluate those costs), and risk. If technological change will make future emission reductions much less costly, some reductions should be postponed.²⁶ Conversely, research on learning effects shows that if actions taken today will lower costs faced tomorrow, then these dynamic benefits should be included in the calculus (Arrow, 1962; Atkinson and Stiglitz, 1980). In the context of climate change, if emission constraints stimulate technical or other developments that help to lower the costs of continuing or additional emission abatement, then reductions should be accelerated (Grubb *et al.*, 1993a, 1993b, 1995). If discount rates are high, the costs borne by future generations will carry less weight than if discount rates are low. In the presence of risk, nonlinearities, or irreversibilities, the principle of risk aversion suggests a strategy of early mitigation.

The theory of nonrenewable resources contains a second set of lessons for climate change policy. Suppose primary energy sources are divided into four groups: coal, gas and oil, biomass, and noncarbon sources. As a first approximation, gas and oil may be taken to be exhaustible. This means that total carbon emissions from gas and oil are fixed, or at least confined to narrow bounds; the question is not how much will be consumed, only when.²⁷

As an example, Figure 1.3 depicts three phases of fuel use in an economy. In the first phase, the economy relies on nonrenewable resources, such as oil and gas; in the second, on coal and perhaps nuclear power; in the third, on backstop



Note: If the price of the nonfossil backstop technology is given by A, all oil and gas reserves will be exhausted and coal will be used for some time before being displaced by the backstop technology. If the price of the nonfossil backstop is given by B, it will be adopted before the oil and gas reserves are exhausted, resulting in lower greenhouse gas emissions.

Figure 1.3: Influence of the cost of backstop technologies on energy use and greenhouse gas emissions.

technologies,²⁸ such as biomass combined with noncarbon sources. The switch points depend on rising energy prices and improving technology, which lowers the costs of the backstops. The figure shows alternative long-run scenarios. In alternative A, the price of the backstop technology falls sufficiently slowly that, for a time, the economy relies on coal. In alternative B, the price of the backstop technology falls fast enough to eliminate the intervening stage of primary reliance on coal.

Since, to a first-order approximation, the total carbon load from oil and gas is fixed (and limited), the total carbon load on the atmosphere is ultimately primarily related to coal usage. From this perspective, an important uncertainty is the pace at which the cost of the backstop decreases. If it decreases fast enough, the intermediate stage of coal dependence will be short, and the total carbon load low, whereas if the price decreases slowly, the carbon load could be much larger.

From this perspective, rational use of gas and oil is an important part of a risk strategy, for it provides insurance against the possibility of a delay in the arrival of backstop energy sources.²⁹ This, in turn, has important implications for the "leakage" debate, which asks whether, in the event that the developing countries impose carbon taxes but the undeveloped countries do not, the latter's response will largely offset emission reductions made by the former. It is also possible that lower prices for gas and oil will induce coal-rich countries to decrease their reliance on coal, thus possibly producing negative leakages. But to the extent that such leakage occurs, the insurance provided by greater conservation of oil and gas is eliminated, and it is this insurance that should be an essential part of a dynamic strategy. If the backstop arrival is delayed, then earlier fuel switching by China and India, to mention the most pertinent examples, will yield no long-run benefits. On the other hand, if the backstop arrival is early, the whole issue is largely moot. Thus, leakage needs to be looked at, not from the static perspective of what occurs in a single year, but from a dynamic perspective that corresponds to the long-run nature of the global climate problem.

1.3.4 International public goods

The atmosphere is an *international public good*, in that atmospheric concentrations are the result of combined actions by all countries. A pure public good (Samuelson, 1954) has two properties: *nonrivalry* and *nonexcludability* (see Box 1.2).³⁰ The atmosphere has both characteristics. That means that if one country's greenhouse gas reductions thwart global warming, all countries benefit.³¹

Since countries will be affected differently by climate change, the benefits of avoiding greenhouse warming will also differ from country to country. Further, some actions will simultaneously affect local atmospheric conditions (providing local public goods) and greenhouse concentrations. For example, actions that reduce urban driving improve local air quality and at the same time reduce greenhouse gas emissions.³²

1.3.4.1 Property rights

An important strand of economic thought associates externalities with a failure to assign property rights (Coase, 1960). Assigning property rights to the atmosphere is particularly difficult, however, since this would require the agreement of many sovereign states. Tradable greenhouse emission permits, discussed below, can be thought of as an attempt to resolve the problem by explicitly assigning property rights to greenhouse emissions.

Establishing property rights for emissions is not the same thing as considering the climate system itself as a public good. The FCCC refers to the climate system (not the atmosphere) as a "common concern of humankind." Atmospheric concentrations are the net result of emissions plus the contributions and effects of other factors such as the oceans, forests,

BOX 1.2: PUBLIC GOODS AND EXTERNALITIES

Externality: An externality, or spillover, arises when the private costs or benefits of production differ from the social costs or benefits. Because the social costs or benefits are external to the private costs that firms face, the economy will tend to produce too little of a public good (like education) and too much of a public bad (like pollution).

Public good: A public good has two properties: nonrivalry and nonexcludability. Nonrivalry means that additional consumers do not have to compete with each other to use the good and therefore drive up its cost: the marginal cost of an additional individual using the good is zero. Nonexcludability means that the marginal cost of exclusion – of stopping an individual from enjoying the good – is prohibitive. Public goods thus permit "free riding." Lighthouses, for example, are public goods: when lighthouse services are provided to one person, others may enjoy the same services without cost.

Market failure: Private markets may sometimes fail to provide a good at the most desirable level: private markets alone will likely provide too few lighthouses and too much pollution.

and agricultural activity. Establishing property rights over emissions does not provide guidance for the consideration of these other influencing factors. Thus, establishing property rights for the atmosphere is only one of the mechanisms necessary to regulate climate change.

1.3.4.2 *Paying for an international public good*

Who should pay for a global public good? Every country faces this question internally in determining who should pay for the public goods it provides. Who should, for instance, pay for pollution control within a country? Economists generally agree on the following principles:

First, for the purposes of analysis, *it is useful to separate efficiency from equity*. The implication of this principle is that because pollution is a social cost of production (and consumption), everyone should be made to pay the full social costs of the pollution they generate. Thus, if there is a social cost to a unit of greenhouse gas emissions, that cost is the same no matter who produces the emissions. All should pay the full social costs of their actions, whether rich or poor. In this perspective, corrective (Pigouvian) taxes should be imposed uniformly.

Second, *it is inappropriate to redress all equity issues through climate change initiatives*, although climate change should not aggravate disparities between one region and another.

No scientific consensus exists on the framework for deciding the burden of financing mitigation and adaptation. At least four approaches have been proposed to determine how the burdens of taxation should be shared. One approach looks at *benefits*: Just as those who benefit from private goods must pay for them, those who benefit from a public good should be made to pay for it. The principle has some force when large differences in preferences exist within any income class. Providing a particular public good benefits some of those individuals more than others, creating inequalities in the absence of benefit taxes. A major problem frequently encountered, particularly for pure public goods, is that it may be difficult to determine who benefits. It is, in general, possible to ascertain the *economic benefits* of mitigation, and these are likely to be quite unequally distributed. But this principle, by itself, does not fully determine who should bear the costs. Appropriately designed mitigation strategies will produce a surplus of benefits over costs, a surplus that must somehow be divided.

A second approach looks at ability to pay. It is often held that richer countries (or individuals) should pay more than poorer ones. This approach sometimes rests on the claim that all people are entitled to a certain minimum consumption (Dasgupta, 1982). But this principle does not answer the question of how much extra the richer countries should pay.

A third approach is based on contribution to the problem. Because the industrialized countries have contributed more than two-thirds of the stock of anthropogenic greenhouse gases in the atmosphere today, this approach seems to suggest that they have a larger responsibility for bearing the costs. On the other hand, by the time greenhouse gas concentrations double from preindustrial levels, the developing countries are projected to be contributing more than half of annual emis-

sions, and roughly half of the total stock in the atmosphere (IPCC, 1990a; Cline, 1992). Thus, under this criterion, the developing countries might eventually pay far more of the mitigation costs than under the other principles described earlier.

Economists have turned to a fourth approach – the social welfare function – to answer the question of how much extra different parties should pay, as well as the question of how to distribute the surplus. The discussion of equity below differentiates between the Rawlsian and utilitarian approaches. In this case, both approaches yield similar results: In the absence of incentive problems, both imply that all of the surplus should be allocated to the poorer countries, or that all of the burden of effort should be borne by the richer countries.³³

Yet a different approach holds that social scientists as such have nothing to say about these ethical issues. Coase (1960), for instance, approaches the problem of externalities by emphasizing that (a) in the absence of bargaining costs, an efficient solution can be obtained by assigning property rights³⁴ and (b) this solution is independent of how property rights are assigned.³⁵ Coase also emphasizes the importance of transaction costs, which will often influence the choice of policies.

A simple approach that yields efficiency but does not require redistribution (and is thus consistent with the two principles enunciated above) requires coordinated tax rates so that all countries face the same energy prices. This approach makes the cost of emitting an extra tonne of carbon equal across all countries, with each country retaining the revenues thus generated.³⁶ The net cost of such a tax (ignoring the benefits from reduced greenhouse gas emissions) will, in general, be smaller for poorer countries, as a percentage of their national output. The burden of the tax is progressive in its distribution across countries, even though the tax is levied at the same rate in all countries.³⁷

Accounting for past emissions. Article 3.1 of the Framework Convention on Climate Change directs the Annex I (i.e., developed) countries to take the lead in responding to the threat of climate change “on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities.” Some have argued in addition that because the industrialized countries have been the major contributors to current levels of greenhouse gases, they should bear most of the costs of mitigation. This view says that costs should be borne, not in proportion to benefits expected, but in proportion to contribution to pollution. This argument, however, is not based on the principle of economic efficiency. Efficiency requires that incentives be prospective (forward looking), not retrospective.³⁸ No incentive effects result from imposing charges based on *past* actions. Whether to charge nations that contributed CO₂ to the atmosphere is an issue of ethics, not efficiency.³⁹

The controversial issues of population growth and consumption patterns, although central to economic development, bear on climate change largely through their effects on emissions. Population growth in developing countries may also exacerbate the ecological and socioeconomic impacts of climate change. At the same time, high per capita consumption in industrialized countries, where populations have nearly stabilized, will also affect mitigation and adaptation

costs and strategies. The relation of population to sustainable development, although important, is beyond the scope of this paper.⁴⁰

1.3.4.3 Enforcement

Both externalities and public goods need a legal framework within which the problems they pose can be addressed. Without compulsory taxation, there is an incentive for each individual to be a free rider, though there is some empirical evidence that the free rider effect may not be as significant as economists have previously assumed (Bohm, 1993). In the absence of compulsory taxation, externalities can only be addressed with well-defined property rights (Coase, 1960)⁴¹ and a legal system that enforces compensation for externalities.

Enforcing compliance with international legal agreements presents a number of legal and political problems. Many states resist compulsory use of the judicial process; this provides an incentive for free riding. The FCCC provides several means of settling disputes, including judicial recourse and arbitration. It also requires the parties to consider establishing a “multilateral consultative process” to assist in implementation of the Convention and to anticipate and prevent confrontations concerning compliance and enforcement.

1.3.4.4 Knowledge

A key element in addressing the problem of global warming is knowledge – knowledge about climate science as well as about the economic and social aspects of impacts, mitigation, and adaptation. Much of this knowledge is in the nature of an international public good. Developing ways of increasing energy efficiency will benefit all countries. Although in some cases, those countries engaged in the research will be able to appropriate for themselves a significant fraction of the *private* benefits (mostly in reduced energy costs), they will not be able to appropriate the broader social benefits, except through an energy tax (or permit fee) that is high enough that the price fully internalizes the emissions externality. Even then, the social benefits of innovation tend to far exceed the private benefits.

This suggests the need for an international agreement to fund basic research and subsidize applied research, particularly in energy-related technologies for the developing countries. There need not be a central funding agency, or a central directorate determining which research should be undertaken. This calls for some mechanism, possibly including joint implementation, for sharing research results and for ensuring that the fruits of this research are made available.

1.3.5 Efficiency

With some exceptions noted below, efficiency and equity can be analyzed separately.⁴² Analysts agree that any actions responding to climate change should be cost-effective: no matter who bears the cost of emission reductions, reductions should occur where their cost is lowest.⁴³ Because of the low energy efficiency in many developing countries, many have proposed that more attention be paid to emission reductions there.

Mechanisms for reducing emissions equitably and efficiently, including joint implementation, tradable permits, and coordinated tax policies, are discussed below and in Chapter 11. All these approaches, however, attempt to confront all individuals and producers in all countries with the same cost of emissions. Emission control is an international public good, in that greenhouse emission reductions have the same effect wherever they occur. Just as efficiency in the production of steel or any other commodity requires that all consumers and producers face the same price, so too with emissions. This can be achieved either through coordinated energy taxes or through tradable permit requirements; but unless the rules are applied in a systematic way to both developed and developing countries, emission reductions will be inefficient.

Partial participation in an international emission reduction programme will significantly reduce its effectiveness. The growth of international trade has resulted in important links between the developed and developing countries, and the total effects of any policy undertaken in the former can only be evaluated in terms taking into account the systemic responses, including responses from the developing countries, as discussed under the heading of “general equilibrium” in Section 1.3.6 below.⁴⁴

1.3.5.1 Bankable permits

Efficiency imposes several requirements. One, just described, is that at any moment, the costs of reducing emissions should be minimized. The second is *intertemporal efficiency*: The marginal cost of reducing emissions at two points in time must be the same. If it will cost less to reduce emissions at some future date, adjusting for time discounting, option values (risk), and impacts on atmospheric concentrations, then the reduction schedule should be adjusted accordingly.

Intertemporal efficiency would be promoted by allowing banking of permits (allowing a source to use fewer permits in one year and more in another), and by the development of futures and options markets. A bankable permit system would address some equity issues between developed and developing countries, including the concern among developing countries that delays in mitigation now by the industrialized economies would leave a greater burden for the future.

1.3.5.2 Exchange/risk efficiency

When different parties to an agreement hold widely differing views about risk and the probability of loss, significant efficiency gains can result from transferring risk among them. In Section 1.3.1.2 we discussed the importance of establishing an international insurance market for those facing the threat of losses under global warming and noted the advantages of establishing a market within which countries that are less concerned about these risks can assume more of the insurance burden. Any efficient international system for addressing the problems of global climate change must include both mitigation and insurance obligations. Governments that believe they have a comparative advantage in assuming climate risks can assume a larger share of those risks, trading off other obligations and substantially reducing the overall costs of responding to climate change.

1.3.5.3 Comprehensiveness

Efficiency also requires that the cost of reducing all greenhouse emissions be minimized. This principle implies that any mitigation programme must include not only all greenhouse gases (taking into consideration their heat-trapping potentials and atmospheric lifetimes⁴⁵) but also carbon sinks.

Finally, and perhaps most controversially, it implies that mitigation strategies should focus on all elements of the Kaya identity, ensuring that the marginal cost of reductions is the same for each of the possible strategies. Thus, population control may be an element in a long-term mitigation strategy, no less than a shift in the composition of production or an increase in the energy efficiency of the economy.

1.3.6 General equilibrium

General equilibrium theory, an important element of economic research over the last century, demonstrates the advantage of looking beyond first-stage effects. It offers two important insights for climate change analysis. First, the various parts of an economic system are interrelated; perturbations to one part have ramifications for other parts, which may be quite distant. Second, when all the reverberations are taken into account, the net effect of an action may be markedly different from the initial (and intended) effect.

One implication of general equilibrium theory has already been noted: Taxes imposed on one part of the global economy may have little if any effect on global emissions; they may simply result in a relocation of economic activity. Increasingly, the world's economic system must be viewed from a global perspective. Location of economic activities is determined primarily by relative factor prices, taking into account certain specific locational advantages and specialized competencies. If, for example, the OECD countries impose carbon taxes on energy-intensive industries, those industries may relocate outside the OECD. Further, if greenhouse mitigation puts an economic drag on the developed countries, developing countries would be affected through trade.

If different countries have different obligations to reduce greenhouse emissions, different implicit tax rates will result. This will interfere with world economic efficiency – decreasing world real output – possibly with little effect on total greenhouse gas emissions. For example, the most energy-intensive activities – such as aluminum production – may well relocate to developing countries.⁴⁶

Whereas many of the energy-economy-carbon models described in subsequent chapters attempt to estimate the magnitude of such carbon “leaks” (where carbon-intensive production moves to areas in which it is least regulated), most are based on standard international trade models, in which the location of production of various goods and machines is fixed (Whalley and Wigle, 1991).⁴⁷ Thus, estimates of carbon leakages are based only on commodity substitution.⁴⁸ But in the very long run, which is the time span of interest for an analysis of global warming, leakages may well be higher, owing to the relocation of industries. No consensus now exists on the magnitude of long-run leakages.

1.3.6.1 Intertemporal substitution

General equilibrium issues also arise when production can be shifted from one period to another. For example, in a partial equilibrium analysis, a tax on gas or oil raises the price of the fuel taxed, thereby reducing its consumption, and thus associated emissions. But over the long run an exhaustible natural resource like gas or oil has, by definition, an inelastic supply (ignoring for the moment extraction costs, which, in the case of gas and oil, are small relative to the price). The general theory of incidence argues that when a commodity is in inelastic supply, a tax affects the price, but not the level of consumption. That is, *when all countries impose a tax on gas or oil, the producer price of oil falls, by an amount just equal to the tax*. The full incidence falls on producers; as a first approximation, *the level of consumption – and thus the level of emissions – remains unchanged*. Obviously, if the tax is large enough, the price will fall below the cost of extraction for some output, and supply will be reduced. Moreover, in the case of exhaustible natural resources, taxes may affect the timing of consumption of the oil and gas (Stiglitz, Dasgupta, and Heal, 1980).⁴⁹

1.4 Equity

Who will be allowed to increase their greenhouse emissions and who will pay for greenhouse gas abatement and adaptation are among the most contentious issues in climate change. Equity issues such as these have immediate implications for policy as well, because the initial allocation of emission rights and emission constraints will largely determine the distribution of costs. The Framework Convention on Climate Change explicitly directs the parties to consider the problem of equity:

The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof. . . .

[Account must be taken of] the differences in their starting points and approaches, economic structures and resource bases, the need to maintain strong and sustainable economic growth, available technologies and other individual circumstances, as well as the need for equitable and appropriate contributions by each of these Parties to the global effort regarding [the Convention's] objective.⁵⁰

1.4.1 General issues

Within the limits of cost-benefit analysis, equity arises because of the principle of compensation, discussed in Section 1.3. For example, suppose it could be shown that a business-as-usual path produced higher total benefits than a path with lower greenhouse emissions. We could not conclude from this that the world as a whole would be better off. Indeed, if the losers are not compensated, and their loss is counted more heavily than the winners' gain, the world as a whole would be

worse off. Or suppose the costs of warming fall predominantly on one group or one generation, while the benefits accrue to another. (For example, some have speculated that the costs of damages from warming would fall largely on developing countries, without a compensating increase in benefits (Parikh, 1994).) Unless the gainers actually compensate the losers for their losses, cost-benefit analysis cannot conclude that the change has, on balance, been good for society. Compensation is particularly difficult if future generations bear most of the costs, because no “fund for future greenhouse victims” exists (Birdsall and Steer, 1993). Thus, some have argued that, in the absence of mechanisms to make these transfers, we should not rely on possible future transfers from gainers to losers but should instead insist that the gainers pay the costs up front. An alternative explanation addresses these equity concerns by assigning different weights, perhaps based on economic status, to changes in consumption of different individuals (Atkinson, 1970).

No consensus exists among either economists or philosophers about the appropriate ethical responses to the changes that would come with global warming. Should, for instance, owners of resources be compensated for the losses they incur as a result of mitigation actions and the consequent change in prices or values? Economists have often argued no, for several reasons. First, some wealth is not a reward for productive activity, but merely an accident. It is not because country X did something that \$200 billion worth of minerals or oil was discovered to lie beneath its territory. One position is that these random allocations of wealth have actually contributed to world inequality, and that eliminating a part of these wind-fall gains would, from the perspective of an egalitarian social welfare function, be welfare-increasing. Another view denies that government policies would be taking value from assets that by right should be there; until now, according to this view, these resources have simply been underpriced, not fully reflecting the social costs imposed by their use. In this view, actions to discourage overuse would simply rectify a previous mistake.⁵¹

Whether investors or countries should be compensated for the adverse effects on their market values remains controversial. There is, however, reasonable consensus on three general principles: First, workers in adversely affected sectors may need assistance to switch occupations (the market failure here is that workers cannot purchase insurance against these kinds of adverse shocks). Second, gradual transitions may significantly lower the absolute cost of the transition. For instance, workers leave jobs through natural attrition; if those leaving are not replaced, the industry will be scaled down, with no transition cost to any individual worker. Third, the magnitudes of the uncompensated redistributions associated with any change in policy are often correlated with the magnitude of the political opposition.

Most policy changes produce winners as well as losers. If the relative price of natural gas increases, owners of natural gas deposits may actually be better off. In economies with progressive taxation of either capital gains or consumption, some part of those gains is implicitly shared more broadly.

Virtually all policies discussed below also have different effects on different groups. Residents of very hot and very cold climates consume more energy for heating and cooling, and thus would be worse off, relative to those in more moderate climates. In some countries, city dwellers can choose less energy-intensive modes of transport than those in the countryside.

Many of these impacts will be reflected in capital costs. Thus, the value of land is likely to rise in temperate climates and to fall in extreme climates. (Similar points can be raised, of course, about the costs imposed by climate change itself.) This capitalization effect has both favourable and unfavourable implications. In the long run, residents of colder climates are likely to consume less heating fuel, but perhaps at a higher price, which would leave them on balance about where they started. Energy prices are likely to rise and land rents to fall, in an almost offsetting way. On the other hand, current owners of land would bear the full brunt of the present discounted value of all future increases in taxes (or the tax-equivalent cost of regulations designed to reduce energy utilization). As a result, unless policy changes are introduced gradually, dramatic changes in land values may occur, with possibly large effects on financial institutions and the economy as a whole. Anticipation of these policies would partially offset these effects.⁵²

National security. Climate change itself may affect the national security of many countries. At the same time, policies to reduce greenhouse emissions may affect the export earnings and therefore the national security of the energy exporting countries.

Although countries may be willing (or forced) to accept changes in national wealth as a result of changes in world prices induced by the response to the threat of global warming, countries are less likely to be willing or able to accept what they may perceive as implied threats to national security over which they have some control. Thus, a country with a large endowment of coal becomes more vulnerable if it comes to rely on imported oil or gas – supplies of which could be cut off in time of war. These countries may feel it imprudent to switch, even if private economic gains were to be had; and they are particularly unlikely to switch if the benefits take the form of an international public good.

Increasing world political stability would clearly address these concerns. But even were that successful, it would not suffice. To increase national security, policies will need to focus on increasing energy efficiency and reducing energy demand. This is an example of the necessity of allowing sufficient flexibility in the design of an international structure for greenhouse gas emissions that the particular circumstances of each country can be appropriately taken into account.

Benchmarks. The earlier discussion of equitable distribution of the burdens of responding to greenhouse gases, employing generally accepted principles of public finance, avoided the concept of benchmarks, that is, setting target emission reductions in relation to past emissions. These have played an important role in international negotiations. Indeed,

the only quantitative target in the FCCC (Article 4.2a and b) requires developed country parties to aim to return their emissions of CO₂ and other greenhouse gases not controlled by the Montreal Protocol to 1990 levels by the year 2000. Although this target suggests equitable treatment, were it to be accepted as legally binding on developed countries without further qualification, it would in fact result in unequal burdens, as it fails to take into account relative incomes and therefore imposes unequal tax rates.

But this criterion can also be criticized as inequitable in a more fundamental sense, since it pays no attention to past efforts at achieving energy efficiency, or to other circumstances that might affect the implied tax rate. For instance, a country that during the preceding ten years had made every effort to increase energy efficiency and switch consumption to less energy-intensive commodities would face the burden of reducing its emissions still further. Because the marginal cost curve for emission reductions rises steeply beyond a certain point, the implied tax rate would be considerably higher than for a country that had previously encouraged overconsumption of energy, for example, by energy subsidies. For the second country, achieving the emission targets might only require elimination of the energy subsidies, a policy with an implied negative tax rate. For a similar reason, countries with large endowments of hydroelectric power may find it relatively difficult to meet an emission target of this form.

Public finance theory has focused extensively on "second-best" policies, recognizing the difficulty of achieving first-best objectives of either economic efficiency or distributive justice. In this context, the central issue is whether alternatives to benchmarking exist. When the U.S. government recently issued tradable emission permits for sulphur dioxide, it took account of emission reductions already achieved. Benchmarking reflects information that would not be reflected in a simple criterion such as a particular emission level per unit population or GDP. Thus, a strong case can be made for including benchmarking, if not in the final allocation of permits (obligations), at least in the transition rules.

1.4.2 Intergenerational equity

Efforts to control greenhouse emissions will provide benefits primarily for our grandchildren and their descendants. We face a difficult task in estimating and judging what aspects of climate and environment they will value and how best to preserve those aspects for them. If we take aggressive action to limit climate change, they may regret that we did not use the funds instead to push ahead development in Africa, to better protect the species against the next retrovirus, or to dispose of nuclear materials safely. Chapter 4 addresses directly the most important issue in intergenerational equity: choice of an appropriate discount rate.

A similar argument applies to actions with differential impacts on different regions. If greenhouse warming turns out to be a major threat to developing countries and if the developed countries fail to reduce emissions aggressively now, the developing countries may suffer additional damage later. Alter-

natively, if the developed countries choose to embark on an aggressive control regime now, and if this cuts into their growth rates, the result will shrink export markets for developing countries and thus reduce growth there. In addition, if developed countries view their greenhouse efforts as, in effect, aid to developing economies, they may cut back on other programmes (sanitation, water, education for women, etc.) that have a more immediate impact on life expectancy, health, and well-being.

1.4.3 Within-country equity

Most discussions of equity and climate change have so far focussed on developed and developing country issues or on issues between one country and another, but issues of equity within a country are also important, and indeed play a central role in the political debates about appropriate responses to climate change. Most policy recommendations involve large within-country losses for certain groups. For instance, any policy leading to less use of coal and lower producer prices for it will lead to large losses for coal mine owners and workers.⁵³

The net efficiency gains (in reduced emissions) relative to the distributive effects may differ markedly across resources. Thus, if the price elasticity of world oil supply is small, a tax on oil will be reflected in the prices received by producers and have little effect on the cumulative consumption of oil, though it may result in some short-run substitution against coal. Policies aimed at bringing closer the date of arrival of substitutes for fossil fuels could lead to an increase in current emissions, though long-run effects on atmospheric concentrations would be positive.

1.5 Economics of Policy Actions

Earlier sections set forth a basic framework for analyzing policies related to global climate change, including a combination of mitigation, adaptation, and possibly climate engineering. Striking the appropriate balance requires taking into account the costs, benefits, and risks associated with each strategy. For instance, setting aside risk, governments should reduce emissions to the point at which a dollar of extra spending would yield a dollar of expected savings from preventing damages imposed by climate change or would save an extra dollar of expected costs of adaptation. Adding risk and sequential decision making complicates the analysis but leaves the basic principles unchanged. Because of the lasting impact of climate change and the magnitude of the resulting economic uncertainties, most policy analysis has focussed on a narrower set of questions:

- (1) What actions would improve economic efficiency (including the social costs of implementing the policy) and reduce net greenhouse gas emissions? How much could emissions be reduced by these means?
- (2) Beyond these zero-cost options, what are the least-cost methods of reducing greenhouse gas emissions? What

do the cost curves look like?⁵⁴ What are the alternative policy measures, and how do they compare?

- (3) What are the essential ingredients of an adaptation strategy, and to what extent will market forces, on their own, provide the appropriate adaptive responses?

1.5.1 Zero-cost options

A variety of inefficiencies in the energy sector – many of them government-induced – would, if eliminated, increase economic efficiency and reduce greenhouse gas emissions at the same time. How large is the reservoir of conservation opportunities? Proponents of the two major approaches to the question have debated this point for more than a decade. *Top-down models* extrapolate observed behaviour into the future. *Bottom-up models* combine cost estimates derived from engineering analyses with economic models of individual choice. Top-down models generally show significant costs to reducing greenhouse emissions in the future.⁵⁵ Bottom-up, or technology-specified models, have been used to show the existence of significant reductions in the cost of energy as new low-emission technologies are adopted. Some proponents of bottom-up models argue that emission reductions can be achieved at essentially no cost.⁵⁶

Much of the disagreement turns on empirical estimates. Economists have catalogued the unintended consequences of government regulation. Many have also identified important market failures that could give rise to inefficiencies within the private sector itself. The next two sections will examine each of these effects.

1.5.2 Policy reform

A variety of government reforms could enhance energy efficiency, including removing energy subsidies, reforming or clarifying property rights, reducing nongreenhouse gas externalities, and administrative reforms.

1.5.2.1 Removing energy subsidies

Energy subsidies induce inefficient energy use, reducing the total output of the economy as well as increasing CO₂ emissions.⁵⁷ Shah and Larsen (1991) estimated world energy subsidies in 1990 to have been \$230 billion. They calculated that their elimination would reduce global carbon emissions by 9½% in addition to improving allocative efficiency and thereby generating a welfare gain in subsidizing countries. Burniaux *et al.* (1992) obtained similar results using the GREEN model, concluding that the elimination of all existing distortions on energy markets would yield an increase in world real income of 0.7% per year in addition to cutting world emissions by 18% in 2050 (Dean, 1994). Agricultural subsidies also distort the outcome, especially by affecting the size of forests.

1.5.2.2 Property rights reform

One responsibility of governments is to define property rights and enforce contracts. Ill-defined property rights encourage overconsumption of resources. A clearer definition of prop-

erty rights could be particularly important in helping to decrease deforestation, for example, while improving economic efficiency. Uncertainties about *future* property rights may also contribute to economic inefficiency. Thus, for example, in those developing countries where large forests are owned by a few large landowners, excessive deforestation may result from the landowners' fear that their tenure will be limited.

1.5.2.3 Administrative reforms

Defining property rights and eliminating energy subsidies are two important actions governments can take to reduce greenhouse emissions. At the same time, many less sweeping reforms can improve economic efficiency and simultaneously reduce greenhouse gas emissions. For example:

Pricing of government-produced electricity. Many governments price electricity not at the market price but at the cost of production. Economists generally recommend that electricity, like any good, be priced not at its cost of production but at the competitive price. In countries with a mix of plants, this means that electricity from all sources should be priced the same – at the highest marginal cost of production.⁵⁸

Land use and other regulation. Changes in land use policy can also reduce energy consumption (especially for transportation, space heating, and air conditioning) and thus greenhouse gas emissions.

Full utilization of nonfossil fuel energy sources (taking account of other environmental impacts). When hydroelectric power generation, which does not increase greenhouse emissions, can be cost-effectively expanded without other environmental effects, it should be done.⁵⁹

1.5.2.4 Regulating nongreenhouse externalities

Many activities producing greenhouse emissions also generate pollution of other types. For example, fossil fuel combustion releases conventional air pollutants; rush hour auto use contributes to road congestion. In the presence of these spillover effects or externalities, market solutions will not properly reflect the externalities generated, leading to the overconsumption of environmental resources. Energy taxes, congestion pricing, or tradable permits can correct these market signals, resulting in lower emissions of both greenhouse gases and other pollutants. Some reforms, such as congestion pricing, also reduce the need for roads and other physical capacity.

1.5.2.5 Special problems of economies in transition

The economies in transition provide special opportunities for mitigating greenhouse emissions. In the former Soviet bloc, high energy subsidies and other price distortions affected energy usage directly, as well as indirectly through the composition of output (i.e., a bias towards heavy industrial production). Spotty environmental regulation meant that Eastern Bloc nations lacked the environmental controls common in the OECD. The capital shortage of the past decade has contributed to the problem through a general deterioration of physical capital stock.

Although these problems are largely of governments' making, the remedy is likely to rely on a combination of public and private actions: effective environmental regulation, elimi-

nation of government-caused price distortions, and an economic environment in which foreign and domestic investment can enhance the efficiency (including energy efficiency) of the economy. For example, many analysts believe that cutting methane leakage from gas pipelines will yield both high economic benefits and cost-effective reductions in greenhouse emissions (IPCC, 1990a).

1.5.2.6 Examples of policies that affect efficiency

Policies that cause individuals not to take into account the full social costs of their actions often result in greater energy use and greenhouse emissions. The National Action Plans of many countries have revealed examples of such policies and have also suggested remedies,⁶⁰ including:

Unit pricing of waste disposal to encourage recycling. The life-cycle social cost of consuming a good includes its costs of production plus disposal. Most consumers, and many businesses, pay a flat fee for trash disposal; with a flat fee, the marginal cost of throwing away an extra pound of trash is zero. By moving from flat fees to unit pricing, the actual price consumers pay to buy and dispose of a good will more closely match its full life-cycle social cost.

Pay-at-the-pump automobile insurance. In most countries, drivers pay automobile insurance yearly or monthly. Once the premium is paid, the marginal insurance cost of driving an extra mile is zero, even though driving more does increase the chance of being in an accident. As an alternative, drivers could be required to pay a portion of their insurance bill at refuelling. With pay-at-the-pump insurance, a tax would be levied on gasoline and earmarked to pay for insurance premiums. This would raise the cost of gasoline at the pump, but lower auto insurance premiums.⁶¹

Eliminating subsidies for auto travel. Many countries subsidize auto travel in various ways. In some industrialized countries, employers may provide parking to employees at no cost or lower-than-market cost, thus lowering the relative price of commuting by car relative to public transportation. A distortion arises when governments tax income spent on public transportation but not income implicit in the parking subsidy.

Eliminating subsidies that increase housing size. In some industrialized countries, home mortgage interest is tax-deductible. In all but a few countries, the implicit income on owner-occupied housing is not taxed. These tax provisions encourage individuals to consume more housing space than they otherwise would. In cold or hot climates, where more housing space requires more energy for heating and cooling, this tax treatment increases CO₂ emissions.

Eliminating subsidies for trucking. Studies suggest that virtually all road damage is caused by heavy trucks, which pay only a portion of the expense of building and maintaining the road system. Many countries thus subsidize trucking compared with rail or barge transport, probably increasing greenhouse emissions.⁶²

1.5.3 Market failures and government responses

Policies exist that would increase economic efficiency at the same time that they reduce greenhouse emissions. For exam-

ple, in some countries, fuel prices do not reflect the full social cost of fuel burning. Taxes can correct this market failure. There is less agreement about whether, *given market prices*, firms fail to take advantage of all the energy efficiency opportunities available to them. This controversy underlies the bottom-up versus top-down controversy treated at greater length in Chapter 8. Engineers have identified a host of seemingly profitable actions that would also save energy. Many economists, however, view this as evidence that the engineering analysis has omitted characteristics important to consumers.

The substantial differences in practices both within and between countries suggest scope for significantly increasing energy efficiency. Moreover, even best practices within a country may not put it at the technological frontier. In deciding whether to adopt a new production process, businesses look only at the private costs and benefits. Many technologists, however, conclude that, even considering private costs only, firms should be undertaking many energy efficiency improvements. This section attempts to reconcile the different schools of thought by reference to information-based market imperfections as well as the criteria by which businesses make decisions.

Information dissemination. Acquiring information is costly. Moreover, providing and disseminating information has many features of a public good (Stiglitz, 1988). In the absence of government intervention, there will be too little production and dissemination of information. This is particularly true for information with widely dispersed impacts, as opposed to information about, for example, the production of certain chemicals, which is primarily of value to a few companies.⁶³

Moreover, both theory and evidence support the view that markets, on their own, do not provide an efficient level of disclosure of information (see, *inter alia*, Stiglitz, 1975a; Grossman and Stiglitz, 1981). Indeed, some evidence indicates that markets may try to obfuscate relevant information.⁶⁴ This provides the rationale for government provision of information, or laws that in many countries require disclosure of interest rates and other consumer-relevant information, including appliance energy consumption.

Bureaucratic structure and limited scope of attention. In recent years, economic and organizational theory⁶⁵ has emphasized that large organizations are not, in general, run by owners; that the managers, even with the best-designed incentives, do not in general maximize the firm's market value; and that among the principal scarce factors within an organization are time and attention. How managers direct their attention has much to do with what the firm does.⁶⁶ The information services and disclosure requirements noted above, as well as a number of other government programmes focusing on energy efficiency in consumer products, electric lights, and motors, help focus management attention on energy efficiency. The marginal managerial time required to make efficient energy decisions may be small, and focussing attention on this issue – when information is being freely provided through government and other sources – may thus yield *private* returns well beyond these slight marginal costs.

Returns to scale and system effects (network externalities). Some technologies might be economically attractive at a large scale of production but not on the much smaller scale on which they might initially be adopted. Other technologies exhibit dynamic scale economies: Unit cost falls over time as a function of the cumulative output of firms or industries. Technology “networks” may also affect diffusion rates. For example, cars and trucks powered by electricity, natural gas, methanol, or other alternative energy sources, require a refuelling infrastructure, which itself competes for resources with the conventional fuel infrastructure already in place.⁶⁷

Building codes can be justified both in terms of these effects on network externalities and in terms of information failures. Consumers often have limited information concerning the construction of their houses, and obtaining the information after the house is completed is often difficult. Even were they to be provided with construction details, they would have difficulty interpreting the implications.

Capital market imperfections. A major explanation of the difference between best-practice and actual-practice technology is that bottom-up models often compute cost-effectiveness using a discount rate substantially lower than the cost of capital calculated by firms.⁶⁸ Studies of implicit discount rates consistently show that households and firms use discount rates substantially above the market rate for long-term government bonds. Two explanations have been offered:

- (1) *Risk:* Interest rates facing firms and households reflect the risk premium that lenders require to compensate them for the probability of default. Firms often use discount rates that include a risk premium to reflect the riskiness of projects.
- (2) *Capital constraints:* Individuals and firms often face rationing in capital markets, both for credit and equity. Recent research has provided a rationale for this rationing based on the fact that information is imperfect and costly.⁶⁹

These capital market problems have one important implication: Models analyzing best-practice, cost-effective technologies using discount rates lower than those typically employed by firms will overestimate the rate of dissemination of these technologies and underestimate the perceived costs (to the firms and households adopting these technologies) of mitigation strategies.

But these capital market problems raise three other questions: (1) Are firms rational in using such high discount rates? (2) Does the use of such high discount rates imply a market failure? (3) If so, will government intervention improve on the market outcome?

Economists emphasize that an analysis of the costs and benefits of a project must separate four issues: timing, risk, capital constraints, and information. Discount rates are only to be used for timing. Risk should be treated by converting costs and benefits into certainty equivalents, then discounting costs and benefits for each year at the relevant discount rate.⁷⁰ Higher risks should not result in higher discount rates.⁷¹ Similarly, capital constraints should be reflected in the shadow price of capital, not in the discount rate.⁷² Because of limited

information (and a version of the “winners’ curse”⁷³) firms often require threshold rates of return significantly greater than the market rate of interest. In doing so, they may confuse time and information risk; that is, the rules of thumb firms use to evaluate investments may sometimes lead to market inefficiencies, including some perhaps in the area of energy-efficient technologies.

Even were firms to follow the economists’ guidelines, in the presence of capital constraints, market outcomes would not, in general, be socially efficient (i.e., they are not constrained to be Pareto optimal). There may be significant discrepancies between social and private returns on investment (even apart from the externalities associated with greenhouse gases or technological diffusion). This provides part of the rationale for possible government interventions in capital markets.⁷⁴ Though these capital market imperfections imply that there is no presumption that market allocations are efficient, there is no consensus that they lead to significant underinvestment in energy-efficient technologies in particular.⁷⁵

1.5.3.1 Revising national accounts

Some have suggested revising the conventional systems of national accounts to incorporate full social pricing of resources. An early contribution suggested a new measure of economic welfare based on consumption that increases quality of life (Nordhaus and Tobin, 1973). These authors and others recognized that national income accounting, widely adopted after World War II, measures aggregate income and expenditure flows but does not incorporate environmental costs and benefits.

Many researchers have noted deficiencies in standard national income accounts. First, national income accounts do not, in general, provide an adequate measure of welfare; second, they do not provide the correct information for making policies relevant to sustainable development. Sustainable development is concerned with society’s resources; an economy is growing when its resource base (capital stock combined with natural resources) is growing. GDP does not, and is not intended to be, a measure of resource availability. Firms have two sets of accounts – cash flow (income) statements and balance sheet statements. GDP is a statement of the former type.

Standard accounting procedures require that firms, in an attempt to present an accurate account of “true income,” take account of depreciation. GDP measures gross output; it does not take into account depreciation, either of natural or physical capital stocks. The reason is simply that it is hard to get accurate measures of depreciation. Net national product, however, does consider depreciation, the change in capital stock. And it is this account that should be most subject to criticism, since it accounts for changes in the physical capital stock but not in other capital assets, in particular, environmental assets and natural resources.

Conventional national income accounting does not fully report three categories of resource expenditures: (a) defensive expenditures, either for pollution prevention before the fact or for cleanup after the fact (although these expenditures are not separately reported, they are counted in GDP); (b) consumption of environmental goods (such as exhaustible resources);⁷⁶

and (c) conflicting uses of environmental services (such as the atmosphere, used by producers as an input into production and by households as a consumption good).

One proposal would include in GDP the effect of changes in quality of the environment. In Eastern Europe and the former Soviet Union, steady increases in reported postwar GDP masked the effects of decades of environmental degradation; for part of that period, environment-adjusted GDP almost certainly declined.⁷⁷

However, important conceptual problems in defining levels and changes of environmental assets, complicate the task of modifying national accounts. First, the stock of natural resources has no obvious definition. Although most geologists would agree on the size of coal stocks – their location is known and their *in situ* value can be estimated – this cannot be said for oil or minerals.⁷⁸ Second, environmental assets, such as air quality, present another set of problems, because no market prices exist to value the asset.

Four approaches are commonly used to calculate changes in the natural environment (Peskin and Lutz, 1990):

- (1) The environmental expenditure approach, used recently in the United States, which subtracts pollution abatement expenditures from GDP;
- (2) The physical accounting approach, used in Norway and France, which establishes satellite accounts using physical units of measurement to account for flows and stocks of resources;
- (3) The depreciation approach, which adjusts gross and net product by subtracting the value of natural resource depletion (Repetto, 1989; El Serafy, 1989); and
- (4) The comprehensive approach, which uses both physical measures and value (United Nations Statistical Office 1992).

Another measure of broad-based welfare, although it does not include environmental amenities, is the UN's human development index or HDI (UNDP, 1992). The HDI gives a composite measure of human development by combining three key indicators: longevity (measured by life expectancy at birth), education (measured by adult literacy and mean years of schooling), and income (real GDP per capita adjusted for purchasing power). Although the HDI is not directly related to global environmental issues, both global warming and abatement policies may affect it.⁷⁹

1.5.4 Innovation

Standard competitive analysis argues that, *given all required information and technology*, market economies produce efficient outcomes. But recent economic analyses have shown that, in general, market economies need not result in the efficient allocation of resources either to information production and dissemination or to innovation. The first of these issues was discussed earlier. The second is more complex.

In the absence of intellectual property rights, firms would have less incentive to innovate. With standard patent terms, firms are not able to appropriate all the returns from their innovative activity. Setting the optimal patent life involves bal-

ancing off the inefficiencies resulting from the exercise of monopoly power during the duration of the patent (static inefficiencies) with the increased incentives for innovation.⁸⁰ Largely because innovators seldom appropriate all the returns from their innovations, there is a general consensus that markets provide insufficient incentives for research and development, and the greater the unrewarded spillovers, the greater the undersupply of innovation.⁸¹ The fact that spillovers are likely to be greater at more basic levels of research suggests a role for government in subsidizing basic and near-basic research. In the same way, the high cost of establishing intellectual property rights impedes the transfer of technology to developing countries.

Still, there is a general consensus among economists that the patent system provides a better basis for financing applied research than do government grants, largely because of the difficulties government has in picking those innovations most likely to produce high returns. Consequently, it should be asked if market failure because of insufficient innovation is more likely than market failure for other reasons. In other words, are there any special grounds for arguing for government research and development subsidies, provided the government has corrected energy prices to reflect the externalities generated? Obviously, in the absence of such corrections, market incentives to provide energy-saving innovations will be distorted, just as market incentives to adopt energy-saving technologies are reduced.⁸² (Tradable permits have effects similar to those of corrective taxes: They encourage firms to place a higher value on new technologies that reduce emissions because reductions will require them to purchase fewer permits.)

Innovation is important, because it provides perhaps the best opportunity for low-cost methods of reducing emissions. Several studies have confirmed the impact of accelerated deployment of advanced energy technologies on the future rate and timing of anthropogenic climate change.⁸³

1.5.5 Carbon taxes and tradable permits

Economic efficiency requires all agents in the economy to pay the full marginal social costs of their actions. But firms and households are not charged for the additional warming potential they add to the atmosphere, and so do not pay the full social costs they impose. Two economic instruments can correct this market failure: carbon taxes and tradable permits. (Note on terminology: More detailed treatments, as in Chapter 11, often reserve the term "emission permits" for domestic instruments and "emission quotas" for international instruments. This section treats the issue of tradable emission rights in a general way, most often using the term "permits"; whether the meaning is domestic or international should be clear from the context.)

Implementing either one of these instruments could raise issues of national sovereignty, because to be effective either carbon taxes or permits would require the creation of institutions with the authority to allocate, administer, and enforce agreements. Although these issues lie outside the immediate concern of economics, they are relevant to any discussion of practical implementation.

A tradable permit scheme involves a determination of the total level of permits and a distribution of the initial allocation, with emission levels for any firm limited to the number of permits held. The initial distribution may be made by an auction or allocation according to benchmarks (e.g., per capita emissions as of a given date), or by historical emission levels ("grandfathering"). Alternatively, emission rights could be grandfathered in at current levels and gradually shifted over to a per capita allocation as of a given date.

Once permits are distributed among the regulated entities, a market is set up, allowing companies to buy and sell permits according to their plants' planned emissions. The cost of production then includes not only the costs of conventional inputs, but also the costs of additional permits to offset additional emissions. Plants whose cost of mitigation is low will find it relatively easier to abate pollution rather than to buy permits. Plants with higher costs of mitigation will have a greater preference for buying permits than for abating pollution. The price of the permits, which are artificially created scarce resources, is determined by the market. With the use of tradable permits, companies have an incentive to improve the efficiency of their production and thereby reduce their emission levels, as they can sell excess permits on the market and generate revenue.⁸⁴

Although permits thus create a marginal cost of production related to the marginal emissions, carbon taxes impose a tax directly on the marginal emissions. Both systems thus force producers and households to face the true social costs of their actions.⁸⁵ In principle, either could be adjusted to achieve the level of emissions desired, although adjustments of this sort may be difficult in practice.

The initial allocation of permits will largely determine the distribution of costs of abatement (Chapter 3 discusses these issues of equity at greater length) and at the same time influence the growth path of participants' economies. For example, an allocation based on population at a given date would provide an incentive for population control.⁸⁶

Imposing carbon taxes can have large distributive consequences. A system of grants can largely offset these distributive consequences, but such offsetting grants might well not be made. Providing tradable permits equal to existing levels of emissions seemingly makes no firm or household a loser. But granting permits in that way effectively represents a grant of money (such permits have monetary value) in a way that may not accord well with standard ethical principles. For instance, by embarking on an ambitious programme to reduce emissions, a firm may qualify for *fewer* permits than it would otherwise. Not only does this violate ordinary notions of fairness, but anticipation of granting permits in this way would, accordingly, have strong adverse effects on emissions.⁸⁷

Although presenting a political impediment to its introduction, the fact that a tax has large distributive consequences is not necessarily an argument against it. Some argue that those who failed to pay the full social costs of their actions earlier are not therefore entitled to special allotments now.

Once it is recognized that the distribution of permits across countries will inevitably be decided by some principle other

than current levels of emissions, then it becomes clear that both taxes and tradable permits will have distributive consequences. An agreement among countries to impose uniform corrective taxes, with each country retaining its own revenue, would have few consequences for redistribution between countries, and the burden of the tax would, as noted earlier, likely be progressive.

Governments in the developed countries might decide to use some of the revenues so generated to encourage activities that benefit less developed countries (such as research and development directed at technology appropriate for developing economies) or to provide other forms of assistance. Decisions about such uses could be made bilaterally or collectively. In contrast, decisions about how tradable permits would be allocated across countries would have to be made multilaterally. Arriving at a formula for distributing these property rights may be far more difficult than arriving at a tax rate and a procedure for its revision, as any such formula may entail substantial redistribution.

1.5.5.1 *A double dividend?*

Many measures that reduce emissions of greenhouse gases also yield other environmental or economic benefits, such as reductions in emissions of other pollutants and energy savings. These are called secondary benefits or double dividends. Some analysts argue that using carbon tax revenues to reduce existing distortionary taxes is an economic double dividend.

Revenues from carbon taxes may allow a reduction in distortionary taxes elsewhere in the economy. If the (compensated) elasticity of demand of labour is relatively high, and the revenues from the carbon tax are used to reduce taxes on labour income, then there would be a double dividend from the carbon tax in the reduced deadweight loss from the labour tax, which would otherwise be significant.

At least three objections have been raised to this idea. First, conceptually, rationalizing the tax system by reducing the most distortionary taxes is certainly a worthy goal but is not equivalent to imposing a carbon tax. Distortions can be reduced without a carbon tax, and a carbon tax could be imposed without reducing the existing distortions. Second, empirically, if the (compensated) labour supply elasticity is relatively low, then the deadweight loss from the labour tax is low, and the commensurate welfare gain is reduced. Third, politically, if carbon tax revenues are used to offset the existing deficit rather than to reduce taxes on labour and capital, then the carbon tax acts more like an ordinary tax increase, increasing distortions from taxation to pay for budget items with a lower return than the extra burden imposed. The gains to total welfare (reductions in deadweight loss) depend on the welfare losses associated with these other distortionary taxes, as well as the cross-elasticities of demand between carbon and other taxed commodities.⁸⁸

Even though carbon taxes may have a positive effect on economic welfare, they can at the same time have a negative effect on *measured* economic growth, since those measures typically do not include the value of environmental degradation. Researchers differ on the size of the loss. The wide

spread in the numerical results, however, should not obscure agreement among researchers on a number of important points. All models used in the major comparison studies to date have projected, first, that intervention would be required to achieve the emission targets; second, that the size of the required tax increases with the stringency of the carbon limit; and third, that the size of the appropriate carbon tax varies over time, even for the same emission or concentration target.⁸⁹

1.5.5.2 Energy taxes

Energy taxes as a means of controlling greenhouse emissions must be viewed as "second-best" taxes, in that they do not directly tax the externality, greenhouse emissions. Whereas carbon taxes directly penalize the externality-generating activity, less targeted alternatives, such as energy taxes, may be politically more acceptable. Carbon taxes reduce emissions, first directly, by moving up the demand curve; second indirectly, by encouraging consumers to switch to less carbon-intensive energy sources. On the other hand, energy taxes work through the first path by reducing total energy consumption. But to the extent that certain kinds of energy, like hydroelectric, have, at least in the short run, a relatively inelastic supply, there will be a major impact on oil, gas, and coal; and to the extent that oil and gas supplies are best described by a model of an exhaustible natural resource, with relatively low extraction costs, most of the supply reduction will occur in coal. Thus, indirectly, there will be a considerable amount of switching, through the indirect effects.

1.5.5.3 Tradable permit markets

In order for systems of emission permits to achieve reductions in emissions efficiently, there needs to be a market for emissions *across international boundaries*. There is some debate about the role of government or international organizations in establishing a market for such emissions. Some believe that there are private incentives for the establishment of markets; others contend that government can play a key market facilitation role through establishing centralized clearinghouses for information or even providing for permit banking (storage) or brokerage (trading) to facilitate trades between private parties. These services would prove especially useful in the more complex international context.

1.5.5.4 Combining taxes with tradable permits

Although carbon taxes and tradable permits are typically presented as alternatives, policymakers may prefer to combine them. The major disadvantage is the additional administrative cost. The advantage is more subtle: The market value of tradable permits is reduced as taxes increase. With an optimal carbon tax, and with a tradable permit supply set equal to the optimally chosen level of emissions, the price of a permit should be zero. More generally, the greater the tax, the less the value of a permit (for a fixed supply of permits), and thus, the less the distributive consequences of alternative rules for allocating the initial endowments of permits. Another possible

combination would utilize permits for large sources and a tax (set to equal the permit price) on small sources.

1.5.5.5 Intertemporal patterns of taxation

If the target is the long-run atmospheric concentrations of greenhouse gases, then climate change damages will be approximately the same for emissions in any particular year, although the optimal carbon tax must be adjusted for differences in costs, discounting, and risk.⁹⁰ The focus on concentrations also implies that early reductions are more valuable than later reductions.

For exhaustible natural resources such as oil, economic efficiency requires that those deposits with the lowest cost of extraction be extracted first. Hotelling (1931) argued that competitive equilibrium implies that rents (price minus costs of extraction) must rise at the rate of interest. The price of the backstop technology (an energy source assumed to be available in unlimited quantities at a certain price after a certain date, such as electricity from solar photovoltaic cells) determines the set of resources to be ultimately exploited, namely, all resources for which the cost of extraction is less than the price implied by the backstop technology's price. Thus, it is the tax on oil or gas at the date of switching to the backstop technology that determines the ultimate amount of oil and gas that will be extracted, and thus the total burden of CO₂ placed on the atmosphere by oil and gas. If that were the only matter of concern, one could simply announce a commitment to impose such a tax sometime in the future when relevant backstop technologies become available and competitive. That announcement would, if believed, have an immediate effect on current prices.

1.5.6 Regulatory approaches

Regulation of greenhouse emissions may take many forms, including fuel restrictions, technology standards, and various economic incentives. Chapter 11 discusses these options in detail. Economists have long argued for the use of economic incentives for environmental management, although governments have so far relied on traditional regulations almost exclusively, as traditional approaches have been more acceptable to the public and industry.

Proponents of the traditional approaches often claim that these approaches "force" technology (i.e., stimulate technological innovation or refinement), with less redistribution than forcing technology through taxes. Thus, if automobile makers are required to attain a certain mileage standard, they will meet the standard; on the other hand, gasoline taxes might have to rise significantly to reduce fuel consumption by the same amount. Evidence for the claim of technology forcing, however, is equivocal. In several cases in which industry failed to meet the applicable standards, regulators withdrew the standard in the face of unacceptably high economic costs. The apparent advantage of technology forcing – one large instrument of coercion instead of the subtle and continuous incentives provided by market forces – is often in fact a disadvantage.

There are other disadvantages to the traditional approach as well. First, traditional regulations do not in general result in economic efficiency, since those in one sector face implicit or explicit incentives at the margin that differ from those in other sectors. Second, traditional regulations fail to account for offsetting private responses that may neutralize the regulation's intended effects and even cause environmental harm. Third, traditional regulations provide no incentives for exceeding the given target, even when doing so might result in little additional cost.⁹¹

Traditional regulations that focus on inputs and technology rather than outputs have the further disadvantage of not directing research toward meeting performance objectives at least cost. For instance, when stack gas scrubbers are required, research will be directed at producing scrubbers at least cost, rather than reducing emissions at least cost. Hence, a dynamic inefficiency is added to the obvious static inefficiencies. Finally, because of the nature of the regulatory process, traditional regulatory designs are more likely to be captured by special interest groups.⁹²

It should be kept in mind that government policies to address external effects (market imperfections) are likely to generate their own external effects, in part because of the difficulty in identifying the gainers and losers from changes in policy. Thus, the likely cost of "market failure" must be compared to the likely costs imposed by governments' attempts to remedy the problem.

1.6 Sustainable Development

The concept of sustainable development was formulated about 1980 as a response to the apparent conflict between environmental concerns and the need for economic growth, especially in developing countries. At the time, preserving biodiversity and maintaining environmental quality seemed incompatible with a five- or tenfold increase in world output, as would be necessary if per capita incomes of the developing countries were eventually to approach those enjoyed by the developed countries now. The sustainable development debate rekindled interest in the question of resource scarcity, originally addressed in the economics literature by Malthus (1798) and revived in the policy arena with the publication of *The Limits to Growth* (Meadows and Meadows, 1972). Recently, the field of "ecological economics" has extended this approach (Howarth and Norgaard, 1992).

A variety of definitions of sustainable development have been proposed. The Brundtland Commission offered this interpretation (World Commission on Environment and Development, 1987):

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Although the Commission clearly had in mind environmental considerations, its report did not spell out exactly what sustainable development included.

1.6.1 The economic concept of sustainable development

Although sustainable development began as an ethical principle, it is at the same time an economic concept, focussing on two issues: (1) intertemporal equity and (2) capital accumulation and substitutability.

Intertemporal equity. Robert Solow's definition of sustainable development (Solow, 1992), which focusses on intertemporal equity, has enjoyed wide currency among economists. Sustainable development, he argues, requires that future generations be able to be at least as well off as current generations. The central implication is that any environmental degradation should be offset by increases in capital stock sufficient to ensure future generations at least the same standard of living. Sustainable development does not preclude the use of exhaustible natural resources but requires that any use be appropriately offset.

In practice, sustainability as defined by Solow provides few constraints on growth paths for the developed countries, so long as steady increases in productivity continue. Technical change alone, without further capital accumulation, may well sustain future living standards and offset any effects of environmental degradation. To see this with a numerical example, note that even if estimates of adaptation costs are taken to be 1-3% of GDP should significant warming occur, and if even moderate rates of technical progress of 1-1.5% per annum continue to occur, then future generations 45 to 70 years from now will have twice the income of the current generation. Even with no discounting, it would be hard on this account alone to justify the sacrifice of further consumption by this generation in order to enhance the standard of living of the future generation.

Capital accumulation and substitutability. To what extent can technology, skills, and capital equipment substitute for a decline in exhaustible resource stocks or a decline in per capita environmental amenities? Solow's definition, in common with much economic theory to date, implicitly assumes that substitutes exist or could be found for all resources. Pearce (1989, 1991) argued that if substitution possibilities are high, as most evidence from economic history indicates, then no single resource is indispensable, and intertemporal equity stands as the only crucial issue. If, on the other hand, human and natural capital are complements or only partial substitutes for each other (e.g., if, because of the irreversibility of extinction,⁹³ capital accumulation is only a partial substitute for biodiversity), then different classes of assets must be treated differently, and some assets are to be preserved at all costs.

Pearce *et al.* (1994) distinguished between strong and weak sustainability. Weak sustainability requires that any depletion of natural capital be offset by increases in human-produced capital – the Solow criterion – or by the substitution of other forms of natural capital, such as renewable assets in place of nonrenewable assets. Strong sustainability requires that some natural capital, being irreplaceable, must be preserved.⁹⁴ It has been argued that there are no close substitutes for the atmosphere and the climate it produces, implying no

substitution possibilities and hence the need to preserve the atmosphere.

1.6.2 Implications of sustainable development for developing countries

In many developing countries, Solow's definition would not be viewed as acceptable, since it seems to place no weight on their aspirations for growth and development. Developing countries have also implicitly criticized the debate over substitutability for the same reason: If some natural assets must be preserved at any cost, then there may be no trade-off with development. Tariq Osman Hyder of Pakistan, a leading spokesman for the G-77 group of developing nations, has emphasized the importance of economic growth in achieving sustainable development:

None of these linked [development] issues can be resolved unless and until there is broad-based development in the South. Only such broad-based development can provide the foundation of international security. The Northern approach is to attack the symptoms, with a residual emphasis on poverty eradication. But the international community must insist on addressing the underlying causes for concern. Development, environmental protection, peace, and security are indivisible. (Hyder, 1992)

Similarly, the G-77 and China emphasized the need for economic growth in the following statement on sustainable development and the environment introduced during the INC-2 negotiations in 1991:

Protection of the global climate against human-induced change should proceed in an integrated manner with economic development in light of the specific conditions of each country, without prejudice to the socioeconomic development of developing countries. Measures to guard against climate change should be integrated into national development programmes, taking into account that environmental standards valid for developed countries may have inappropriate and unwarranted social and economic costs in developing countries. (Hyder, 1992)

Endnotes

1. Some analysts believe that the justification for costly and more restrictive actions rests on intangible costs (Nordhaus, 1993). Intangible refers to the difficulty of measuring; intangible costs are related to such factors as migration, comfort, health, leisure activities, urban infrastructure, and air pollution (Fankhauser, 1994; Cline, 1992). A warmer climate would improve human comfort in cold areas, and in the winter generally, while decreasing comfort in warm areas. Mearns *et al.* (1984) calculate a threefold increase in heat waves for a 1.7°C rise in U.S. mean temperature. It is not yet clear whether net comfort averaged over the globe will rise or fall for a given rise in temperature. Chapter 6 covers these issues in more detail.
2. Both the natural rate of species loss and the human contribution to the process are difficult to estimate (U.S. EPA, 1989). Predicting the effect of climate change on species distribution is more difficult

still. The magnitude and even the sign of these intangibles remains in dispute, for uncertainty about the duration and types of environmental changes that would be caused by climate change makes the long-term projection of species change highly complex. Population pressures have added to pressure on ecosystems, particularly in the Third World. Climate change may exacerbate these damages, particularly in Africa, where environmental degradation has been particularly pronounced during the last fifteen years (UN, 1989).

3. For greater warming – such as might be experienced over the next two centuries, or which could occur sooner if modest near-term warming triggers the release of large amounts of carbon from the biosphere and oceans to the atmosphere – the probability of large losses increases. These losses refer to global losses, which represent an aggregation of individual losses. Impacts will differ across individuals, groups, and regions. For some, the probability of large losses will be high over the next century, despite the expectation that aggregate global losses will be small.

4. Recent ice core data from Greenland point to the occurrence of earlier temperature rises of several degrees within a few decades (IPCC, 1995). Reasons for these sudden changes are still not understood, but might have come from changes in deep ocean currents. The other side of this debate holds that on the whole the biosphere is homeostatic or self-correcting. This “Gaia hypothesis” compares the biosphere to a living being: Once moved away from equilibrium, self-correcting forces naturally move it back to equilibrium (Lovelock, 1979). The two hypotheses are not necessarily inconsistent. Within a range of variation, homeostatic properties could dominate, even if stability were not guaranteed outside that range.

5. A warmer climate might also increase climate variability, though climatologists cannot say with assurance whether climate will become more or less variable daily and seasonally. The normal variability of existing climate also makes it difficult to detect any warming that might be occurring. The “signal-to-noise” problem makes it possible for observers to mistakenly consider a normal extreme event as evidence of a trend or to fail to see a trend in a noisy data series. Because of the signal-to-noise problem, the scientific community is unable to indicate confidently, for example, whether the extremely warm years of the 1980s are evidence of climate change or not (IPCC, 1992; Solow, 1990).

6. Countries make century-long choices implicitly, for example, when they choose population policies, policies affecting long-term capital formation and productivity growth, or policies to protect environmental assets.

7. Bargaining theory has contributed some basic principles, however, such as the importance of threat points (i.e., the outcome in the absence of an agreement).

8. Although the global warming potential (GWP) measure, endorsed by the IPCC, is useful in formulating comprehensive approaches to greenhouse mitigation policies (Stewart and Wiener, 1990), some analysts have recently criticized it on the grounds that GWP implicitly makes the opportunity costs of an increment in radiative forcing equal for all periods in the future (Schmalensee, 1993). If all greenhouse gases had the same rate of decay, then this problem would not arise.

9. Aerosols have very short lifetimes, so their effects are far more regional than those from longer-lived greenhouse gases. It may not be possible to develop an analogue of global warming potential for aerosols.

10. Forests cannot be expanded indefinitely, however. Thus, increased carbon sequestration is not a permanent solution to increasing greenhouse gas emissions.

11. Advances in cost-benefit analysis have allowed the introduction of risk and equity issues in a systematic way.

12. Knight's often-quoted distinction (Knight, 1921) separates risk, for which the probabilities of different outcomes are known, from uncertainty, in which either the probabilities are unknown or some potential outcomes are not specified.

13. This transfer of risk is made easier by dividing the risk into small parts, so that any individual faces only a small risk and thus requires only a small risk premium in compensation.

14. This conclusion assumes decreasing absolute risk aversion (about which there is a general consensus). Even if developing countries were adversely affected, so long as the adverse economic effects were proportionately smaller, then, assuming decreasing relative risk aversion (about which there is less consensus), the developed countries would be in a position to insure the undeveloped.

Insurance contracts may also be created because of differences in judgments concerning the probability of the insured event occurring. This suggests the potential of an important principle to be invoked in future international negotiations or agreements: Countries that believe that the risks of climate change are low, and are therefore seemingly unwilling to take strong actions to mitigate these risks, ought to be willing to provide insurance against climate change at low cost, since it has, from their perspective, an actuarially low value (Chichilnisky and Heal, 1993), although enforcement issues may complicate the problem.

Insurance markets, if appropriately designed, have one further advantage: They encourage actions that diminish the potential size of any loss, because insurance firms have an interest in minimizing the cost of losses. Some of the losses associated with climate change can be easily avoided or reduced (e.g., by making ocean-front houses more durable to reduce vulnerability to storm damage). In designing insurance for climate change risks, either the insurance should be based on exogenous events (e.g., not on the dollar losses incurred, but on the rise in sea level), or the insurance companies should be given broad discretion to require the insured to undertake actions to mitigate losses.

15. Chapter 6 provides estimates of expected regional damage.

16. In the absence of such requirements, moral hazard problems arise. It may be desirable to focus government intervention not on the primary insurance market but on the reinsurance market. See recent U.S. government analyses of failures in insurance markets for natural disasters and the design of appropriate responses to these.

17. Computer modellers participating in the Energy Modeling Forum (EMF) examined an "accelerated R&D" scenario in which the cost of nonelectric backstop falls from \$100 to \$50 per barrel of oil equivalent, and the cost of the electric backstop falls from 75 to 50 mills per kWh. The four models used were remarkably consistent in their estimates of economy-wide costs, reporting GDP losses falling by 65% for the 20% emission reduction scenario (EMF, 1993).

18. Weitzman *et al.* (1981), cited in Lind (1994), make these points in formulating a sequential decision strategy for developing synthetic fuels.

19. Manne and Richels (1992), Nordhaus (1993), and Peck and Teisberg (1993) all report a high value for better scientific information on

climate change, including the cost and timing of new supply and conservation strategies.

20. Richels and Edmonds (1993) provide a demonstration of this proposition; they calculate relatively low costs for stabilizing CO₂ concentrations if flexibility in timing is allowed, compared to capping and stabilizing emissions to achieve the same atmospheric concentration.

21. Alternatively, the Kaya identity may be written

$$\text{Growth rate of CO}_2 \text{ emissions} = \text{growth rate of output} - \text{decline in energy per unit output} - \text{emissions per unit of energy use}$$

That is, CO₂ emissions will not rise as long as output grows no faster than the combined decline in energy intensity per unit of production and CO₂ emissions per unit of energy use. This formulation applies most usefully to the developed countries.

22. Chapter 8, Estimating the Costs of Mitigating Greenhouse Gases, treats the important issue of inertia and technology.

23. Note that energy-efficient development paths for developing countries have been proposed (Goldemberg *et al.*, 1988).

24. That is, for conventional exhaustible resources, there is a stock, S . Welfare depends on flows out of the stock each year:

$$U(S_1 - S_0, S_2 - S_1, \dots, S_t - S_{t-1}, \dots)$$

where U is utility or welfare, and S_t is the stock at the end of period t .

In the case of climate change, welfare depends *directly* only on the stock of carbon in the atmosphere, though indirectly also on emissions, through the consumption of goods.

$$U(S_0, C_1(S_1 - S_0), S_1, C_2(S_2 - S_1), \dots, S_t, C_t(S_{t+1} - S_t), \dots)$$

25. Even when the flow exceeds the long-run sustainable level, it will not be optimal to reduce the flow instantaneously, unless there are zero costs of adjustment. For the atmosphere, a sustainable stock of greenhouse gases means stable concentrations. Current emissions are estimated to be at about twice the level consistent with stable concentrations.

26. Postponing action may lead to some irreversible damages, such as the flooding of low-lying states.

27. As noted, this is a simplification. Recent literature in resource economics often treats fossil fuels as depletable rather than exhaustible; that is, price affects incentives for exploration, and some marginal wells would not be drilled if oil prices fell too low. It is also a simplification to treat coal reserves as inexhaustible. With the more realistic assumptions of a steeply rising supply curve for oil and gas reserves (over the next century or two) and a rather flat supply curve for coal, the results quoted still hold.

28. Energy economic models often use the assumption that alternative sources of energy will become available at some future date from nonfossil (noncarbon-emitting) sources. The means to supply this energy is often called *backstop technology*. The modeller must specify the quantity, cost, and date of availability of the backstop technology.

29. For analyses of market and optimal responses to uncertainty about the arrival of backstop technologies, see Dasgupta, Gilbert, and Stiglitz (1979) and Dasgupta and Stiglitz (1981).

30. For counterexamples to the received wisdom, see Coase (1960).

31. Formally, if A measures the quality of the atmosphere, then each individual's or country's welfare, U^i , is a function of its own consumption, C^i , and the shared public good, A : $U^i(C^i, A)$. This does not mean that value changes in A are the same for all individuals and countries; that is $(\partial U^i / \partial C^i) / (\partial U^i / \partial A)$ may differ in magnitude, and even in sign.

32. Although there may also be trade-offs. Reductions in gases that contribute most to local pollution may sometimes be achieved at the expense of increased emissions of greenhouse gases.

33. This kind of optimization problem was first studied by Edgeworth (1881). The importance of incentive effects for the analysis of distributional issues was first emphasized by Mirrlees (1971). There are, obviously, important incentive effects: If the less developed countries were able to classify any expenditure that had some effect on mitigation as a mitigation expenditure, with the cost borne by the developed countries, they would have an incentive to undertake excess expenditures of this type. The GEF (Global Environmental Facility) directly addresses this issue by providing funds only for incremental costs, that is, those costs that go beyond what would have been the efficient level of expenditures if the public good benefits of greenhouse gas mitigation were ignored.

34. The importance of the assumption that bargaining or transaction costs are absent (and perfect information is present) has only gradually come to be recognized. See Stiglitz (1988) for an elementary textbook treatment.

35. For instance, it makes no difference whether smokers or non-smokers are given the property rights to air. Rather, it is whether smokers value smoking more or less than nonsmokers value clean air that will determine whether smoking occurs. How property rights are assigned *does* make an important difference for the distribution of welfare. Coase's conclusion that outcomes are unrelated to the initial assignment of property rights obviously ignores potentially important income effects.

A slight extension of this perspective says that social scientists should simply *describe* the outcome of the bargaining process by which property rights are assigned. Beginning with the important work of Nash (1955), a variety of bargaining theories has been developed, most of which emphasize the importance of "threat points" – the outcomes which arise in the absence of a bargaining agreement – to the determination of the eventual outcome. In this case, the fact that the net losses of many developed countries may be limited relative to those of many of the less developed countries suggests a bargaining solution in which much more of the costs of mitigation are borne by the less developed countries than under the "social welfare function" allocations described earlier.

36. In the case of small taxes, these are "compensated" taxes and have no welfare effect, though they have a substitution effect, and therefore do reduce pollution.

37. The loss in welfare (ignoring the benefits from reduced greenhouse gas warming) are the Harberger triangles, and can thus be shown to be proportional to the product of the elasticity of demand for energy and the share of energy in national output. Since poorer countries are likely to have less access to alternatives that increase the elasticity of demand, and since the share of energy is larger in richer countries, the burden of the tax is progressive.

38. The *polluter-pays principle* endorsed by the OECD is exclusively prospective.

39. Many have challenged the ethical basis for assigning responsibility based on past damages. Using either an egalitarian social welfare function approach or a Rawlsian "behind the veil of ignorance" analysis (Rawls 1971) leads to the rejection of the polluter-pays principle. Since at the time the relevant actions are taken, the polluter is not cognizant of the effects, such fees have no incentive effects, but rather appear as random taxes, lowering each person's expected utility, and in particular the expected utility of the worst-off individual.

There is a further ethical issue: It is generally difficult to ascertain who actually benefits from escaping the obligation of paying for the pollution. It need not be the individual, firm, or country actually engaging in the pollution-generating activity. In competitive markets, when firms are not charged the full social costs of production, product prices will fall, giving consumers a substantial fraction of the benefits.

40. Manne and Richels (1992) show that, under the IPCC emission scenarios, even the most drastic controls on emissions from developed countries would be insufficient to stabilize greenhouse gas concentrations without some means of controlling emissions from developing countries.

41. Public goods exist when property rights are not or cannot be clearly assigned. The atmosphere is an international public good because assigning property rights to the atmosphere is difficult for one nation acting alone, and particularly difficult when many sovereign states must agree among themselves. Tradable greenhouse emission permits, discussed below, attempt to resolve the problem by explicitly assigning property rights to greenhouse emissions.

42. Coase's discussion of externalities (1960), emphasized the separability of efficiency and equity issues. Though there have been several important qualifications to Coase's conjecture, emphasizing the importance of public goods, imperfect information, and transaction costs, the basic insight still remains applicable here.

43. Chapter 7 discusses this issue at greater length.

44. These concerns are not just theoretical possibilities, as the following two examples illustrate. Assume that the developed countries impose high energy taxes, but the developing countries fail to do so. Energy-intensive industries, such as aluminum, migrate from the developed to the developing countries. But energy efficiency in the developing countries is much less than in the industrialized countries, so the total energy used to produce a tonne of aluminum could increase substantially. Although economic efficiency would call for locating energy intensive industries where energy efficiency is greatest, a system of partial controls would result in energy-intensive industries being located where energy efficiency is lowest. Similarly, the reduced energy consumption by the developed countries will result in lower *producer* prices of oil and gas, leading to increased consumption of energy in the developing world, partially offsetting any energy conservation induced in the industrialized countries.

45. The precise manner in which this should be done is a technical matter, treated in the literature on Global Warming Potential (see, e.g., IPCC, 1990a, 1995). To the extent that there are large differences in atmospheric lifetimes, then the relative weighting of different greenhouse gases should change over time, since the "shadow price" associated with effects on relative concentrations at different dates will differ.

46. Similarly, if the developed countries restrict forest cutting, the price of lumber may rise, inducing the developing countries to cut

down more of their own trees. Thus, total global carbon sequestration may not increase. Furthermore, if hardwood forests in the less developed countries are the least desirable ones to cut down from an ecological or economic perspective, as some researchers have concluded, then environmental and economic efficiency will decrease if these forests are exploited more intensively (Edmonds and Reilly, 1983).

47. Only a few models take into account international capital flows. Thus, most models do not address issues of industry relocation (McKibben and Wilcoxon, 1992). It is also doubtful whether computed general equilibrium models can realistically represent capital relocation from one country to another. Chapter 11 provides a more complete discussion of leakages.

48. In the case of production of highly substitutable commodities, carbon leakage will be much greater.

49. Whether taxes, in fact, have this effect depends in part on the shape of the demand curves. With intertemporal separability in demand curves, constant elasticity, and no backstop technology, a constant ad valorem tax has no effect on the pattern of consumption.

Coal presents markedly different issues, not so much because of its greater emissions per unit energy, but because of its higher cost of extraction-to-price ratio. Lowering producer prices may result in less coal being consumed, provided alternative energy sources become available. Thus, taxes on coal are likely to have significant general equilibrium as well as partial equilibrium effects; the increase in the price of coal will lead to a substitution of gas and oil. If alternative energy sources are not available, such policies will only affect the intertemporal timing of coal consumption (given the much more limited resources of gas and oil). But even that might be of some value in reducing long-run greenhouse gas emissions, as the ability to extract energy from coal may increase significantly over time. Analyzing the optimal intertemporal structure of taxes to minimize long-run ambient levels of greenhouse gases, taking into account both intertemporal substitution and substitution across energy sources, is a complicated technical issue that to date has not been adequately analyzed.

50. United Nations Conference on Environment and Development, Framework Convention on Climate Change, May 9, 1992.

51. The most difficult problem is posed by investors who invested in these resources under a previous regime (where these resources were not taxed). Do they have any special claim to compensation for a "change in regime." Changes in demands and supplies occur for virtually all resources and are an inevitable part of the risks in investing. Most economists would argue that arbitrary and capricious changes in policies contribute to business uncertainty, and therefore have an adverse effect on economic growth, but reasoned changes in policies in response to changes in information are an inevitable part of business risk.

52. For example, some electric utilities in the U.S. are already making decisions in anticipation of some future policies to limit greenhouse emissions.

53. These issues also arise among countries. Countries with large coal deposits will find the value of their natural wealth eroded and, quite naturally, will be less enthusiastic about international agreements that reduce coal use or lower producer prices.

54. Studies show variation in GDP losses across models. For example, it is estimated that stabilizing emissions at their 1990 levels would reduce U.S. GDP by 0.2% to 0.8% in the year 2010 – roughly

a \$20 billion to \$80 billion loss for that year. Estimates of the costs of reducing emissions by 20% below 1990 levels in the year 2010 range from 0.9% to 1.7% of GDP. Aggregated models (top-down) have generally reported higher costs, whereas disaggregated models (bottom-up) have shown lower costs. Chapter 9 contains a more complete discussion.

These GDP losses occur when carbon taxes lead to investments that are more expensive than those that would take place in the absence of the taxes. The higher the carbon taxes, the greater the investment in price-induced conservation and the greater the extent of fuel switching toward less carbon-intensive substitutes.

The overall impact of a carbon tax will depend not only on the size of the tax but also on the uses to which the revenues are put. In the standard Energy Modeling Forum (EMF) scenarios, it was assumed that tax revenues would be redistributed in a neutral manner (i.e., without affecting the marginal tax rates). There are, of course, numerous ways in which tax revenues can be used. These include reducing budget deficits; reducing marginal rates of income, payroll, corporate, or other taxes; granting tax incentives to preferred activities; or increasing the level of government expenditures. The costs of the tax will vary widely depending on how the revenues are recycled. 55. Top-down models estimate that for developing countries there exist low-cost options for reducing emissions in the near term, but eventually costs would exceed 1% to 2% of GDP (EMF, 1993). For economies in transition, because of historical inefficiencies and energy subsidies, there exist large opportunities to reduce emissions at little or no cost. For developing countries, problems of informal economies make hard estimates difficult, but the cost of stabilizing emissions would likely be large enough to cut into economic growth.

56. Recent comparisons indicate that the most important differences between top-down and bottom-up models arise from differences in input parameters rather than from differences in model structure.

57. Government institutions and regulations often hinder the efficient use of energy. Developing countries are least able to absorb the costs of these inefficiencies. Thus, although some developing countries argue that they cannot afford to reduce greenhouse emissions, or cannot eliminate the subsidies to poor people implicit in below-market energy prices, the same countries often have the most to gain from reforming government-caused inefficiencies. At least in the short run, international agreements committing countries to eliminate at least the most egregious of these practices might go a long way to addressing the problem of emission reductions.

58. This may also be a problem with electricity generated by the private sector, as regulation has historically set price equal to average cost, rather than allowing it to match the competitive price. In many countries, the increase of competitive pressures has moved electricity prices closer to the marginal cost of production.

59. Further examples include:

Eliminating regulations impeding efficient energy utilization. Many, perhaps most, countries have a host of regulations that increase energy use as they impede economic efficiency. For instance, the U.S. has had a policy of restricting oil exports from Alaska. Whatever the merits of that policy, it has forced Japan to import oil from Indonesia and Saudi Arabia. World oil transportation costs have thus been greatly increased at the expense of the American economy. Another example of government reform, included in the U.S. Action Plan (Clinton and Gore, 1993), encourages efforts to expand and im-

prove natural gas markets through continued regulatory reform. These reform efforts include guidelines to allow greater natural gas use in the summer in coal- and oil-fired power plants.

Other regulation. Unintended effects of many tax, expenditure, and other policies have contributed further to inefficiencies in land use. Among the unfortunate effects of the U.S. Superfund programme for the management of hazardous wastes, for example, has been the creation of large unoccupied holes in the centres of major cities.

60. In actual practice, some of these proposals would likely present practical obstacles, including the cost of implementation.

61. Pay-at-the-pump insurance also has several potential drawbacks. For example, most such proposals fail to link the factors that most influence insurance rates (driver history, vehicle location, vehicle repair costs) with actual insurance payments.

62. Consider the following thought experiment: Compare an optimally designed road system that only carries cars with an optimally designed road system that also carries trucks. The incremental cost of carrying trucks is, in most countries, much larger than the proportionate share of the cost they bear in fuel taxes and other fees.

63. For example, in many countries, governments have taken an active role in the dissemination of information to the agriculture sector. These programmes are in some measure responsible for the large increase in agricultural productivity in countries with agricultural extension services.

64. This is because those who would be at a competitive disadvantage under "true" disclosure have an incentive to add "noise" and because there are strong market forces for product differentiation. In markets with homogeneous commodities, profits will be driven to zero (in Bertrand competition), even with a limited number of suppliers. For a discussion of these and related issues, see Salop (1977), Salop and Stiglitz (1977, 1982), and Stiglitz (1988).

65. The standard reference in the organizational literature is March and Simon (1958). Economic theories emphasizing the nonvalue maximizing behaviour of managers include those of Baumol (1959) and Marris (1964). The principal agent literature (Ross, 1973; Stiglitz, 1974) provided the informational microfoundations for understanding the divergences of interests. See Stiglitz (1988). A more recent overview is provided by Stiglitz (1991) and the symposium in the *Journal of Economic Perspectives*, Spring 1991.

66. The facts that time is a scarce commodity and that decision making in large organizations is decentralized do not in themselves constitute a market failure; they do not prove that resources are not efficiently allocated, given the real constraints facing society, which include time. However, Greenwald and Stiglitz (1984, 1988) have established a very general theorem showing that when information is imperfect and costly, market equilibrium is, in general, not Pareto efficient. Thus, there is no presumption concerning the efficiency of the market economy, even in the absence of the kinds of externality and public goods problems that are associated with greenhouse gases. For a more extended discussion, see Stiglitz (1994).

Recent advances in the economics of information have provided sounder microfoundations for these theories of the firm. And indeed, the importance of the limitations on the availability of information, and the consequent importance of attention-directing efforts, applies to individuals as well as to organizations. Some studies have suggested that the limited success of the special tax provisions in the U.S. designed to encourage savings (IRA accounts) was primarily

due to the competitive efforts of banks to recruit these accounts and the attention that savings got as a result.

67. Network externalities are manifested in other ways. Builders fail to install energy-efficient light bulbs, because customers dislike them and stores do not carry replacements; and stores do not carry them because the demand for them is too low.

When there are important network externalities, market equilibria are frequently inefficient. The economy might, for instance, get "stuck" in the wrong equilibrium. Government action can, in these instances, "force" the economy to move from one equilibrium to another.

68. This is not the only explanation of differences between bottom-up and top-down models. There are several other features of market behaviour that bottom-up models often ignore.

(a) *Hidden costs:* Consumers value a range of attributes difficult to include in an engineering model. For example, auto buyers value not only initial costs and fuel economy (which computer models can easily calculate) but also performance, safety, and durability, which they typically do not.

(b) *Divergence between laboratory and in-use performance:* Especially for new technologies, actual energy use often differs significantly from energy use calculated in the laboratory. It is the latter on which purchasers focus.

(c) *Variation across individual consumers:* Engineering models generally assume an average consumer, but actual consumers may display a wide range of characteristics and usage patterns. Except when demand functions are linear in the relevant variables, the consumption of the "average" individual is not equal to the average consumption, and what is optimal for the average person may not be optimal for a significant fraction of the population.

69. For a survey, see Jaffee and Stiglitz (1990). The basic theory of credit rationing was developed in Stiglitz and Weiss (1981), and the theory of credit rationing is further developed in Greenwald *et al.* (1984) and Myers and Maljuf (1984).

70. This generally accepted methodology is, for instance, reflected in the guidelines issued by the Office of Management and Budget in the U.S. for the evaluation of projects and regulations. The applied literature does not address the question of whether this procedure is appropriate in the presence of certain types of time and risk nonseparabilities.

71. Though if the variance of the net benefits is increasing over time in a particular manner, the differences in the two methodologies may not be large.

72. Again, under certain restrictive conditions, where the shadow value of a capital constraint is changing systematically over time, the differences in the two methodologies may not be great.

73. See Wilson (1977). The "winner's curse" describes the tendency for the winner of an auction to fail to realize a competitive return; that is, in retrospect, to have paid too much. Though the original discussion of winner's curse focussed on bidding in auctions, it has subsequently come to be applied to a range of other market phenomena.

74. For a discussion of the role of the state in capital markets, see Stiglitz (1994).

75. In some industrialized countries, energy-efficient home mortgage lending may help correct the problem. Lenders generally set criteria for the maximum loan amount based on the borrowers' ability to repay, which, in turn, depends on income and wealth. The fact

that a particular expenditure would enhance efficiency and reduce utility bills is not given special attention. Energy-efficient mortgages provide funds to households to make energy efficiency-enhancing investments that are intended to pay for themselves by reducing utility bills by an amount equal to or greater than the interest payments. With capital constraints, builders may have an incentive to trade off initial capital costs for higher maintenance costs (lower energy efficiency). Building codes specifying minimal levels of energy efficiency and full disclosure of expected life-cycle energy costs may help address these market distortions.

76. A country that rapidly depletes its natural resources may show a high rate of growth under conventional income accounting, but a lower rate of growth when resource depletion is taken into account. Repetto (1989, 1991) calculated resource-adjusted GDP for several countries that were rapidly harvesting their stocks of hardwoods and other resources, arguing that conventional measures sharply overstated GDP.

77. Daley and Cobb (1989) have even claimed that U.S. per capita GDP, when adjusted for environmental damage, was stagnant between 1950 and 1986. This assertion is hard to reconcile with the steady improvement in most measures of environmental quality since 1970, when measurement standards were established.

78. Analysts now use two methods to estimate stocks. The first assumes a fixed stock of a natural resource such as oil. Consumption of oil then depletes the stock by the amount of consumption. The second begins by treating discovered reserves as the asset. Thus, additions to reserves increase the asset, while consumption reduces it. If in any given year, new discoveries match resource utilization, then according to this method no net depletion has occurred.

79. A number of difficult conceptual problems face the analyst defining levels and changes in levels of these assets.

First, how should the “stock” of natural resources be defined? Coal poses perhaps the easiest situation. The location of coal reserves is known. Costs of extraction are high, so the rents (the value of coal *in situ*) are low. The depletion can be measured not by the coal used times the market price, but the coal used times the *in situ* value. But for oil and other minerals, information about where reserves are located is vital. Two models have been proposed. One sees the world as having a fixed stock of natural resources (say oil). When one uses oil, one is depleting this stock. Thus, to calculate the value of depletion, one does not need to know the entire stock; the flow (the amount of oil consumed) provides an accurate measure of the change in stock.

The alternative model looks at the size of discovered reserves. Reserves are treated as the asset. Additions to reserves thus are viewed as increasing the resource base. If, in any given year, new discoveries match resource utilization, then there is no net depletion. This is the approach being taken by the U.S. Department of Commerce. This accounting framework would be correct if there were an infinite supply of the resource (reflected in zero rents). The essential “capital” good is information about where the resource is located.

Environmental assets – such as air quality – present another set of problems, because there are no market prices to value the asset. Dynamic optimization problems of the kind described earlier can be used to calculate shadow prices. How sensitive these shadow prices are to specific assumptions remains to be investigated.

Accounting systems do not, however, have to aggregate all information together. Just as information about longevity and other indi-

cators of well-being (see below) serve to complement information from national income accounts concerning standards of living, so too can information about *physical* environmental measures be used to complement information from the extended national income accounts.

80. There is some concern that excessively broad and long patents may actually impede innovation. When technological progress occurs by building on previous innovations, later innovators require the permission of earlier innovators to realize the returns on their innovation. Although advocates of broad patent coverage argue that the parties always arrive at efficient bargaining solutions, critics point out that the outcomes of bargaining models with incomplete information often entail large inefficiencies.

81. Matters are more complicated, since the patent does not reward the innovator with his marginal contribution – the increase in the present discounted value of benefits as a result of the innovation occurring earlier than it otherwise would have occurred. For a fuller discussion, see Stiglitz (1994) and Dasgupta and Stiglitz (1980).

82. If less developed countries fail to implement fully a set of corrective taxes or tradable permits, or if less developed countries fail to adopt and effectively enforce intellectual property rights, there will be insufficient incentives to produce energy- and emission-saving innovations, particularly those appropriate for the level of technological knowledge, human capital, and factor prices in those countries. If less developed countries do take these actions, there is concern that they will result in higher prices for innovations, and thus the pace of adoption will be retarded. An effective form of aid, targeted to reducing greenhouse gas emissions, might take the form of subsidies directed at producing appropriate energy-saving and emission-reducing technologies for LDCs.

83. Edmonds *et al.* (1994) have studied the importance of available advanced energy technologies such as those proposed by Johannson, *et al.* (1993). Edmonds *et al.* use the Edmonds-Reilly-Barnes model for energy-related greenhouse gas emissions; the MAGICC model for atmospheric composition, climate response, and sea level rise; the IPCC scenario IS92a (IPCC, 1992) as the reference base case, and five alternative energy scenarios that are far more advanced than today’s energy supply and transformation technologies. The five energy scenarios are:

- advanced fossil fuel technologies
- advanced liquefied hydrogen fuel cells
- advanced hydrogen fuel cells without liquefied hydrogen
- low-cost biomass
- accelerated rate of exogenous end-use energy intensity improvement

Combined, the energy technologies reduce annual emissions from fossil fuel use to levels that stabilize atmospheric concentrations below 550 ppmv (i.e., double the concentration prior to the Industrial Revolution). The tax rate used, which was assumed to apply globally, was the marginal cost of stabilizing fossil fuel carbon emissions in the reference case. With values reflected for only carbon dioxide emission reductions, the estimated cost of global emission reductions grew from approximately \$35 (U.S.) billion in 2005 to \$230 (U.S.) billion per year in the year 2095. With advanced fossil fuels, low-cost solar electric power, low-cost fuel cell vehicles, the present discounted value of adding low-cost biomass fuel to the energy tech-

nology bundle is almost half a trillion dollars (U.S.). The present discounted value of the advanced energy technologies taken together is \$1.8 trillion (U.S.).

The introduction of advanced biomass energy production technology was found to play a key role in reducing emissions. Biomass energy at \$2.00/GJ, growing to become the core energy supply technology by 2050, could significantly reduce emissions. This possibility highlights the potential role of technology development and deployment relative to that of fiscal and regulatory intervention.

These results should be viewed as illustrative rather than predictive. In this analysis, the gains from introduction and deployment of advanced energy technologies depend on the sequence of technologies evaluated in the study.

84. The literature has identified three types of permit systems. The ambient permit system (APS) works on the basis of permits defined according to exposure at the receptor points. Each polluter, then, may face quite complex markets – different permit markets according to different receptor points, and hence different prices. The simpler emission permit system (EPS) issues permits on the basis of source emissions and ignores what effects those emissions have on the receptor points. Within a given region or zone, the polluter would have only one market to deal with and one price. Finally, there is the pollution offset (PO) system, wherein the permits are defined in terms of emissions and trade takes place within a defined zone. However, the standard has to be met at all receptor points. The exchange value of the permits is then determined by the effects of the pollutants at the receptor points. The PO system thus combines characteristics of the EPS and the APS (Pearce and Turner, 1990). These distinctions are of limited relevance for greenhouse gases, where what is of concern is global emission levels. The specific location of the emissions is of no concern.

85. The choice between taxes and tradable permits depends on the objectives of the policymaker and the nature of the uncertainty about the marginal cost and marginal benefit curves for carbon emission reductions (Weitzman, 1974). Theory tells us that if the nature of the curves is known with very little certainty, but the marginal cost curve is known to be relatively steeper (i.e., a change in the level of pollution allowed brings about a greater change in the marginal costs of mitigation than in the marginal benefits) then taxes should be the policy of choice. This is because, in this case, an erroneous estimation of the optimal tax rate will lead to a relatively small deviation from the optimal pollution level. On the other hand, an erroneous estimation of the optimal level of total emissions in a permit scheme will lead to a relatively large deviation from the optimal cost of the permits.

If the marginal benefit curve is known to be relatively steeper than the marginal cost curve, however, tradable permits are the better option. Here, an erroneous estimation of the optimal tax rate will lead to a relatively large deviation from the optimal level of emissions, whereas an erroneous estimation of the optimal level of emissions in a permit strategy will lead to a relatively small deviation from the optimal cost of the permits.

In the case of greenhouse gas emissions, the time horizon for adjustment is sufficiently long that many of these uncertainties become less important. If the tax rate initially chosen yields too high a level of emissions in one year, it can be increased, and the net impact of the erroneous initial estimate on global warming (or the total cost of achieving a given level of atmospheric concentration) will be negli-

gible. In any case, as the earlier discussion of sequential decision making has emphasized, there is likely to be a need for continued revisions in either tax rates or permit levels.

Still, there is some argument that the required adjustments under a permit scheme may be less burdensome (Tietenberg, 1992). For instance, if the authority feels that the old standard needs some tightening it may enter the market itself and buy some of the permits, holding them out of the market.

There must be effective, competitive markets in tradable permits if such schemes are to achieve efficient outcomes. There are transaction costs of running such schemes, just as there are transaction costs associated with collecting tax revenues. Whether transaction costs give one system a decided advantage over the other is not clear. There seems to be no compelling reason to believe that good markets in tradable permits would not develop.

86. It is possible to design allocations of trading permits that (a) on average, impose no net burden on developing countries (thus conforming to the ability to pay principle); (b) provide those economies that are growing faster per capita with commensurately greater permits, thus imposing no net drag on economic growth, provided the economy exhibits an increase in fuel efficiency at least equal to the average of fast-growing, less-developed countries; and (c) rewards those economies that are able to reduce greenhouse gas emissions faster than benchmark rates, either through greater control of population growth, larger increases in energy efficiency, or switching from higher- to lower-carbon fuels.

The extent to which individual circumstances of countries should be taken into account in setting benchmarks remains a question for international negotiations. To the extent that high emissions are due to natural endowments (e.g., the availability of coal rather than natural gas as a source of energy), a persuasive case can be made for benchmarks to reflect initial emission levels. To the extent that high emissions are due to inappropriate energy pricing policies, the case that benchmarks should reflect initial emission levels is far more tenuous.

87. Similarly, some developing countries have asked, should the developed countries be given higher levels of permits, simply because they have, in the past, been the chief source of greenhouse gases?

88. Standard tradable permit schemes essentially take the revenue from a carbon tax and distribute it to current user emitters, rather than using the revenue to reduce other taxes. An alternative to these standard schemes is for the government to auction off the tradable permits.

If taxing carbon leads to reduced labour supply or reduced savings, then government revenues from wage or capital taxes may be reduced, more than offsetting the direct revenue gain from the carbon tax. Cross-elasticities of this magnitude are unlikely, though any such cross-elasticity will reduce the net gain from the carbon tax. The magnitude of the double dividend has been the subject of some dispute, with Goulder (1994) and Repetto *et al.* (1992) taking opposite views.

89. Two main studies provide insights into the root of the variance in estimates of the economic effects of carbon taxes: the Energy Modeling Forum Study-12 and the OECD comparison project. In each case, sophisticated sensitivity analyses were run by standardizing key economic assumptions and using these in conjunction with common reference-case scenarios of reductions. The magnitude of the effect on economic growth in these studies depends both on

assumptions concerning the effect of carbon taxes on savings and labour supply, and the induced investment to offset the higher energy prices. If higher energy prices do not lead to much capital substitution, and if the cross-elasticity with savings and labour is low, then the likely effect on economic growth will be small.

The OECD model comparison project was conducted to compare economy-wide estimates of the effects of carbon taxes. Time horizons as well as the key economic assumptions on growth, population, and resource prices, and the reduction scenarios for six global models were standardized. The global models compared were the GREEN model, the IEA model, and four North American models (the Edmonds-Reilly Model (ERM), the Global 2100 model of Manne and Richels (MR), Rutherford's Carbon Rights Trade Model (CRTM), and the Whalley-Wigle model) (Dean, 1994).

Because of differing assumptions about several key considerations, the models showed significant variation in tax rates and costs for the same amount of emission reduction. Several factors explain the differences between model results. The most important factors are:

- the degree of substitution between fuels – the ease with which producers and consumers can switch from high-carbon-content fuels to low-carbon-content fuels
- expectations about future energy prices and taxes
- the speed of emission reduction
- the way in which revenue is recycled
- the treatment of the removal of energy subsidies
- assumptions regarding backstop technology and a host of other technical and economic factors

Because of the varying approaches to these questions, the range of estimated tax rates and costs is quite wide. For a 45% reduction in baseline emissions by 2020, the required tax would be in the range of \$150–325 per tonne of carbon and the cost might be in the range of 1.5–2.9% of world GDP. A 70% reduction in baseline emissions by 2050 could require a tax of between \$230 and \$880 per tonne and a loss in world GDP of 2.4–3.8% (Dean, 1994).

The required carbon taxes and associated costs vary significantly across regions in all of the models. This indicates that the same proportional reductions in emissions across all regions would give rise to very different costs in different regions and would thus be globally inefficient – with great potential for savings in the global cost of reducing emissions through the use of emission trading between countries or regions or a global carbon tax.

Three insights emerging from the OECD study (Dean, 1994) are:

- Small amounts of emission reduction can probably be achieved with low taxes;
- Large reductions can only be achieved at high tax rates (i.e., marginal reduction costs rise with emission reductions);
- Carbon-free backstop technologies are likely to slow the rise of the carbon tax, or halt it altogether, if they are available at constant marginal cost.

The Energy Modeling Forum-12 (Impact of Carbon Emission Control Strategies) examined the cost of reducing CO₂ emissions (EMF, 1993). A diverse group of economic models, employing common assumptions for selected numerical inputs, were used to analyze

a standardized set of emission reduction scenarios. In all, fourteen top-down models participated in the study.

The EMF model comparison provides the most comprehensive application of top-down methodologies to date. The study addresses a wide range of policy questions. How large are emissions likely to grow in the absence of controls? How much market intervention will be required to meet alternative targets? What will be the price tag? In exploring economic costs, the modellers were asked to examine the impacts of timing, research and development, and revenue recycling.

The EMF exercise provides a wealth of useful information for policymaking. Although the focus was primarily on the U.S., many of the insights are applicable to developed countries in general.

In selecting parameters for standardization, the EMF study focussed on what were felt to be the most influential determinants of mitigation costs. These included GDP, population, the fossil fuel resource base, and the cost and availability of long-term supply options. In addition, although the EMF models differed considerably in their technology representation, the study attempted to impose uniformity with regard to world oil prices, the oil and gas resource base, and the cost of backstop technologies. For its reference case, EMF adopted the average of the 1990 IPCC high and low economic growth cases (IPCC, 1990c). To be consistent with the IPCC scenarios, the study also adopted the population growth projections of Zachariah and Vu (1988).

The modellers generally used taxes based on the carbon content of the fossil fuels to achieve a prescribed emission reduction. The magnitude of the tax provided a rough estimate of the degree of market intervention that would be required to achieve the carbon emission target. Estimates ranged from \$20 to \$140 per tonne for the carbon taxes required to hold emissions at 1990 levels in 2010. Estimates of the carbon taxes required to reduce emissions by 20% below 1990 levels in 2010 ranged from \$50 to \$330 per tonne.

Two parameters are particularly important in explaining the differences in tax projections: the price elasticity of energy demand and the speed with which the capital stock adjusts to higher energy prices. Neither was controlled in the EMF experiments. Those models using lower price elasticities required higher taxes to achieve the same emission goal. Those models that assumed greater malleability of capital required lower taxes.

90. Rapid capital stock retirement may add to the cost of immediate CO₂ reductions. Also, reductions may be cheaper later because of technical changes in the intervening years.

91. Indeed, the "ratchet effect," a commonly observed phenomenon in command and control economies (Stiglitz, 1975b; Weitzman, 1978), leads firms to do no more than just satisfy the target.

92. Two examples from the experience of the United States Clean Air Act: (1) the expensive and evidently counterproductive requirement in the 1977 amendments that coal-burning power plants install stack-gas scrubbers even if they burn low-sulphur Western coal has been attributed to an unusual alliance between environmental activists and Eastern U.S. high-sulphur coal interests; (2) the mandates for ethanol in the motor fuels market are generally attributed to the political power of the corn and ethanol interests.

93. It has been argued that new species and varieties produced by genetic engineering may be able to more than offset the loss in genetic variability from climate impacts, particularly because of the increasing capacity to direct those mutations toward socially desirable objectives.

94. Other views represented in the debate on sustainable development but not generally accepted in the economics profession include those of Daly (1991) and Daly and Cobb (1989), and those of the new field of ecological economics (Costanza, 1991).

References

- Arrow, K.J., 1962: The economic implications of learning by doing, *Review of Economic Studies* 29, 155–173.
- Atkinson, A.B., 1970: On the measurement of inequality, *Journal of Economic Theory*, 2, 244–263.
- Atkinson, A.B., and J.E. Stiglitz, 1980: *Lectures on public economics*, McGraw-Hill, New York.
- Baumol, W.J., 1959: *Business behavior, value, and growth*, chapters 6–8. Macmillan, New York.
- Birdsall, N., and A. Steer, 1993. Act now on global warming – but don't cook the books, *Finance and Development* 30(1), 6–8.
- Bohm, P., 1993: Making carbon-emission quota agreements more efficient: Joint implementation vs. quota-tradability. Paper presented at Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, October.
- Burniaux, J.M., J.P. Martin, and J. Oliviera Martins, 1992: The effects of existing distortions in energy markets on the costs of policies to reduce CO₂ emissions: Evidence from GREEN. OECD Economic Studies no. 19, OECD, Paris.
- Chao, Hung-po, 1992: Managing the risk of global climate catastrophe. Electric Power Research Institute, Palo Alto, CA.
- Chichilnisky, G., and G. Heal, 1993: Who should abate carbon emissions? An international viewpoint. National Bureau of Economic Research (NBER) working paper no. 4425, Cambridge, MA. August.
- Cline, W.R. 1992: *The economics of global warming*. Institute for International Economics, Washington, DC.
- Clinton, W., and A. Gore, 1993: *The climate change action plan*. Executive Office of the President, Washington, DC.
- Coase, R., 1960: The problem of social cost, *Journal of Law and Economics* 1, October, 1–44.
- Costanza, R., 1991: *Ecological economics: The science and management of sustainability*, Columbia University Press, New York.
- Daly, H., 1991: *Steady-state economics*, 2d ed., Island Press, Washington, DC.
- Daly, H., and J. Cobb, 1989: *For the common good: Redirecting the economy toward community, the environment, and a sustainable future*, Beacon Press, Boston.
- Dasgupta, P., 1982: *The control of resources*, Basil Blackwell, Oxford.
- Dasgupta, P., and J.E. Stiglitz, 1980: Industrial structure and the nature of economic activity, *Economic Journal* 90(358), June, 266–293.
- Dasgupta, P., and J.E. Stiglitz, 1981: Resource depletion under technological uncertainty, *Econometrica* 49(1), January, 85–104.
- Dasgupta, P., R. Gilbert, and J.E. Stiglitz, 1979: Energy resources and research and development, in *Erschöpfbare Ressourcen*, S. Brand, ed., Duncker and Humboldt, Berlin.
- Dean, A., 1994: The effectiveness of carbon taxes at the international level. In *Climate change: Policy instruments and their implications*: Proceedings of the Tsukuba Workshop of IPCC Working Group III, 17–20 January, 1994, pp. 46–59, Environmental Agency of Japan, Tokyo.
- Edgeworth, F.Y., 1881: *Mathematical psychics*, C. Kegan Paul & Co., London.
- Edmonds, J., and J. Reilly, 1983: Global energy and CO₂ to the year 2050, *The Energy Journal* 4, 21–47.
- Edmonds, J., M. Wise, and C. MacCracken, 1994: Advanced energy technologies and climate change: An analysis using the global change assessment model (GCAM), Global Environmental Change Program, Pacific Northwest Laboratory, Washington DC. Draft.
- El Serafy, S., 1989: The proper calculation of income from depletable natural resources. In Ysuf J. Ahmad, S. El Serafy, and E. Lutz, *Environmental accounting for sustainable development*, World Bank, Washington, DC.
- EMF (Energy Modeling Forum), 1993: *EMF-12 global climate change: Impacts of greenhouse gas control strategies*, Stanford University, Palo Alto, CA.
- Fankhauser, S., 1994: The social costs of greenhouse gas emissions: An expected value approach. In N. Nakicenovic et al. (1994).
- Goldemberg, J., T. Johansson, A. Reddy, and R. Williams, 1988: *Energy for a sustainable world*. Wiley Eastern Limited, New York.
- Goulder, L., 1994: Environmental taxation and the “double dividend”: A reader's guide, Stanford University Department of Economics, Palo Alto, CA. Draft.
- Greenwald, B., and J.E. Stiglitz, 1984: Pecuniary and markets externalities: Toward a general theory of the welfare economics of economies with imperfect information and incomplete markets. NBER Working Paper No. 1304. National Bureau of Economic Research, Palo Alto, CA.
- Greenwald, B., and J.E. Stiglitz, 1988: Pareto inefficiencies of market economies: Search and efficiency wage models. *American Economic Review* 78(2), May, 351–355.
- Greenwald, B., and J.E. Stiglitz, 1989: Impact of the changing tax environment on investments and productivity, *The Journal of Accounting, Auditing, and Finance* 4(3), Summer, 281–301.
- Greenwald, B., J.E. Stiglitz, and A. Weiss, 1984: Informational imperfections in the capital market and macroeconomic fluctuations, *American Economic Review* 74(2), May, 194–199.
- Grossman, S., and J.E. Stiglitz, 1981: Stockholder unanimity in the making of production and financial decisions, *Quarterly Journal of Economics* 94, May, 543–566.
- Grubb, M., Thierry Chapuis, and Minh Ha Duong, 1995: The economics of climate change: Implications of adaptability and inertia for optimal climate policy. Forthcoming.
- Grubb, M., J. Edmonds, P. ten Brink, and M. Morrison, 1993a: The costs of limiting fossil-fuel CO₂ emissions: A survey and analysis, *Annual Review of Energy and the Environment* 18, 397–478.
- Grubb, M., Minh Ha Duong, and Thierry Chapuis, 1993b: Optimising climate change abatement responses: On inertia and induced technology development, IIASA Workshop on Integrative Assessment of Mitigation, Impacts, and Adaptation to Climate Change, Laxenburg, Austria, October.
- Hicks, J.R., 1939: The foundations of welfare economics, *Economic Journal* 49, December, 696–712.
- Hotelling, H., 1931: The economics of exhaustible resources, *Journal of Political Economy*, April, 137–175.
- Howarth, R., and R. Norgaard, 1992: Environmental valuation under sustainability. *American Economic Review* 82(2), May, 473–477.
- Hyder, T.O., 1992: Climate negotiations, the North/South perspective. In *Confronting climate change: Risks, implications, and responses*, I. Mintzer, ed., Cambridge University Press, Cambridge.
- IPCC (Intergovernmental Panel on Climate Change), 1990a: *Climate change: The IPCC scientific assessment*, J.T. Houghton, G.J. Jenkins, and J.J. Ephraums, eds., Cambridge University Press, Cambridge.

- IPCC (Intergovernmental Panel on Climate Change), 1990b: *Climate change: The IPCC impacts assessment*. Report Prepared for IPCC by Working Group I, World Meteorological Organization and United Nations Environment Programme, New York.
- IPCC (Intergovernmental Panel on Climate Change), 1990c: *Emissions scenarios prepared by the response strategies working group of the IPCC. Report of the expert group on emissions scenarios*. World Meteorological Organization and United Nations Environment Programme, New York.
- IPCC (Intergovernmental Panel on Climate Change), 1992: *The supplemental report to the IPCC scientific assessment*, J.T. Houghton, B.A. Callander, and S.K. Varney, eds., Cambridge University Press, Cambridge.
- IPCC (Intergovernmental Panel on Climate Change), 1995: *Climate change 1994: Radiative forcing of climate change and an evaluation of the IPCC IS92 emission scenarios*, J.T. Houghton, L.G. Meira Filho, J. Bruce, Hoesung Lee, B.A. Callander, E. Haites, N. Harris, and K. Maskell, eds., Cambridge University Press, Cambridge.
- Jaffee, D., and J.E. Stiglitz, 1990: Credit rationing. In B. Friedman and F. Hahn, eds., *Handbook of monetary economics*, pp. 837–888, Elsevier Science Publishers, Amsterdam.
- Johannson, J., Goldemberg, R. Williams, and H. Kelley, 1993: *Renewable energy: Sources for fuels and electricity*, Island Press, Washington.
- Kaldor, N., 1939: Welfare propositions of economics and interpersonal comparisons of utility, *Economic Journal* 49, December, 549–552.
- Kaya, Y., 1989: Impact of carbon dioxide emission control on GNP growth: Interpretation of proposed scenarios, Intergovernmental Panel on Climate Change/Response Strategies Working Group, May.
- Knight, F., 1921: *Risk, uncertainty, and profit*. Houghton Mifflin, Boston.
- Lind, R.C., 1994: Intergenerational equity, discounting, and the role of cost-benefit analysis in evaluating global climate policy. In N. Nakicenovic et al. (1994).
- Lind, R.C., K.J. Arrow, G.R. Corey, P. Dasgupta, A.K. Sen, T. Stauffer, J.E. Stiglitz, J.A. Stockfish, and R. Wilson, 1982: *Discounting for Time and Risk in Energy Policy*. Washington, DC: Resources for the Future.
- Lovelock, J., 1979: *Gaia: A new look at life on earth*, Oxford University Press, London.
- Malthus, T., 1798: *Essay on the principle of population* (reprinted Macmillan, London, 1926).
- Manne, A.S., and R.G. Richels, 1992: *Buying greenhouse insurance: The economic costs of CO₂ emission limits*, MIT Press, Cambridge, MA.
- March, J., and H. Simon, 1958: *Organizations*, Wiley, New York.
- Marris, R., 1964: *The economic theory of managerial capitalism*, Macmillan, New York.
- McKibben, W., and P. Wilcoxon, 1992: The global costs of policies to reduce greenhouse gas emissions. Brookings Discussion Papers in International Economics no. 97, Brookings Institution, Washington, DC.
- Meadows, D.H., and D.L. Meadows, 1972: *The limits to growth: A report to the club of Rome's project on the predicament of mankind*, Universe Books, New York.
- Mearns, L.O., P.W. Katz, and S.H. Schneider, 1984: Extreme-high temperature events: Changes in their probabilities with changes in mean temperature, *Journal of Climate and Applied Meteorology*, 23, December, 1601–1613.
- Mirrlees, J., 1971: An exploration in the theory of optimum income taxation, *Review of Economic Studies* 38, April, 175–208.
- Myers, S., and N. Maljuf, 1984: Corporate financial and investment decisions when firms have information that investors do not have, *Journal of Financial Economics* 13(2), June, 187–221.
- Nakicenovic, N., W.D. Nordhaus, R. Richels, and F.L. Toth, eds., 1994: *Interactive assessment of mitigation, impacts, and adaptation to climate change*. Proceedings of a workshop held on 13–15 October 1993 at the Institute for Applied Systems Analysis, Laxenburg, Austria.
- Nash, J.F., 1955: The bargaining problem, *Econometrica* 18, 155–162.
- Nordhaus, W.D., 1993: *Managing the global commons: The economics of climate change*, MIT Press, Cambridge, MA.
- Nordhaus, W.D., and J. Tobin, 1973: Is growth obsolete? *Income and Wealth*, vol. 38, National Bureau of Economic Research, New York.
- Parikh, J.K., 1994: Vulnerability vs. responsibility in climate change outlook. Proceedings, Australian Bureau of Agricultural and Resource Economics (ABARE), 1–4 Feb., 1994, Canberra Australia.
- Pearce, D.W., 1989: Sustainable development: Towards an operational definition and its practical implications. OECD Economics and Statistics Department/Environmental Directorate Joint Seminar on the Economics of Environmental Issues. 2–3 Oct., Paris.
- Pearce, D.W., 1991: Evaluating the socio-economic impacts of climate change: An introduction. In OECD, *Climate change: Evaluating the socio-economic impacts*, chapter 1, Paris.
- Pearce, D.W., G. Atkinson, and W. DuBourg, 1994: The economics of sustainable development, *Annual Review of Energy and the Environment* 19, 457–474.
- Pearce, D.W., and R.K. Turner, 1990: *Economics of natural resources and the environment*, Johns Hopkins University Press, Baltimore.
- Peck, S., and T. Teisberg, 1992: CETA: A model for carbon emissions trajectory assessment, *The Energy Journal*, 13(1), 55–77.
- Peck, S., and T. Teisberg 1993: Global warming uncertainties and the value of information: An analysis using CETA, *Resource and Energy Economics*, 15(1), 87–102.
- Peskin, H., and E. Lutz, 1990: A survey of resource and environmental accounting in industrialized countries. The World Bank Environment Working Paper no. 37, August.
- Polasky, S., A.R. Solow, and J.M. Broadus, 1993: Searching for uncertain benefits and the conservation of biological diversity, *Environmental and Resource Economics* 3, 171–181.
- Rawls, J., 1971: *Theory of justice*, Belknap Press, Cambridge, MA.
- Reddy A., and J. Goldemberg, 1990: Energy for the developing world, *Scientific American*, 263(3), 111–118.
- Repetto, R., 1989: *Wasting assets: Natural resources in the national income accounts*, World Resources Institute, Washington, DC.
- Repetto, R., 1991: *Accounts overdue: Natural resource depletion in Costa Rica*, World Resources Institute, Washington, DC.
- Repetto, R., R. Dower, R. Jenkins, and T. Geoghegan, 1992: *Green fees: How a tax shift can work for the environment and the economy*, World Resources Institute, Washington, DC.
- Richels, R., and J. Edmonds, 1993: The economics of stabilizing atmospheric CO₂ concentrations. Draft manuscript.
- Ross, R., 1973: The economic theory of agency: The principal's problem, *American Economic Review* 63, 134–139.
- Rothenberg, J., 1993: Time comparisons in public policy analysis of global climate change: An economic analysis, MIT Press, Cambridge, MA.
- Salop, S., 1977: The noisy monopolist: Imperfect information, price dispersion, and price discrimination, *Review of Economic Studies* 44(3), October, 393–406.

- Salop, S., and J.E. Stiglitz, 1977: Bargains and ripoffs: A model of monopolistically competitive price dispersion, *Review of Economic Studies* 44, October, 493–510.
- Salop, S., and J.E. Stiglitz, 1982: The theory of sales: A simple model of equilibrium price dispersion with identical agents, *American Economic Review*, Dec., 1121–1130.
- Samuelson, P., 1954: The pure theory of public expenditure, *Review of Economics and Statistics* 36, Nov., 387–389.
- Schmalensee, R., 1993: Comparing greenhouse gases for policy purposes, *The Energy Journal* 14(1), 245–255.
- Shah, A., and B. Larsen, 1991: *Carbon taxes, the greenhouse effect and developing countries*, World Bank, Washington, DC.
- Solow, A.R., 1993: The response of sea level to global warming. In *The world at risk: Natural hazards and climate change*, R. Bras, ed. AIP Conference Proceedings 277, pp. 38–42, American Institute of Physics, New York.
- Solow, A.R., 1990: Is there a global warming problem? In *Global warming: Economic policy responses*, R. Dornbusch and J. M. Poterba, eds., MIT Press, Cambridge, MA.
- Solow, R.M., 1974: Intergenerational equity and exhaustible resources, *Review of Economic Studies* (symposium volume), pp. 29–45.
- Solow, R.M., 1992: An almost practical step toward sustainability, *Resources for the Future*, Washington, DC.
- Steer, A., and E. Lutz, 1993: Measuring environmentally sustainable development, *Finance and Development* 30(4), 20–23.
- Stewart, R., and J.B. Wiener, 1990: A comprehensive approach to climate change: Using the market to protect the environment. In *The American Enterprise*, Vol. 1.
- Stewart, R.B., and J.B. Wiener, 1992: The comprehensive approach to global climate policy: Issues of design and practicality, *Arizona Journal of International and Comparative Law*, 9(1), 83–113.
- Stiglitz, J.E., 1974: Incentives and risk sharing in sharecropping, *Review of Economic Studies* 41, April, 219–255.
- Stiglitz, J.E., 1975a: Information and economic analysis. In *Current economic problems*, Parkin and Nobay, eds., pp. 27–52, Cambridge University Press.
- Stiglitz, J.E., 1975b: Incentives, risk, and information: Notes toward a theory of hierarchy. *Bell Journal of Economics* 6, Autumn, 552–579.
- Stiglitz, J.E., 1977: Monopoly and the rate of extraction of exhaustible resources, *American Economic Review* 66(4), Sept., 655–661.
- Stiglitz, J.E., 1982: The efficiency of the stock market equilibrium, *Review of Economic Studies* 49, 241–261.
- Stiglitz, J.E., 1985: Information and economic analysis: A perspective, *Economic Journal* 95, Supplement, 21–45.
- Stiglitz, J.E., 1988: Economic organization, information, and development. In *Handbook of Development Economics*, H. Chenery and T.N. Srinivasan, eds., pp. 94–160. Elsevier Science Publishers, Amsterdam.
- Stiglitz, J.E., 1991: Symposium on organizations in economics, *Journal of Economic Perspectives* 5(2), 15–24.
- Stiglitz, J.E., 1994: *Whither socialism?* Wicksell Lectures, MIT Press, Cambridge, MA.
- Stiglitz, J.E., and P. Dasgupta, 1971: Differential taxation, public goods, and economic efficiency, *The Review of Economic Studies* 37, 151–174.
- Stiglitz, J.E., P. Dasgupta, and G. Heal, 1980: The taxation of exhaustible resources. In *Public policy and the tax system*, G.A. Hughes and G.M. Heal, eds., George Allen & Unwin, London.
- Stiglitz, J.E., and A. Weiss, 1981: Credit rationing in markets with imperfect information, *American Economic Review* 71(3), June, 393–410.
- Tietenberg, T., 1992: Introduction and overview. In *Innovation in environmental policy: Economic and legal aspects of recent developments in environmental enforcement and liability*, by T. Tietenberg, pp. 1–17, Elgar, Aldershot, UK.
- UNDP (United Nations Development Programme), 1992: *Human development report 1992*, Oxford University Press, Oxford.
- United Nations, 1989: African alternative framework to structural adjustment programmes for socio-economic recovery and transformation, UNECA/OAU, E/ECA/cm.15/6/Rev 3. United Nations, New York.
- United Nations Statistical Office, 1992: *SNA draft handbook on integrated environmental and economic accounting*, provisional version. New York.
- U.S. EPA (Environmental Protection Agency), 1989: Sea level rise. In *Report to Congress on the potential effects of global climate change on the United States*, Washington, DC.
- Weitzman, M.L., 1974: Prices vs quantities, *Review of Economic Studies*, 41(4), October, 477–491.
- Weitzman, M.L., 1978: Optimal rewards for economic regulation, *American Economic Review* 68(4), Sept., 683–691.
- Weitzman, M.L., W. Newey, and M. Rabin, 1981: Sequential R&D strategy for synfuels, *The Bell Journal of Economics* 12(2), 574–590.
- Whalley, J., and R. Wigle, 1991: Cutting CO₂ emissions: The effects of alternative policy approaches, *Energy Journal* 12(1), 109–124.
- Wilson, C.A., 1977: A model of insurance markets with incomplete information. *Journal of Economic Theory* 16(2), Dec., 167–207.
- World Commission on Environment and Development, 1987: *Our common future*, Oxford University Press, London.
- Zachariah, K.C., and M.T. Vu, 1988: *World population projections 1987–88*. Johns Hopkins University Press, Baltimore.

Lisa

U.S. Submission on
Elements of a New Legal Instrument
(October 15, 1996)

General

In the U.S. view, the new legal instrument should respond effectively to the environmental challenge posed by climate change; should reflect outcomes that are real and achievable; should be consistent with economic prosperity; should allow for maximum flexibility and cost-effectiveness in its implementation; and should lay the foundation for continuing progress by all countries.

We believe that the following elements would serve as a useful basis for the consideration of the issues -- and ultimately, of legal language -- to be included in this instrument. Given the continuing uncertainties surrounding the form of such an instrument, we have noted particular aspects of these issues that may differ depending on whether the parties choose a protocol or an amendment to the FCCC to codify their agreement.

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If the legal instrument takes the form of a protocol, it might include a preamble. If it takes the form of an amendment, it would not, although the decision adopting the amendment could.

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A protocol would need to incorporate some or all of the definitions in Article 1 of the convention, include its own definitions, or some combination of the two. An amendment, to the extent it introduces new terms, might also require amendment of Article 1.

Objective

An amendment would, and a protocol should incorporate the objective in the convention; we do not believe it is either necessary or desirable to develop a separate objective for this legal instrument.

Post-it® Fax Note	7671	Date	10/18	# of pages	5
To	Alicia Munnell	From	Ray SAVITIERI		
Co./Dept.	CEA	Co.			
Phone #	395-	Phone #	622-1301		
Fax #	395-6958	Fax #	-1294		

*Alicia -
Our comments of 10/16.*

Level and Structure of the Target¹

The Geneva Declaration calls for a legally-binding target and timetable. The Berlin Mandate calls for adoption of the protocol/other legal instrument at COP-3, making negotiation of differentiated commitments in this timeframe impracticable. Therefore, it will be important that the target/timetable be sufficiently specific (to facilitate compliance), flexible (to encourage broad participation) and straight-forward (to ensure negotiation and adoption by COP-3).

² Ideas proposed thus far include.

- a flat target (measured against a fixed year or baseline trend)
- a cumulative or aggregate target (reducing total emissions over a particular time period by an agreed percentage)
- a target based on a rolling average
- a collective target (e.g., "Annex I", OECD, EU)
- individually pledged (binding) targets
- differentiated targets (possibly based on a formula)

Analysis of the effects of each of these ideas will depend not only on the level agreed upon but also on the extent of participation (number of Parties) in the process. [The United States is currently developing a toolbox to facilitate analysis of these and other options.] We anticipate that, by March 1997, the full array of choices would be tabled by Parties, and that the development of specific language for inclusion in the instrument could be considered. *ugh!*

Advancing Article 4.1 Commitments

In the U.S. view, next steps must involve actions by all Parties, recognizing their common but differentiated³ responsibilities and capabilities, and these must be reflected in the Kyoto agreement- There are a number of assumptions that underlie U.S. views on next steps:

• Article 4.1:

- Applies to all Parties, not just to developing country Parties;
- Speaks to issues ranging from inventorying emissions to reporting, to adopting policies and measures;

¹ What about language saying that the target level will be chosen based upon a review of health and other benefits, and implementation costs.

² We suggest either deleting this list, or adding banking, global targets and other ideas.

³ This draft seems very weak on the need for inclusion of developing countries. How about referring to the fact that, without them, greenhouse emissions will increase?

- Speaks to the requirement to promote the development and transfer of technologies;
- The Convention anticipates that the status of countries will evolve over time (e.g., Article 4.2(f))⁴
- Provisions of the Berlin Mandate govern what will be included in the Kyoto agreement

Bearing in mind these assumptions, there are a number of approaches that can be taken through a new legal instrument. The Parties can agree to:

- continued and more systematic support for efforts to develop national action plans (particularly in developing countries) following the revised Annex I Guidelines for National Communications and the newly adopted Non-Annex I Guidelines for Initial Communications
- redoubled efforts to adopt and implement "no-regrets" measures⁵
- expanded programs aimed at developing, diffusing and deploying climate-friendly technologies (including through systematic efforts to identify and remove barriers to technology transfer, working with the multilateral development banks and to improve the performance of existing financial institutions)⁶
- further consideration of thresholds at which the status of countries would change, and the process involved in such a change in status
- further consideration of future steps (post-Kyoto) toward the objective of the Convention

Emissions Trading/Joint Implementation

In the U.S. view, emissions trading/joint implementation will be an essential element of the Kyoto agreement; it will therefore be a priority task to establish the guidelines for a credible emissions trading/joint implementation regime by December 1997

Various design questions will need to be resolved by the Kyoto Conference, including, for example, whether inter-gas trading will be allowed⁷; how trades would most effectively be monitored and reviewed; what distinctions might be drawn with respect to participation in an emissions trading/joint implementation regime (e.g., absent national targets, could project-specific baselines be used?)

-
- ⁴ How, in practice, will this occur? *intelligible to wide audience*
 - ⁵ What are "no regrets measures"? *This is relatively obscure jargon.*
 - ⁶ I don't think we should be insulting the World Bank
 - ⁷ The US position should be that all gases should be considered as a group. *↗*

A number of principles must underlie an emissions trading/joint implementation regime. Such a regime must be efficient, transparent and verifiable⁸ and must produce real reductions.⁹ A preliminary elaboration of these principles should already be possible; in the U.S. view, the regime should:

- allow parties to trade or exchange credits toward and against national greenhouse gas reduction or limitation commitments;
- ensure that emissions reductions are created by actions that verifiably and reliably reduce accrued, net emissions beyond those which would occur without the system⁹;
- minimize costs, especially transaction and administrative costs;
- motivate parties to achieve and strengthen national commitments to reduce or limit greenhouse gas emissions;
- motivate economic actors to find and implement on a continuous basis cost-effective greenhouse gas emission reductions;
- be as flexible as possible to accommodate differing national approaches to achieving emissions commitments;
- promote compatibility among national approaches to facilitate trading/exchanging credits
- be as inclusive of Parties, sub-national entities, gases and sectors as possible;
- ensure transparency through stringent¹⁰ monitoring, record-keeping and reporting;
- provide incentives for compliance -- and mechanisms to limit the benefit accorded to non-compliant Parties, and to ensure that non-compliance does not adversely affect environmental progress under the agreement.
- should consider banking and borrowing.

Institutions

For reasons of administrative efficiency and in light of budgetary constraints, a new legal instrument should utilize existing institutions to the maximum extent practicable.

A protocol would need to specify its institutions. In the case of an amendment, the institutions established under the Convention would apply (Note: we do not believe it would be appropriate for non-parties to the protocol to be officers of a body servicing the protocol.)

⁸ Unnecessary and may be used against market-based measures.

⁹ How do you get ironclad proof that something wouldn't otherwise have occurred?

¹⁰ How about "accurate"? Stringent can be used to prevent anything.

Compliance

Ensuring effective compliance will be critical for environmental as well as economic reasons. Unless parties comply, actions taken are likely to be inadequate and global warming will continue unabated. Uneven compliance will undermine confidence in the Convention and encourage "free-riding,"

The term "compliance" is used in this context to refer to the cluster of processes/mechanisms that provide incentives for the Parties to abide by their legal commitments.

In addition to promoting compliance by including commitments that are realistic and verifiable (as noted above), the instrument should provide supplementary means, for example, with respect to ascertaining whether Parties are meeting their obligations and with respect to appropriate consequences for non-compliance.

An amendment to the Convention would be covered by the Convention's reporting requirements, as well as dispute settlement provisions and multilateral consultative process, once established. A protocol would need to specify whether any of these Convention mechanisms would apply as well as any additional compliance-related provisions.

Decision-Making

Only the Parties to the protocol or amendment should have decision-making authority with respect to that instrument.

Final Clauses

A protocol would need to contain several final clauses, including, for example, provisions on entry into force and amendment. An amendment's final clauses are already set forth in the Convention.

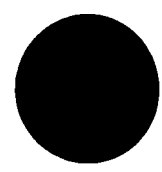


United States Department of State

Assistant Secretary of State for Oceans and
International Environmental and Scientific Affairs

Washington, D.C. 20520

October 17, 1996



Handwritten notes in the top right corner: "h3", "com b", "DEJ", "DARK", "RP", "MM".

MEMORANDUM

TO: Distribution

FROM: OES - Rafe Pomerance, Acting *RP*

SUBJECT: Submission to Secretariat of the UN Framework
Convention on Climate Change

Attached is a revised draft of the proposed United States submission to the Secretariat of the UN Framework Convention on Climate Change. This draft has been revised to reflect comments and suggestions raised by several agencies. In order to ensure that agencies have an opportunity to review the final draft before submission to the Secretariat, I am sending the document for your final clearance.

As background, you should know that this submission is designed to outline in broad terms the key elements of a final agreement that are important for further discussion and consideration. More detailed policies and positions will be developed by the USG in the months ahead with your participation. Our submission at this time is intended to help maintain the momentum we have established in defining the negotiations on terms that are consistent with our interests. In order to ensure that our views are fully reflected in the documentation prepared for the next round of negotiations in December, it is essential that we provide our suggestions for key negotiating elements at this time. The U.S. submission will be compiled along with those of other nations by the Secretariat and will be circulated publicly.

To comply with the Secretariat's deadlines, we would appreciate your clearance by noon, Friday, October 18, 1996. Please fax or phone your comments to me on (o)647-2232 or (f)647-0217.

Thank you for your assistance.

Attachment:
As stated.

Draft Rev. 3 -- 10/17/96

U.S. Submission on
Elements of a New Legal Instrument
(October 15, 1996)

General

In the U.S. view, the new legal instrument should respond effectively to the threat posed by global climate change; should reflect outcomes that are real and achievable; should be consistent with economic prosperity; should allow for maximum flexibility and cost-effectiveness in its implementation; and should lay the foundation for continuing progress by all countries.

Meeting the ultimate objective of the Convention will require concerted, long-term efforts by all Parties. While it is important for developed countries to take the lead, it is also essential that the Kyoto agreement recognize the growing contribution of developing country emissions and begin to plan for appropriate, cost-effective ways to address these emissions in a sustainable manner. In this connection, at COP-2 the United States called for continued work toward a longer-term concentration goal (e.g. for the next 50-100 years), recognizing that scientific understanding and technology will improve over time.

In putting forward these suggestions for a new legal instrument, the United States has rejected proposals by some countries calling for short-term targets that we believe could not be realistically achieved. We have also rejected the use of inflexible, harmonized policies and measures. In the spirit of providing individual countries greater flexibility in meeting any agreed upon limitations, we believe that it is critical that flexibility in implementation be accorded all countries, including through emissions trading and joint implementation among nations.

We believe that the following elements would serve as a useful basis for the consideration of topics that would need to be included in a new legal instrument. Given the continuing uncertainties surrounding the form of such an instrument, we have noted particular aspects of these issues that may differ depending on whether the Parties choose a protocol or an amendment to the FCCC to codify their agreement.

-2-

Preamble

If the legal instrument takes the form of a protocol, it might include a preamble. If it takes the form of an amendment, it would not, although the decision adopting the amendment could.

Definitions

A protocol would need to incorporate some or all of the definitions in Article 1 of the Convention, include its own definitions, or some combination of the two. An amendment, to the extent it introduces new terms, might also require amendment of Article 1.

Objective

An amendment would, and a protocol should incorporate the objective in the Convention; we do not believe it is either necessary or desirable to develop a separate objective for this legal instrument.

Level and Structure of the Target

The Geneva Declaration calls for a legally-binding target and timetable, consistent with the U.S. call at COP-2, to shift the negotiations away from unrealistic, near-term proposals to medium-term targets that are both realistic and achievable.

The Berlin Mandate calls for adoption of the protocol/other legal instrument at COP-3, making calls to date for differentiated commitments in this timeframe impracticable. Therefore, it will be important that the target/timetable be sufficiently specific (to facilitate compliance), flexible in terms of its implementation (to encourage broad participation) and straight-forward (to ensure negotiation and adoption by COP-3). As we noted at COP-2, the United States opposes efforts to develop inflexible, harmonized policies and measures.

A number of ideas and approaches have been suggested thus far in the discussions within the Ad Hoc Group on the Berlin Mandate (AGBM). Many of these ideas and approaches have focused on a single-year target, but we believe it will be important to consider a broader range of possibilities (e.g., cumulative or aggregate targets, multiple-year rolling average targets, flexibility over time through banking or

-3-

borrowing, etc.) We anticipate that more such ideas and approaches will be tabled and considered as we work toward a new legal instrument for adoption at COP-3.

The United States is continuing its domestic analysis and assessment efforts so as to contribute to this discussion in upcoming negotiating sessions.

Advancing Article 4.1 Commitments

"Continuing to advance the implementation of Article 4.1 commitments" will be a critical component of next steps and must be reflected in the Kyoto agreement. Given the global nature of this problem, we must work together toward a global solution, recognizing our common but differentiated responsibilities and capabilities. A number of assumptions underlie U.S. views on next steps:

- Article 4.1:
 - Applies to all Parties;
 - Speaks to issues ranging from inventorying emissions, to reporting, to adopting policies and measures;
 - Speaks to the requirement to promote the development and diffusion of technologies;
- The Convention anticipates that the status of countries will evolve over time (e.g., Article 4.2(f))
- Paragraph 2.b of the Berlin Mandate governs what will be included on this issue in the Kyoto agreement

Bearing in mind these assumptions, there are a number of approaches that can be taken through a new legal instrument. For example, the Parties could agree to:

- continued and more systematic support for efforts to develop national action plans (particularly in developing countries) following the revised Annex I Guidelines for National Communications and the newly adopted Non-Annex I Guidelines for Initial Communications
- redoubled efforts to adopt and implement "no-regrets" measures
- expanded programs aimed at developing, diffusing and deploying climate-friendly technologies (including through

-4-

systematic efforts to identify and remove barriers to technology diffusion and to enhance the role of international financial institutions in responding to the threat of global climate change)

- further consideration of thresholds at which the status of countries would change, and the process involved in such a change in status
- further consideration of future steps (post-Kyoto) toward the objective of the Convention

International Emissions Trading/Joint Implementation

In the U.S. view, emissions trading/joint implementation will be an essential element of the Kyoto agreement; it will therefore be a priority task to establish the guidelines for a credible emissions trading/joint implementation regime by December 1997.

We believe that emissions trading and joint implementation regimes will motivate parties to achieve and strengthen national commitments to reduce or limit greenhouse gas emissions because the cost savings potential in these types of programs can achieve more environmental protection than less flexible, less cost-effective regimes.

Various design questions will need to be resolved by the Kyoto Conference, including, for example, whether inter-gas trading will be allowed; how trades would most effectively be monitored and reviewed; what distinctions might be drawn with respect to participation in an emissions trading/joint implementation regime (e.g., absent national targets, could project-specific baselines be used?)

A number of principles must underlie an emissions trading/joint implementation regime. At a minimum, such a regime must be efficient, transparent and verifiable.

Institutions

For reasons of administrative efficiency and in light of budgetary constraints, a new legal instrument should utilize existing institutions to the maximum extent practicable.

A protocol would need to specify its institutions. In the case of an amendment, the institutions established under the Convention would apply. (Note: We do not believe it would be appropriate for non-Parties to a protocol to be officers of an institution serving the protocol.)

-5-

Compliance

The term "compliance" is used in this context to refer to the cluster of processes/mechanisms that provide incentives for the Parties to abide by their legal commitments.

Ensuring effective compliance will be critical for environmental as well as economic reasons. Unless parties comply, there will be little incentive to act and we will not achieve our environmental objectives. Uneven compliance will undermine confidence in the new legal instrument and encourage "free-riding."

A key means of promoting compliance will be to ensure that commitments are realistic and achievable (as noted above). In addition, it will be important to consider supplementary means for promoting compliance, including ways to ascertain whether Parties are meeting their obligations and ways to encourage them to do so. In this context, we will need to consider elaborating existing reporting and review mechanisms.

Unless otherwise provided, an amendment to the Convention would be covered by the Convention's reporting requirements, as well as dispute settlement provisions and any multilateral consultative process that might be established. A protocol would need to specify whether any of these Convention mechanisms would apply, as well as any additional compliance-related provisions.

Decision-Making

Only the Parties to the protocol or amendment should have decision-making authority with respect to that instrument.

Final Clauses

A protocol would need to contain several final clauses, including, for example, provisions on entry into force and amendment. An amendment's final clauses are already set forth in the Convention.

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(FAX CONSIST OF 7 PAGES INCLUDING COVER SHEET)

**United States Department of State****Bureau of Oceans and International
Environmental and Scientific Affairs****Washington, D.C. 20520**

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MEMORANDUM

TO: Rosina Bierbaum
Alicia Munnell
Elgie Holstein
Lois Schiffer
Doug Hall
Mark Chupka
Charlie Rawls

OCT 16 1996

FROM: OES -Rafe Pomerance *RP*

SUBJECT: Submission Paper from the Climate Change Meeting with
Eileen Claussen on Tuesday, October 15.

The attached paper was handed out at the Climate Change Meeting on Tuesday. Please read and provide me your comments by COB today, Wednesday, October 16. I can be reached at 647-2232 or fax me your comments at 647-0217. Thank you.

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-3-

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Emissions Trading/Joint Implementation

In the U.S. view, emissions trading/joint implementation will be an essential element of the Kyoto agreement; it will therefore be a priority task to establish the guidelines for a credible emissions trading/joint implementation regime by December 1997.

Various design questions will need to be resolved by the Kyoto Conference, including, for example, whether inter-gas trading will be allowed; how trades would most effectively be monitored and reviewed; what distinctions might be drawn with respect to participation in an emissions trading/joint implementation regime (e.g., absent national targets, could project-specific baselines be used?)

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A number of principles must underlie an emissions trading/joint implementation regime. Such a regime must be efficient, transparent and verifiable and must produce real reductions. A preliminary elaboration of these principles should already be possible; in the U.S. view, the regime should:

- allow parties to trade or exchange credits toward and against national greenhouse gas reduction or limitation commitments;
- ensure that emissions reductions are created by actions that verifiably and reliably reduce accrued, net emissions beyond those which would occur without the system;
- minimize costs, especially transaction and administrative costs;
- motivate parties to achieve and strengthen national commitments to reduce or limit greenhouse gas emissions;
- motivate economic actors to find and implement on a continuous basis cost-effective greenhouse gas emission reductions;
- be as flexible as possible to accommodate differing national approaches to achieving emissions commitments;
- promote compatibility among national approaches to facilitate trading/exchanging credits
- be as inclusive of Parties, sub-national entities, gases and sectors as possible;
- ensure transparency through stringent monitoring, record-keeping and reporting;
- provide incentives for compliance -- and mechanisms to limit the benefit accorded to non-compliant Parties, and to ensure that non-compliance does not adversely affect environmental progress under the agreement.

Institutions

For reasons of administrative efficiency and in light of budgetary constraints, a new legal instrument should utilize existing institutions to the maximum extent practicable.

A protocol would need to specify its institutions. In the case of an amendment, the institutions established under the Convention would apply. (Note: We do not believe it would be appropriate for non-parties to the protocol to be officers of a body servicing the protocol.)

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Compliance

Ensuring effective compliance will be critical for environmental as well as economic reasons. Unless parties comply, actions taken are likely to be inadequate and global warming will continue unabated. Uneven compliance will undermine confidence in the Convention and encourage "free-riding."

The term "compliance" is used in this context to refer to the cluster of processes/mechanisms that provide incentives for the Parties to abide by their legal commitments.

In addition to promoting compliance by including commitments that are realistic and verifiable (as noted above), the instrument should provide supplementary means, for example, with respect to ascertaining whether Parties are meeting their obligations and with respect to appropriate consequences for non-compliance.

An amendment to the Convention would be covered by the Convention's reporting requirements, as well as dispute settlement provisions and multilateral consultative process, once established. A protocol would need to specify whether any of these Convention mechanisms would apply, as well as any additional compliance-related provisions.

Decision-Making

Only the Parties to the protocol or amendment should have decision-making authority with respect to that instrument.

Final Clauses

A protocol would need to contain several final clauses, including, for example, provisions on entry into force and amendment. An amendment's final clauses are already set forth in the Convention.

U.S. Submission on
Elements of a New Legal Instrument
(October 21, 1996)

General

In the U.S. view, the new legal instrument should respond effectively to the serious threat posed by global climate change; should reflect outcomes that are real and achievable; should be consistent with economic prosperity; should allow for maximum flexibility and cost-effectiveness in its implementation; and should lay the foundation for continuing progress by all countries.

Meeting the ultimate objective of the Convention will require concerted, long-term efforts by all Parties. While it is important for developed countries to take the lead, it is also essential that the Kyoto agreement recognize the growing contribution of developing country emissions and begin to plan for appropriate, cost-effective ways to address these emissions in a sustainable manner. In this connection, at COP-2 the United States called for continued work toward a longer-term concentration goal (e.g. for the next 50-100 years), recognizing that scientific understanding and technology will improve over time.

In putting forward these suggestions for a new legal instrument, the United States has rejected proposals by some countries calling for short-term targets that we believe are neither realistic nor achievable. We have also rejected the use of inflexible, internationally harmonized policies and measures. In the spirit of providing individual countries greater flexibility in meeting any agreed upon limitations, we believe that it is critical that flexibility in implementation be accorded all countries, including through emissions trading and joint implementation among nations.

We believe that the following elements would serve as a useful basis for the consideration of topics that would need to be included in a new legal instrument. Given the continuing uncertainties surrounding the form of such an instrument, we have noted particular aspects of these issues that may differ depending on whether the Parties choose a protocol or an amendment to the Convention to codify their agreement.

Preamble

If the legal instrument takes the form of a protocol, it might include a preamble. If it takes the form of an amendment, it would not, although the decision adopting the amendment could.

Definitions

A protocol would need to incorporate some or all of the definitions in Article 1 of the Convention, include its own definitions, or some combination of the two. An amendment, to the extent it introduces new terms, might also require amendment of Article 1.

Objective

We do not believe that it is either necessary or desirable to develop a separate objective for this legal instrument, whether an amendment or a protocol. The Convention's Article 2 would apply to an amendment. A protocol should incorporate Article 2 of the Convention.

Level and Structure of the Target

The Geneva Declaration calls for quantified, legally-binding objectives within specified timeframes. This is consistent with the U.S. call at COP-2 for a shift in the negotiations away from unrealistic, near-term proposals to legally-binding, medium-term targets that are both realistic and achievable.

A number of ideas and approaches regarding the structure of the target have been suggested thus far in the discussions within the Ad Hoc Group on the Berlin Mandate (AGBM). Many of these ideas and approaches have focused on a single-year target, but we believe it will be important to consider a broader range of possibilities (e.g., cumulative or aggregate targets covering a number of years, multiple-year rolling average targets, flexibility over time through banking and borrowing, etc.) We anticipate that more such ideas and approaches will be tabled and considered as we work toward a new legal instrument for adoption at COP-3.

The Berlin Mandate calls for adoption of the protocol/other legal instrument at COP-3, making calls to date for differentiated commitments in this timeframe impracticable.

In addition to being realistic and achievable, it will be important that the target/timetable be sufficiently specific (to facilitate compliance), flexible in terms of its implementation (to encourage cost-effectiveness and broad participation) and straight-forward (to ensure negotiation and adoption by COP-3). As we noted at COP-2, as a general proposition, the United States opposes mandatory, harmonized policies and measures. However, we are open to the possibility of exploring consensus on agreed procedural measures, for example, those that might be necessary to implement an international trading regime or ensure enhanced reporting.

The United States is continuing its domestic analysis and assessment efforts so as to contribute to this discussion in upcoming negotiating sessions.

Advancing Article 4.1 Commitments

"Continuing to advance the implementation of Article 4.1 commitments" will be a critical component of next steps and must be reflected in the Kyoto agreement. Given the global nature of this problem, we must work together toward a global solution, recognizing our common but differentiated responsibilities and capabilities. A number of assumptions underlie U.S. views on next steps:

- Article 4.1:
 - applies to all Parties;
 - speaks to commitments ranging from inventories of emissions, to reporting, to adopting measures to mitigate climate change;
 - speaks to the requirement to promote the development and diffusion of technologies;
- The Convention anticipates that the status of countries will evolve over time (e.g., Article 4.2(f))
- Paragraph 2.b of the Berlin Mandate governs what will be included on this issue in the Kyoto agreement

Bearing in mind these assumptions, there are a number of approaches that can be taken through a new legal instrument. For example, the Parties could agree to:

- continued and more systematic support for efforts to develop national action plans (particularly in developing countries) following the revised Annex I Guidelines for National Communications and the newly adopted Non-Annex I Guidelines for Initial Communications

- redoubled efforts to adopt and implement "no-regrets" measures
- expanded programs aimed at developing, diffusing and deploying climate-friendly technologies (including through systematic efforts to identify and remove barriers to technology diffusion and to enhance the role of international financial institutions in responding to the threat of global climate change)
- further consideration of thresholds at which the status of countries would change, and the process involved in such a change in status
- further consideration of future steps (post-Kyoto) toward the objective of the Convention

International Emissions Trading and Joint Implementation

In the U.S. view, flexibility will be an essential element of the Kyoto agreement, including international emissions trading and joint implementation; it will therefore be a priority task to establish the guidelines for a credible emissions trading and joint implementation regime by December 1997.

Properly designed emissions trading and joint implementation regimes will motivate parties to achieve and strengthen national commitments to limit or reduce greenhouse gas emissions, because the cost savings potential in these types of programs can achieve more environmental protection than less flexible, less cost-effective regimes.

A number of principles must underlie an emissions trading and joint implementation regime. At a minimum, such a regime must be credible, efficient, transparent and verifiable.

Various design questions need to be addressed, and we intend to present our further thinking in this regard in the near future.

Institutions

For reasons of administrative efficiency and in light of budgetary constraints, a new legal instrument should utilize existing institutions to the maximum extent practicable.

A protocol would need to specify its institutions. In the case of an amendment, the institutions established under the Convention would apply. (Note: We do not believe it would be appropriate for non-Parties to a protocol to be officers of an institution serving the protocol.)

Compliance

The term "compliance" is used in this context to refer to the cluster of processes/mechanisms that provide incentives for the Parties to abide by their legal commitments.

Ensuring effective compliance will be critical for environmental as well as economic competitiveness reasons. Unless Parties comply, there will be little incentive for each Party to act and we will not achieve our environmental objectives. Uneven compliance will undermine confidence in the new legal instrument and encourage "free-riding."

A key means of promoting compliance will be to ensure that commitments are realistic and achievable (as noted above). In addition, it will be important to consider supplementary means for promoting compliance, including ways to ascertain whether Parties are meeting their obligations. In this context, we will need to consider elaborating existing reporting and review mechanisms.

Unless otherwise provided, an amendment to the Convention would be covered by the Convention's reporting requirements, as well as dispute settlement provisions and any multilateral consultative process that might be established. A protocol would need to specify whether any of these Convention mechanisms would apply, as well as any additional compliance-related provisions.

Decision-Making

Only the Parties to the protocol or amendment should have decision-making authority with respect to that instrument.

Final Clauses

A protocol would need to contain several final clauses, including, for example, provisions on entry into force and amendment. An amendment's final clauses are already set forth in the Convention.

October 1996

A Treaty on Global Climate Change: Problems and Prospects

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The Framework Convention on Climate Change signed in 1992 in Rio de Janeiro drew wide international attention to the potential for global climate change -- most particularly, a gradually global warming -- as a result of collective human activities, and committed signatory governments to do something about it, without however committing them to specific actions. Since then governments of most rich countries have undertaken to reduce their levels of carbon dioxide emissions to the levels estimated to have taken place in 1990, within the relatively near but unspecified future. They committed themselves in 1995 to agree at Kyoto in 1997 on emission targets beyond the year 2000.

Actions actually taken to reduce emissions of greenhouse gas (carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons) have not matched stated intentions. A slowdown in emissions of CFCs has occurred as a result of the Montreal Protocol of 1987 to protect the layer of stratospheric ozone; and a slowdown in the growth of carbon dioxide emissions has occurred because of lower-than-expected economic growth since 1992 in Europe, Japan, and the former Soviet Union. On one projection, nonetheless, energy-related carbon dioxide emissions will grow by 30 percent between 1990 and 2010.¹

This paper will address the structure of the task in reducing greenhouse gas emissions by formal treaty among the world's states, the major characteristics of such a treaty, the problems of ensuring compliance with any agreement that is reached, and the prospects of reaching an agreement in the next decade on the basis of current knowledge. It will as appropriate draw on the characteristics of and experience with other multinational regulatory treaties, of which there are several hundred.²

Structure of the Task

It is useful to identify the structural characteristics involved in attempting to mitigate global warming through formal collective action. There are three key features:

First, climate change brought about through an increased atmospheric concentration of greenhouse gases is a global issue, since whatever their origin the gases are widely dispersed in the upper atmosphere. Effective restraint must therefore involve all (actual and prospective) major emitters of greenhouse gases. Today's rich industrialized countries (taken to be the 24 members of the Organization of Economic Cooperation and Development in 1994) account for most of the emissions today, but the Soviet Union was a major contributor before its dissolution and economic

collapse in 1991, and can be expected to become a major source with economic recovery; and rapidly growing developing countries will become major contributors within a time frame that is relevant for managing the issue. By 2010 developing countries are expected to contribute 45 percent of total greenhouse gas emissions, and China and India alone will experience greater growth in emissions than all OECD countries combined. Thus effective action cannot be taken by a small group of countries alone, as was possible with the agreement to cease atmospheric testing of nuclear weapons. Here, while the same requirements need not be imposed on all countries from the beginning, the agreement needs to be structured so that all countries need to participate after certain conditions have been met.

Second, the rewards from restraints on greenhouse gas emissions will come in the (politically) distant future, while the costs will occur in the political present. Moreover, the rewards are highly uncertain. Much controversy still surrounds the expected impact of further greenhouse gas emission on the earth's ecological system, and in particular on conditions of habitability for humans. Moreover, the residents of some of today's states, e.g. Canada or Russia, may even expect to benefit from the indicated climate change. It will thus be difficult to persuade

publics that they should make sacrifices in level or growth of living standards today for the sake of uncertain gains to their grandchildren and great-grandchildren. The wide distribution of expected but distant benefits in response to collective action today provides an incentive for every country to encourage all to act, but then to shirk acting itself -- the so-called free-rider problem.

Third, the pervasive sources of greenhouse gas emissions -- notably use of fossil fuels, wetland cultivation, and raising cattle -- imply that restraint will involve changes in behavior by hundreds of millions if not billions of people, and not merely the actions (or restraint in action) by at most 180 governments, as in the typical treaty. Thus the most important part of an effective regime to limit climate change involves not the relationships among states, but the effective influence of governments on their domestic publics.

No major legally binding regulatory treaty involves all of these characteristics to the same degree. Typically either governments themselves are the major actors, or a relatively few firms in a relatively few countries. The Convention on International Trade in Endangered Species (CITES) perhaps comes closest in its comprehensiveness; it requires states to prohibit

international trade in the agreed products. The Chemical Warfare Convention is extremely intrusive in its monitoring requirements, but has not yet been ratified. The various agreements for management of international fisheries require cooperation of hundreds of fishermen, but with a few exceptions they have not been notably successful to date.

Characteristics of an Effective Treaty on Climate Change

What is the substance of a treaty to restrain the emission of greenhouse gases? The first, and currently preferred, approach is to impose agreed national targets on emissions, possibly permitting some of the allowed emissions to be transferred from one state party to another, a feature that would significantly reduce the costs of a given reduction in emissions. A second approach that has received less emphasis would reach agreement on a set of actions that state parties would agree to undertake, with a view to reducing emissions. In my view, mutually agreed actions have better prospects of success than national targets.

National Targets. If targets are to be set, on what basis should they be set? When quantitative targets are imposed within countries they almost universally respect recent history, being allocated roughly in proportion to recent use (e.g. emission of

pollutants or fish catch). Targets based on emissions in a fixed base year such as 1990 have a similar character. Targets allocated on this basis will be completely unacceptable, however, to countries that are or expect to be industrializing rapidly, with disproportionately rapid growth in demand for fossil fuels. They will argue that most of the existing stock of greenhouse gases generated by humans were emitted by today's rich countries, and that those countries should therefore bear a disproportionate responsibility for cutting back. Thus developing countries did not commit themselves to reduce emissions at Rio, and within Europe Spain and Greece have expressed similar reservations.

At the other extreme, some observers have suggested that simple distributive justice would require that emissions targets be based on population. Such an allocation would favor heavily populated poor countries such as China, India, Indonesia, Bangladesh, and Nigeria. To be meaningful in limiting climate change they would require drastic cutbacks in emissions by today's rich countries, implying a radical change in living conditions there. Such change could be mitigated by sale of unused emission rights from poor countries to the rich countries. But the financial transfers involved would be immense relative to foreign assistance today, far more than is likely to be tolerable. In any

case, the transfers in practice would be made to governments, despite the underlying moral rationale for basing targets on population, and many these days would question the desirability of transferring large sums to governments whose responsiveness to the needs of their own citizens has been indifferent or worse (think of contemporary Iraq or Nigeria).

A natural compromise has been suggested: base the national targets on GDP (or recent past emissions) initially, and gradually convert them to targets based on population over, say, 25 years, to avoid the wrenching impact on life styles in the rich countries and the implausibly large transfers to governments of developing countries. Here, however, we encounter some unpleasant arithmetic with respect to population-based emission rights. In 1994 India's per capita income (on a purchasing power basis) was about 5.3 percent that in the United States. Suppose that per capita income in India grows at 5 percent a year over the next 25 years, and per capita income in the United States grows at 1 percent a year (this is a plausible scenario, although in reality the gap in growth rates is not likely to be so wide). Under those assumptions, Indian per capita income 25 years later (in 2019) would still equal only 14 percent of per capita income in the United States, and consumption of energy would be many times higher in the United

States than in India, even if the ratio were not so high as seven to one. Thus under national emission targets converging on population after 25 years either India would not be effectively constrained or the United States would be very tightly constrained or (under tradable emission permits) there would be huge transfers from the United States and to India. The sense of global community is not likely to be great enough by 2019 to sustain such large transfers -- it is not that great within the United States today -- and in any case such large transfers either to governments or directly to citizens, by fostering a rentier mentality, would probably not be desirable, as some of the high oil-dependent countries have discovered.

Perhaps the most reasonable basis for allocating emission rights and the obligation to reduce emissions would be to calculate a "business-as-usual" trajectory of emissions for each country on the basis of recent history, development prospects, and past experience with the evolution of greenhouse gas emissions in relation to economic development. Then each country could be charged with reducing emissions by a uniform percentage, chosen in relation to some measure of global reduction requirements, relative to the assigned trajectory. But of course even if this principle of allocation of rights and responsibilities were

accepted as reasonable, the debate would simply shift to the choice of trajectories for each country.

Implementation. Once national targets have been established, they must be translated into conditions that induce firms and households to change their consumption patterns away from activities that emit greenhouse gases. For large firms, e.g. generators of electricity, that could perhaps be done by fiat, that is by setting quantitative limits for each generating plant.

But for most economic agents the only practical way to alter behavior is to create price disincentives, that is, to tax the activities that generate the emissions. As noted above, a treaty to inhibit greenhouse gas emissions differs fundamentally from one which requires governments to act in a particular way, or proscribes governments from acting in a particular way. In this respect a treaty on greenhouse gas emissions differs from most treaties, although it would be similar to other treaties governing pollution of various kinds, and those governing the harvesting of the biosphere, especially fish.

Every international agreement must address the question of compliance, to be discussed below, and the associated question of monitoring behavior to discover if it deviates from the treaty requirements. In principle, given the objective, all significant

greenhouse gases should be covered. In practice, given the many actors involved and the many sources of emissions, such broad coverage would be impossible to monitor and police. For practical reasons, therefore, attention is usually focused on fossil fuel consumption (plus a few other concentrated emitting activities, such as cement production). Monitoring the consumption of fossil fuels is more or less manageable, since most of it must pass through some relatively narrow choke points, e.g. gas pipelines, oil refineries, electricity generating stations. Most coal production can be monitored at mine-head or on the barges and railroads that transport it.

But this still leaves out a lot of greenhouse gas emissions. Only about half of the greenhouse gas emissions (measured by radiative forcing, which is what is relevant for climate change) since 1850 came from the burning of fossil fuels.³ Important contributions have also been made by changes in tropical land use (e.g. burning tropical forests), fuel wood, livestock and rice cultivation, town dumps, and gas pipeline losses. Omitting these sources from a regime based on national targets thus would represent a significant shortfall in coverage, but it is probably necessary on practical grounds because most changes in emissions from these sources could not be easily monitored. Their omission

would probably create a bias in the regime in favor of developing countries.

If the fossil fuel carbon emission targets for rich countries are demanding, how are they to be met? Conceptually, there are four ways: 1) greater efficiency at converting fossil fuels to usable energy in existing plant; 2) switching fuels from high to low carbon per unit of energy (basically, from coal to natural gas); 3) building new plant and machinery that uses less carbon per unit of usable energy (e.g. nuclear power plants); and 4) reducing end-user demand for energy. Unfortunately, there is little scope for further change at the easiest monitoring points.

Obsolete generating plants can be replaced with more efficient or less carbon dependent ones, but replacement demand in the OECD will be modest over the next 20 years, and to replace faster than required by obsolescence becomes extremely expensive. In developing countries the demand for electric power is rising rapidly, by 300 percent between 1990 and 2010, vs. 20 percent in OECD, so most of the 2010 generating capacity in those countries 2010 could in principle be designed to use low carbon-dependent technology.

The consequence is that most of the reduction in the rich countries must come from downstream, at or near the points of

final demand, where the number of consumers is greatest. Quantitative rationing is neither desirable nor feasible at this point in market economies, so the reductions must be achieved by some combination of price (dis)incentives and exhortation through publicity and education on best practice. Many consumers are not aware of the ways they can conserve energy without radical changes in life style. But in either case, as noted above, the key to success is not at the inter-governmental treaty level, but rather in the incentives each government can provide to its own citizens. The treaty merely provides a vehicle for rough "burden-sharing" across countries and some international discipline in pursuit of the targets.

Agreed Actions. There is an important alternative to setting national emission targets. That is to agree internationally on a set of actions, of course calibrated to achieve the desired emissions (ultimately, as stated at Rio, set to stabilize the atmospheric concentration of greenhouse gases, an objective that is too radical for specification in the near future). Since to accomplish their quantitative objectives governments must in any case create the appropriate behavior-altering incentives for their citizens, and since as we have seen setting a national allocation of global emission rights is likely to prove so contentious as to

be impossible, it may be far easier simply to agree on a common use of instruments. For problems such as reducing emissions, the favorite instrument of economists is to tax the offending activity. All countries would agree to impose a common carbon tax, which would increase the price of fossil fuels in proportion to their carbon content (with possible tax exemptions for uses that do not produce carbon dioxide, such as production of some plastics). Such a tax would have at least two major advantages. First, it would encourage reduction of emissions to take place where that can be done at least cost, since all emitters would have the same incentive to reduce emissions, but only those who saved more in tax payments than it cost to reduce emissions would undertake reductions; others would simply pay the tax. It would provide encouragement everywhere for fuel switching toward natural gas (with benefits accruing mainly to Russia and Iran, the countries with the largest known gas reserves) and more importantly to conserve generally on the use of fossil fuels.

Second, it would generate revenues for governments that have trouble finding sources of revenue that do not have negative effects on economic incentives to work, save, or undertake commercial risks. That should make it attractive to finance ministries everywhere. Where the revenues are large, as they

eventually would be, the new tax should be phased in gradually, and growth can be encouraged by reducing other taxes, e.g. those on foreign trade or on earnings. Taxes on fossil fuels would of course have some undesirable effects, such as delaying the switch from fuel wood to fossil fuels in poor countries. But it would be impractical in most cases to tax fuel wood.

In principle, it would be possible to extend the idea of a common carbon tax to methane as well, covering wetland rice production, decomposable refuse, gas pipeline losses, and cattle raising, but that more difficult step could perhaps wait until a later stage.

The imposition of a common carbon tax would be easy to monitor. Enforcement of the tax would be more difficult to monitor, but all important countries except Cuba and North Korea hold annual consultations with the International Monetary Fund on their macroeconomic policies, including the overall level and composition of their tax revenues. The IMF could by agreement provide reports to the monitoring agent of the treaty governing greenhouse gas emissions. Such reports could if necessary be supplemented by international inspection both of the major tax payers (e.g. electric utilities) and the tax agencies of participating countries.

Imposition of taxes by international agreement imposes a major problem for democratic countries, however, since taxation goes to the heart of parliamentary prerogative, and most will not welcome taxation by international agreement, even with the requirement for parliamentary ratification.

Moreover, as 1993 experience in the United States with a btu-based energy tax illustrates, even modest energy taxes are at present politically unpopular. The European Commission proposed a somewhat more ambitious tax for energy, rising to the equivalent of about \$10 a barrel (roughly 50 percent) of oil by 2000. That tax has yet to be enacted. Moreover, the proposal paradoxically but not surprisingly gave special preference to coal (which is produced at high cost in a number of EC countries), the most carbon-intensive of the fossil fuels, and would also levy a tax on nuclear power, the least carbon-intensive major source of energy.

Two additional possible problems need to be mentioned, neither insuperable.⁴ The first concerns the fact that energy (especially oil) is taxed differentially among countries in the mid 1990s, and some countries continue to price both coal and oil well below world levels. Should a uniform tax be levied on an uneven initial condition? Ideally not, but if existing pricing practices are taken to reflect existing national preferences with

respect to how best to use each country's authority over the allocation of resources, a case can be made that the new carbon tax should be uniform, not the total tax burden on fuels. Of course, national policies would have to be monitored to assure that the effect of the new tax was not undermined by other changes in tax or subsidy policy.⁵

The second possible problem concerns the disposition of revenue. Such estimates as we have suggest that to have a significant impact on emissions the tax might have to be substantial (more on this below). A substantial tax on a major input to modern economies would generate much revenue. To whom should it accrue? Oil-producers will suggest that if oil is to be taxed, they should levy it and get the revenue -- indeed, that is what OPEC's attempts to control oil prices amount to.⁶ Oil-consuming countries, however, would feel doubly aggrieved if they must charge more for oil to discourage its consumption yet they do not get the revenue; they will insist that the tax be levied on consumption and accrue to them, not least so that they may reduce other taxes to assure their continued prosperity and growth. In practice, that view is likely to prevail.

There is, however, a third possible claimant for the revenue: the international community. The international community has

accepted a number of collective obligations that are cumulatively expensive. Caring for refugees and peacekeeping are only the most apparent. Refugees alone cost the United Nations \$1.3 billion in 1995, and peacekeeping operations also cost around \$1.3 billion. Special assessments are now made for these activities, and several countries, including Russia and the United States, are in arrears.

The regular UN budget runs at \$1.2 billion a year. In addition, donor countries finance UNDP and IDA (at about \$5 billion a year) for economic assistance to the poorest developing countries. The Rio Convention conditions cooperation by developing countries in reducing emissions on new financial support from the rich countries. Some or all of these activities could be financed in part from revenues from an internationally-agreed tax levied by all countries in pursuit of a common objective; obviously the major emitters, currently the rich countries, would pay most of the tax. But as poor countries develop, their contribution would increase automatically, an attractive feature of such an arrangement. These collective needs, while substantial, are nonetheless modest in terms of the total revenue likely to be available from an effective carbon tax.

Estimates from several global energy-environment models suggest that a uniform reduction in carbon emissions from a

"business-as-usual" baseline for each country or region would require very different carbon tax rates if that were the policy instrument used to reduce emissions. That result suggests that a uniform tax rate across the regions studied would result in quite different reductions from the baseline -- as one would expect from the observation that countries around the world use energy with very different degrees of efficiency. Table 1 reports the carbon tax (in \$1990 a ton) that would be required in five regions in the year 2050 to reduce carbon emissions by two percent per year from the baseline trajectory. Since the baseline trajectories project an increase in energy-related carbon emissions from roughly 6 billion tons a year in 1990 to 11 to 19 billion tons in 2050, the two percent a year reduction would leave emissions that ranged between 3.3 and 5.7 billion tons in 2050, i.e. below the levels of 1990.

Two points are noteworthy about Table 1. First, there are large differences among the columns (each reporting a different study), reflecting different assumptions about baseline trajectories, inter-energy and factor substitution possibilities, energy-saving technical change, and the presence or not of a non-carbon-emitting backstop source of energy. So at this stage there

is little agreement on the costs of reducing emissions by an agreed amount.

Second, in each of the studies there are substantial variations in the required carbon tax across the rows, that is, from region to region, reflecting markedly different opportunities for reduction of carbon emissions. That suggests that global economic efficiency calls for diverse responses across regions, keyed to a common "shadow price" for emissions of carbon (full efficiency would impose analogous charges on production of methane -- e.g. from rice and cattle -- and other greenhouse gases, which are not included in the studies reported here). Countries that cut more would of course pay less tax.

By 2050 the world price (in 1990 dollars) of oil, 56 percent carbon by weight, is assumed to be \$50 a barrel, two and half times the current price; the price of coal, 75 percent carbon by weight, is assumed to be \$60 a ton, about 50 percent above the current price at points of importation. Thus a tax of \$208 per ton of carbon in 2050 would represent a 31 percent tax on oil at that time, and a 260 percent tax on coal. The loss in GDP engendered by this emission reduction program ranges (across the studies) from 1.3 percent to 4.9 percent in 2050 for the United States, from 2.3 to 6.4 percent for the former Soviet Union, and

from 2.1 to 5.1 percent for the rest of the world (today's developing countries, minus China) (Dean and Hoeller, 1993, p.157). These results must be regarded as merely exploratory rather than definitive, but even the low estimates suggest a substantial cost to bringing energy-related CO₂ emissions below 1990 levels. As noted above, permitting trades among regions -- a uniform carbon tax achieves a similar result -- would reduce these costs significantly, but would still leave them substantial.

The revenue these taxes would raise is also substantial. For instance, a \$208 per ton carbon tax in the United States would raise nearly \$300 billion in revenue, 1.8 percent of 2050 GDP. A \$329 per ton carbon tax in the rest of the world would raise \$610 billion in 2050, nearly 3.2 percent of rest-of-world GDP in that year.

Compliance

A major concern with all regulatory treaties concerns how to assure compliance. Parties are sovereign states, and there is no over-arching disciplinarian, as there is (in principle) within countries. This suggests the possible use of fines (currently being contemplated within the European Union for violations of the fiscal stabilization pact) or economic sanctions (limited trade

sanctions are foreshadowed in the Montreal Protocol on ozone depletion). But Chayes and Chayes (1995) have made a persuasive case that neither in fact nor in theory need treaty law rely predominantly on sanctions, and indeed that in many cases they are counter-productive. They conclude that most actual or apparent deviations from treaty provisions arise from ambiguity and indeterminacy of treaty language, from limitations on the capacity of governments to carry out their undertakings, or from major changes in circumstance from those prevailing at the time of treaty ratification. Deliberate violation of treaties is rare, and when it occurs on important issues (e.g. the non-proliferation treaty) major participants exert extreme pressure outside the treaty for resumption of compliance, as can be noted with the violation of the NPT by Iraq and the threatened withdrawal by North Korea.

The key factors in assurance of compliance is commitment to the treaty objectives by the signatories plus a high degree of transparency in their actions. Many regulatory agreements have the potential problem of "free riders;" countries are more likely to adhere to the provisions if other governments are seen to be adhering to the provisions, so a regular system for monitoring and

reporting on the activities and actions covered by the treaty is very important.

These days the very legitimacy of many governments arises from their responsibility for international relations and their integration into the community of nations. "...modern states are bound in a tightly woven fabric of international agreements, organizations, and institutions that shape their relations with each other and penetrate deeply into their internal economics and politics. The integrity and reliability of this system are of overriding importance for most states, most of the time. [Even the largest and most powerful states] cannot achieve their principal purposes...without the help and cooperation of many other participants in the system, including entities that are not states at all. Smaller and poorer states are almost entirely dependent on the international economic and political system for nearly everything they need to maintain themselves as functioning societies." (Chayes and Chayes, 1995, pp. 26-27) External and increasingly domestic pressure will usually keep governments from flouting internationally agreed behavior.

Prospects

Developing countries are not likely to constrain their economic growth, hence their demand for energy, for the sake of environmental improvement. Furthermore, they will argue with some plausibility that apart from local air and water pollution the contribution to global environmental degradation is made overwhelmingly by the rich countries, with significant help from the former centrally planned economies. This position is largely correct with respect to present and past conditions, and the fact that the relative contributions can change markedly with successful economic development is a matter that they are likely to be willing to take into consideration only after that development has actually occurred.

The bottom line is that many developing countries will cooperate with developed countries in reducing the emission of greenhouse gases into the atmosphere so long as it does not require great commitment on their part (e.g. in terms of domestic political conflict) and so long as the developed countries incur the extra costs associated with that cooperation, a position that was taken at the Rio conference.

For these reasons, the international negotiating environment for mitigation actions is likely to be very complicated, to say the least. One strategy is for the OECD countries to take on the

assignment among themselves, in the hope that developing countries will later join the consensus actions after their incomes and their fossil fuel consumption have risen considerably. This strategy does not exclude actions within developing countries, provided the OECD countries are willing to pay for it, e.g. through World Bank loans that take climate change considerations into their design.

The problem with this strategy is that there seems to be no right time for a country to graduate from developing to developed status, especially if it is costly, as we have seen in resistance to being graduated from eligibility for highly concessional IDA loans or from tariff preferences under the Generalized System of Preferences. Yet as we have seen the participation by the larger and more successful developing countries is critical for minimizing climate change.

I conclude that an effective treaty cannot be based on the allocation of emission rights, since there will be no generally agreed principle for allocation. Rather, if the international community is to organize itself at all for the significant mitigation of greenhouse warming it is much more likely to be on the basis of mutually agreed actions, such as the imposition of a more-or-less uniform carbon tax on the use of fossil fuels.

International cooperation in other fields has progressed most successfully when there was agreement not only on the objective, but also on how best to achieve it. As the prolonged and sometimes acrimonious history leading to international cooperation in containment of contagious diseases suggests, absence of scientific consensus on key aspects of how greenhouse gas emissions translate into global temperature changes, and on how those temperature changes in turn affect the human condition, will make difficult agreement on how to share costly actions, or indeed on what actions should be taken (Cooper, 1989). Large differences in assessments of the costs of mitigating action will simply magnify the difficulties.

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Endnotes

- ¹. The GEM model, cited by Martin et al. (1996), p.89.
- ². For a list of 138 treaties and their major protocols, see Chayes and Chayes (1995), pp. 287-301.
- ³. Calculated from data provided in Climate Change 1995, pp.18-22.
- ⁴. The following paragraphs draw on Cooper (1994)
- ⁵. Anderson in Anderson and Blackhurst (1992) points out that simply removing the subsidies and price controls that now exist for use of coal in many countries would simultaneously increase trade and improve air quality -- as well as reducing greenhouse gas emissions -- by raising the world price of coal.
- ⁶. Indeed, the Rio Convention enjoins its Parties to "take into consideration" in implementing their policies the adverse effects on developing countries that are highly dependent on production and export of fossil fuels, among others (Art.4.10).

References

Anderson, Kym, and Richard Blackhurst, eds., The Greening of World Trade Issues, London: Harvester Wheatsheaf, 1992.

Chayes, Abram, and Antonia Handler Chayes, The New Sovereignty: Compliance with International Regulatory Agreements, Cambridge: Harvard University Press, 1995.

Chayes, Abram, and Antonia Handler Chayes, "Adjustment and Compliance Processes in International Regulatory Regimes," in Jessica T. Mathews, ed., Preserving the Global Environment, Norton, 1991.

Climate Change 1995: the Science of Climate Change, Working Group I contribution to the Second Assessment Report of the Intergovernmental Panel on Climate Change, 1996.

Cooper, Richard N., Barry Eichengreen, Gerald Holtham, Robert D. Putnam, and C. Randall Henning, Can Nations Agree?, Washington: Brookings Institution, 1989.

Cooper, Richard N., Environment and Resources Policies for the World Economy, Washington: Brookings Institution, 1994.

Dean, Andrew, and Peter Hoeller, eds., The Costs of Cutting Carbon Emissions, Paris: OECD, 1993.

Martin, William F., Ryukichi Imai, and Helga Steeg, Maintaining Energy Security in a Global Context, New York: Trilateral Commission, 1996.

Ramakrishna, Kilaparti, "Building an Effective Climate Regime," in Oran R. Young et al, eds., Global Environmental Change and International Governance, Hanover, NH: University Press of New England, 1996.

Sand, Peter H., "International Cooperation: the Environmental Experience," in Jessica T. Mathews, ed. Preserving the Global Environment, Norton, 1991. [an excellent summary of rule-making and implementation in many, especially environmental, international agreements]

Skolnikoff, Eugene B., "Implementation Strategies, Mechanisms, and Institutions," in Brian P. Flannery and Robin Clarke, eds., Global Climate Change, London: IPIECA, 1991.

Table 1

Tax Required by 2050 to Achieve a Two Percent per Year
Reduction in Carbon Emissions from Baseline
(\$1990 per ton of carbon)

Model Region	Edmonds/ Reilly	Manne/ Richels	Green	Carbon Rights Trade Mode
USA	1096	208	340	754
Other OECD	734	208	299	365
FSU	325	990	180	2245
China	341	240	67	1109
ROW	1012	727	329	763

Source: Dean and Hoeller, 1993, p.153.