Tues, 6/20/95, 1.30p
Environment - climate change

From: Michael A. Toman (TOMAN_M)
To: STIGLITZ_J
Date: Monday, June 19, 1995 8:17 pm
Subject: climate change deputies mtg

McGinty, Gibbons, Wirth, Cutter, Claussen are meeting tomorrow (6/20) (Tues) at 1.30 to go over a number ofissues from a broader policy/politics/message prespective: CarTalk, New CAFE standards for trucks, the "gap" in meeting the existing 2000 goals for emission stabilization, budget, and the longer-term (post Berlin) issues. I would say that the last issue is the most important, though you may have some thoughts on the others. My understanding is that your schedule is pretty tough tomorrow PM. What do you want to do? If you don't want to go, do you want me to cover? What role should Sally play? I will leave some info with Lisa re: the meeting.

CC: BRANCH_L

[redacted]

ACMI

NATIONAL SECURITY COUNCIL
Global Environmental Affairs Directorate

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TO: Jack Gibbons
Tim Wirth
Katie McGinty
Bo Cutter
Joe Stiglitz

FROM: Eileen Claussen

DATE: June 19, 1995

No. of Pages 5 (including cover sheet)

CLIMATE CHANGE: NEXT STEPS NEGOTIATIONS

ISSUE:

What posture should the United States adopt with regard to forthcoming negotiations of a protocol under the climate convention?

ESSENTIAL FACTORS:

The United States agreed in Berlin to a negotiating process that will lead to a protocol/another legal instrument in 1997.

Since then, a number of items have become clearer. First, the gap between our commitment to return U.S. greenhouse gas emissions to 1990 levels by 2000 and results under current programs is about as large as the initial gap we faced two years ago when the action plan was developed (i.e., plus or minus 100 million metric tons), while our ability to close the gap has significantly diminished. Second, the 104th Congress has slashed FY 95 funding for our voluntary programs and will likely dismantle them altogether in FY 96. This could put us further behind by as much as 60-70 MMT. Third, the 104th Congress is likely to cut the Administration's funding request for the Global Environment Facility by more than 50 percent and our ability to support developing country efforts to deal with climate change will be seriously retarded in other areas as well. Fourth, the 104th Congress is threatening to e[illegible] funding for many global change research programs as well as funding for various U.N. activities related to climate change, including funding for the climate convention.

Under these circumstances, the Administration will be hard pressed to deliver on existing commitments, much less enter into a new round of negotiations aimed at further commitments in the post 2000 period.

Before embarking on these negotiations, we must consider carefully the options before us.

OPTION #1 - Withdraw

Indicate to our Annex I partners that we are not prepared to enter into negotiations on next steps at this time since we have no way of delivering on the kinds of commitments they will seek; lay the blame clearly on Congress.

OPTION #2 - Advance

Engage actively in negotiations of next steps because the threat to the global environment from climate change is simply too serious to ignore; be prepared to consider approaches such as caps/trading and coordinated fiscal instruments (e.g.

carbon/energy taxes), recognizing from the outset that Congress and many parts of industry will howl; either forward such a protocol to Congress for it to reject or defer transmitting it until a more receptive Congress emerges.

OPTION #3 - Muddle Through

Engage in negotiations but reject far-reaching commitments; seek to argue the Europeans back to reality and cajole the Congress/industry to support a modest result.

PROS AND CONS

Option #1

Pro:

- Accurately reflects current domestic situation in which Congress will not deliver on Administration commitments
- Avoids having the Administration slammed from left and right for the next two years
- Avoids downstream accusations of bad faith
- Lays blame for inaction where it belongs and could ultimately force a change in Congressional attitudes

Con:

- Totally inconsistent with Administration belief in the need for action to counter the serious climate change threat
- Allows Congress to dictate Administration policy
- Administration, not the Congress, might be blamed by U.S. NGOs and other governments
- Would destroy momentum of Berlin Mandate and cripple international efforts to deal with climate change

Option #2

Pro:

- Buys important time if the threat of climate change ultimately materializes as many fear and sends a clear signal to U.S. industry and the rest of the world

- Takes the moral "high road," clearly signalling the Administration's belief in the problem and resolve to deal with it seriously
- Would be warmly endorsed by environmental NGOs and other governments
- Would lay blame for any failure to act on the protocol negotiated clearly on Congress

Con:

- Would assure "holy war" between the Administration and Congress and invite further Congressional efforts to cut funding/programs and otherwise make political hay out of the climate issue
- Would likely alienate a large segment of the U.S. private sector
- Would open the Administration to charges of environmental extremism that might resonate with voters
- Could backfire on Administration if public chose to blame Admistration for going too far rather than Congress for not going far enough

Option #3

Pro:

- Avoids extreme decisions on climate change with their potential for serious political fallout
- Could take advantage of the known fears of some foreign governments and their private sectors with far-reaching actions and might avoid having the United States shoulder the entire blame for modest results
- Could enlist support from Congressional and industry moderates for important, but modest results
- Would be perceived as a sober approach and avoid public backlash against the Administration

Con:

- Would likely do little to advance meaningful solutions to the threat of climate change

- Risks criticism from the left (environmental NGOs and advanced European countries) for not doing enough and from the right (Congressional and industry conservatives) for going too far

- Provides no guarantee that ultimate agreements reached will reflect U.S. concerns and avoid anti-competitive results nor that Congress or the U.S. private sector will ultimately endorse the results

- Potentially subjects the Administration to two years of difficult negotiations and bad press when the Administration's ability to deliver is essentially controlled by Congress

DRAFT AGENDA FOR JUNE 20 CLIMATE CHANGE MEETING

I. Specific Items That Will Require Administration Decision in the Near Term

A. Car Talk -- Advisory group of stakeholders convened to recommend policy options to the President on returning greenhouse gases from transportation to 1990 levels. Group's charter ends in September. No consensus is emerging, and auto industry is inflexible in favoring fuel tax as primary policy. How hard does the Administration want to push this group, and particularly the auto industry, to come to a more workable proposal? Would high level Administration involvement with the industry make it more or less likely that consensus would emerge?

B. Light Truck Fuel Economy Standards -- DOT is required to set fuel economy standards for these vehicles (including jeeps and minivans) each year, and must issue a final rule for 1998 by March 1996. DOT has published an advance notice of rulemaking seeking comment on setting such standards with longer lead times (e.g., 1998-2006 set at one time) to allow the industry to meet higher standards. Notice of proposed rulemaking will come to White House for review soon. DOT presently plans to propose very small increase for 1998 and moderate increase through 2006. Auto industry will violently oppose longer term standard, and Administration has begun getting calls from Dingell, et al. Enviros will oppose long term standard as insufficient. What is White House position?

C. CCAP Report -- Administration promised to issue report in October on progress toward achieving 2000 goals of CCAP. Preliminary analysis indicates that CCAP if fully funded would fall about 60MMT short of goal. Certain Republican budget proposals, by failing to address the problem, would lead to a doubling of the original projections for necessary reductions. When should this info be released? Should it be used in budget battles with the Hill? How far can the October report go in proposing additional measures to close the gap?

D. Budget -- Some in House are attempting to zero out large portions of the climate change budget. How does this fit into the Administration's budget priorities? How public or aggressive should Administration be in trying to maintain that funding?

II. International Climate Change Issues -- See State/NSC memo.

ENVIRON - Climate Chg for 3pm meeting

From: Sally M. Kane (KANE_S)
To: Stiglitz_J
Date: Monday, May 8, 1995 12:46 pm
Subject: climate policy - needs attention now

The President asked Katie McGinty to move quickly on developing climate policy -- this happened last week.

So the climate change action plan report (due in October 1995) and the next round of negotiations (also October) need to coordinated.

Katie McGinty is already staffing up with detailees from EPA and will most likely run the entire climate policy process. We should try to insure that economic analysis is fully considered in the policy process.

One main area under discussion is the staffing and oversight of 1) government analysis and 2) techical outreach to the external community. Plans for long-term analyses have not been finalized.

We need to consider options for CEA involvement in the analysis of the analytic and assessment phase of negotiations.

Note: A paper on the substance of analysis for the negotiations and climate action plan review was developed at the staff level by CEA, OSTP, and DOE. (Abe Haspel, Rosina Bierbaum, me, and Mike Toman -- I drafted the piece). No office assignments or recommendations about staffing (inside or external were made).

see attached

CC: Branch_L

FYI - This mtg also includes Mike T.

May 4, 1995

David:

Here is a draft discussion of the assessment and analytic phase that reflects the thinking of a small group: Rosina Bierbaum, Abe Haspel, Mike Toman, and me. It hopefully provides a clear description of the analysis that we think should be undertaken and raises a few important issues, such as outreach to the technical community and WH/agency staffing, without making specific recommendations.

Sally

cc: R. Bierbaum
H. Gruenspecht
A. Haspel
M. Toman

Draft -- Close Hold

ASSESSMENT AND ANALYSIS PHASE

In thinking about the US' efforts in the analysis and assessment (A&A) phase of climate negotiations, it seems clear that several general topics will need to be addressed. The information generated will be useful in both the domestic and international analytic exercises, i.e. CCAP report and preparation for October's negotiating session. Three major categories of questions can be identified: 1) economic costs of different objectives (including stabilization), 2) the effects of unilateral (or regional) actions on concentrations and emission levels and 3) evaluation of policies and measures to reduce greenhouse gases. Additional information useful to the negotiating process includes refinement of estimates of the impacts of climate change.

- *WH/Agency Collaboration*: A mix of agency and WH staff can work to complete initial analyses of the three topics prior to the October negotiating session in Geneva (an alternative is to do a quick evaluation of only category three by October). Given its importance in meeting commitments made by the Administration, a true partnership among all staff offices and quick response by agencies is required. More detailed analyses can continue in each of the areas following the October meeting as needed. Organizational division of labor and oversight responsibilities will need to be assigned shortly, before work can proceed.

- *Outside Experts*: In general, expertise in industry, government, and academia and elsewhere will be useful in building agreement on technical issues, thereby helping to improve the chances for effective negotiations. Various on-going research efforts can be utilized to evaluate specific questions or provide technical review of prepared material. There are political and research benefits that would result from pursuing a serious effort that extends beyond the fall of 1995.

  Outside experts can be gathered to interact with government staff for a quick examination of issues relating to assumptions, methods, costs of policies and measures, and objectives in the pre- and post-2000 analyses. For example, in the pre-2000 analysis, external advice is needed to properly score voluntary measures.

  The nature of the interaction with non-government experts needs to considered early in the process, so participants know what is expected and a productive working relationship can be established. The balance of the technical group by affiliation/view and the overall objectives of the interactive process need to be evaluated carefully. The technical group would be formed separately from that of the stakeholder outreach group.

The Berlin mandate specified two major areas of negotiation under the "aim" of strengthening the commitments in Article 4.2 (a) and (b) of the Convention. The study areas

identified below correlate closely with the Berlin mandate. The mandate calls for negotiations on the following:

- *"to set quantified limitation and reduction objectives within specified time-frames, such as 2005, 2010, and 2020, ...* (see categories I and II below)

- *"to elaborate policies and measures, .."* (see category III below)

QUESTIONS FOR ANALYSIS AND ASSESSMENT

I. ECONOMIC COSTS TO THE US AND THE WORLD OF OBJECTIVES, INCLUDING STABILIZATION, OF ANNEX 1 OR GLOBAL EMISSIONS AT 1990 LEVELS BY THE YEAR 2005, 2010, AND 2020. SENSITIVITY ANALYSIS WOULD BE CONDUCTED AT LOWER AND HIGHER LEVELS OF EMISSIONS. THE ANALYSES WOULD BE DONE WITH AND WITHOUT JOINT IMPLEMENTATION.

Approach: Use macroeconomic models, such as the Oxford world economy model and/or the DRI world model. These models generate economic costs estimates and can be used to show the impact of unilateral energy sector changes on the economies of other countries/regions. The Oxford model specifies most EU countries separately and the other regions of interest are aggregated in a useful way, even though they are less detailed in the model. To examine the costs of stabilization in the long-term, Edmonds-Reilly-Barnes among others can be used.

Challenges: 1) *Leakage:* The treatment of international trade in the models is very important. The most critical climate-related issue is the extent to which the re-location of carbon emitting industries away from the countries/regions that imposed the actions and/or the substitution away from products produced in regions with the cost-increasing measures will actually lead to increases in global emissions. 2) *Linkage:* the issue of linkage between the economic welfare of OECD countries and that of developing countries needs to be explored and, 3) *Mid-term emission trajectories:* evaluating emissions paths up through 2020 is useful in negotiations. Many groups have generated trajectories, yet little agreement on underlying assumptions exists across the broad community that consists of government, private, and research groups.

II. IMPACTS OF ANNEX 1 OBJECTIVES, INCLUDING STABILIZATION, ON GLOBAL GREENHOUSE GAS LEVELS AND CONCENTRATIONS. IMPORTANT DETERMINANTS WILL BE EVALUATED SUCH AS THE TIMING OF REDUCTION GOALS AND PARTICIPATION OF NON-ANNEX 1 COUNTRIES.

Approach: Some work has been done on this topic already (most prominently by J.

Edmonds at Battelle Northwest Lab).

III. CCAP RE-ASSESSMENT AND POST BERLIN EVALUATION OF POLICIES AND MEASURES THAT WOULD CONTRIBUTE SIGNIFICANTLY TO CONTROLLING US EMISSIONS IN 2000, 2005, 2010, AND 2020. AN ADDED AREA FOR CONSIDERATION IS THE IDENTIFICATION OF A SET OF COORDINATED MEASURES THAT CAN BE PURSUED TO REDUCE US OR GLOBAL EMISSIONS.

a. *CCAP re-assessment.* This activity involves the re-calculation of the gap between a revised baseline and the emissions reductions expected with the implementation of new and current emission reduction programs. For CCAP, DOE will complete initial evaluation of US emissions in 2000 pending EPA submissions on non-energy related greenhouse gases and USDA submissions on carbon sequestration in trees and soils (and reductions in nitrous oxide reduction through fertilizer use). Agencies will submit any promising additional pre-2000 measures for consideration and evaluation.

b. *Post-Berlin evaluation of policies and measures.* Building on the original post-2000 analysis, selected measures can be evaluated. The timing (and administrative costs) of the various policies and measures are important to examine because they have ramifications for the economic costs and effectiveness of policies and measures.

ADDITIONAL INFORMATION THAT SHOULD BE INCLUDED IN THE ANALYSIS AND ASSESSMENT PHASE.

- *Damages from climate change.* This area, while very important, is highly contentious and is the focus of two of the three working groups in the current IPCC effort. Little new economic information is included in the IPCC work, as seen in the current drafts. However, new research has been done and is out for evaluation; a lengthy workshop on the topic is being held this August. This topic may be suitable for long-term evaluation (well beyond the October meeting). Given the level of disagreement about the quantitative estimates of total damages, both globally and regionally, as well as sectoral estimates a careful assessment by the technical community could be useful for negotiations and help identify mid-term research needs.

Environ- Climate Change

D R A F T 7.1

Intergovernmental Panel on Climate Change
Working Group III

Chapter 3

Equity and Social Considerations

Lead Authors:
Tariq Banuri, Karl Goran-Maler, Michael Grubb,
Harold K. Jacobson, and Farhana Yamin

DRAFT 7.1

Intergovernmental Panel on Climate Change
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Summary

Equity and social considerations are central to discussions of steps to be taken to implement Framework Convention on Climate Change because widespread participation is essential if the objectives of the Convention are to be gained. This is why the concept of equity is so prominent in the Convention. Countries are unlikely to participate fully unless they perceive the arrangements to be equitable. This applies particularly to equity among regions and countries, but equity within countries, and associated social considerations, are also important influences upon what is possible and desirable. Mitigating and adapting to climate change will require actions on the part of individuals. Governments will find it easier to comply with international obligations if their citizens feel that the obligations and benefits of compliance are distributed among them equitably. And richer countries are unlikely to burden their poorer citizens to benefit relatively rich citizens in poor countries.

Scientific analyses cannot prescribe how social issues should be taken into consideration and how equity should be applied in implementing the Climate Convention, but analysis can clarify the implications of alternative choices and their ethical basis. There are a variety of meanings of equity and there are various principles that have been designed to achieve equity. On some issues different equity principles point to similar responses, suggesting clear guidance, while on others they may conflict. In either case, there is a need for judgment, drawing on concepts of equity.

Issues relating to equity among regions and countries stem from the substantial differences that exist among countries. Countries differ not only in terms of size, resources, population, and wealth, but also in terms of emissions of greenhouse gases, vulnerabilities to climate change, and institutional capabilities to respond effectively to climate change. There is no single method of aggregating these differences, or decision rule for dealing with them. The Framework Convention on Climate Change provides considerable guidance for applying the concept of equity so as to take account of the many differences among countries. However, the application of equity to specific circumstances will require further elaboration of the Convention's principles and obligations, many of which were designed to be ambiguous and remain so.

Equity issues involved in responding to climate change may be divided into four distinct categories:

- distributing the costs of adaptation;
- distributing future emissions rights;
- distributing the costs of abatement; and,
- ensuring institutional and procedural fairness.

The Framework Convention on Climate Change offers some guidance on all of these issues. It requires developed country Parties to take the lead in limiting their emissions whilst

recognizing that developing countries' emissions are relatively low and will need to grow to meet their legitimate social and developmental needs. It also requires developed country Parties to assist developing country Parties to cope with both the costs of abatement as well as the costs of adaptation to the adverse effects of climate change. Such assistance must be provided by the Convention's financial mechanism which must have "an equitable and balanced representation" and transparent governance to ensure procedural equity between donor and recipient country Parties.

This North-South focus is also apparent in much of literature, which seeks to clarify issues of equity between developed and developing countries much more than among developed countries. Since developed countries have obligations under the treaty to take immediate action, this is a serious lacunae. There are however a variety of specific analyses that propose schemes for distributing costs of coping and abatement and emission rights, and analyze the distributional effects of these schemes, across the range of countries.

Social considerations, and the experience of the implementation of structural adjustment policies, point to the need to consider and target for special consideration specific groups. Countries (such as island and other low-lying states, or drylands) and special groups within society (such as the poor, and sometimes women or children, or specific occupations or regions) that are especially vulnerable to climate change--those on whom the costs of abatement and coping would be especially burdensome--merit special attention.

Concern about equity and social impacts points to the need to strengthen institutional capacities, particularly in developing countries, to make and implement collective decisions in a legitimate and equitable manner. These institutional capacities surely include developing resources to analyze equity and social issues.

Institutional weaknesses also inhibit the ability of developing countries to participate effectively in international negotiations. Assistance to help these countries develop a greater capacity to assimilate and analyze information and proposals, and to participate effectively in international discussions, would increase the prospects for achieving effective, lasting and equitable agreements on how best to address the threat of climate change.

Intergovernmental Panel on Climate Change
Working Group III

Equity and Social Considerations

Lead Authors:
Tariq Banuri, Karl Goran-Maler, Michael Grubb,
Harold K. Jacobson, and Farhana Yamin

I Introduction

The first principle in Article 3 of the Framework Convention on Climate Change states:

> "1. 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."

Because of its inclusion in this principle equity must be a key consideration in all actions taken under the Convention. In common language equity means "the quality of being fair or impartial," or "something that is fair and just." (Flexner, 1987, pp. 656-657)

Science cannot prescribe or decide what would be equitable actions under the Climate Convention. This is the task of the Parties to the Convention. Science, religion, and philosophy can, however, illuminate the meaning of equity and clarify the choices that the Parties face. This is the task of this chapter. It considers concepts of equity and issues that must be considered in efforts to apply these concepts. It then views these broad concepts within the tradition of international law and the specific context of the Framework Convention, and considers the several ways in which this text assigns specific meaning to equity. It next analyzes in detail several specific aspects of equity: international equity in coping with the impacts of climate change and associated risks; international equity in efforts to limit climate change; equity and social considerations within countries; and equity in international processes. Equity among generations (or intergenerational equity) is the subject of the next chapter. Social considerations enter into the discussions of equity in all of the sections.

I.1 The role of Equity

In considering equity issues it is useful to make several points at the outset. No international agreement has ever been founded purely on a logical consideration of equity issues; a whole range of other factors, ranging from basic economic and political power structures to accidents of timing and personalities, influence the outcome. Yet nor is the

converse--the cynical view that equity considerations play no role at all in the real world of international politics--true. A broad view of self-interest often points towards explicit consideration of equitable outcomes because of the longer-term risks that grossly inequitable behaviour may pose to stability and cooperation in the international system.

This analysis focuses upon the equity issues relating to climate change responses that might be considered by the international community. There are many more general issues associated with environmental ethics and values, that have attracted a substantial body of literature. Also there are many inequities in the world, among and within countries, the subject of long international discourse and analysis. It is no more realistic to suppose that climate change can be a vehicle to resolve all the international inequities than to suppose that it can resolve all the inequities within countries--but there is an important difference. Within countries, institutions exist to address a wide range of issues of common interest to members of that society. The institutions have developed in part to provide a way of taking decisions about constitutes acceptable behaviour, and decisions about the distribution of wealth and resources--in most countries, through regulation of market structures backed by legal codes and with taxation as a way of redistributing resources to help provide social goods.

Equity--in the form of views about what constitutes justice--is an important influence and measure of the legitimacy of these institutions and their decisions. The actual strength and perceived legitimacy of these institutions varies widely, but policies to address climate change at the level of national implementation fall within the remit of national institutions and accepted processes. By contrast, institutional parallels at the international level are relatively weak. In responding to climate change, the international community faces unavoidable decisions about the distribution of effort and burdens, and what constitutes acceptable behaviour, in circumstances where the internal activities of one state may directly impact upon all others. Whilst on a modest scale there are precedents, climate change is wholly unique in the scale and scope of its potential implications and the coordinated international response it requires. Yet international institutions dedicated to coordinating such a response are relatively new (such as the IPCC) or in the process of being established as a result of the Framework Convention on Climate Change. Consequently, examination of international equity issues is relatively recent and may need greater explicit analysis and consideration by international institutions if these are to support the international community's response to climate change. Climate change, and strategies for responding to it, will also have implications for equity within countries that should be considered.

I.2 Concepts of Equity

Since Confucius, Plato, Aristotle, and the Vedantic texts, theorists who have dealt throughout the ages with economic, political, and social issues have developed and explored concepts of equity. Several broad points emerge from this extensive literature. The first is that equity applies to two separate categories of issues. It applies to both procedural issues--how decisions are made--and consequentialist issues--the outcomes of decisions.

One prominent view of procedural equity is that it mandates equal treatment before the law. Similar cases must be dealt with in a similar manner. Exceptions must be made on a principled basis. In this sense, the principle of equity not only requires that law should govern decisions but also provides guidance in how laws should be applied. All of the circumstances in which a law would be applied cannot be foreseen at the time of its formulation. Starting with Aristotle, theorists have argued that laws be applied in an equitable manner to achieve what the legislators would have intended in the specific circumstances of a particular case (Shapiro, 1990, p. 220). The concept of equity also embodies a higher notion of justice that goes beyond the rules no matter how fairly they were devised. The Anglo-American common law tradition, for example, often introduces equity into judicial decisions to correct a potential injustice by too rigid an application of the law.

The principle of equal treatment before the law is closely allied to notions of basic, minimum rights for individuals. Securing these rights is central to a number of conceptions about procedural equity. For instance, John Rawls (1971) has argued that all individuals have equal rights to the most extensive system of equal political liberties compatible with a similar system of liberty for everyone else. A similar but stronger view has been put forward by Robert Nozick (1974) who has argued that all individuals have a sphere of moral rights in which no one, including the state, is allowed to interfere, irrespective of the consequences for well-being from such interference. These theories shed some light on how their conception of procedural equity can be achieved.

It is important to recognize that these particular theories were originally developed for dealing with questions of justice within a state. Rawls, for instance, draws a sharp distinction between the principles of justice that prevail among persons within a society and "justice between states" to which his theory was not intended to apply (Stone, 1993). The application of these theories to the subject of international justice--justice between states--presents problems (Van Dyke, 1975, Stone, 1993). Not least is the fact that as holders of the rights of sovereignty, it is nation-states, rather than individual human beings, that dominate international society.

Nevertheless, by extrapolation and analogy, these theories offer insights about the application of procedural equity as between states. For example, the notion that procedural equity demands that basic rights (of individuals or states), however they are defined, must be respected in decision-making is commonly accepted in domestic and international law. Article 2, paragraph 7 of the UN Charter, for instance, states that nothing contained in the Charter shall authorize the United Nations to intervene in matters which are essentially within the domestic jurisdiction of any state, but that the principle should not prejudice the application of enforcement measures. Other elements of procedural equity between states are discussed in more detail in the next section on international law.

Consequentialist equity has to do with the outcome of decisions, particularly the distribution of burdens and the allocation of benefits. There are several broad traditions defining the meaning of equity in this sense (Young, 1994). They may be summarized in the

following categories: parity, proportionality, priority, classical utilitarianism, and Rawlsian distributive justice.

Parity is a formula for equal distribution of burdens or benefits. Parity demands that all claimants receive equal shares; it is closely associated with egalitarianism.

Proportionality is a principle which dates back at least to Aristotle; it asserts that burdens or benefits should be distributed in proportion to the contributions of claimants.

Priority argues that those with the greatest need should be advantaged; this forms the basis of the "basic needs" approach which puts the emphasis on the absolute right of individuals to goods and services necessary to sustain their lives at some minimum standard of well-being making it worth living. This would include potable water, minimum nutrition, and health care and general environmental resources.

Classic utilitarianism proposes that burdens and benefits should be distributed so as to achieve the greatest good for the greatest number. This Benthanite formula can be expressed mathematically in terms of maximizing total utility, which of course requires the measurement and comparison of utilities, an issue which will be considered below.

Rawlsian distributive justice (Rawls (1971)) carried the concept of utilitarianism a step further, arguing for an equal distribution unless an unequal distribution operates to the benefit of the least advantaged. It therefore requires that deviations from equality should benefit the least advantaged.

No society has ever had complete consensus on any one of these approaches alone as an adequate criterion for defining consequentialist equity. Some (such as basic needs) are incomplete, prohibiting certain outcomes but not helping choices between other alternatives. Single principles may also not be appropriate or practical as the only standard, because among other reasons, cases and individuals are rarely identical and burdens and benefits may not be divisible, or if they are they may not be divisible into shares that are susceptible to precise, cardinal measurement so that it is impossible to apply the principles directly.

In practice, when societies try to achieve equity, they do so in nuanced and subtle ways, applying several criteria and seeking to achieve a balance among them. The balance is also affected by self-interest; in the real world, people tend to seek for and emphasize principles that may advantage them. Nevertheless, the principles are useful guides to what might constitute equitable decisions. Illustrating the likely consequences of their application may clarify the choices that have to be made in seeking equitable solutions as in the implementation of the Framework Convention on Climate Change.

The theme of there being different and sometimes conflicting principles, and the need for compromise between them, is extended by Rayner (1994), who argues that a number of fundamentally different "world views" are adopted towards climate change. These views span not only different ideas of equity but also differ concerning basic assumptions about the

urgency of abatement action and appropriate management strategies, and can be correlated with different institutional types identified by cultural theory.[1] The process of developing a response is seen as a process of compromise between these different world views, each of which tries to influence policy to correspond more closely to its own perceptions--perceptions which again tend to be influenced by interests.

I.3 Utility, equity, and economic efficiency

Welfare economics is based upon utilitarianism. It requires some measure of welfare (utility), as a function of various factors that can determine the welfare of an individual: for example, the amount of goods and services that the individual can access, different aspects of the physical and spiritual environment, and rights and liberties. The idea of a `utility function' is to aggregate a rather long list of factors affecting individual well-being into one single measure of welfare. There remains the much more difficult task of aggregating these utilities over different individuals. In a sense, this is the real ethical problem in connection with climate change.

There is no inherent conflict between economics and equity, as some people assert; but it can arise because of differing ideas or assumptions, sometimes hidden, about how individual utilities should be defined, compared and aggregated. It is important to understand that economics itself cannot determine this question. Explicit discussions of equity are essential because they reflect differing ideas about how--and indeed whether--individual utilities should be measured and aggregated.

Arrow (1951) addressed the fundamental question whether individual preferences--irrespective of what they look like--can be aggregated in a reasonable way into overall societal preferences. He concluded that in general it is impossible to aggregate individual preferences to a social welfare function if we require that the aggregation should satisfy some very natural and reasonable conditions, including that no individual should be allowed to be a dictator. Thus, it is in general not possible to deduce "objectively" a socially preferred distribution of well-being from individual preferences. However, if it is known that individual preferences are restricted to certain types, then it may still be possible to aggregate individual preferences in a consistent and reasonable way to form a social ordering (see Sen 198?).

It can be argued that there is a rough consensus on what constitutes an equitable distribution of welfare over time. This is so because of the apparent agreement on the concept of sustainable development, as introduced by the World Conservation Strategy (IUCN 1980) and popularized after The World Commission of Environment and Development--the Bruntland Commission--published its report *Our Common Future* (1987). The central idea behind the concept of sustainable development is that the present generation should not make changes that reduce the possibilities for future generations to achieve comparable well-being. The concept of sustainable development has received widespread support from all states as evidenced by its inclusion in, for example, the Rio Declaration, Agenda 21. It is specifically mentioned in paragraph 5 of Article 3 of the Framework Convention on Climate Change. Despite its widespread acceptance, the precise meaning of the concept is not universally agreed

and as a result, its application is not straightforward. Issues of intertemporal justice, especially implications in terms of the "discount rate" used to value future impacts, are discussed primarily in the next chapter.

The comparison and aggregation of utilities across different countries and across different individuals is much more contentious. The GNP indicator avoids this by focusing simply upon the total measured consumption in a country; in principle, it lays no claim to represent welfare directly, nor does it claim that aggregating GNP across different countries is a valid measure of global welfare. In practice however, maximizing GNP does often become a primary focus of policy and economic analysis. This implicitly embodies an assumption either that a given amount of additional wealth is equally valuable to everyone; or that the additional welfare can and will be redistributed so as to fulfill some more explicit measure of aggregate social welfare. The latter is achieved by a balance between the focus upon GNP and the establishment of institutions and processes charged with redistribution, social protection and provision of various social goods.

Internationally, as noted, such processes and institutions are weak or non-existent. Hence the debate about whether and how to compare national utilities internationally is central. Views range from asserting that countries should act as if they value all countries equally (i.e. assume equivalent utility functions and aggregate all with the same weight), to asserting that utilities can and should not be estimated and aggregated at all across countries, so that countries bear no responsibility for impacts on others. International negotiations are to an extent about trying to reach a compromise between these two extremes, especially concerning policy on issues where the activities of one country may directly affect another - like climate change.

It is in this issue of whether and how to aggregate separate utilities that debate about apparent conflict between equity and economic efficiency can arise. Really it all depends upon how efficiency is defined. "Pareto efficiency" is a modest goal, namely that of seeking a situation in which no-one can be made better off without making anyone else worse off. Pareto efficiency is thus generally neutral with respect to equity because it allows an infinite variety of possible distributions. More often however, the term `economic efficiency' is used in terms of seeking to maximize 'something' with the resources available. Maximizing GNP--or perhaps 'Gross World Product'--could involve highly inequitable outcomes. Seeking to maximize some explicit measure of aggregate welfare--which requires defining a social welfare function--may result in a very different concept of "efficiency"--and a very different "optimal" outcome.

Whether there is any inherent conflict between equity and efficiency therefore depends entirely upon how "efficiency" is defined, in terms of what we are trying to maximize. Equity is thus essential to climate change discussions because there is no consensus about whether and how to measure and aggregate welfare within and, still less, between countries. On the contrary, there are fiercely competing views grounded in differing interests and philosophies. The objective--and hence the optimal policy--is thus inherently a matter for debate, negotiation and compromise between conflicting interests and ethical philosophies.

II. Equity in International Law and in the Framework Convention

International law and the Framework Convention on Climate Change both provide a context for efforts to apply principles of equity in implementing the convention. This section examines how the basic rights and obligations of states established under international law, through treaties, custom, the general principles of law, and judgments and awards of courts and international tribunals, provide a framework for consideration of issues concerning procedural and distributive equity.[2] In addition to the general rules and principles of international law, the UN Framework Convention on Climate Change contains principles and specific provisions concerning equity. These provisions have important implications for the implementation of the Convention, including for the elaboration of further commitments and mechanisms for burden sharing on an equitable basis.

International Framework

One of the basic tenet of international law is the sovereign equality of all states. Each state has jurisdiction over its territory and has the right freely to choose and develop its political, social, economic and cultural systems, including the right to develop its own policies and laws regulating the exploitation of its natural resources. As a corollary to these principles, each state has a duty to refrain from threatening the territorial integrity of another and the obligation not to intervene in matters within the domestic jurisdiction of any other state.

Principle 2 of the Rio Declaration on Environment and Development states:

> States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their environmental and developmental policies, and the responsibility to ensure that activities within their own jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.[3]

Each state may devise its own climate change policies and programs. Accordingly, the extent to which national measures are equitable in allocating costs and benefits among various regions, economic sectors, social groups or individuals within its territory, is primarily a domestic matter. The allocation of responsibilities for mitigation and adaptation, and mechanisms to implement these, as between states is however, an international matter and subject to the general rules and principles of international law and for states that are Parties, to the specific provisions of the Framework Convention on Climate Change concerning equity. It is important therefore to understand the meaning of equity in international law, in particular what factors have been included in the concept of equity and their practical procedural and distributive consequences.

The concept of equity

The International Court of Justice (ICJ) explained the legal nature of equity in its judgment on the 1982 Continental Shelf Case (Tunisia/Libya).[4] It stated:

> Equity as a legal concept is a direct emanation of the idea of justice. The Court whose task is by definition to administer justice is bound to apply it.[5]

The Court explained that "the legal concept of equity is a general principal directly applicable as law."[6] This means that equity can be a source of law as well as consisting of considerations necessary for the sensible application of the law.[7] In its 1982 Judgment, the Court recognized that equity was relevant when the Court was called upon to apply international law and found that it could choose among several possible interpretations of the law. The Court interpreted this as meaning not that it could fashion new law but that when it could choose among several interpretations of the law it was bound to choose the interpretation "which appears, in the light of the circumstances of the case, to be the closest to requirements of justice".[8] The Court explained that in international law the application of equity consists of the application of equitable principles to achieve an equitable result taking into account all the legal and factual circumstances relevant to the case in hand.[9]

This concept of equity encompasses both procedural and distributive elements which means that from a legal perspective, the application of equity cannot be generalized as principles and factors relevant to the application of equity to one context cannot necessarily be transposed and applied in another. The following examination of equity in different international environmental contexts is intended to provide background information about the role of equity in benefit and burden sharing arrangements between states concerning access to and use of natural resources. The legal insights and practical experience gained by states and the ICJ in dealing with equity in these contexts may be relevant for climate change.

Continental shelf

The ICJ has examined the role of equity in a series of cases concerning rights of access and use of the continental shelf between states. In a dispute between Malta and Libya the Court said that the concept of equity included the principle of good faith negotiations to resolve disputes between parties.[10] This highlights the important procedural components of the concept of equity which also include:

> "the principle of respect due to all such relevant circumstances [and] the principle that although all States are equal before the law and are entitled to equal treatment.."[11].

As far as distributive equity is concerned it went on to declare that the application of equitable principles cannot be used for "refashioning geography or compensating for the

inequalities of nature ...."[12]. The Court pointed out that so far as the relevant law concerning continental shelf delimitation is concerned,

> "equity does not necessarily imply equality ... nor does it seek to make equal what nature has made unequal."[13]

The Court also went on to state that equity includes "the principle that there can be no question of distributive justice."[14] Accordingly, in that case the Court rejected Malta's claim to a greater share of continental shelf based on its argument that it was resource poor and had greater socio-economic and developmental needs than oil-rich Libya.[15] In a recent ICJ case concerning between Norway and Denmark, the Court again considered the relevance of socio-economic factors, including population, and rejected these as relevant in determining a state's entitlement to continental shelf resources.[16] In a case between the USA and Canada, however, the Court indicated that where the overall result might entail "disastrous repercussions on the subsistence and economic development of the populations concerned," it may be inequitable to not take this into account.[17]

It is not possible to derive general conclusions about equity from the foregoing as the Court has stressed that each case must be examined in the light of its legal and factual circumstances. What this body of law does make clear, however, is that the Court has not yet had to deal with interpreting obligations that are related to or conditional upon the consideration of complex factors such as socio-economic development or the needs of the present and future populations. Moreover a closer reading of these cases illustrates the Court's reluctance to use equity as a basis to achieve distributive justice on a wider scale. This suggests that, in the absence of clear legal rules requiring the consideration of factors such as socio-economic development and population, the ICJ may not necessarily regard them as relevant or of paramount importance in other contexts where disputes concerning access to and use of natural resources raise wide-ranging distributive justice concerns.

This may have significant legal and practical consequences in the climate change context where implementation of a range of Parties' obligations under the Convention is conditional upon taking into account their socio-economic development, national needs and wide-ranging list of geographical factors. It is also particularly important in the context of negotiating future greenhouse gas emission reductions or devising a joint implementation systems as both raise fundamental distributive questions about the basis on which countries are entitled to continue their emissions.

The role of equity in the legal regime established for the deep seabed in Part XI of the 1982 United Nations Conference on the Law of the Sea (UNCLOS) differs markedly from principles and rules concerning the continental shelf. UNCLOS aims at distributing the benefits of exploitation as widely as possible. because it incorporates a notion of equity that includes a substantial element of distributive justice.[18] The equitable principle that inspires this regime is that the Area (the deep seabed) and its resources are the "common heritage of mankind."[19] Article 140 provides, for example, that activities in the Area "shall be carried out for the benefit of mankind as a whole, irrespective of the geographical location of States,

whether coastal or land-locked, and taking into particular consideration the interests and needs of developing States and of people who have not attained full independence..."

Unlike the law on continental shelf delimitation, these provisions expressly call for the consideration of socio-economic factors and economic needs, particularly of developing countries or other States disadvantaged by geography, to be taken into account in apportioning benefits. No definition of equity was included in UNCLOS. To give effect to these provisions, Parties to UNCLOS may have to elaborate equitable sharing criteria to distribute any financial and other benefits arising from the Area which may have implications for the climate change context.

Perhaps the clearest international example for the application of equity is the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer which arose as a result of the 1985 Vienna Convention for the Protection of the Ozone Layer. Many developing countries had argued that, in view of their marginal contribution to the ozone problem, limited financial resources and more pressing developmental concerns, they should not be expected to take on the same commitments as richer, developed countries whose emissions had caused the ozone problem.[20] Participation in the Montreal Protocol of a large number of developing country Parties is widely viewed as a measure of its success in addressing fairness or equity concerns of developing countries and also for balancing environmental needs with economic imperatives and flexibility for industrial producers of ozone depleting substances.

It is the use of innovative legal techniques to implement these equitable concerns that distinguishes the Montreal Protocol from other conventions. The following list provides a brief outline of the way in which the Protocol's substantive provisions give practical expression to equity concerns. These "equitable" techniques include:

- differentiated standards for developed and developing country Parties including provision of grace periods for compliance for the latter; allowing increased developed country Party production to enable developing country Parties to meet their "basic domestic needs"; and allowing developing countries to base their emission entitlements on a per capita basis;

- financial assistance to developing countries, over and above overseas development assistance, to cover "all agreed incremental costs" and enable compliance;

- transfer of technology, especially of best available, environmentally safer substitutes under fair and most favorable conditions, facilitated by the Protocol's financial resources if necessary;

- limited operation of a tradable permit or joint implementation scheme to achieve "industrial rationalization" to minimize economic disruption and provide flexibility to producers of ozone depleting substances and

- an acknowledgment that developing countries' abilities to comply is conditional upon the "effective implementation" of developed countries' financial cooperation and technology transfer obligations.

As a result of its success in attracting developing country Parties, the Montreal Protocol approach was extensively discussed as a "model" for the Framework Convention on Climate Change.[21]

What is the role of equity in the Framework Convention on Climate Change so far as rights and responsibilities to protect the climate system are concerned? Unlike the Montreal Protocol which mentions equity only once in the Preamble, the Climate Convention includes refers to equity three times in its substantive provisions. As was mentioned in the opening paragraph of this chapter, the Convention specifically mentions "equity" in Article 3.1 concerning principles by stating that:

> "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."

This principle, which is intended to "guide" Parties in implementing all the provisions of the Convention mentions equity in the context of burden sharing between all Parties, in particular, as between developed and developing country Parties. It also mentions future generations suggesting that equity requires consideration of the responsibilities of present generations to future ones as part of burden sharing arrangements.

Equity also appears in Article 4.2(a) which requires developed country Parties to commit themselves to:

> ". . . adopt national policies and take corresponding measures on the mitigation of climate change . . . . These policies and measures will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objective of the Convention, . . . taking into account the differences in these Parties' starting points and approaches, economic structures, 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 that objective".

The reference to the term "equitable" concerning the specific commitments of developed country Parties concerns burden-sharing as between these Parties reflecting Parties' intention that equity should be applied not only between developed and developing countries, but among developed countries as well.

Finally, Article 11.2 requires the Convention's financial mechanism to:

> "have an equitable and balanced representation of all Parties within a transparent system of governance."

Equity in this context appears to reflect developing country concerns. These concerns are of an essentially procedural nature reflecting the fact that the implementation of procedural elements may be essential for guaranteeing distributive outcomes that are perceived to be equitable.

What then is the significance of equity in the Convention and what practical consequences flow from its mention? It is clear that the application of "equity" in these contexts is intended to respond to quite different concerns. Equity cannot therefore have one meaning as its meaning will depend on the legal and factual circumstances of particular situations. Particular disputes will themselves depend on the interpretation of the nature and extent of Parties' obligations under the Convention. International legal rules on interpretation provide that "[a] treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose."[22] For the purposes of interpretation, the context includes the preamble and any annexes.

The terms "equity" and "equitable" in the Framework Convention on Climate Change are closely related to its virtually all of its other substantive provisions. Accordingly, these terms must be interpreted in the light of the Convention's overall objective, approach and context. This task is made more complex by the fact that the Convention itself requires Parties to use the principles contained in Article 3 to achieve its objectives and guide implementation of its provisions. Equity is mentioned in the context of Article 3.1, which concerns the principle of common but differentiated responsibilities for the climate system which the Preamble states is a "common concern of humankind". This is however, only one of the five principles found in Article 3. Other principles include: the right to promote sustainable development; the precautionary principle; the need to take into account the specific needs and special circumstances of developing country and vulnerable Parties; and commitment to promote a supportive and open international economic system.

The meaning of much of these complex principles, including concepts such as "common concern of humankind," remain open to interpretation. It is clear however, that these interlocking concepts and principles bound the way in which Parties' obligations can be interpreted and in which equity can be applied in a particular case. The application of equity is also bounded by the structure of differentiated commitments set up by the Convention. Like the Montreal Protocol, the Convention requires developing country Parties to accept a smaller share of the global burden of combating climate change in view of their smaller contribution to the problem and their limited financial capabilities.

The differentiated set of commitments, set out in Articles 4.1 - 4.5 of the Convention, distinguish between developed and developing country Parties and those with "an economy in

transition," All developed country Parties, including those with economies in transition, (countries listed in Annex 1 of the FCCC, or Annex 1 countries[23] are required to take the lead in mitigating climate change (Article 4.2 (a)). These parties:

> ". .. may implement such policies and measures jointly with other Parties and may assist other Parties in contributing to the achievement of the objective of the Convention. . . ." Thus joint implementation (JI) is possible, and could be seen as a vehicle for transfer of resources.

Developed country parties and other developed parties listed in Annex II of the FCCC (the European Union and the member countries of the Organization of Economic Cooperation and Development) are obligated to assist developing country Parties vulnerable to the adverse effects of climate change meet the costs of adaptation (Article 4.4). They must transfer technology and financial resources to developing countries to enable the latter to implement their more limited commitments to combat climate change (Article 4.5). In view of their limited financial resources, Parties with economies in transition however, are not obligated to provide such assistance. In discussing the obligations

Articles 4.6 - 4.10 provide a range of factual or other circumstances that must be given consideration so far as implementation of Parties' differentiated commitments are concerned. These Articles are therefore of particular relevance in considering what factors might or might not count as a relevant "equitable factors" in a particular case where implementation of commitments is in question.

For example, Article 4.6 provides that a certain amount of "flexibility" must be given to Parties with economies in transition in the implementation of their Article 4.2 (a) obligations. Article 4.7 makes the implementation of developing country Parties commitments conditional on the implementation by developed country Parties of their financial and technology transfer commitments and recognizes that

> ". . . economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties."

Article 4.8 provides that Parties are required to give full consideration to the specific needs and concerns of the developing country Parties with the special features referred in (a) - (i) of this Article. These features include for example, geographical, biological and economic factors such as whether a country is small island, is prone to natural disasters or desertification, or highly dependent on income from fossil fuel consumption or production. Article 4.9 provides that full account must be taken of least developed countries for funding and technology transfer. Finally, Article 4.10 provides that consideration should be given to all Parties whose economies are highly dependent on income generated from the production or consumption of fossil fuels or energy intensive products and for which Parties have serious difficulties in switching to alternatives.

Several other sections of the Framework Convention, though they do not specifically mention equity, are relevant to ways in which equity should be interpreted. The broad statement of the Convention's objective in Article 2 states the goal of stabilizing greenhouse gas concentrations at a level "that would prevent dangerous interference with the climate system." It then goes on to specify a time-frame within which this objective should be achieved.

> "Such a level should be achieved within a time-frame sufficient to allow ecosystems to adopt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in as sustainable manner."

This stricture bounds the way in which equity should be achieved.

In other words, equity is to be achieved in ways that allow all Parties continued economic growth and international trade is to be an essential instrument in this growth. Strategies are to be tailored to the specific conditions of Parties.

The preamble of the Framework Convention on Climate Change singles out several categories of Parties for special consideration, thus broadly defining how the concept of equity should be applied. One perambulator paragraph notes the particular vulnerability of: small island and low-lying countries; countries with low-lying coastal areas; countries with arid and semi-arid areas; those that are liable to floods, drought and desertification; and those that have fragile mountainous ecosystems. Another preambular paragraph acknowledges the special difficulties that will be faced by developing countries that have economies that are particularly dependent on the production, use, and exportation of fossil fuels as a consequence of limiting greenhouse gas emissions. While these preambular paragraphs do not create specific legal obligations they were intended to condition the way that the treaty is interpreted and implemented.

By differentiating obligations and by including the foregoing factors the Framework Convention on Climate Change appears to have dealt comprehensively with the equity concerns. On a practical level however, the implementation of the Convention on an equitable basis will require further agreement between Parties about the significance of these factors, the relative weight to be given to each in particular situations and the precise meaning of commitments undertaken by each of them. This in turn will require agreement about the meaning of principles such as the principle of common but differentiated responsibilities, the right to sustainable development and concepts such as "common concern of humankind" as this is a new concept in international law. Reaching agreement about these matters will be a critical bearing on the allocation of benefits and burdens of combating climate change between states.

The continental shelf cases and the general rules of international law concerning procedural equity suggest that states enter in to good faith negotiations to resolve differences of

views about access to and use of natural resources. Further negotiations between Parties to the Framework Convention on Climate Change would certainly assist the implementation of the Convention on an equitable basis. To the extent Parties do not enter into such negotiations or where disagreements persist, the general rules and principles of international law will remain relevant to resolving disputes about equity.

III. Principal differences among regions and countries

III.1 Introduction

Equity is not the same thing as equality, but issues of international equity are clearly related to a variety of differences between countries. This section summarises ways in which countries differ that are relevant to the question of equity between countries in responding to climate change. Subsequent sections then review some of the issues and conclusions that writers have drawn concerning implications for policy towards climate change.

- Five main dimensions of difference are cited in the literature: Wealth and consumption
- Emissions - past, present and future
- Impacts - the distribution of and vulnerability to climate change
- Social considerations and institutional capabilities
- Endowment with resources that may be affected by responses to climate change

This section of the chapter looks at the first two of these in turn and then considers the other three, which are addressed more fully elsewhere in the report, together.

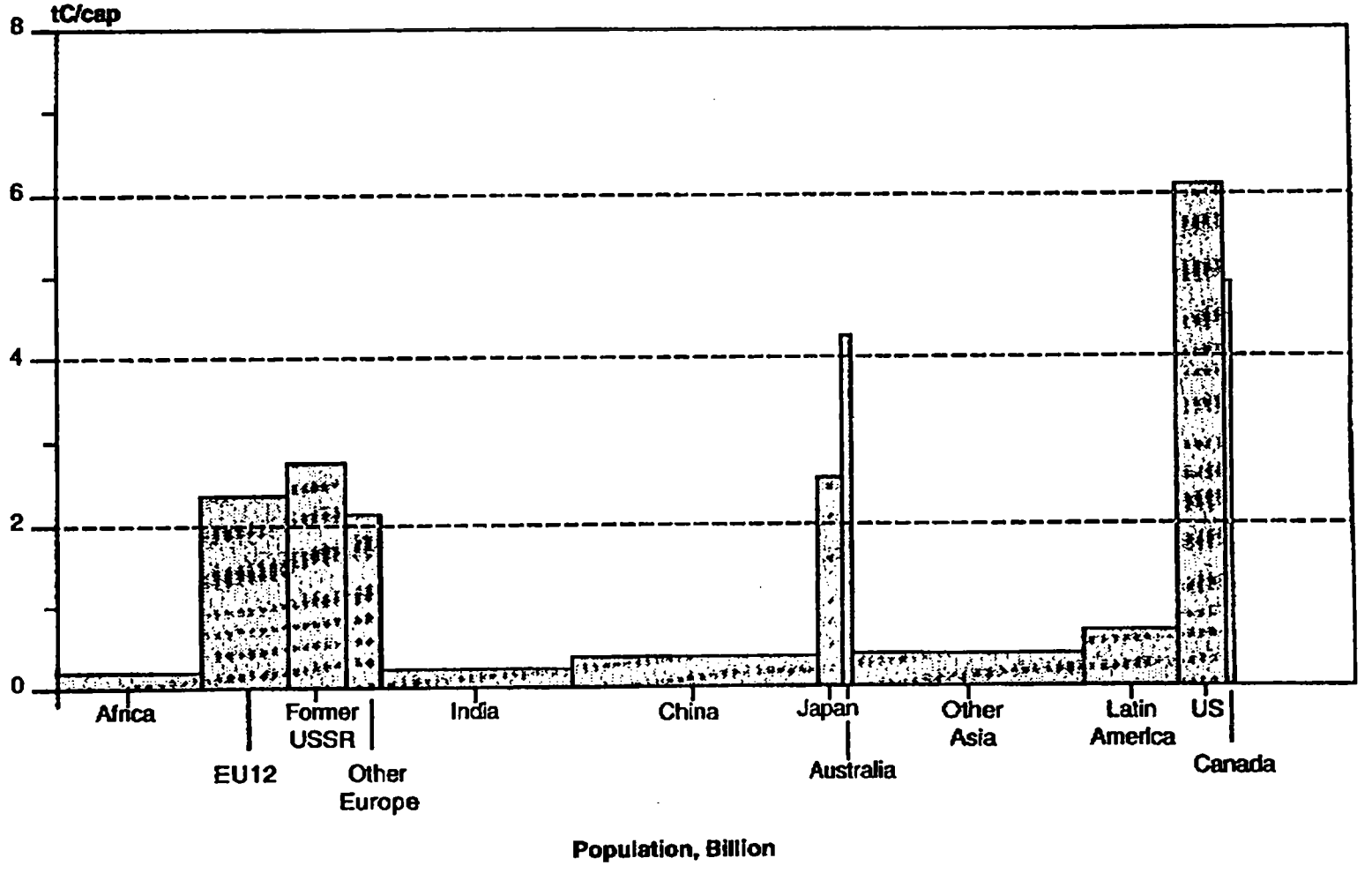
III.2 Wealth and consumption

Wealth is one of the most obvious and pervasive differences between countries. Much of the literature on international equity starts from this issue, and the statistics need little elaboration. More than half of the world's population (58.7 percent) live in the forty-two countries that are classified as "low income" in the World Bank's *World Development Report 1994* (World Bank, 1994, p. 162). These countries have an average per capita gross national product (GNP) of $390. The 15.2 percent of the world's population that live in the twenty-three countries that the World Development Report classifies as "high income economies" have an average per capita GNP of $22,160, almost *sixty times* that of the low income economies; the remaining sixty-seven "middle-income economies" have an average per capita GNP of $2,490, just slightly more than one tenth that of the that "high income" countries. The discrepancies are smaller in terms of purchasing power--but are still very large.

These differences have a direct bearing upon the issue of climate change in various ways. Activities of the poor that result in emissions of greenhouse gases are mostly those that relate most closely to "basic needs," often at little more than subsistence levels--energy for cooking or keeping tolerably warm, emissions from agricultural activities, perhaps energy for light to enable reading, and occasionally for travel by public transport. Emissions from the

Figure 1

Carbon Emissions per Capita and Population, 1993

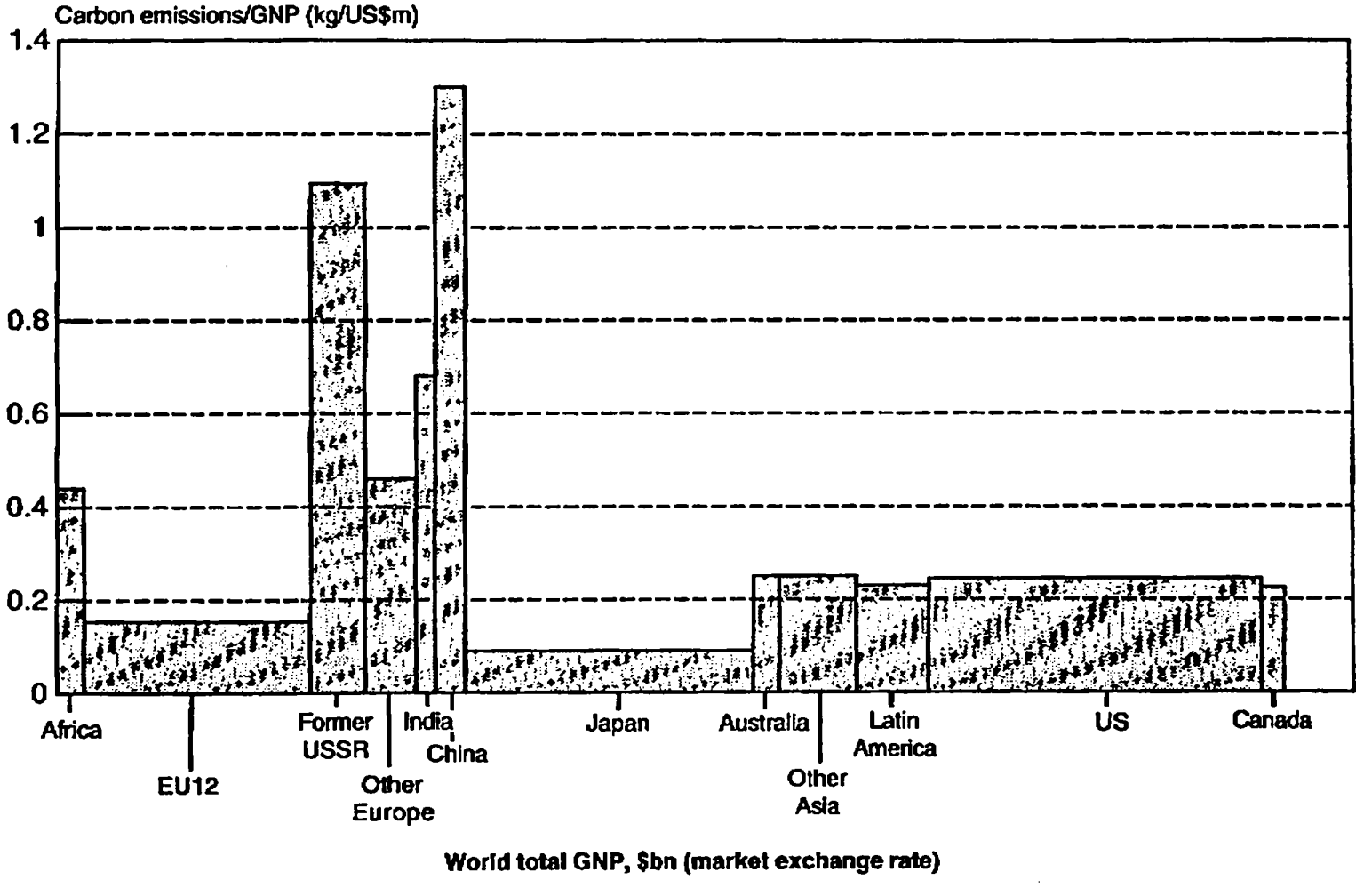


Source: Derived by M. Grubb from BP Statistical Review of World Energy 1994 and World Population Prospects, UN

938005.fig1 1/95.ai

Figure 2

Carbon Emissions/GNP and Total GNP, 1992



Source: Chapter 3

938005.fgr.1/93.ap

766 rich tend to be dominated by activities such as driving private cars, home central heating, and
767 energy embodied in a wide variety of manufactured goods and the use of such goods. The
768 welfare impacts of cutbacks of greenhouse gas emissions may thus differ greatly according to
769 the level of personal wealth (WCED, 1987; DCCSD, 1993). Although it is a different point,
770 it should be noted that cutbacks of greenhouse gas emissions could have significant impacts on
771 countries where the production of carbohydrate fuels accounts for a substantial portion of their
772 national income.
773
774 Obviously there are great variations within countries, but in aggregate the same broad
775 issues apply concerning wealth disparities between countries. The aggregate relationship
776 between wealth, consumption of a variety of natural resources, and emissions of various
777 pollutants have been explored methodically by a number of authors. Using cross-sectional
778 data, Parikh (1992) shows that consumption of a wide variety of resources--many of which
779 involve emissions of greenhouse gases in their extraction, processing and application--is
780 closely related to the level of wealth. Williams *et al* (1987), Drucker (1990) and others have
781 argued that in many developed economies, a decoupling of wealth from the volume of material
782 consumption has occurred since the 1970s and that this will accelerate, though others have
783 disputed this (Herman *et al*, 1989); but the aggregate relationship at middle and lower income
784 levels seems undisputed. The *World Development Report 1992* (World Bank, 1992) notes that
785 direct emissions of many pollutants declines beyond a certain stage of economic development,
786 but considers that this point has not been reached for most greenhouse gases, particularly CO_2
787 and (to a lesser extent) CH4 from sources other than land use.
788
789 Wealth is not only one of the most important determinants of greenhouse gas emissions
790 (at present), it also has a very important bearing upon vulnerability to climate change. Richer
791 countries, because they are richer, will tend to find it easier to deal with the costs of coping
792 with climate change and measures to abate climate change. Poorer countries, because
793 agricultural production--which is particularly vulnerable to climate change--comprises a larger
794 share of their economies that that of richer countries, will be more vulnerable to climate
795 change. Climate change could lead to substantial migration within and among poorer
796 countries, creating environmental refugees.
797
798 Poverty also has an important bearing upon national priorities and the timescales
799 considered in policy. Economists have long noted that personal discount rates decline with
800 rising income. Richer people can afford to look further ahead, have greater security, and can
801 afford to invest more for the future (though in fact the pattern of investment as a fraction of
802 wealth is very variable). Poor people tend to be focused more upon short-term concerns,
803 including those of striving to ensure that they can meet basic needs. This has important
804 implications for the potential equity impact of policies to address climate change within
805 countries, as noted earlier in this chapter, and the same applies at the level of national
806 economic and political systems.

Thus, in poorer countries interest rates tend to be higher, capital is scarcer, and the whole focus of policy and politics tends to be upon meeting pressing short-term needs ranging from poverty alleviation and employment generation to the management of fiscal crises, often driven partly by the needs of debt repayment. At the industrial level, the focus may for example be upon the scramble to construct infrastructure and capacity fast enough to meet rapidly rising demand, rather than the more considered examination of optimal investments over longer periods that may be possible in richer countries. Thus the context both for actual investment behaviour and broader public policy is strongly affected by national wealth in ways that are directly relevant to the climate problem (Mathur, 1991).

Some of these issues were addressed by the IPCC Special Report on Developing Countries (1990), which stated that 'the priority for the alleviation of poverty continues to be overriding concern of the developing countries; they rather conserve their financial and technical resources for tackling their immediate economic problems than make investments to avert a global problem which may manifest itself after two generations . . . .' Article 4.7 of the Framework Convention on Climate Change also recognises that "economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties" and that will influence implementation of their commitments.

III.3 Patterns of Greenhouse Gas Emissions

A second important dimension of difference is that countries vary widely in the nature and degree of their contribution to climate change. Contributions to climate change span many different gases and sources.[24] Although the range of sources and sinks may not in itself be regarded as an equity issue, it is clear the conclusions that may be drawn from different ways of aggregating and presenting the data can be., This section summarizes the main approaches that have been taken and the results obtained.

During the negotiations of the FCCC, many of these considerations came to be discussed in terms of whether the Convention should adopt a "comprehensive" approach and if so, whether it should focus on "gross" greenhouse gas emissions or "net" emissions derived by subtracting the removal of greenhouse gases by sinks from total emissions by sources (Bodansky, The UN Convention on Climate Change: A Commentary, Yale Journal of International Law, Summer 1993, Volume 18, 2). Adoption of the comprehensive approach means that all sources and sinks of different greenhouse gases have to be considered in formulating policy. Accordingly, global warming potentials are calculated for each gas to permit emissions of different gases to be compared according to a single metric. During negotiations many developing countries viewed the comprehensive approach as inequitable, arguing that methane emissions from subsistence agriculture should not be compared with carbon dioxide emission, because the former are "survival emissions" which cannot be controlled without irreparable social and economic damage whilst the latter are due in large part to profligate lifestyles in the North (Bodansky, p. 518). Developing countries also argued that the Convention should include a principle that all states have an equal right to ocean sinks as these are part of the global commons (Bodansky, p. 502).

This principle did not find its way into the Convention and the question of entitlements to global sinks therefore remains open. The Convention does, however, mention the comprehensive approach favorably in both the preamble and Article 3.3. Notwithstanding this mention, the final language of the Convention leaves open the possibility that policies and targets for individual gases can be adopted.

Many of the equity concerns about how sources and sinks should be dealt with, and which gases should be controlled on what timescale, continue to manifest themselves in fierce methodological disputes about the calculation, aggregation and presentation of data. This was vividly illustrated in an important debate about data relating to emissions and sinks presented initially by the World Resources Institute (see box).

In terms of controlling emissions, it is relevant to note that CO_2, is the biggest anthropogenic contributor to radiative change to date, and is projected to continue to be so. Methane is also significant, though it decays much more rapidly and emissions are much more uncertain, and in recent years the growth rate in the atmosphere has slowed dramatically. CFC emissions, almost entirely from industrialised countries, grew very rapidly until the late 1980s, but the overall impact on radiative forcing, taking into account indirect effects, is such that even the sign is not certain (IPCC, 1992). Also, since these emissions are now being rapidly phased out under the Montreal Protocol and amendments, with limited interim growth in developing countries, they are less relevant to future policy. The replacement of CFCs by HCFCs, which have a high radiative impact and are not controlled by the Montreal Protocol, however, is a matter of concern and their increased use deserves close scrutiny. Similar remarks apply to sulphur dioxide--not a greenhouse gas, but one thought to have considerable indirect impact upon radiative balance. The role of other anthropogenic gases is not big enough to affect the equity issues discussed here.

III.3.a Historical and cumulative emissions

Cumulative past emissions account for the build-up of gases in the atmosphere. Smith (1993) provides the most thorough account of how indices of past emissions can relate to current concentrations, and gives data for cumulative carbon emissions in the period 1950-86. The most extensive database of cumulative emissions are those developed by the International Institute of Applied Systems Analysis (IIASA), with estimates of fossil fuel and biotic carbon emissions back to 1800, and methane, presented to a useful but manageable degree of regional breakdown. Their results are shown in Table 1.

Considered on this basis, these results suggest that North America accounts for about a third of the contribution from fossil fuels, Europe over one quarter, and the former USSR 14 percent; the industrialised countries together account for 84 percent of the total. When estimates of biotic (mostly deforestation) emissions are included, the North American figure is reduced to about 30 percent, and the contribution from a number of developing countries becomes significant; in total the North accounts for about two thirds of the total.

896

. The WRI data controversy and allocation of sink capacity

In 1990 the World Resources Institute (WRI, 1990) published an extensive set of data on national greenhouse gas emissions, from which they concluded that responsibility for climate change was shared widely between countries in the industrialised and developing world. Their methodology and conclusions were vigorously attacked by Agarwal and Narain (1991), who claimed that the analysis was inherently biased against poor countries; they presented an alternative approach, which led them to conclude that developing countries bore no responsibility for the problem, but were in fact contributing to cleaning up emissions from the industrialised world. The dispute attracted widespread academic, public and political attention.

There were important disagreements over the accuracy of data and the range of gases included (Ahuja, 1992; Thery, 1992), and it has now been recognised that emissions from deforestation, and probably methane, in many developing countries are much lower than in the original WRI estimates. But the heart of the dispute was over the assignment of `natural sink capacity'--the natural processes that remove greenhouse gases.

Because of all the difficulties associated with estimating, comparing and projecting greenhouse gas removal over time, WRI took the *measured increase in concentration* of each gas--which gives a direct measure of the radiative change--and assigned this to each country *in proportion to estimated emissions in that year* (or an average of recent years).

Agarwal and Narain raised two central objections to this measure. First, that it took no account of the distribution of historical emissions, which are in fact largely responsible for current concentration levels. Second, that by distributing the *net* concentration in proportion to *gross* emissions, the natural reabsorption--the `sink capacity'--was implicitly being allocated in proportion to emissions. This, they contended, was a grossly inequitable approach, because the sink capacity was a natural, global common resource which should be allocated equally to all people. By dividing the total annual absorption of each greenhouse gas (the difference between gross emissions and measured atmospheric increase) in proportion to national population, they showed that most developing countries' share of the global reabsorption of greenhouse gases on this basis exceeded their actual gross emissions; and hence concluded that far from bearing any responsibility for the problem, were in fact helping to clean up the excessive emissions from industrialised countries.

An important difficulty with Agarwal and Narain's approach, in turn, is that the rate at which greenhouse gases are removed from the atmosphere depends upon the concentration gradient and thus the level of gross emissions: the more that is emitted, the more is removed. Indeed the simpler physical models use a constant "airborne fraction" and decay rate, so that the fraction of gross emissions removed in the atmosphere is a fixed percentage of gross emissions. Thus it does not follow from Agarwal and Narain's approach that concentrations would decline if all countries did emit at the per-capita rate of the poorer countries; after a few years it is likely that concentrations would still rise, but at a much slower rate. Conversely however, the "airborne fraction" is a crude proxy for a much more complex process, and it is widely believed that it declines with increasing global emissions; thus as global emissions grow, the absolute removal increases but not in constant proportion (Ahuja, 1992).

To avoid this complication, and in keeping with much of the literature, in considering current and projected emission rates the data in this chapter are given in terms of gross emissions. Most analysis recognises that from a policy perspective it will also be necessary to consider *anthropogenic* stimulation of sinks (primarily tree planting), and probably human impacts on the ability of natural ecosystems to act as sinks (absorb greenhouse gases). For the present at least, these impacts are not thought to be major contributions to the overall flow of greenhouse gases, though the spread of land management for agriculture and other purposes, and desertification, have probably reduced the sink capacity in many diverse countries.

Table 1
Historic CO2 and Methane Contributions by Region

	Past contribution, 1800-1988 in percentages		
	Industrial CO2	Total CO2	CO2 + CH4
OECD North Am	33.2	29.7	29.2
OECD Europe	26.1	16.6	16.4
Eastern Europe	5.5	4.8	4.7
Former USSR	14.1	12.5	12.4
Japan	3.7	2.3	2.3
Oceana	1.1	1.9	1.9
China	5.5	6.0	6.3
India	1.6	4.5	4.8
Other Asia	1.5	5.0	5.2
N. Africa & Md-East	2.2	1.7	1.8
Other Africa	1.6	5.2	5.2
Brazil	0.7	3.3	3.3
Other Lat Am.	3.2	6.5	6.5
"North" (1-6)	83.8	67.8	66.9
"South" (7-13)	16.2	32.2	33.1
World	100.00	100	100

Source: Grubler & Nakicenovic, 'International Burden Sharing in Greenhouse Gas Reduction,' Table 3.6.

Including methane makes very little different to these results, partly because of the shorter residence time in the atmosphere. Compared to *current* populations, the ratio of cumulative emissions per capita between the "North" and "South" is more than 10 to 1.

These estimates can be subjected to the criticisms that Agarwal and Narain (1991) raised in connection with an index of current net emissions (see box). By "discounting" emissions to reflect absorption of gases, there is an implicit assignment of the earth's past "sink capacity" in proportion to emissions. Fujii (1990) and Meyer (1992) furnish calculations to show that if the total CO_2 absorption were assigned on an equal historic per capita basis, most developing countries are in fact "in credit"--their cumulative emissions are smaller than the global average per-capita absorption, and so on this basis their past contribution is not merely small but actually negative.

Some logical problems with this latter approach are noted in the box. On a more directly physical definition of "relative contribution to the build-up of greenhouse gases"[25] the contribution of developing countries is positive, but probably (even) less than that indicated in Table 1. On any measure, the contribution of the world's poorer regions to the total build-up

of greenhouse gases over the past century is modest, and even more so when considered in relation to population.

III.3.b Current emissions

"Responsibility" for the problem is much more sensitive to the index chosen for current emissions than it is for cumulative contributions. The most important issue is whether one focuses upon total or per-capita emission rates. Developing countries tend to focus upon the latter, as an index which highlights the extent of North-South disparities in emissions associated with individual lifestyles, and consequently as a way of emphasising what they consider profligate and unsustainable Northern lifestyles as the root of the problem. Commentators from industrialised countries more often point out that in terms of climate change it is total emissions that matter, and that per-capita indices ignore the important element of gross population itself as a causal factor.[26]

In reality of course both aspects matter, and the illuminating way of presenting the data is in a form which displays both simultaneously. This is done in Figure 1, in which 1993 emissions of CO_2 from fossil fuels are illustrated on a graph of per-capita emissions against population: the area of each block, as the product of the two, represents total fossil CO_2 emissions from the country or region.

Figure 1 About Here

Projection against the per-capita axis illustrates the scale of these disparities, not just North-South but within groups. North America and Australia emit between 4.5 - 6 tonnes of carbon per person on average. The figure for the industrialised regions of the "Old World"--including Russia and the former Central/East Europe after the contractions of recent years--are between 2-3 tC/cap. Average per-capita missions in many parts of East Asia and Latin America are in the range 0.5-1 tC/cap, though some of the Asian "Tiger" economies have already risen well above this. Per-capita emissions on the Indo-Pakistan subcontinent and much of Africa rarely exceeds 0.3tC/cap--a tenth or less of the per-capita emissions in the industrialised world. Others--such as the Middle-East and various island states--vary widely within this range.

Considering the population axis gives a counterpoint to this picture--many of the blocks which are much lower in Figure 1 (low per-capita emissions) are also much wider (high population). The developing economies of Asia alone account for more than half the global population. Despite their lower per-capita levels, this makes them significant contributors to the total--the area of the individual blocks shown in Figure 1. In total, in 1993 the OECD countries accounted for about 50.5 percent of global fossil carbon emissions, with about half of this being from the US; the former USSR and Eastern European countries accounted for 17 percent (with half of this being from Russia); and the developing countries contributed just under a third of gross fossil carbon emissions (with over 40 percent of this from China).

Another basis for comparing emission profiles is to consider the "productivity" of emissions--emissions per unit of economic output as conventionally defined. This tends to receive more emphasis in developed countries, that are generally more efficient, and again has its counterpart in considering total economic output, indicating what some developing countries characterise as over-consumption. Northern economists tend to put the spotlight on the lower efficiency levels in developing countries, whilst others attack the overall high level of Northern consumption as the root of the problem. Again, it is possible to demonstrate both dimensions on a single graph of emissions intensity versus GDP (Figure 2). This illustrates the somewhat lower carbon intensity of most developed economies, and the extent to which this is offset--or swamped--by higher overall consumption levels.

Figure 2 about here

Data for sources other than fossil CO_2, as noted, are much more uncertain, but in general the disparities between industrialised and developing countries are greater for CFCs, and less for all other sources, than those noted here for fossil CO_2. Most notably, almost all emissions from deforestation--thought to be in the range 15-25 percent of total CO_2 releases in the early 1990s--are from a relatively small group of developing countries, whilst anthropogenic methane emissions are probably predominantly from Central/East Europe (fossil methane) and Asia (agricultural methane) [to be checked against recent IPCC estimates]. How these emissions compare with fossil CO_2 data depends upon the data and comparison basis chosen, as discussed in the IPCC 1992 supplementary report. The statement that the industrialised and developing worlds account for about half of gross anthropogenic greenhouse gas emissions each is within the range of data and comparison uncertainties (SEI, 1991), but as noted this obscures both large disparities in average per-capita emissions, and important regional, national and sub-national variations within each group.

III.3.c Future emissions

The pattern of emissions is changing--it has indeed changed markedly in the last 5 years--and is expected to continue changing. Work on scenarios for this IPCC report has shown the very large number of emission scenarios that have now been prepared, with a variety of assumptions, timescales and degrees of regional breakdown.

From an equity perspective it is important to distinguish "business as usual" projections from assumptions about the location of abatement, and to have a sufficient regional breakdown to relate emission patterns to economic and other regional differences. The scenarios of the first IPCC Assessment Report (unlike the 1992 update) had sufficient clarity on both counts, and were criticised as embodying highly inequitable assumptions, both in the reference scenario and in the apportioning of emission reductions in abatement scenarios. Parikh (1992) noted that the reference scenario 'permitted' substantial increase in North American emissions, but considered that 'cuts for the South are already built into the reference models' compared with the rates of growth that might otherwise be expected; and she argued that 'the stabilisation scenarios stabilise the lifestyles of the rich and adversely affect the development of the poor.'

The IPCC 1992 scenarios span a very wide range, with little geographical detail, and thus do not embody a clear view of the distribution of emission trends. A more recent and much more thorough development of emission scenarios for fossil fuels is that by the World Energy Council (WEC, 1993), which developed regional scenarios both from a global perspective and with regional teams. Interestingly, their reference scenario was also criticised by participants from the developing world and former USSR for being too optimistic about the prospects for improved energy efficiency in these regions; taking account of these concerns led to a variant of the reference scenario with much higher emissions particularly in South Asia, Central/East Europe, and Africa.

Whichever variant of future scenarios is considered--and especially for the higher growth cases favoured by many in the developing world--the vast majority contain a clear message. The ambiguities about whether the developing world holds significant responsibility for contributing to climate change will not persist for long. Even in relatively restrained scenarios of emissions growth from the developing world, such as the original WEC reference case, fossil CO_2 emissions alone from these countries those of the OECD by 2020. And in many scenarios, before the year 2050, fossil CO_2 emissions from the current developing nations exceed the global total emissions today--despite still being considerably lower in per-capita terms (both factors of course partly reflecting population growth). Furthermore, in terms of the distribution of abatement efforts, there are significant spill-over effects, both positive and negative.[27] Bradley *et al* (1994) note on the basis of a range of abatement scenarios, 'anthropogenic climate change cannot be controlled by the OECD nations alone'.

Emissions from deforestation do not--probably cannot--keep pace with projections of fossil fuel emissions; the projections reviewed in the IPCC 1992 assessment almost all stay below 2GtC/year, and decline after 2030, compared with global projections of global fossil fuel emissions rising above 10GtC/yr by this date in many 'reference' scenarios. Methane projections are highly uncertain but also suggest slower growth. Clearly, neither is likely to alter substantially the overall trend in the distribution of emission sources. Whatever the past and current responsibilities and priorities, it is not possible for the rich countries to control climate change through the next century by their own actions alone, however drastic. It is this fact which necessitates global participation in controlling climate change, and hence, the question of how equitably to distribute the burden of climate change on a global basis.

III.4 Vulnerability to climate change

Another aspect--distinct but again partly correlated with both wealth and institutional capabilities--is the likely differential impact of climate change. The work in both the IPCC Working Group II, and the chapter in this report on assessing and valuing the impact of climate change, note that impacts may vary considerably between countries. Small island states and countries with low-lying coastal areas are an obviously vulnerable group, not only because of their greater susceptibility to sea-level rise, but also their heavy dependence upon natural resources that may be affected by climate change, and traded commodities that may be affected by abatement (Saha, 1994). In addition to these adverse economic impacts, these countries may face

destruction or uninhabitability of all or part of their territories. This in turn may have profound consequences for their human communities as well as entire ecosystems. This is an important equity issue not only because the impacts differ, but also because those most vulnerable to climate change are to a large extent those contributing very little to its causes. For small islands, but also for may other developing countries, adaptation to climate change may be a more important, and more urgent, task than planning and undertaking national mitigation policies.

Possible implications of this for international responses aimed at coping with climate change and minimising the impacts are considered in the next section. Here it is important to note that assessing the consequences of the vulnerability of countries to climate change requires valuing the damage that may arise from climate change. Any attempted valuation of damage unavoidably requires estimating and aggregating impacts on different people in different countries across different timescales. But as discussed in the introduction this chapter, there is no single "right" way to do this; it can only be done by making ethical judgements about what to measure, and how to measure and compare the welfare of different people in different countries across time. Considering only impacts on Gross World Product is a poor enough indicator for the reason outlined in the introduction (and discussed in the chapter on evaluating impacts below) that this indicator makes no pretence to be a real measure of welfare. But if it is predominantly poorer people who are affected, it is even worse as an indicator, because poor people add very little to aggregate wealth--and impacts on them are similarly discounted (Ayres and Walter, 1991).

Attempts to allow for 'non-market' impacts, such as those on human health and environment, require assumptions to be made about how to value and aggregate such impacts on different people in different countries. Scaling impact costs according to relative GDP implies valuation of human impacts based upon average earning power. Implicit valuation also differs greatly between countries, partly because it is constrained by aggregate wealth, and the blunt fact is that societies clearly do not value people in other countries equally. One of the most significant aspects of climate change is that activities of people in one country can have destructive consequences for people in other countries. Any aggregation that evaluates and aggregates impacts in relation to national wealth (such as impacts on GWP, plus non-market impacts related to national GNPs) in effect embodies an assumption that the human impact is less significant if it is poor people, or people in poorer countries, that suffer

If poorer countries are more vulnerable and are likely to suffer more, the dominant impacts are likely to be precisely in those regions. The question of how they are valued thus becomes central to any evaluation, and cannot be passed off simply as inevitable economic logic (Grubb, 1993). Hence, it needs to be recognised that attempts to quantify the costs associated with climate change involve inherently difficult and contentious value judgements, concerning which different assumptions may greatly alter the conclusions.

III.5. Social Considerations

Methodological disputes about the best way to measure vulnerability may also disguise the fact that it may be impossible or inappropriate to attempt an economic evaluation of some of

the impacts of climate change. For some small islands and countries with low-lying coastal areas, climate change may lead to the destruction of all or part of their territories. This loss may have profound social impacts for their communities including, inter alia, destruction of indigenous cultures and whole communities, with the loss of their attendant heritage and spiritual, cultural and social values. This loss in human diversity does not appear to command as much attention in literature as the loss of biological diversity which is valued in itself as well as its scientific and economic values.

It is also important to bear in mind the human dimension of physical impacts such as storm surges, hurricanes, sea level rise and changing climate patterns. The burden of "adapting" to these events will fall more heavily on the parts of the communities that may already be disadvantaged and unable to adapt without further hardship. The more extreme of these events may result in the creation of environmental "refugees" and changed patterns of migration as human communities adapt to climate change. Climate change thus could well exacerbate problems of both domestic and international refugees.

Methodological debates about how best to value damage may overlook the fact that no amount of monetary compensation may be sufficient for communities that have had no choice but to bear the burden of adaptation. This has important equity implications for deciding whether mitigation or prevention of climate change is preferable to adaptation. The language of the Framework Convention on Climate Change does not give mitigation absolute priority as it accepts that some countries and communities will have to adapt to climate change. However, the acceptance that developed country parties must assist developing country parties that are particularly vulnerable in meeting the costs of adaptation indicates that negotiators agreed it would be inequitable for members of the international community that were vulnerable to climate change to bear the costs of that vulnerability alone.

Adapting to climate change will also present a social and institutional challenge for many countries. Countries are not equal in their capabilities to deal with such challenges and it is important to note that countries differ in these respects. Some are strong nation-states, with a large degree of societal, consensus and strong institutions that can formulate and implement policy effectively, and which can act to protect weak and vulnerable groups--for example, against the effects of climate change. Others may be driven by internal differences, and have fragile governing institutions that may be unable, or unwilling, to formulate and implement effective policy or to protect the most vulnerable groups--institutional structures which indeed may themselves be vulnerable to the stresses that climate change may bring.

Relatively little literature exists examining public perceptions and social responses to climate change, in particular, how different social groups view global environmental problems. Such research would appear necessary as a first step to increasing public participation in ameliorating these problems (see "Human Dimensions of Global Warming: They Should Not be Ignored", Ragner E. Lofstedt, Centre for Environmental Strategy, University of Surrey).

At a lesser but still important level, some countries may have strong traditions of independent research and analysis to help them understand complex issues, and have the

resources to back such work and bring it to bear on international decisions; others may have neither.

To a degree--but not entirely--these differences correlate with wealth. The IPCC Special Committee on Developing Countries for the 1990 Assessment also highlighted the importance of such differences, which affect a whole range of aspects of climate change, including the ability of countries to participate effectively in international analysis and negotiations, and the ability to implement efficient response strategies both for mitigation and adaptation.

Possible implications of this for responses aimed at coping with climate change and minimising the impacts are considered in the next section. Here it is important to note that this issue can also profoundly affect attempts to value the damage that may arise from climate change. This unavoidably requires estimating and aggregating impacts on different people in different countries. But as discussed in the introduction to this chapter, there is no single `right' way to do this; it can only be done by making ethical judgements about how to measure and compare the welfare of different people in different countries. Considering only impacts on Gross World Product is a poor enough indicator for the reason outlined in the introduction (and discussed in the chapter on evaluating impacts below) that this indicator makes no pretence to be a real measure of welfare. But if it is predominantly poorer people who are affected, it is even worse as an indicator, because poor people add very little to aggregate wealth--and impacts on them are similarly discounted (Ayres and Walter, 1991).

Attempts to allow for 'non-market' impacts, such as those on human health and environment, require assumptions to be made about how to value and aggregate such impacts on different people in different countries. Scaling impact costs according to relative GDP implies valuation of human impacts based upon average earning power. In welfare economics this approach is contentious; for example many societies, directly or by implication, clearly value life much more than a "foregone earnings" measure implies (Frankhauser, 1993; and see Evaluation chapter in this report).

Implicit valuation also differs greatly between countries, partly because it is constrained by aggregate wealth, and the blunt fact is that societies clearly do not value people in other countries equally. But climate change concerns impacts caused by the activities of other people--predominantly more wealthy people--mostly in other countries. Any aggregation that evaluates and aggregates impacts in relation to national wealth (such as impacts on GWP, plus non-market impacts related to national GNPs) in effect embodies an assumption that the human impact is less significant if it is poor people, or people in poorer countries, that suffer.

This is a highly contentious ethical assumption. But if it is correct that poorer countries are more vulnerable and are likely to suffer more, the dominant impacts are likely to be precisely in those regions. The question of how they are valued thus becomes central to any evaluation, and cannot be passed off simply as inevitable economic logic (Grubb, 1993). Hence, it needs to be recognised that attempts to quantify the costs associated with climate change involve inherently difficult and contentious value judgements, concerning which different assumptions may greatly alter the conclusions.

III.6 Differing resource endowments

Finally, countries differ widely in their endowment of resources that may be affected by efforts to *mitigate* climate change, and in their current reliance upon production or conversion of these resources. Coal resources and production are relatively widespread globally, though with major variations within regions. Remaining oil reserves are heavily concentrated in the Middle East, Central America and former Soviet Union; for some Middle Eastern countries especially, oil is their only significant export and source of foreign exchange. Proved gas reserves are also quite concentrated in the Middle East and Russia (though their value would probably be enhanced by mitigation efforts). Forests, and timber exports, are likewise concentrated, to a limited number of developing countries. The value of such resources can be affected by action to limit climate change, though the actual equity implications may be complex as discussed later in this chapter.

III.7 Conclusions

This section has illustrated several ways in which countries differ that are relevant to formulating climate change responses. A number of these group along a "North-South" axis: the implications for developing countries are different because they are generally poorer, have contributed much less to past emissions and still emit much less per-capita, and they may have shorter policy time-horizons, weaker institutions, and be more vulnerable to climate change. Yet in other respects the divisions are much more complex. There are substantial variations within the "north" and within the "south" in terms of absolute and per-capita emissions, the likely impacts of climate change, institutional strengths and preferences, and endowment of natural resources that may be affected by mitigation. Similarly, in the next century some developing countries will continue to make marginal contributions to the problem whilst emissions from others may well start to dominate it. A rigid "north-south" delineation of equity issues in the debate is thus inappropriate and may indeed be highly damaging in the long run, though it inevitably permeates many components of the debate at present.

The rest of this chapter concerns the implications of the various differences for what might constitute equitable responses. In structuring it, we draw upon the observation by Shue (1992) that the equity issues in responding to climate change comprise at least four distinct questions:

- distribution of the costs of coping with climate change;
- distribution of future emissions;
- distribution of the costs of measures to limit emissions; and
- the background allocation of resources and capabilities and consequent basis for fair bargaining and fair processes

All these questions are interrelated. For example, a "fair" distribution of future emissions may depend somewhat upon how much countries help others with the costs of coping; a fair distribution of abatement costs depends upon various background circumstances; and debates about allocating the "burden of abatement" in general, and joint implementation and tradable emission quotas in particular, highlight a particularly strong link between ii) and iii). Few authors in fact have distinguished these different components; but they are distinct and it is useful to address the equity issues each raises in turn, even if two or more of them may in practice be tied or even addressed through the same instruments.

This next section considers the question of the costs and risks of coping. The following then considers the common issues surrounding distributing emissions and the costs of abatement, before summarising specific proposals concerning each in turn. The final sections then examine internal equity, and procedural equity issues.

IV Distributing the costs of coping: impacts, risks and international insurance

The previous section has noted the fact, analysed more fully elsewhere in the IPCC SAR report, that some countries are likely to be much more affected by climate change than others. To an important degree, poor countries may be much more vulnerable than richer countries. But all projections of impacts are fraught with uncertainty--in some scenarios parts of the developed world could also be badly affected for example--and thus the issue is also about sharing and minimising risks. This section reviews these issues.

IV.1 Nature of impacts and uncertainties

Predictions of climate change remain highly uncertain. The uncertainty about the future average temperature is high enough, but it is local effects that really matter, and predictions of regional changes are even more uncertain and can vary substantially between different climate models. It may even be that in some areas the temperature will go down, but we cannot predict with any confidence where, because it depends upon atmospheric and ocean current patterns that are not well understood. The impact from climate change will also depend heavily upon changes in precipitation and winds; the climate models predict in general that precipitation will go down in the interior of continents while it will increase elsewhere but again with wide uncertainties. Sea level rise is predicted, with widely differing impacts, but again the rate is uncertain and could vary between regions because of shifting pressure patterns and other factors. Climate change could increase the frequency and/or severity of droughts, heavy storms and hurricanes, and in general the frequency of violent fluctuations in the weather. These fluctuations will not in general be predictable (except in a probabilistic sense), and will therefore add to the uncertainty.

It is not likely that such uncertainties can be resolved quickly, and it may always remain impossible to make reliable local predictions or to associate particular local impacts with human-induced climate change, because to an extent the climate is inherently chaotic; variations may be extremely sensitive to the initial situation (for a popular discussion of dynamical systems and their inherent unpredictability see Gleick (1987)).

Thus, in discussing climate impacts it is better to refer to `expectations' of costs and benefits, in the mathematical sense of an average of possible outcomes; and to recognise simultaneously the importance of uncertainties. This implies there is a another cost item--the cost of bearing risk. Thus, we can categorise the distributive issues arising from climate change impacts into four groups:

- aggregate welfare impacts over time (intertemporal distribution of expected global utility)
- welfare impacts between countries (international distribution of expected utility)
- welfare impacts within countries (interpersonal distribution of expected utility within countries)
- the distribution of the cost of risk bearing associated with each of the above.

The question of aggregate intertemporal distribution is the subject of the next chapter. Concerning impacts within countries, over and above implementing policies promoting redistribution, governments generally accept responsibility for trying to manage, respond to and mitigate the worst impacts of extreme events--for example, with government relief programmes for victims of major storms. Big disasters in the developing world will also often in addition mobilise international relief efforts, though as noted by Rahman (1993) in the context of Bangladeshi cyclone disasters, these tend to be quite short-lived; after the initial effort, the local people, with some assistance from the government, tend to be left to rebuild their lives.

The new aspects introduced by human-induced climate change thus concern the broader impacts upon international welfare distribution, and the cost of associated risks. We consider each in turn.

IV.2 Paying for the costs of coping

If there are no international transfers or other assistance connected directly with the measures to cope with actual or potential impacts of climate change, each nation in effect is expected to cope using its own resources. The available literature appears to be unanimous in considering this inequitable, for two main reasons.

The first arises directly from the observation above that poor countries are likely to be much more vulnerable to climate change. Climatic change is thus likely to exacerbate existing inequalities. Most ethical systems would anyway expect richer parties to contribute more to addressing a common problem; the rationale is much stronger still when the cause is shared but the impacts are disproportionately large on the least well off parties.

The second factor, which applies irrespective of this inequitable distribution of impacts (but is much reinforced by it) is the direct causal link: the fact that the actions of some people (emitting greenhouse gases) may directly harm others. There are few if any ethical systems in which it is acceptable for one individual knowingly to inflict potentially serious harm upon

another and not accept any responsibility in helping or compensating the victim, or to pay in some other way. An analogous principle in international law provides that a state may exploit its resources but has the responsibility to ensure that activities in its jurisdiction do not cause harm to the environment of other states or to areas beyond its national jurisdiction. This principle is generally accepted as a rule of customary international law. Its application to the climate change context is problematic, however, as it is extremely difficult for one state to prove before an international court or tribunal a direct causal link between another states' emissions and its own environmental damage. Although upon signature of the Framework Convention on Climate Change a number of small island countries indicated that they may rely on traditional rules of international law to address damage to their environment from climate change, it is widely recognized that it would be factually and legally difficult to use these rules successfully.

This points to the need to develop general rules of international law regarding liability and compensation which was formally accepted at the intergovernmental level in Principle 21 of the Stockholm Declaration, and re-emphasized in Principle 13 of the Rio Declaration which provides:

> ". . States shall also cooperate in an expeditious and more determined manner to develop further international law regarding liability and compensation for adverse effects of environmental damage caused by activities within their jurisdiction or control to areas beyond their jurisdiction."

In the absence of new rules of liability the traditional "fault-based" rules of responsibility of international law could provide a basis for vulnerable, generally poorer, states adversely affected by climate change to receive compensation from richer states whose past and present emissions of greenhouse gases had caused environmental harm. The issue of historical emissions could be of direct relevance here as climate impacts are a function of atmospheric concentrations which depend strongly upon cumulative emissions. Whilst the Convention's preamble recognizes that the largest share of historical and current global emissions of greenhouse gases originated in developed countries, and that per capita emissions in developing countries are relatively low and will need to grow to meet their social and development needs, its legal ramifications remain unclear.

IV.3 Sharing risks

The question of who should pay is not solely about equity; is also concerns more classical economic issues about sharing risks. Chichilnisky and Heal (1993) (drawing on Cass, Chichilnisky and Wu (1991)) note that the risks involved have four important characteristics--they are:

I. poorly understood - we cannot assign clear probabilities to different impacts;

II. endogenous - they are created or affected by our own actions;

III. collective - given climate impacts may affect large numbers of people and so risks are not statistically independent and hence cannot be greatly reduced by "pooling";

IV. irreversible - impacts cannot in general be reversed and indeed may be committed long in advance.

This results in a complex combination of issues of equity and decision-making under uncertainty. Decision-making when the probabilities of different outcomes are known or reasonably estimated ("risk") is a field of extensive economic study, for which techniques of expected utility can be applied (Ramsay, 1931; von Neuman and Morgensteern, 1944). Rational decision-making when the probabilities of different outcomes are not known is more difficult but is still a subject of considerable analysis, for example using notions of subjective probability distribution (Savage 1951, 1954). Luce and Raiffa (1964) give a discussion which is still very much up to date, and the issues are discussed further in the decision-making chapter of this report.

One criteria for decision-making under extreme uncertainty is the `maxi-min' criteria, which is to select the strategy that minimizes the worst outcome. Its basis is similar to that of Rawl's criteria for equity. It recommends avoiding those strategies that could generate the worst outcomes. The maxi-min principle bears some resemblance to the precautionary principle expressly included in the Convention in Article 3.3 which provides that:

Parties should take precautionary measures to anticipate, prevent, or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.

A philosophic and economic examination of risk-bearing, including the max-min principle, may provide insights relevant to the application of the precautionary principle. The maxi-min criteria is however, rather conservative because it takes into account only the worst outcome and not the nature of the other outcomes from a strategy. In practice, climate change is not a situation of total ignorance--we have some idea of plausible outcomes and their relative probability. This increases the appropriateness of approaches based upon subjective probabilities, combined with an appropriate measure of risk aversion to reflect the cost of bearing risk (see box).

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The Cost of Bearing Risk:

In order to understand the meaning of the cost of risk bearing, consider a very simple case with two outcomes, A and B. In A the monetary gain is M_A and in B the gain is M_B. Let the probabilities for the two outcomes be p and 1-p. The expected gain is then $pM_A + (1\text{-}p)M_B$ which we will denote by M. Is the decision-maker indifferent between the uncertain prospect $(pM_A, (1\text{-}p)M_B)$ and the certain gain of M? If yes, he or she is said to be risk-neutral and if their utility function is u, it implies that:

$$pu(M_A) + (1\text{-}P)u(M_B) = u(M) = u(pM_A + (1\text{-}p)M_B),$$

i.e., the utility function is linear. However, most evidence indicate that the utility function is concave, i.e., it increases with the gain but the rate of increase goes down as the gain goes up. This has the important implication that:

$$pu(M_A) + (1\text{-}P)u(M_B) < u(pM_A) + (1\text{-}p)M_B).$$

The individual would prefer the certain outcome M to the uncertain prospect, although they have both the same expected value. This also means that the individual would be willing to sacrifice an amount in order to ensure a certain outcome. This willingness to pay is defined as the c= of risk-bearing. Let C be this cost. Then it is defined from:

$$pu(M_A) + pu(M_B) = u(pM_A + (1\text{-}p)M_B)\text{-}C)$$

C is the maximum insurance premium the decision-maker would be willing to pay in order to eliminate the uncertainty. If the uncertainty is not eliminated, then it is the cost he or she has to bear for that uncertainty.

These simple ideas have some powerful implications on equity issues in connection with global warming. The classical approach to reducing the costs of risk is with insurance. But markets do not exist in which individuals or countries could insure themselves against impacts due to changes in climate or due to changes in abatement policies; Wilford (1993), Chichilnisky and Heal (1993) and others note several reasons why commercial insurance markets cannot adequately cover against such risks; [28] to the limited extent they can the insurance premiums would presumably fall primarily upon the potential victims and thus represent an inequitable burden. This means that people and organizations have to bear an unnecessary burden corresponding to the cost of risk-bearing. Establishing global insurance in an appropriate form could increase both efficiency and equity by reducing exposure to risk.

Climate risk is an equity issue for several reasons. There are good reasons to believe that the distribution of the cost of risk-bearing is very uneven. First of all, industrialized countries have in general better insurance markets. This means that individuals in those countries can reduce their cost of risk-bearing substantially (but not completely, partly because global warming is a collective risk and partly because the incompleteness of markets). These possibilities are not open to most individuals in developing countries, and they have therefore to bear a higher cost of risk-bearing. Secondly, the cost of risk-bearing may be much higher in some developing countries than in industrialized countries because of the nature of the impacts. For example, a range from 20 cm to 60 cm may imply a quite low cost of risk-bearing in a country like USA and the expected damage would be a good proxy for the total cost of sea level rise. For a country like Bangladesh, the difference between 20 and 60 cm may mean a substantial difference in utility, which is not accounted for in the expected damage. Thus the cost of risk-bearing in Bangladesh is much higher than in the US. The same holds true for countries that may be threatened by increase in both the frequency and the severity of droughts. The variation in utility will probably be much greater than the variation in actual damages among different outcomes and therefore, the cost of risk-bearing will be high. In the absence of empirical studies on the cost of risk-bearing the values involved are highly uncertain, but the nature of the conclusions seem reasonable.

The problem of risk becomes more severe when changes in the environment are irreversible, because irreversible change means losing future options. This was studied by both Arrow and Fisher (1974) and Henry (1974) and they showed that the combination of uncertainty and irreversibility implied that the expected net benefit is not the correct decision criteria; irreversibility should amplify aversion to risk.[29]

IV.4 Policy implications

Most of the discussion on the economic and equity aspects of climate change impacts have focused on the `expected' changes over time and between and within countries. But uncertainties combined with irreversibilities--both in abatement and in impacts from climate change--makes the issue of risk-bearing also of great importance. Analysis is technically difficult but not impossible, and more study is needed. For example, the combination of the idea of basic needs and risk-bearing could have far-reaching implications. If we accept that

individuals have the right to some basic goods--food, shelter, access to environmental resources--and if emitting greenhouse gases threatens the availability of these basic goods, then those who do so should be prepared to protect potential victims against losing these rights to basic goods.

The Framework Convention on Climate Change mentions the concept of insurance in Article 4.8 which provides that

> "Parties shall give full consideration to actions relating to what actions are necessary under the Convention, including actions related to funding, insurance and technology transfer to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures."

In addition, Article 4.4 provides that the developed country Parties must ". . .assist developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting the cost of adaptation to those adverse effects."

This is a specific example, but at least two general conclusions can be drawn from the above discussion:

1. It is necessary to include the cost of risk-bearing in any equity discussion related to global warming. In particular, estimates of the costs of impacts should also include this cost component in addition to expected cost.
2. Policy should seek to establish appropriate global insurance against impacts from climate change.

The appropriate form of insurance is not however a simple matter. The characteristics of climate change discussed above lead to particular requirements for approaches to insurance, some economic principles of which are summarised in the box.

Also relevant is that fact that there are three broad kinds of costs that may be incurred in coping with climate change:[30]

A. preparation (or protection) to minimise the potential impacts of climate change, for example through the construction of sea defences, improved water storage or water transfer capabilities, or changing the kind or diversity of crops;
B. costs arising directly as a result of changes in the resource base (e.g. loss of land to the sea, other loss of agricultural land), and the social costs that may follow from this (Suleman, 1994);
C. costs caused directly by extreme events, such as freak storms and droughts.

Insurance against climate risks: economic principles

The characteristics of the risks associated with climate change noted in the text create particular requirements for approaches to insurance. Simply on grounds of risk sharing (as distinct from equity), Chichilnisky and Heal (1993) argue that two classes of insurance contract need to be considered. One is in the nature of a mutual insurance contract, which is an agreement between parties subject to similar risks that `those which are harmed will be compensated by others'; there are many precedents, for example in agricultural co-operatives. In the context of climate change the parallel would be a binding agreement in which countries that are hurt by climate more than the average (or expected) would be helped by those affected less.

The second type of `insurance contract' is required because the overall nature of the risks, as well as its specific distribution, are uncertain. The formal treatment of an appropriate insurance structure (Arrow, 1953) is complex: it requires defining "securities" for each possible outcome, which pay out only if that outcome is realised. In the climate change case the analogy would be that each country would be required to make commitments to compensate as insurance against a particular climate "outcome". To efficiently distribute the risks, however, countries would then be allowed to trade these "securities".

This (in combination with mutual insurance contracts) would not only allow a fairer distribution of the risks, but also allows for differing beliefs about the overall risks. For example, if a country genuinely believes that climate change is unlikely to have serious global impacts, it will be more prepared to see those "securities" that pay out under these conditions. These issues are discussed in detail in Heal (1993), and a formal two-country treatment is summarised in Chichilnisky and Heal (1993), who note that creating such securities who help to provide an objective test of the honesty of national positions on the risks of climate change: if a country were to argue that climate change does not involve substantial risks as part of a negotiating ploy to avoid onerous abatement commitments, for consistency it should be prepared to see associated high-pay off securities; and "there would be a cash cost to convincing and consistent misrepresentation of true beliefs. These cash costs could offset some of the incentive to free ride on other countries' efforts to reduce greenhouse emissions."

Whilst these analyses are primarily concerned with efficient risk-bearing, they have equity implications in terms of both outcome and process, and could ease some of the dilemmas. The feasibility, credibility and equity of such securities (would and should countries that "gambled wrong" be made or allowed to suffer accordingly?) remains to be considered and could be an important research topic.

Although the underlying equity issue of who should pay is similar in each case, some of the practical issues differ. Even if there is agreement on the underlying equity principles, major practical differences and disputes may arise because of all the uncertainties surrounding climate change. General protection measures (i) have multiple benefits; views will differ on the extent to which they should be funded primarily on the basis of concerns about climate change. It is likely that victims of both underlying climatic changes (ii) and extreme events (iii) will attribute their suffering to human-induced climate change more readily than those responsible for the emissions. Insofar as international help is based on the second `fault-based' rationale, this raises important issues about fair processes for deciding about the probability of events being tied to human-induced climate change, which none of the literature addresses explicitly.

The different nature of these costs has also led to different proposals about how to tackle them. Notably, there have been suggestions (for example in the Toronto Conference, 1988, and Beijing Declaration, 1992) for a "climate fund" to help developing countries pay for protection measures of type (i); international funding of such measures can be considered both as a matter of equity and as a way of reducing overall risks.

Also, the Alliance of Small Island States (AOSIS) have proposed creating an insurance pool to provide some cover against the impacts of sea-level rise and associated salt intrusion and storm surge damage. This was elaborated as a proposed Annex to the draft Climate Convention but removed at a late stage under pressure of the Rio deadline, and is discussed by Wilford (1993). AOSIS proposed that an insurance pool be created with international funding from governments. Two precedents are noted:

- The 1971 International Convention on the Establishment of an International Fund for the Compensation for Oil Pollution Damage, which is funded by agreed levies on oil importers; and

- The 1963 Brussels Supplementary Convention (an OECD agreement, amended by 1964 protocol) to the 1960 Paris Convention on Third Party Liability in the field of Nuclear Energy. This is funded half on the basis of GNP, and half on the basis of nuclear capacity.

The draft Insurance Annex to the Framework Convention on Climate Change proposed, by analogy with the nuclear precedent, funding through a combination of GNP and CO_2 emissions, the latter component suggested both on grounds of responsibility and to give an incentive to limit emissions.

The main criterion for entitlement to claim put forward in the draft annex was proved loss attributable to sea level rise, including storm surges. There is no reason why such an insurance pool should not, in principle, be available for countries other than small islands and for damage other than sea level rise. It could appear more equitable to extend the scope of

such a fund to insurance against all kinds of climate impacts though determining cause and effect may be more difficult in cases other than sea-level rise. The literature does not appear to explore this issue, nor does the question of compensation or other support for other kinds of climate coping appear to have been explored more fully, though some elements are implicit in the more general economic treatment of insurance (see box above).

V Distributing future emissions and abatement costs

V.1 Introduction

Issues of how future emissions (or abatement efforts) should be allocated, and who should pay for abatement, form some of the most contentious equity issues in climate policy. As noted above, the two questions are closely intertwined; in the absence of separate international transfers associated with abatement, the initial distribution of emission constraints will largely determine the distribution of costs. Much of the literature has focused upon the question of future emissions allocation, but some has addressed more directly the distribution of costs. This section considers first issues which are common to both topics, and then considers in turn some of the specific proposals for fair allocation of emissions and abatement costs.

The applied research literature on these questions--relating specifically to climate change policy--is limited compared to that on climate science, impacts or the economics of responses. There are of course many short articles and statements of positions made in newspapers, newsletters, `non-papers' at negotiating sessions, etc.; and also some important official declarations developed through extensive discussions to reflect consensus positions among groups of countries (e.g. the *Beijing Declaration*, and various regional statements). Also, the UNCED agreements themselves contain innumerable references related to equity. Most of this is cast in North-South terms, with important additions concerning the interests of particular groups.

This section attempts to reflect this material, whilst recognising the impossibility of ensuring comprehensive coverage, and drawing heavily upon the limited deeper analysis of international equity issues in the more conventional academic literature of books, substantive reports and articles in peer-reviewed journals. Interestingly, of those that have contributed such analysis, few are professionally employed as academics in the discipline which might seem to be of greatest direct relevance--moral philosophy.

V.2 Principles for shorter-term action

In approaching the topic it is useful to distinguish short-term from long-term allocation issues. In the long term, decisions will have to be taken--by design or default--about the overall allocation of greenhouse gas emissions. The appropriate allocation depends upon the conception of equity, and different ethical approaches may have very different implications. But in the short term, the position is simpler. All ethical systems, and all the applied literature, appears to point in the same direction (Shue, 1991):

> "Even in an emergency one pawns the jewellery before selling the blankets .. whatever justice may positively require, it does not permit that poor nations told to sell their blankets [compromise their development strategies] in order that the rich nations keep their jewellery [continue their unsustainable lifestyles]."

The Framework Convention on Climate Change certainly requires that developed country Parties take the lead in combating climate change and its adverse effects. It also recognizes that the extent of developing country Parties' implementation of their commitments under the Convention depends on the effective implementation of developed country Party commitments to transfer financial and technological resources and must fully take into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties. These provisions flow from the Convention's principle of common but differentiated responsibilities and Parties' respective capabilities, rather than being predicated on rich countries' unsustainable lifestyles.

The observations about what is not fair in initial distribution of emissions obligations extends to other measures of abatement effort. Notably, some earlier and overly simplified economic studies assumed that a uniform carbon tax, as an indicator of abatement effort, would distribute the "burden" equally, fairly, and efficiently. None of these three suppositions have stood up to closer scrutiny in the literature:

- a uniform carbon tax would not impose equal burdens upon different countries because of differences in existing tax structures (Shah and Larsen 1990; OECD 1992; etc.), resource endowments (Whalley and Wigle 1989; others?); and stages of development;

- even in a scheme involving "equal burdens," most observers argue that this would not be fair because of the many differences outlined in the previous section, notably differences in historical and current emissions and current wealth and consequent priorities;

- a uniform tax would also be Pareto-inefficient in the absence of optimal international lump-sum transfers, because of the differing marginal utilities between countries at different stages of development (Chichilnisky 1993a).

The literature thus demonstrates a degree of consensus about relative responsibilities and equitable directions of response in the short term, and some elements of what would not be equitable in longer term allocations. Beyond this, and in the attempt to develop more precise allocation principles, there is a far wider range of perspectives, which derive from a range of ethical approaches. We consider first some of these underlying ethical assumptions, and then consider more specific proposals for allocation of future emission entitlements and abatement costs in turn.

V.3 *Longer-term allocation: underlying principles*

General ethical principles underlying discussions about fair allocation fall into several categories. Several authors have sought to classify and in some cases critique equity principles applied to this question. Those attempting a fairly broad coverage include d'Arge (1989), Rose (1990), Young (1990), Grubb et al (1992), Ghosh (1993) and Bhaskar (1993). Underlying a number of these are various conceptions of utilitarianism--the "greatest good for the greatest number". As noted in the introduction this in principle underpins the quest of modern welfare economics to maximise the sum of individual utilities, but there is no consensus about how to compare and maximise individual or national utilities at the international level; some of the principles sketched here are in part an attempt to formulate more specific interpretations of utilitarianism, as well as to apply alternative or complementary ethical frameworks.

Egalitarianism

This reflects the underlying Parity principle that each human being should have equal rights, in this case with respect to access to common global resources. It underlies several specific proposals considered in the next section.

Basic needs and Rawlsian criteria

A basic needs approach in the present context involves allowing countries the right to emit the minimum levels of greenhouse gases needed to meet the basic needs of their citizens, defined as the minimum consumption levels needed to support full participation in society, and then forcing countries to buy (or pay taxes on) the rights to emission levels above these. It would perhaps be close to the allocation of emission permits according to population, although basic needs could vary from country to country depending on climate and other matters. Chichilnisky introduced, formalized and developed empirically the idea of development aimed at satisfaction of basic needs while creating a society intrinsically compatible with the environment.

This can be related to a Rawlsian philosophy. At an absolute minimum it suggests that developing countries be left at least as well-off under an emissions control regime as they would be in its absence; a stronger interpretation is that the regime should be used specifically to improve their position.[31]

The only target in the Convention requiring developed countries to aim to return carbon dioxide emissions to 1990 levels by the end of the decade applies a uniform target approach based on historical or current emissions (often referred to as the "grandfathered emissions" approach) (Bodansky, 1993). Developed country parties with economies in transition are allowed "a certain degree of flexibility" with implementation of this obligation. Developing countries are not required to limit their current emissions and the Convention's preamble recognizes that developing countries' emissions will grow to meet their social and economic development needs. These provisions could implicitly support some kind of concept of basic needs emissions entitlements varied according to national circumstances. However, it is

important to bear in mind that the Convention's negotiators could not agree on the bases of present and future entitlements to emissions (Bodansky). The inclusion of the stabilization target does not preclude the relevance of the basic needs approach to future discussions about emissions entitlements.

Proportionality and polluter pays principle

This reflects the ancient Aristotelian principle that people should receive in proportion to what they put in, and pay in proportion to their contribution to damage caused. This has a clear potential relationship with the polluter pays principle, which is formulated as a principle of economic efficiency that in the context of international pollution can be interpreted in a number of ways as discussed below.

Historical responsibilities

Many authors consider that allocation should be strongly influenced by the patterns of past emissions. This has been a particularly persistent theme in North-South debates. Hyder (1992) draws together several of the underlying rationales in expressing the perception of many developing countries:

> "It is difficult for most of the developing countries to accept the proposition that they should enter into commitments which would adversely bind them, either now or later on, for the sake of a problem caused by the developed countries--who neither wish to equitably share the remaining emission reserves in the atmosphere, nor to share (even in a small way) the benefits and resources that they have built up by plundering the world's greenhouse gas reservoir capacity."

This illustrates that several issues are involved in the general assertions about historical responsibility: ownership of the emissions potentially responsible for transboundary impacts; prior use of a finite stock (the atmosphere); and current monopolisation of the benefits derived from these activities.

Comparable burdens and ability to pay

Another general approach to emissions allocation is the sentiment, frequently stated but not subject to more detailed analysis, that allocation should affect all countries similarly or involve "comparable burdens", or "sharing the effort equally." This is not to imply that countries should incur the same monetary costs (e.g. per capita); some conceive of it as a fixed proportion of GNP (Burtraw and Toman, 1991), others in terms of a more general measure of ability to pay, including more complex measures (e.g. the Human Development Index--see below).

The Convention's principle of common but differentiated responsibilities and respective capabilities embodies elements of proportionality and historical responsibility as well as the comparable burdens/ability to pay approach.

Willingness to pay

Another principle is simply that countries should bear costs based upon what they are--or objective "should" be--willing to pay, give the potential damages they face from climate change. According to this principle, contributions should be determined by a combination of ability to pay (reflecting current wealth) and, national benefits gained in terms of reduced climatic stresses, and level of general concern about climate change.

This approach reflects the principle of welfare economics that subjectively perceived benefits ought to affect the distribution of burdens (and hence allocations). Dorfman (1991) draws the important distinction that for a common property resource (degradation of the atmosphere), willingness to pay should be based not on how a country values a given reduction in its own emissions, but instead, how much it would value a reduction in world-wide aggregate emissions. Presumably those valuing such reductions to a greater extent should be more willing to abate. This basically accords with Kant's Categorical Imperative (1785), which states that one should act as if the maxim of one's act were to become a universal law of nature. An idealized application of this Kantian Rule for abatement is analyzed by Barrett (1992) for emissions allocation.

One concern is that this could lead to a situation of "victim pays", though in the greenhouse case the wealthiest countries may be both the greatest polluters and the most willing to pay. At present an intractable difficulty is the lack of knowledge concerning the regional impacts of climate change, and in practice such a criteria would imply piecemeal negotiations in which each country had an incentive to underestimate the potential damages from climate change, and overestimate the costs of abatement, so as to obtain a lax allocation for itself.

Applications of distribution theory in welfare economics

A very large welfare economics literature exists on the distribution of income within countries, and clearly there is limitless practical experience on how countries handle distribution issues. It is an interesting question whether and how any of this analysis and experience should be brought to bear on the issue of climate change. Interestingly however, none of the climate change literature at present appears to attempt this.

Conclusions

The various approaches outlined offer general criteria, which have been most widely raised in the context of wealth and other north-south differences, but which can in principle be extended to reflect other differences. Although complex, the provisions of the Convention are consistent with or reflect a number of these approaches. Neither the Convention or these approaches, however, give specific rules to determine a unique, maximally equitable allocation of emission entitlements or abatement costs.[32] We turn now to consider specific, equity-based proposals for allocating future emissions and/or abatement costs.

V.4 Specific emissions allocation proposals

This section considers proposals for fair distribution of emissions--and by implication abatement effort--separated from any substantive financial transfers related to climate change. The distribution of emissions / abatement effort then directly determines the payments, and any abatement-related transfers would be similarly determined directly by the initial emissions allocation, through the mechanisms of joint implementation or by more formal emissions trading. The subsequent section then considers other approaches which consider directly the question of 'who should pay' abstracted from the question of distribution of emissions.

There are three reasons for dividing the issues in this way. First, it provides a useful way of classifying the literature: although much of the general writing does not explicitly distinguish issues of who should pay from emissions distribution, most of the more analytic material in practice focuses upon one or other as the "output". Second, it provides an analytically clear delineation which may help to remove some of the confusion in understanding the literature. Much of the economics literature *assumes* that an international market--mediated by large international transfers to produce a global least-cost response--exists or will naturally come into being. This debatable assumption explains much of the division between economic and other perspectives. Third, by the same token it provides a politically useful clarification; many are skeptical of the prospects that an international fund, with payments though it on some equitable basis on support of a globally optimal response, will in reality ever be created, and this explains much of the fear about inequitable global responses. Focusing initially upon allocation in the absence of separated big international transfers helps to clarify these issues.

Ad-hoc proposals

Various ad-hoc allocation schemes have been proposed. Krause *et al* (1993) suggest that an overall cumulative limit for emissions of 300GtC over the period 1985-2100 be established and divided equally between the current industrialized and developing countries. The general characteristics of this allocation are argued to be ethically appealing--it requires substantial cutbacks from the industrialized world and allows for some interim growth from developing countries--but no more detailed division is offered and no more formal justifications for a 50:50 aggregated division of future emissions are presented.[33] Westing (1989) suggests land area as a basis for allocation, but without any particular justification and with some perverse consequences (Grubb et al, 1992).

More widely suggested is some proportion of GNP; Wirth and Lashof (1990)[34] and Cline (1992) for example suggests that this could be a component of an allocation on the grounds that carbon emissions are partially tied to economic activity. One difficulty is that the relationship is quite variable between countries for a variety of reasons, and pure GNP allocation faces the objection that on its own it would directly rewards richer, thus

exacerbating inequalities (especially since poorer countries generally have lower GNP/carbon ratios); there could also be technical difficulties associated with definitions and manipulation of GNP comparisons (Grubb, 1989).

Equal per-capita entitlements

The most widely cited specific proposal for allocation in the literature is that derived directly from egalitarianism, suggesting that all human beings should be entitled to an equal share of the atmospheric resource. This takes two general forms, with minor variations.

Equal contemporary entitlements--allocation in proportion to national population--is proposed by Grubb (1989), Bertram (1989, 1992), Epstein and Gupta (1990), and Agarwal and Narain (1991), among others. To prevent this providing an inducement to population growth, Grubb (1989) suggests that it should be restricted to population above a certain age. This has been criticized for 'discriminating against children' (though of course, like all international allocation proposals, it says nothing about distribution within countries): Grubb et al (1992) note a wider range of possibilities for avoiding any incentive to population growth, including `lagged' allocation (related to population a fixed period earlier); apportioned to a fixed historical date; or including an explicit term related inversely to population growth rate. The net effect in all cases would be to give developing countries, with much lower per-capita emissions, a substantial excess entitlement, whilst the industrialized countries, with emissions well above the global average, have a deficit.

This effect is much stronger still in proposals for equal historical or stock entitlements. Fujii (1990), Ghosh (1991) and Meyer (1992) propose that everyone should have an equal right to identical emissions regardless of country and generation. Fujii and Meyer take the equability of this allocation as self-evident; Ghosh (1993) argues that it can be derived from a range of diverse ethical principles including Rawlsianism, traditional utilitarianism, and even libertarianism.[35] The general justifications for historical responsibilities in various forms are discussed further below. Grubler and Fujii (1991) and Meyer (1992) develop detailed systems of accounts involving intergenerational transfer of the responsibility for past excess per-capita emissions by the industrialized countries, with the former allowing for progressive absorption of past emissions; den Elzen *et al* (1993) apply the idea with an energy model to a total carbon budget defined over 1800-2100. All these studies indicate that the industrialized countries have 'overused' the atmosphere in the past, and on most such approaches have built up a large "debt", the developing countries are in "credit."

Solomon and Ahuja (1991) propose that allocations should be based on "national historical per capita emissions"--the "natural debt" index as introduced by Smith and discussed in section III above--but do not elaborate quite what this means in terms of emission allocation (Smith's own application of the "natural debt" concept is in terms of obligation to pay, and is discussed below).

Egalitarian allocation, in either the contemporary or historical form, would be compatible with some of the more general principles noted above (such as Rawlsian and basic needs) but not others (such as comparable burdens and willingness to pay).

Status quo

At the opposite end of the spectrum, an alternate principle for emissions allocation has been suggested--but not necessarily advocated--for example by Young and Wolf (1992) as "status quo"--not only that past emitters should be held harmless but that their current rate of emissions constitutes a status quo right now established by past usage and custom. Analogies are drawn with the common law principles of adverse possession, such as "squatter's rights". Ghosh (1993) comments that "pollution rights have no common law sanction.

It is important to recognize, however, that international law has allowed a state to establish preferential rights to fisheries, a natural resource that is otherwise a common, limited resource, where another state has recognized that state's long-established use and its particular economic dependence on that resource. Whilst the law concerning the allocation of fisheries cannot be transposed to the climate change context, it is conceivable that the general principles of equity could be invoked to justify developed countries' use of the climate system at present day rates, particularly in the absence of developing countries' challenges to such use (Yamin, 1994). An important general equitable principle in this regard is the principle of "estoppel" which according to Franck and Sughrue "imposes a duty on States to refrain from engaging inconsistent conduct vis-à-vis other States" (Franck and Sughrue 1993). A failure to address and challenge explicitly the global basis of entitlements to GHG emissions could be characterized as acceptance of current use levels and have significant legal implications for establishing a basis of entitlements to GHG emissions under the Convention.

A strict status quo allocation--proportionate to current emissions--would violate all the more general principles outlined in the previous section. In fact, none in the literature appear to advocate strict status quo as an equity principle in its own right. It has however received widespread reference as a basis from analysts taking a pragmatic or game-theoretic approach (e.g. Barret, 1991), in that it is the default allocation that would arise in the absence of agreement (and hence a focal point), and the only specific allocation basis which does not automatically impose big burdens upon the industrialized countries. In such treatments the ethical basis, where considered, is usually referred back to concepts of equal burdens. It should be emphasized that in this context "status quo" is not a static concept, but rather refers to starting from a baseline of what emissions would have been in the absence of abatement, and thus would allow for more rapid growth from developing countries.

Mixed systems

The number of specific, single-criteria proposals for emissions allocation is thus rather limited. A comparative study by Burtraw and Toman (1992) also considers just the two main dimensions of equal per-capita entitlements, and equal percentage cuts. There are of course many other proposals which approach the question directly in terms of "who should pay",

considered below. Before turning to them, an emerging theme in the literature has been the possibility of combining different criteria.

Wirth and Lashof (1990) propose allocations based on an equal (50:50) mix of population and GDP, and Cline (1992) proposes an alternate allocation which consists of a weighted combination of population, GNP and current emissions.

A form in which historical contributions are considered as a determinant of emissions allocation, other than historical egalitarianism, is a scheme examined by Grubler and Nakicenovic (1991) in which countries have to cut back from current levels in direct proportion to their responsibility for past increases. In a sense therefore this is a mixed system. In requiring cutbacks from all countries--albeit more from the richer countries--it is probably inconsistent with the other principles sketched in the previous section (though modifications could be considered to address this).

Grubb and Sebenius (1992), supported by Shue (1993), examine a mixed system in more detail, and an almost identical formulation was proposed independently by Welsch (1993). These authors suggest an allocation which combines egalitarian and status quo / comparable burden principles, in the form of a combination of population and current emissions, but do not specify an equal weighting of these components. Rather they argue that the weighting accorded to population should increase over time towards a more pure per-capita allocation. Grubb and Sebenius suggest that the weighting would have to be determined on the basis of negotiation, reflecting partly the strength of competing equity arguments employed; Welsch proposes a 50-year transition from current emissions in the year 2000 to per-capita allocation in the year 2050, and presents sample calculations of the distributions of the costs this could involve.

V.5 Proposals for distributing abatement costs including international transfers

The proposals in the previous section focus upon "fair" approaches to distributing emission "entitlements"; financial transfers are considered insofar as they might arise from exchanging these entitlements. Most analysts suggest that both equity and efficiency considerations suggest a case for large international resource transfers as part of any regime for substantial reductions in greenhouse gas emissions, and some treatments focus upon this explicitly.

Three main approaches have been taken to consider how, and how much, such transfers might occur.

V.5.a Basis of the Climate Convention

One is based upon the principles in the Framework Convention on Climate Change. Concerning paying for abatement, the Convention effectively divides Parties into three groups. Annex 1 countries (all the industrialized countries) are expected to bear their own abatement

costs. Those also listed in Annex II (industrialized countries minus those with economies in transition) agree in addition to fund the efforts of the third group, developing countries. The Convention states that Annex II countries: " . . . shall provide new and additional financial responses to meet agreed full costs incurred by developing country Parties" in preparing reports under the convention (Article 12), and "shall also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the full incremental costs of implementing measures that are covered by paragraph 1 of this Article and that are agreed [between that country and the funding agency]."

This wording was very delicate; exactly how the term "agreed full incremental cost" is to be interpreted, and just who has to agree and how, is a question that is exercising the minds of experts in many different countries and Institutions, and which raises both process and outcome equity issues in its own right. The concept of incremental costs does not imply anything about the level of abatement developing countries are to achieve and as yet there is no clear agreement about its meaning and application to specific situations. Some of these issues will need to be addressed by the Convention's Conference of the Parties including a number of procedural equity issues relating to the structure, interim nature and independent operation of the Global Environment. Facility as the interim financial mechanism of the Convention.

In addition to the financial and other resource flows through the financial mechanism, a number of countries have proposed using the Convention's provisions on joint implementation to permit a second avenue of funding and technology to assist abatement efforts in developed and developing countries. The concept of joint implementation via offset investments in third countries and the concept of tradable permits or "entitlements", which are the subject of strenuous debate at present, are considered further below.

V.5.b Transfers determined by emission allocation and tradable entitlements

This second approach to international transfers is to let them be generated directly by determining a fair initial allocation, and allowing these "entitlements" to be traded (UNCTAD, 1992).

The initial allocation would be the principal means of determining resource transfers. Since most of the allocation proposals noted above would give poorer countries entitlements greater than their needs, and leave richer countries with a deficit, this would generate a transfer of resources to the poorer countries. The "outcome" equity issues involved thus parallel those noted above in discussing emissions allocation; indeed, many of the specific allocation proposals noted were only advanced in the context of them being *initial* endowments as the starting point for such a tradable entitlement system, on the ground both that this would both be more efficient and the only feasible way of introducing allocations radically differing from current emission patterns.

A number of concerns have been raised about practical and legal aspects of such systems, including their possible fairness in operation without institutional safeguards. Several analysts,

including both those supporting and opposing tradable entitlement schemes, have raised concerns about the legal and equity implications of allowing countries to sell forever and "right" to emit (Yamin, Joint Implementation and the Framework Convention on Climate Change: Legal, Institutional and Procedural Issues, 1993). For this reason, it has been proposed that entitlements should be either leasable (Grubb 1989; Agarwal and Narain 1991), or issued with a finite lifetime (probably overlapping) and reissued periodically according to the agreed allocation scheme (Bertram 1992; Grubb and Sebenius 1992). Negotiating and overseeing any such system would also involve a range of other process equity issues parallel to those considered below.

V.5.c Direct payment accountability approaches

The third approach is to seek a basis directly to determine "who should pay" for abatement, rather than to treat this as a consequence of future emission allocations. To a large extent the general equity issues involved parallel those involved in considering fair emission allocations, with ideas based for example upon interpretations of Rawlsian criteria, equal burdens, and willingness to pay. But the limited literature addressing the question in this form places relatively more emphasis upon two other components: *responsibility* for emissions, often including past emissions; and *ability* to pay for abatement. Smith *et al* (1993) draw this distinction directly in terms of indices of historical responsibility and ability to pay; Grubb (1990, pp. 281-286) draws a more general distinction between *responsibility-based* and *burden-based* criteria.

Polluter pays principle

A general basis for responsibility may be considered in terms of the Polluter Pays Principle. The OECD formally adopted a form of polluter pays principle in 1974 as a guide to environmental policy in stating that if measures are adopted to reduce pollution, the costs should be borne by the polluters. In particular, the costs:

> " . . . should be reflected in the cost of goods and services which cause pollution in production and/or consumption. Uniform application of this principle...would encourage the rational use and the better allocation of scarce environmental resources and prevent the appearance of distortions in international trade and investment." (OECD Council, 14 November 1974 C(1974) 223, Paris, 1974).

This is an economic principle which is essentially concerned that polluters should bear the costs of abatement without subsidy. The principle does not explicitly state that all polluters of a common pollutant should pay in proportion to their emissions, and in fact the literature seems remarkably opaque about how the principle should be applied in a context like climate change. The principle clearly points towards responsibility-based rather than burden-based criteria, proportional in some way to emissions: the polluter should pay: but on what basis, who should receive and for what purposes?

A critical distinction that is rarely clarified is whether the principle applies to *gross* payment or *net* payment. Burtraw and Toman (1991) assume that it applies to net payments, so that each country should pay *for abatement* in proportion to its contemporary emissions: this, they note, would be "regressive against national income, a characteristic that is bound to spark developing country opposition", and Chichilnisky and Heal (1994) and others have pointed out that such allocation of payment may be neither efficient nor fair. Other authors assume that the principle means that gross payments should be proportional to emissions, leaving the question of how the resulting revenues should be distributed as a separate question of efficiency and equity; and they also consider different bases for payment as now discussed.

Historical responsibility and natural debt

Smith *et al* propose that responsibility for paying should be determined on the basis of the 'natural debt' index described in section V.3; i.e. in proportion to total cumulative emissions since a specified date. Because this in itself would result in all countries bearing some responsibility for paying (though very much less for developing countries), they modify this by suggesting a lower threshold for "basic needs" emissions, consistent also with the arguments of Agarwal and Narain (1991) and others.

The principle of using cumulative historical emissions directly as a component in determining payment (or future emissions allocation) is considered by these authors as a natural and important matter of equity, and many others also argue the central equity importance of historical emissions in more general terms. Some of these authors recognize a variety of potential practical difficulties: how far back the emission estimates should go; whether and if so how the natural decay (reabsorption) of emissions should be taken into account; which gases should be included, given the highly variable quality and in some cases complete absence of data; and how to relate the emissions to scale (e.g. cumulative population--if so how defined--or current population, etc.). In part this reflects different potential definitions of the "natural debt" concept; in assessing responsibility indices, for illustration Smith *et al* consider total industrial CO_2 emissions since 1950 by country, with a range of lower threshold levels. However, at the same time as espousing the Fujii formulation of intergenerational egalitarianism, Ghosh (1993) criticizes the `natural debt' concept as a basis of historical responsibility on the grounds that it is an abstract, environment-centered focus which `does not acknowledge responsibility to others for one's actions .. does not relate to fairness across human beings'.

Historical responsibility as an equity principle has strong support in the literature and politically in developing countries (see for example the Hyder quote in section V.3 above). However, Young (1990), Kasperson and Kasperson (1993), and Grubb *et al* (1992) note three counter-arguments about the equitability of what the last of these characterize as `making present generations pay, by virtue of their geographical location, for the activities of previous generations' in that country:

- past generations were largely unaware of the consequences of their actions and had no incentive to limit emissions (this issue has some analogies with the issue of strict versus fault-based liability in legal regimes);

- it is not always clear who has benefited from historical emissions, given that the patterns of production, trade, consumption a and migration shift over time and are intricately interwoven. Boundary changes could also created major difficulties for allocating past emissions to current states in some cases (as with recent changes in Eastern Europe).

- although development has generally bequeathed the greatest benefits to descendants in the same country, important benefits have spread much more widely. Positive externalities associated with development (e.g. accumulated knowledge) as well as negative ones (such as pollution) can be transmitted both internationally and intertemporally.[36]

In response to some of these criticisms, Smith *et al* (1993) argue that it is not only equitable but also that `we are asking the present generation to take responsibility for the future .. if we dismiss historical responsibility, what is to keep the next generation from doing so?'; or as Hayes puts it in the same volume, `the current generation of leaders cannot disavow its obligation to pay off its natural debt .. at the same time as it claims to be adopting the principle of intergenerational equity'. Ghosh also rejects objections to historical responsibility as partly inaccurate,[37] but mostly irrelevant to the Fujii principle of equal historical per-capita entitlements since it is based not upon fault, blame or compensation but upon an egalitarian principle of access.

These debates, and the different elements noted in the quote from Hyder above, illustrate several different dimensions to the debate about historical responsibility. A clear statement by Bhaskar (1993) links several of these themes and lays the prime emphasis on the fact that `the current generation [in developed countries] are the prime beneficiaries of resource transfers from previous generations .. developing countries have a claim to part of the transfers, simply because they were made possible by the excessive use of global environmental resources in previous generations in the developed countries .. if the current generation accepts assets from their parents, then it is incumbent upon them to also accept the corresponding liabilities'.

Grubb *et al* in turn note the curious feature that in such reasoning, a `primary justification of consideration *historical* emissions is based upon *current* wealth. And it is intended to compensate for *future* increased costs to developing countries, if they are constrained'; they add hopefully, "tentatively, we suggest that the ethical divide between historical criteria and those focused upon current emissions and current relative ability to pay may not be as large as it appears."

Incorporating Ability to Pay

In addressing the question of "ability to pay", several authors have made reference to GDP, or the UN Scale of Assessments. Smith *et al* suggest an ability to pay element which is proportional to GNP (on a Purchasing Power Parity basis) for all countries subject to a threshold value, determined by Morris's Physical Quality of Life Index (PQLI);[38] countries with a PQLI below this threshold would be exempt.

On the basis of this, the authors argue that countries should have an `obligation to pay' based upon the two elements of historical responsibility and ability to pay (both with lower thresholds). They suggest that equal weight be given to these two components and observe that the resulting obligation to pay could be either the product or the sum, favoring the latter.

Utilitarian formulation

A wholly different quantified approach to the question of who should pay for abatement is provided by Chichilnisky and Heal (1994), who apply the concepts of classical economics to construct a strictly utilitarian formulation that seeks to maximise the sum of utilities across all countries, i.e., aggregate world utility, however, one recovers the classical solution in which marginal abatement costs are equalized at efficient allocations. In this case, only certain ways of distributing a given total emission entitlements between countries are efficient. The orthogonality between distribution and efficiency so central to the welfare economics of markets for private goods is not a characteristic of markets for environmental public goods. As noted above, these authors noted that in a situation without international transfers, efficient marginal abatement costs would vary between countries. If unrestricted lump-sum transfers are allowed, however, to recover the classical solution in which marginal abatement costs are equalized to achieve efficiency, only certain distributions of payment can maximise the aggregate utility. Specifically, they show that for the case of two countries in which both have the same standardized utility function (i.e. both value a given consumption level (and atmospheric quality) equally), then:

> "At a Pareto efficient allocation, the fraction of income which each country allocates to carbon emission abatement must be proportional to that country's income level and the constant of proportionality increases with the efficiency of that country's abatement technology."

This is the only distribution of abatement effort, for a given global total abatement and set of welfare weights, in which no country can be made better off without making another worse off (note however that it can only define relative contributions between different countries when the weights assigned to welfare in each country are specified).[39] The result in turn implies that the total resources each country should put towards abatement would increase as the square of the national income. The paper implies (but does not prove) that a similar conclusion would hold for the more general case of other utility functions (provided these are still similar between countries) and more countries.

Application of funds and transfers

These efforts to address questions of who should pay still do not address the question of who should receive for what purposes. Smith *et al* imply that the payments they consider would go to an international fund which would then be used to finance abatement at the lowest marginal cost, wherever that might be, to the degree determined by total abatement specified. In applying this index to evaluating transfers however, Hayes (1993) develops crude aggregate cost curves which combine abatement costs with protection against sea-level rise (but not other components of adaptation), aggregating Northern and Southern blocs. Combining this index and cost function leads him to conclude that `the incremental cost of abatement and coastal protection in the South that is justifiably the responsibility of the North' is a few tens of billions of dollars annually (in doing so, he draws upon the transboundary impacts as part of the justification for using historical impacts; this as noted is an important but distinct ethical issue from that of paying for abatement). Chichilnisky and Heal (1993) also imply that expenditures would be directed towards the global least-cost options wherever they may be.

V.6 International trade and the incidence of abatement costs

The above analyses all focus upon highly simplified pictures of the abatement problem, in which the only interrelationship between countries is the impact of greenhouse gas emissions and deliberate financial transfers associated with paying for abatement (or, in the context of section 5.3, adaptation). In reality, abatement involves actions that affect the consumption of many goods that are traded internationally and this in itself has other indirect consequences.

One concern expressed has been abatement action by the industrialized world will itself indirectly harm developing countries by slowing economic growth and thereby lessening demand for a variety of traded goods from the developing countries. Given the modest estimates of the impact of abatement on economic growth rates (at least for abatement to the degree currently being considered; see abatement cost chapter) it is likely (but remains to be demonstrated) that this second-order effect would be negligible compared with two other international effects. One is the ultimate benefits from reducing the rate of climate change itself, which for the reasons discussed in this chapter are likely to be greatest for the developing countries. The other is the impact mediated through the effect on the traded volume and price of the commodities which give rise to greenhouse gases--particularly fossil fuels.

This latter factor may introduce substantial variations between countries, depending on how restrictions are applied. If--as is generally assumed--abatement policies are applied to consumption, the likely effect is to reduce the internationally trade volume and price of coal and (to a lesser extent) oil. This effect will tend to benefit net importers of these fuels and reduce the revenues to fossil fuel exporters (see chapter on abatement costs). More generally, `the relative value of non-fossil energy resource would be increased; that of high carbon resources decreased' (Grubb 1990, p.285). Extensive abatement efforts could thus have serious implications for those countries that depend heavily upon coal exports or (to a lesser extent) oil exports--an equity issue already raised in international discussions.

The effects are however complex particularly concerning oil. Firstly, one initial response to reduce CO_2 emissions could be to burn more fuel oil in power stations in place of coal. Furthermore, gas--which in power stations emits about half as much CO_2 as coal--is very likely to be favored in CO_2 abatement strategies, and gas resources are often associated with oil deposits (gas is also associated with many coal mines). The overall impact also depends very much on the time horizon considered. Heal (1984) noted that in general, aversion to climatic risks would tend to flatten the use of carbon resources over time: peak and initial usage would be lower, but usage would also fall more slowly, partly because the resource base would be extended over time. Manne and Rutherford (1994) provide a more detailed energy analysis, concluding that `carbon restrictions tend to depress oil prices in the near term, but to increase them in the long term .. oil is less carbon-intensive than coal-base synthetic fuels, and hence oil enjoys a premium'; they also find that carbon restrictions improve the prospects and price for gas exports.

Such indirect impacts of abatement on fossil fuel exporters (and importers) are thus potentially important, but are frequently not simple.

V.7 North-South Joint Implementation

Joint implementation has emerged as one of the major debates in the post-Rio negotiations. The term is generally applied to the idea that industrialized countries might invest in projects in other countries, particularly developing countries, that displace greenhouse gas emissions. Industrialized countries consider that the main incentives arise if some or all of the emission savings can be credited towards the donor country's emission target, and many economists tend to see JI as a natural way of improving economic efficiency, by allowing industrialized countries to invest in abatement wherever it is cheapest.

North-South JI involves project-level investment, appraisal and crediting of emission savings by a "donor" country on the territory of a "host" country. This involves a host of equity issues that underpin the political debate, many of which illustrate equity issues discussed in this chapter (Note that NSJI contrasts sharply with proposals for international tradable permits, in which the equity issues would arise primarily (though not exclusively) from the allocation of initial emission rights between legally equivalent parties; Dubash (1994) explores the many differences and argues that NSJI is an attempt to lower the political costs associated with allocating tradable permits, "at the price of higher social and environmental costs").

A number of technical and economic concerns about NSJI have been raised, particularly concerning the problems associated with fact that savings have to be measured against a "counterfactual" baseline (i.e. an estimate of what would have happened in the absence of the JI project - what is to prevent inflated baseline estimates or other gaming behaviour?) and uncertainties about project success (who has the responsibility for project success, and what happens if it fails?), and administrative costs arising from both these factors; reviews of these technical issues are given by Loske (1994) and Selrod and Torvanger (1994), the latter being much more optimistic than the former, and in a number of books and conference proceeding

(e.g. Kuik et al (1994), Ramakrishna et al (1994). Here however the focus is upon the underlying equity issues, which can be classified along the lines set out in this chapter.

Allocation issues

Analysts have raised the following concerns about the implications of NSJI for emission abatement responsibilities and associated costs.

- NSJI could impose hidden administrative and/or opportunity costs upon host countries which are only partly recovered through the investment itself (Maya, 1994);

- NSJI could "cream skim" the cheapest projects, so that if and when developing countries are required to adopt emission constraints in the future, they will be faced with higher marginal abatement costs (e.g. Parikh 1993, and many others);

- if NSJI allows industrialized countries to continue increasing their own emissions it will perpetuate - and perhaps even exacerbate - global inequalities in per-capita emissions rather than tending towards any long term convergence (Parikh 1993, Loske 1994, and others);

- by reducing the pressure on ICs domestic action, NSJI may reduce the pressure for technical advance and innovation that could lower costs for all in future abatement (Loske 1993), which may itself differentially increase the future costs to developing countries (Ghosh 1994).

To each of these concerns there are responses that it depends (in part at least) on how the framework for NSJI is defined, and on how future commitments are structured to take account of any previous JI activity (e.g. Jones 1993, Vellinga and Heintz 1994, Heintz *et al* 1994, Metz 1994, Ghosh 1994). This however does illustrate that JI does not really overcome the basic political issue of allocating future emission rights, though it delays (at the expense of complicating) the need to address this core equity issue concerning the role of developing countries.

Efforts to address the technical and allocation issues also highlight concerns about more procedural equity issues. Since JI a project cannot (or is unlikely to) proceed without the consent of the host country, inadequate state participation per se is not a primary matter of concern, but issues of information and power asymmetries are raised in the literature. Concerning information:

- donor countries tend to have a far greater research and analytic capability, so they have a comparative advantage in any negotiations about framing JI projects (Pachauri (1994) comments that "the biggest apprehension that exists on the issue

of JI relates to small countries that lack the capacity to evaluate the implications of specific projects");

- hence the lack of analytic expertise may lead to host countries accepting projects that later prove to be against their interests.

Concerns about power asymmetries include:

- developing countries may find themselves pushed into projects on disadvantageous terms because of the balance of economic power; short term financial pressures, for example, could lead to host countries giving up land to JI projects that could have far greater productive use for the host country in later years (Maya 1994);

- JI projects may be driven by the interests of technology suppliers in the donor countries, perhaps at the expense of indigenous equipment manufacturers (Maya 1994).

Again, protection against at least some of these potential inequities can be developed, with the emphasis in the literature being upon the need for an open, transparent and multilateral framework for JI agreed between Parties to the Convention (e.g. Ghosh 1994, Markandya 1994), and also projects that meet a range of development needs (Imbree 1994).

Others, however, express concern that such an extensive multilateral framework may involve such high administrative costs as to render the idea impotent. And, conversely, it could be considered inequitable to expect industrialized countries to engage in stronger commitments whilst barring them from exploring alternative ways of achieving the same global environmental benefit; therefore, there is also an onus upon developing countries to clarify their concerns so as to allow a basis for a regime that is considered fair and practical by all parties. The purpose here however is not to argue for or against NSJI, but to illustrate the central place, and range, of relevant equity issues in any practical moves towards transnational implementation of measures to address climate change.

VI Equity Within Countries

VI.1 Introduction

This section examines issues within countries. Not only is this important in its own right, it can also shed a new light on the issues discussed in the other sections of this chapter.

- As remarked earlier (pp. 16 and 17 above), institutions to address a wide range of common interests exist primarily within countries, and equity is an important influence and measure of the strength and perceived legitimacy of these institutions. Although, the nature and strength of these national institutions is far from uniform, yet they provide the main working model for incorporating equity into international relations.

- A national focus allows lessons to be drawn from the experience of economic reform programs, especially the structural adjustment programs in Southern countries, but also programs of economic restructuring in industrialized as well industrializing countries.

- Unless intra-national equity issues are addressed explicitly, it may be impossible to mobilize public opinion for amelioratory action in both developed and developing countries as it is only at the intra-country level that we can begin to explore non-technocratic approaches to collective action.

- It is only at the intra-country level that we can begin to explore non-technocratic approaches to collective action.

- Since policies and actions to combat climate change would in any event begin at the national level, the examination of intra-country considerations could help individual countries by clarifying the range of issues involved.

Having said this, however, it must be acknowledged that intra-country equity does not figure (except obliquely, see p. 3 above) in the Framework Convention on Climate Change. It is being introduced here to facilitate the search for optimal national and international policies. It is not its purpose to introduce an entirely new element into international negotiation. Nor is its purpose to side-step the central concern of the Convention and also of this chapter--the issue of international equity and differentiated responsibility. Nor indeed is the intention to legitimize a new period of colonialism in which the scope for sovereign national action is restricted unduly by international agreements on the nature and form of intra-country equity.

As mentioned earlier, equity considerations have become a part of climate change discussions primarily because of the awareness of the diverse situation of both countries and individuals--not only in terms of their contribution to climate change, but also of the impact of the change on their well-being, their individual and collective capacities to cope with this

impact, and on their abilities to undertake mitigating action. Furthermore, there is also a growing awareness that the combination of large-scale changes and iniquitous arrangements will necessarily lead to conflicts and even wars, which will further aggravate the adverse effect on social well-being. Finally, it is also acknowledged that the burden of mitigation must not be placed disproportionately on the poor and vulnerable groups.

The above considerations have influenced decisions in a number of areas. In addition to the agreement to limit emissions to minimize the magnitude of the change, there is also an emerging consensus on the need to compensate the worst affected groups and countries, especially the small island states. Third, is the support, through Agenda 21, for the strengthening of coping systems in vulnerable countries. The agreement to distribute the burden of mitigation in an equitable manner also falls into this category. Finally, the awareness of the need for adjustment has also led some to recommend that countries should begin addressing major sources of inequity.

This can be stated differently. Equity considerations are germane to the climate change issue in two different contexts--equitable distribution of the costs (or benefits) of the change, and equitable contribution to amelioratory and preventive actions. Neither experience is without precedent in national contexts. There is an extensive literature on the distributional impacts of the business cycles, supply shocks (e.g. the oil price increases in the 1970s), economic development, and episodes of structural adjustment and liberalization. In all such cases, the questions are similar to the ones begin raised in the present situation, namely how is the burden of the change to be shared, and who should pay for amelioratory or preventive actions. This literature can be divided into two groups, that which looks at governmental policies within a given institutional context, and that which examines the institutional context itself. In addition to this, there is also a theoretical literature on conditions that will give rise to equitable outcomes within countries.

VI.2 Policy oriented literature

The classic example of policy oriented literature is the UNICEF publication on structural adjustment in Southern countries, *Adjustment With a Human Face* (Cornia, Jolly, and Steward 1983). As the subtitle of this text makes clear, the object of the exercise is to protect the vulnerable while maintaining growth. This book is a part of a critique that emerged in the 1980s against the then conventional approaches. Since then, the critique had gradually come to represent the new mainstream position.

Structural adjustment or 'stabilization' becomes necessary when the aggregate expenditure (or consumption) of a country begins systematically to exceed its aggregate income; the result is the accumulation of debt at an unsustainable and unserviceable rate. In the 1970s, these difficulties were seen as part of the short-term problems of cyclical fluctuations, and were responded to with the short-term measure of stabilization, on the pattern of similar problems and policy responses in Northern countries. Subsequently, it was recognized that the problem was of a longer-term duration and structural rather than cyclical; in other words, the problems emerged not because of the normal functioning of a business

cycle, but because the economic and political structure of some countries was designed to produce these results on a systematic basis. In either case, the symptoms were a growing public debt, deficits in government budgets and international payments, and accelerating inflation.

In the absence of a policy response, these symptoms were likely to be cured through the 'classical adjustment' mechanism, in which the debt squeeze brings about an economic contraction and thus a reduction in expenditures. Since Keynes (19??), this has been recognized as an sub-optimal path because of its high social and economic cost. The main policy response in the 1970s and 1980s was that of a managed economic contraction through budget cuts (especially on such 'non-essential' items as social services, consumer subsidies, and general administration), reduction in domestic credit, devaluation, and the liberalization of foreign trade and payments regimes (see Banuri 1992).

The performance of these policies have come under considerable scrutiny (see e.g., Taylor 199?, Banuri 1992, Comia et al 1983). Earlier critics argued that the orthodox adjustment programs were both ineffective and unnecessarily painful. They proposed heterodox, or supply-side approaches, which aimed to increase production directly through investment promotion, labor training, direct export promotion, and income policies. While many of these recommendations are extremely sound, experience shows that they have to be combined in varying proportions with orthodox demand contraction policies. Also, the hope for a win-win solution, in which the costs of adjustment would be avoided altogether has not been vindicated by experience. The economics profession appears to have come to the conclusion that some degree of economic contraction was inevitable during structural adjustment, if only to dampen the inflationary expectations built up during periods of prosperity.

As a result, attention of many of the critics shifted to the protection of important areas during such contraction. These critics argue that the conventional approach is sub-optimal, in that it leads to the marginalization and immiserization of vulnerable groups,--women, children, the poor, the rural population, labor, and the aged population--who are forced to carry a disproportionate burden of the adjustment. As part of their argument, Comia et al documented successful cases in which government policies managed to protect vulnerable groups while bringing structural adjustment. The result of these studies has been a remarkable turn-around in the conventional wisdom on structural adjustment. From a situation of almost total neglect of the social sector and vulnerable groups in the 1980s, current policies include the protection of these sectors and groups as integral elements of structural adjustment programs.

However, even the modified approach, which seeks to incorporate social and equity concerns, has not been without its critics. A number of writers have suggested that government-directed and targeted programs are not successful in alleviating poverty or delivering social services in many contexts. This criticism has been launched in particular by the Public Choice Theory school (Buchanan et al, 19??, Krueger 19??), and has been accompanied by calls for privatization and de-regulation. Other critics have used similar

arguments to recommend institutional development programs. We shall take up some of these criticisms in the next sub-section.

The analogy of structural adjustment to climate change is quite striking. The climate change threat has also emerged because the aggregate consumption of certain materials (mainly fossil fuels) by the entire planet has begun systematically to exceed sustainable levels. In this case, there is the accumulation of global warming gases in the atmosphere, again at an unsustainable rate. The analogy of the classical adjustment mechanism is the ecological homeostasis, which may bring about a new planetary equilibrium albeit with far fewer humans and after the payment of a very high human and social cost. The Framework Convention on Climate Change is analogous to an agreement to undertake a structural adjustment program.

In other words, the experience of structural adjustment in Southern countries has many lessons to offer for the foreseeable adjustment both at a global level and in Northern countries.

- The first lesson is that 'blind' or neutral policies have not performed well. As a result, the need to protect the social sector and some targeted groups has become widely accepted. In the climate change context, this means that such 'blind' policies as a carbon tax, or even tradable permits will have to be supplemented with policies to protect vulnerable groups and vulnerable sectors.

- In general, the experience of structural adjustment shows that policy responses need to be sensitive to economic, political, and institutional contexts of various countries. Reliance on a formulaic approach has often been ineffective if not counterproductive.

- The experience with heterodox approaches to stabilization suggests that these need to be combined in varying proportions with the orthodox, demand-contraction policies. In the climate change context this means that pure win-win solutions based on technological optimism--namely the expectation that technological improvements alone will suffice to reduce emissions to sustainable levels--are unlikely to produce the desired results unless combined with steps to reduce aggregate consumption.

- Another lesson is that in many cases even the modified approach may be deficient unless accompanied by institutional strengthening programs.

Structural adjustment and stabilization are, however, the most recent of the many arenas for the debate over equity concerns. As is apparent from the above remarks, the experience of stabilization was not restricted to Southern countries. In industrialized countries, similar questions have been discussed in the context of business cycles and stabilization. More generally, the discussion of trade-off between equity and growth also falls in this category.

In this context, equity has been taken to mean income distribution. There is a literature on the appropriate index to be used to measure income distribution. Starting with the Lorenz Curve, and the Gini co-efficient, a number of improvements were proposed. The Gini

coefficient is an index of the inequality of relative income shares, with zero representing complete equality, and one representing complete inequality. Subsequently, attention shifted to other indicators, such as absolute poverty, measured in terms of the number of people below a nutrition-based poverty line and quality of life (see Morris 1979), and basic human needs, namely education, food, health, water supply, sanitation, and housing (see e.g., Streeten 1981).

The conventional view on the relationship between equity and growth was derived from Kuznet's (1955) observation of an inverted-U relationship (the Kuznet's curve) between GNP per capita and the Gini coefficient. This observation was based on both time series and cross-section data. However, subsequent studies have added substantial qualifications to this result (see e.g., Ahluwalia and Chenery 1974).

The thrust of these arguments is that economic development and structural transformation affect income distribution within countries in specific ways. The earlier view was that income distribution would worsen with economic growth before getting better. However, the more recent evidence suggests that the pattern of change is sensitive to policy choices and institutional conditions in individual countries. Countries that followed pro-active policies, and favored investment in social sectors (education, health, social welfare) were able to pursue economic growth and social development simultaneously. In other words, at least insofar as the experience of development is concerned, a win-win solution is possible. There are, however, considerable differences over the contributing factors to win-win solutions. Neo-liberal writers (e.g., Balassa 19??, Krueger 19??) attribute the success of newly industrializing countries to market-based, outward-oriented policies. Others look to institutions of governance as key elements (see e.g., Wade 19??, Alam 19??, Banuri 1992, ESCAP 1994).

VI.3 Institution Oriented Literature

The common element of the above analyses is their rootedness in a technocratic approach to problem solving. As a result, they are focused on what the government can or cannot deliver, either in terms of policies or of outcomes. Dirigistic arguments favor direct interventions by centralized states, in the form of government investment, protection of domestic economic activity, social cost benefit analyses, and others. Even neo-liberal arguments that favor market-based approaches, view the government as virtually omnipotent in bringing about the structural transformation towards a free market economy.

An alternative to this approach is the literature that takes governance as an entry point to the analysis. It covers a broad range of ideas, including capacity building and technical assistance (UNDP 1993), community participation and empowerment (Khan, 19??), people centered development (Korten 19??), sustainable development (Banuri et al 1994). Its unifying theme is the emphasis on collective action and development of institutional and decision-making capacities. At smaller units of aggregation, this focus leads to the analysis of participation, empowerment and community development. At the middle level, it translates into the argument for the strengthening of various organs of civil society, including institutions

of education, research, and monitoring. At the governmental level, the focus is on administrative reform and capacity development.

The relationship of these approaches to the climate change debate on equity issues derives from the analysis that lies behind them. The main idea is that inequitable outcomes are produced by institutions that fail to protect the rights of vulnerable or marginalised groups in society. Similarly, countries cannot take advantage of global opportunities, or suffer disproportionately from adverse global processes, if they lack the institutional capacity to protect their interests. Finally, countries that exhibit superior performance on one indicator of social welfare, also perform better on virtually every other indicator. This means that rather than trade-offs between different goals, there is a clustering of performance along various goals. This can only be explained by institutional factors that favor some countries over others. The solution for countries that perform poorly is to enhance their institutional capacity to protect national their rights, and more generally to pursue collective goals. Analogously, the solution for weak or marginalized groups is also to enable them to make collective decisions and protect their rights.

This provides a somewhat different slant on the literature cited earlier. It could be argued that the need for structural adjustment arises when the sum total of property rights exceed the available aggregate endowment of assets or resources. The solution is then to reduce the command over goods and services by re-allocating or eliminating some property rights. These might include the rights of the government (generated through money creation), or those of groups favored by distributional policies or subsidies, or even of investors who are allowed to borrow at highly subsidized rates. The argument of the critics is that in this reallocation of rights, it would be difficult for the vulnerable groups to protect themselves, partly because of their very weakness, and partly because many of their rights are likely to be informal in character.

One strand of this argument has been made by Sen (1976, and various others) in terms of 'entitlements.' In Sen's approach, crises, such as famines occur not because of a shortage of food, because of a failure of entitlements, namely rights to commodities. However, as Gore (1993) has argued, in much of his work, Sen focuses on entitlements conferred by the formal legal system. Although in the examination of intra-family distribution (Sen 1984) he extends the analysis to include informal entitlements as well, this does not seem to have affected the exclusive focus on the formal legal system in the remaining corpus of his work.

Be that as it may, two points are significant in this debate. First, that it may be more germane to look at property rights, whether formal or informal, rather than consumption or production patterns alone. Second, that there is an inter-relationship between economic and ethical considerations. As Gore points out, "for Sen, policies to counter hunger and famine must ultimately be justified through foundational arguments about what is valuable. Equally, ethical assessment of institutions, such as property rights, requires empirical analysis of causes and effects' (Gore 1993: 430).

From this perspective, the development process appears as a trend towards the formalization of property rights, and in many cases the expropriation of the customary rights of local communities in favor of centralized states. This was justified on the grounds that it would facilitate the pursuit of national goals, such as development or equity. The institutional perspective would argue for the reconstitution of local property rights, in order primarily to enable the protection of the rights of vulnerable communities.

These considerations are relevant for the examination of climate change issues. Insofar as the climate change issue is also one of property rights (or entitlements) exceeding the total endowment of planetary sinks, the response will include necessarily a curtailment of aggregate entitlements. The result is that blind policies are likely to re-allocate the property rights in an inequitable manner by curtailing the entitlements of the poor disproportionately. This is true for countries as well as groups within countries. Given the fact that the South will be affected more by climate change, that it has lesser flexibility, is closer to subsistence, and lacks the institutional infrastructure to protect lives and livelihoods, its rights will be curtailed disproportionately in any adjustment episode. The same is true of groups within countries:

- The recent cyclone in Bangladesh killed 130,000 people, while the hurricane Andrew of the same intensity killed 34 people in the US.

- At an individual level, the choice of protecting the rights of various people will be influenced by cultural arrangements, which favor men over women.

- In most countries, declines in food availability will fall disproportionately on the politically weaker and relatively passive groups, on the poor, the children, women, older people, the unemployed, and the rural people.

- Not only is this likely to produce conflict, the emergence of conflict will further discriminate against the weaker and more pacific groups (Suliman 1992).

- Major technological or political changes in agriculture result typically in expropriation of tenants and landless poor. These were sought to be offset through land reforms, which have had only limited impact (Moyo 1994, Sobhan 1993).

Equally, while there is rhetorical support for amelioratory actions, often only at elite levels, this has neither translated into a broad legitimacy of concerted state action in industrialized countries, nor into change in behavior towards more conservationist patterns. Similarly, the awareness of the primary responsibility of the North for the ecological threat seems to have absolved the affluent groups in Southern countries of their responsibility to respond to the threat.

In other words, it may be idealistic to expect that the nation-state as currently constituted will produce equitable outcomes in the face of disasters, large scale dislocations, and in terms of the response itself. The same considerations apply to the international

situation, where the degree of institutional weakness, the ability of the vulnerable to right back, and absence of a collective morality is even more pronounced. Writers that have been concerned with this weakness have argued that the only solution is to develop the decision-making capacity of vulnerable groups. This has led to programs of community development, rural development, and capacity building. At national levels, it might ask for a broad based program, involving the government as well as non-government and private sector institutions (see Banuri et al 1994).

This still leaves open the question, however, whether there is an ethical framework that can enable national societies, and indeed the global human society, to response to the emerging problems in an equitable manner.

VI.4 The Question of Ethics

Equity, justice, fairplay are all concepts with strong moral and ethical overtones. The above literature exhibits these overtones either explicitly or implicitly. It is fair to say, however, that the policy-oriented literature seeks an ethically neutral stance. It is based on a technocratic approach, which focuses on the means or instruments to given or agreed goals. In this approach, the only ethical considerations pertain to the goals, but not to the means through which the goals are to be achieved. The goal of this literature is to determine a universal formula for decision making. Differences between philosophers pertains not to this search for a universal formula, but to the contents of the formula.

This distinction is not simply that between outcomes and processed. For example, Nozick (19??), argues for liberty as the primary principle not only in its own right, but as the definitive feature of equity. This is generally taken to be an example of process oriented ethics. However, it too is consequentialist, in that it assumes a transcendental goal, which can be achieved through the appropriate institutions--in this case free markets. Similarly, Rawls (1971) analyzes the concept of justice from an individualistic viewpoint to argue for a Solomonic veil of ignorance which would induce each individual to seek a maxi-min solution. If this could be agreed, presumably we could also agree to establish institutions (a government, a judiciary) that will put our values into action.

Both these perspectives, two of the most salient recent analyses of the issue of justice, derive from a 'consequentialist' position, in which values have to be justified by outcomes--even if they are defended by processes. Hannah Arendt (1961) has made a scathing critique of such approaches, by arguing that they are based on a confusion between meanings and values as well as between values and goals. The result is that everything is reduced in the end to means. In this approach, culture and values become mere instruments for the achievement of particular goals (e.g. development). Indeed, even equity is but an instrument for the pursuit of such goals as economic growth or political stability.

This, however, is not the only possibility. An alternative approach, which would be sensitive to Arendt's criticism, sees culture and values (including equity) as foundational, and as developed through experience. This is implicit in Rawls, when he says that 'the primary

subject of justice is the basic structure of society' (Rawls 1971: 7). Following this, Michael Sandel (1982) has commented that 'a just society must have justice as a constitutive of its framework, not simply an attribute of certain of the participants' plans of life. This is the definition of a moral community, and not a society of strangers.

Arendt herself has argued against transcendental principles, by invoking judgment as an alternative entry point--contextual, subjective, interactive, and constructive of community. Judgment requires being able to judge particulars without subsuming them under general rules. Such concepts as justice, courage, truth, goodness, are not based on general rules, but on concrete experiences. If one takes this point of view, the search for universal rules is dangerous as well as futile. Justice lies in experience, not in transcendental rules. Equity and efficiency do not collide as contrasting goals. We cannot have equity in an inequitable society.

However, this perspective presupposes an alternative institutional structure, in which the experience of value creation can become possible again. This structure must build upon small, decentralized communities, in which the scope for judgment is re-established. As such, this would go against the broad trends of twentieth century development. This has been in the direction of greater centralization and concentration. It has also been accompanied by the transfer of all collective rights to the state. In the realm of economics, therefore, it has left an amoral universe, in which equity can only be an instrument towards the achievement of some other goal, not a value in its own right.

VII Procedural fairness in international climate change processes

VII.1 Introduction

The various differences between countries outlined in this chapter have implications for the way in which international responses to climate change are developed--in the context of the different equity issues discussed in the introduction, issues of procedural equity are important as well as the consequences of decisions taken, indeed the two ultimately are likely to be inseparable. Oran Young (1990) notes that:

> "One of the most robust findings of the social sciences is that .. [countries in international negotiations] .. can and often do fail to realize feasible joint gains, thus ending up with outcomes that are suboptimal (and sometimes highly destructive) for all concerned."

Part of the reason is the lack of trust and inadequate information that can arise from negotiations that are, or are perceived as, operating in an unfair or inequitable way. The result can be--and often is--that countries do not even agree things that would benefit each and every one of them. Hence the importance of procedural equity.

One important element of procedural equity has been mentioned in section II: namely, the principle of sovereignty in international affairs, coupled with a responsibility towards the impact of internal actions upon others. The difficulty with climate change of course is that it is an issue in which the activities of every country have impacts on all others; hence the need for processes through which states can seek agreement on mutual changes to reduce such impacts, and/or to compensate accordingly.

These principles apply to the negotiations, associated processes like the IPCC, and any institutional structures and procedures created through negotiations. The principle of seeking consensus among all participating states for international agreements makes it still more important that participants feel that negotiations are conducted fairly and that they feel able to participate effectively; and that states take part in good faith. Countries that do not perceive a process to be fair have great power to obstruct it, ensuring that negotiations make little progress.

Procedural equity is an aspect of institutions and the construction of international institutions is partly about establishing structures that command widespread adherence as containing adequately fair representation; the painstaking negotiations over the Global Environmental Facility can be seen largely as negotiation about fair representation.

The overall literature on institutions is very large, and there is considerable literature (especially in the US) about institutions for managing global environmental affairs (e.g. *Millenium* 1990; WRI, 1992; Young 1991; Choucri, 1994). The academic literature specifically on practical aspects of equity in international institutions for managing global

environmental affairs is however much smaller; among the most important is the report of the IPCC Special Committee on the Participation of Developing Countries (IPCC, 1990).

The main issues in procedural equity include:

- adequate participation (and associated resources);
- adequate information (and associated resources);

Here "resources" is used in the broad sense of the word; it encompasses human resources, financial resources, institutions and infrastructure that can underlie adequate participation in and information for effective negotiations.

These issues are important. The cost of inadequate participation is likely to be low adherence to any resulting agreement. The cost of inadequate information is likely to be a suspicious and obstructive attitude which reduces negotiations to a crawl. We consider each in turn.

VII.2 Participation

Participation in international processes--at the simple level of having nationals or other representatives present--is limited chiefly by limitations in human and financial resources, though delays in obtaining visas and the sheer difficulty of travel from some developing countries can also be important constraints. For some processes (like the IPCC), financial constraints upon travel from poorer countries are addressed through special funds supported by developed countries, though inevitably there are recurring concerns about their adequacy. The matter of human resources is more difficult to deal with, since it depends partly upon long-run education and reflects the contrary priorities in many developing countries outlined in section III.1.

A related problem can be the appropriateness of participants and the load upon them. Many of the smaller and/or poorer developing countries had just a few delegates covering the whole range of UNCED negotiations, compared with several hundred for example from the US. They could not possibly have the specialized knowledge required to participate effectively.

That said, it is obviously unrealistic to expect universal participation in everything, indeed it would be a huge waste of scarce human and financial resources, and would in a sense be unfair to participants with more urgent priorities. In practice, the smaller countries--in both the industrialized and developing world--are selective about their participation through choice as well as need, without necessarily adverse consequences. Smaller countries may be able to rely upon larger neighbors that share common interests, or otherwise be able to ensure that their concerns are reflected through delegated or grouped responsibilities. Luxembourg for example generally has little difficulty signing on to agreements in which it played no direct

part. And as noted earlier, addressing climate change requires widespread but not necessarily universal participation. Where universal participation is impractical or even undesirable, what matters is ensuring that a fair balance of interests and perceptions are represented.

A related problem is that of institutional coordination within countries. Climate change involves an extraordinary diversity of issues and interests, ranging from meteorology to international trade. Frequently governments have trouble coordinating policy between different internal groups--and in the international arena it is indeed not uncommon for meteorologists from developing countries to find themselves discussing issues which are more to do with international trade policy.

Concerns about the ability to participate effective underlie the frequent insistence of many developing countries on Rules of Procedure, such as the development of official negotiating timetables without intercessional meetings. To bigger and more advanced countries this can be an intense irritation and may seem an unnecessary brake on program (which such procedures may indeed turn out to be). To weaker and poorer participants they are seen as a protective device to give them a chance to keep up with discussions. Again, it is an area where a fair compromise between adequate progress and comprehensive participation is called for.

VII.3 Information

Perhaps a bigger problem than adequate participation is adequate information for those who participate. Climate Change issues are complex. The work of the IPCC spans complex issues ranging from atmospheric science to ecology to economics. OECD representatives in particular can draw upon a huge infrastructure of specialist knowledge and analysis in developing policy positions and arguing for them (even if researchers still feel that insufficient attention is paid to their work, and negotiators feel deluged by research of which much is peripheral or naive). Many developing countries feel seriously disadvantaged by not having adequate research capacity to draw upon; it is striking for example that the Indian Minister of Finance expressed such a concern (on a different issue) despite India having one of the most developed policy research capabilities in the developing world (in Ghosh *et al*, 1993).

Again this reflects a mix of problems: a lack of human and financial resources, limited education infrastructure, and weak communications. The IPCC Special Committee recommended a number of steps that could be taken, including the support for regional centers and seminars and the development of regional specialists to help improve information and analytic capabilities in developing countries, particularly as it affects the ability of these countries to get to grips with the climate change issue.

The importance of adequate information cannot be overstressed. Many bad policy decisions can be traced to inadequate information, and so can many of the difficulties in international negotiations. The feeling that some participants are much better informed than others can, and frequently does, lead to a suspicious and obstructive attitude in negotiations which ultimately may be to the detriment of all. It was noted above that in international affairs, countries often do fail even to reach agreements that would be of mutual benefit. Lack

of adequate information and the distrust this can help to generate is one root cause of this. Negotiations are difficult enough when each country is seeking only to pursue a narrowly-defined self interest. They can be even worse when they do not have a clear idea of where their self-interest lies.

VII.4 Links between internal and international processes

The focus in this discussion has been upon state actors and government representatives. But fair representation in international discussions also requires that those attending fairly represent interests within their own countries, and their effective participation also requires them also to draw upon the human and other resources of the non-governmental sector. There is thus increasing acceptance that non-governmental organizations have an important role to play in the process: in harnessing and analyzing information; in developing international links; in assessing the implications of proposed policies; in changing cultural attitudes, including communication across different sectors of society; and in observing and monitoring implementation of decisions agreed internationally (for example Haas et al, 1993; Brenton, 1994; Choucri 1994).

A number of these elements have been discussed in the section VI above. Given the complexity of the climate change issue, this points to the ultimate inseparability of issues such as fair and informed participation between the national and international levels. Addressing climate change--both adaptation and abatement--may require changes at many different levels of society, and the implementation and acceptance of policy at many different levels.

Thus, we come full circle to the observation at the beginning of this chapter. Perceived justice, in terms of representation and consideration of different perspectives in processes and in big decisions, is one of the basic measures of legitimacy for governmental institutions. Equivalent structures internationally are weak or non-existent. But the climate issue forces recognition of global interdependence. For negotiations to be effective, they need to command widespread acceptance as fair processes, reaching decisions that reflect fair compromises between widely divergent views of what constitutes an equitable outcome, and thus reflecting the range of issues addressed in this chapter.

VIII Conclusions

Equity and social considerations are central to discussions of steps to be taken to implement Framework Convention on Climate Change because widespread participation is essential if the objectives of the Convention are to be gained. This is why the concept of equity is so prominent in the Convention. Countries are unlikely to participate fully unless they perceive the arrangements to be equitable. This applies particularly to equity among regions and countries, but equity within countries, and associated social considerations, are also important influences upon what is possible and desirable. Mitigating and adapting to climate change will require actions on the part of individuals. Governments will find it easier to comply with international obligations if their citizens feel that the obligations and benefits of compliance are distributed among them equitably. And richer countries are unlikely to burden their poorer citizens to benefit relatively rich citizens in poor countries.

Scientific analyses cannot prescribe how social issues should be taken into consideration and how equity should be applied in implementing the Climate Convention, but analysis can clarify the implications of alternative choices and their ethical basis. There are a variety of meanings of equity and there are various principles that have been designed to achieve equity. On some issues different equity principles point to similar responses, suggesting clear guidance, while on others they may conflict. In either case, there is a need for judgment, drawing on concepts of equity.

Issues relating to equity among regions and countries stem from the substantial differences that exist among countries. Countries differ not only in terms of size, resources, population, and wealth, but also in terms of emissions of greenhouse gases, vulnerabilities to climate change, and institutional capabilities to respond effectively to climate change. There is no single method of aggregating these differences, or decision rule for dealing with them. The Framework Convention on Climate Change provides considerable guidance for applying the concept of equity so as to take account of the many differences among countries. However, the application of equity to specific circumstances will require further elaboration of the Convention's principles and obligations, many of which were designed to be ambiguous and remain so.

Equity issues involved in responding to climate change may be divided into four distinct categories:

- distributing the costs of adaptation;
- distributing future emissions rights;
- distributing the costs of abatement; and,
- ensuring institutional and procedural fairness.

The Framework Convention on Climate Change offers some guidance on all of these issues. It requires developed country Parties to take the lead in limiting their emissions whilst

recognizing that developing countries' emissions are relatively low and will need to grow to meet their legitimate social and developmental needs. It also requires developed country Parties to assist developing country Parties to cope with both the costs of abatement as well as the costs of adaptation to the adverse effects of climate change. Such assistance must be provided by the Convention's financial mechanism which must have "an equitable and balanced representation" and transparent governance to ensure procedural equity between donor and recipient country Parties.

This North-South focus is also apparent in much of literature, which seeks to clarify issues of equity between developed and developing countries much more than among developed countries. Since developed countries have obligations under the treaty to take immediate action, this is a serious lacunae. There are however a variety of specific analyses that propose schemes for distributing costs of coping and abatement and emission rights, and analyze the distributional effects of these schemes, across the range of countries.

Social considerations, and the experience of the implementation of structural adjustment policies, point to the need to consider and target for special consideration specific groups. Countries (such as island and other low-lying states, or drylands) and special groups within society (such as the poor, and sometimes women or children, or specific occupations or regions) that are especially vulnerable to climate change--those on whom the costs of abatement and coping would be especially burdensome--merit special attention.

Concern about equity and social impacts points to the need to strengthen institutional capacities, particularly in developing countries, to make and implement collective decisions in a legitimate and equitable manner. These institutional capacities surely include developing resources to analyze equity and social issues.

Institutional weaknesses also inhibit the ability of developing countries to participate effectively in international negotiations. Assistance to help these countries develop a greater capacity to assimilate and analyze information and proposals, and to participate effectively in international discussions, would increase the prospects for achieving effective, lasting and equitable agreements on how best to address the threat of climate change.

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Notes

[1] Four main types are identified. A `heirarchical' view believes that a problem like climate change needs to be managed rationally and that this can be achieved by suitable management institutions backed by good science and judgement. A `market' view believes that the problem should be characterised primarily as an economic externality, and that the solution lies in creating property rights and a market structure which enables market actors to internalise these costs in their transactions. An `egalitarian collective' view places the emphasis upon equal rights in limited and perhaps fragile biosphere, emphasising the need for radical abatement and abstinence from excessive consumption. A `fatalist' view considers that humans can adapt to whatever changes are caused and probably cannot manage abatement effectively anyway, thus arguing for no action.

[2] On equity generally, Tom Franck and Dennis Sughrue, "Equity as Fairness," 81 *Geo L.J.* 563 (1993); Dan Tarlock, "Environmental Protection: The Potential Misfit Between Equity and Efficiency," 63 *U. Colo.L.Rev.* 871 (1992); Edith Brown Weiss, "International Environmental Law: Contemporary Issues and the Emergence of a New World Order," 81 *Geo L.J.* 675 (1993); Cheng "Equity, Special Considerations and the Third World" 1 *CoJielp* 57 (1990); *See also*, Oscar Schachter, *Sharing the Worlds Resources*, Columbia University Press (1977) and Philippe Sands, *Principles of International Environmental Law*, Manchester University Press (forthcoming).

[3] U.N. Doc. A/CONF.151/5/Rev.1 (1992), reprinted in 31 *I.L.M.* 876.

[4] *Case Concerning the Continental Shelf (Tunisia/Libyan Arab Jamahiriya)*, 24 February 1982, *I.C.J. Rep.* 1982.

[5] Id. p.60 para. 71.

[6] Id.

[7] *See generally* Bin Cheng, *General Principles of Law as applied by International Courts and Tribunals*, Cambridge, Grotius Publications Ltd, (1987).

[8] *I.C.J. Rep.* 1982, p.59, para.70.

[9] *Id.*

[10] *Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta)*, *I.C.J. Rep.* 1985, p.30, para.46.

[11] Id.

[12] *Case Concerning the Continental Shelf (Libyan Arab Jamahiriya/Malta), I.C.J. Rep.* 1985, p.30, para. 46.

[13]Id.

[14] Id.

[15] Id. p.33, para 50.

[16] *Jan Mayen case, I.C.J. Rep.* 1993, p.29, para. 57.

[17]*Gulf of Maine case, I.C.J. Rep.* 1984, pp.97-102, paras. 230-241.

[18] See, Tom Franck and Dennis Sughrue, "Equity as Fairness," 81 *Geo L.J.* 563 (1993); Dan Tarlock, "Environmental Protection: The Potential Misfit Between Equity and Efficiency," 63 *U. Colo.L.Rev.* 871 (1992).

[19] On the legal status of the common heritage principle see Patricia Birnie & Alan Boyle, *International Law and The Environment*, Claredon Press, Oxford (1992) pp. 120-22.

[20] See Richard Benedick, *Ozone Diplomacy: New Directions in Safeguarding the Planet*, Harvard University Press (1991) and Gunther Handl, "International Efforts to Protect the Global Atmosphere: A Case of Too Little, Too Late?" 1 *EJIL* 250 (1990).

[21] See Daniel Bodansky "The United Nations Framework Convention on Climate Change" 18 *Yale J.Int'l L.* 451 (1993), at. pp. 493-96.

[22] Article 31, 1969 Vienna Convention on the Law of Treaties (Vienna Convention).

[23] Annex I lists the European Community and 35 states, the 24 members of OECD in 1992 (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States of America) and 11 European states that are undergoing the process of transition to market economies (Belarus, Bulgaria, Czechoslovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Russian Federation, and Ukraine).

[24] Smith and Ahuja (1990) present succinct and strong reasons for considering the range of gases in assessing individual projects, together with a general framework indicating a basis on which such comparisons might be developed. At the aggregate level required for international comparisons and considerations of equity the issues are somewhat different. The best data, and most analysis, has focused upon the major contribution from CO_2--especially from fossil fuels, for which national emissions are generally known to within ± 5 percent (uncertainty range of 10 percent) or better. CFC emissions--measured as defined in the Montreal Protocol--are known to similar accuracy. Other sources are more uncertain. National estimates of CO_2 and

other emissions from deforestation and other land use changes can vary by at least ±30 percent, both for individual countries and even in aggregate; most methane emissions are similarly uncertain. Contributions from other gases (N_2O, and various other gases involved in different aspects of atmospheric chemistry) are still more uncertain, but the global impact of these other emissions probably totals less than 10 percent of the major greenhouse gases. Further difficulties are introduced in attempting to compare the radiative impact of different gases, as discussed in earlier IPCC reports. Ahuja (1990) present succinct and strong reasons for considering the range of gases in assessing individual projects, together with a general framework indicating a basis on which such comparisons might be developed. At the aggregate level required for international comparisons and considerations of equity the issues are somewhat different. The best data, and most analysis, has focused upon the major contribution from CO_2--especially from fossil fuels, for which national emissions are generally known to within ±5 percent (uncertainty range of 10 percent) or better. CFC emissions--measured as defined in the Montreal Protocol--are known to similar accuracy. Other sources are more uncertain. National estimates of CO_2 and other emissions from deforestation and other land use changes can vary by at least ±30 percent, both for individual countries and even in aggregate; most methane emissions are similarly uncertain. Contributions from other gases (N_2O, and various other gases involved in different aspects of atmospheric chemistry) are still more uncertain, but the global impact of these other emissions probably totals less than 10 percent of the major greenhouse gases. Further difficulties are introduced in attempting to compare the radiative impact of different gases, as discussed in earlier IPCC reports.

[25] This would apply, for example, if one considered the impact of a single country's emissions in the absence of any ohter emissions, or evaluated the marginal impact of adding each country's emissions in turn, with all the others fixed. None of the literature appears to attempt such an assessment explicitly, and scientific understanding of the carbon cycle may not be sufficient to perform such calculations with confidence.

[26] To a degree there are parallels here with the debate over the allocation of sinks (see box). Looking only at total emissions is similar to the WRI index; focusing upon per-capita emissions gives a very different view more closely related to that of Agarwal and Narain. Considering national per-capita emissions relative to the global per-capita mean (so that they can be negative as well as positive), as advanced by Mukherjee (1992), is directly equivalent to the approach advocated by Agarwal and Narain.

[27] Action by one group of countries to limit fossil fuel emissions, for example, will tend to depress international fuel prices which may accelerate emissions growth elsewhere if other regions do not participate. Conversely, it is likely to accelerate technology developments which may then diffuse, acting in the opposite direction. The net effect is difficult to predict and depends upon timescales and models of elasticities and technology development and diffusion [as discussed elsewhere in this report?].

[28] Wilford cites an insurance study, that irrespective of any equity considerations: `it may become necessary for the government to assume a share in catastrophe covers, at least for losses exceeding a certain level, or to guarantee indemnification in all events, as some governments already do in the case of the risk of flood and inundation' (Ruckversicherungs-Gesellschaft, 1990, p.11).

[29] The correct criteria should include a cost component known as the quasi option value, reflecting the expected value of the losses in options following the irreversible change.

[30] The Coastal Zone Management subgroup of the IPCC Response Strategies Working group suggests a slightly different division of `retreat', `accommodation', and `protection' in response to sea-level rise. The classification given here reflects the different kinds of costs incurred, that may require different instruments.

[31] A detailed descussion of Rawlsian criteria applied to CO2 abatement is given in Benestad (1993).

[32] Footnote on the difficulties of defining comparable burdens, etc.?

[33] 'If the remaining global fossil carbon budget were shared according to strict person-year equity including historic emissions, industrialised countries would have not emission rights left. A reasonable compromise between international equity and practical feasibility would be allocate 150BtC each to industrialised and developing countries' (Krause et al, 1990, Executive Summary).

[34] Davod A. Wirth and Daniel A. Lashof, *Ambio*, Vol.19 October 1990 pp305-310: to be checked.

[35] Note that this does not imply equal benefits over time, as technology development and other factors enable more value to be extracted from a given level emissions. The issue has some elements in common with issues of natural resource depletion and the integenerational equity issues discussed in the previous section but the literature has not explored this in any depth.

[36] As one relevant indication, the peak energy intensities achieved by countries in the process of industrialisation has steadily declined over the century, as those developing later can draw upon better technologies developed elsewhere (Haefele, 11981).

[37] Ghosh (1993) agrees in theory that positive as well as negative externalities associated with development transfer from one country to another, but points out that any such application of the principle `must be comprehensive .. all external contributions of all persons over all time must be accounted for .. allowing for those developing countries which were the cradle of civilisation to claim resource transfers .. it is difficult to devise practical ways of implementing this principle.'

[38] Clarify p. 79

[39] It specifies directly how a country's effort should vary as a function of its own income level and abatement efficiency; if the welfare weights are equal across countries, then it defines directly the optimal relative contribution from each country.

Environment
Climate Change

2

DECISION MAKING FRAMEWORK TO ADDRESS CLIMATE CHANGE

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CHAPTER 2

Draft 05 / December 1994

DECISION MAKING FRAMEWORK TO ADDRESS CLIMATE CHANGE

IPCC Working Group III
Writing Team II

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Chapter 2

DECISION MAKING FRAMEWORK TO ADDRESS CLIMATE CHANGE

Summary for 2.5 & 2.6

Decision makers face strong uncertainties that are characterised by insufficient knowledge and lack of information. There also is the possibility of large damages (low probability) whether climate change is abrupt or not. In addition, models in the North do not usually build in the perspective of the South. The presence of strong uncertainty, however, does not mean inaction. It means filtering paths of action and choosing which strategy with which outcome would be best.

Decision theory leads to the assessment of alternative strategies and the valuation of likely outcomes. As a consequence of insufficient knowledge and data, predictions of the rate and extent and timing of climate change and their effects have been made in terms of scenarios rather than in usual probabilistic terms. This situation reflects the gap between the information that is available on climatic processes and economic effects and the one that would be relevant to Bayesian inference. Bayesian scheme has two limitations with respect to climate change: first the existence of strong uncertainties and, second, the existence of low probabilities attached to large potential damages. Alternatives, however, are available: risk assessment (Chapter 7), fuzzy logic, or evidence theory.

Economic criteria for choice explicitly or implicitly are utility-based criteria. Ultimate choices are made by individuals. Yet, because climate change engages considerations that are new in their globality and relate to unusual time-spans, choices also concern collective decision making. Under collective decision making, the valuation of outcomes is matter of negotiation.

The decision making framework to address climate change is made of stratgies at three different levels. *Sequential decision making*. Sequential decision making paths are elected to hedge against uncertainty and change. "Act–then learn" (then act) decision strategy would be best. Hypothesis: there is an agreement that uncertainties cannot be resolved before a decision is taken. *Exploring insurance analysis*. The word 'insurance' is sometimes abused in climate debate. Yet, the insurance industry (individual, fixed, short-term contracts) cannot afford climate change related risk sharing. New institutions should be envisaged, e.g., a market framework with new financial institutions, mutual contracts and securities to deal with collective risks. *Constructing a portfolio of policy measures.* Numerous policy measures are available to limit the impacts of climate changes. The decision maker's problem is much more complex than the choice of a single policy measure to the exclusion of all others. In practice, it is a question of constructing a *portfolio* of policy measures.

Jan. 18, 1995

2.1. INTRODUCTION

Framework convention of climate change (FCCC) signed by many heads of state at Earth summit at Rio in 1992 has been ratified by more than 50 countries by March 1994 and is now legally binding. To carry out the deliberations of this convention, a decision making framework is needed that encompasses global and national concerns. While short-term decisions are governed by FCCC, there are some long-term considerations, say for several decades, which also need to be looked into in the decision making framework by interpreting their consequences until 2050 and beyond. In the present chapter we construct such a framework.

2.1.1 Questions and Issues:

Climate change due to accumulation of greenhouse gases (GHG) in the atmosphere poses many economic, political and scientific challenges which have to be dealt with in a collective decision making framework by national and international decision making bodies. Policy decisions to address climate change have to be taken in a complex setting characterized by uncertainty. Apart from uncertainties, these decisions often involve use of conflicting criteria such as equity, efficiency, sovereignity and ecological concerns.

Decisions are usually based on one's beliefs about the likely occurrence or not of uncertain events which are relevant to the decisions at hand. The decision regarding climate change have to be made not only in the near future, but have to be reviewed on a continuous basis, or at least periodically. The major decisions concenrning climate change that need to be faced by all countries and their citizens are:

1. What should be the level of concentration of GHG gases that can be tolerated at different times?
2. By how much should GHG emissions be reduced to achieve these chosen levels of tolerable concentrations?
3. How should these abatement levels be distributed among countries taking into account the

responsibilities for current concentrations and development needs? In other words, who should bear the burden of emissions abatement at different phases?

4. What kind of policies will achieve the desired reductions of concentrations of GHG gases and in turn, the emissions?

5. Considering that uncertainties will always remain, shall we wait for more precise information that reduces uncertainties? If we want to collect more information, and since collection of information is expensive, on what aspects of uncertainties should we concentrate? In this connection, we note that according to the earlier IPCC report, even present information is adequate to go for the goal of reducing global emissions by 60% for stabilisation.

To answer these questions, a framework is needed which will be characterized by uncertainties at all levels. We say that a decision situation is governed by uncertainty if the consequences of decisions and the state of nature are not known apriori. The agent(s) who makes the decisions is known as the decision maker(s) (DM in short).

2.1.2 Climate change uncertainties and their relationships:

It is fair to say that most decisions are made under some uncertainty or other. Consider for example, the uncertainties in decision to invest in an energy supply system. During the lifetime of the project there could be changes in demand, interest rates, availability of alternative technologies and environmental and other regulations that may change from time to time. However, the uncertainities of climate change decision making are different from other decisions because:

- Climate change decisions have to be taken collectively and not by a single entity;
- The consequences of these decisions affect everyone differently and for a very long term (Distributional/regional effects).
- Any decision made now with wrong outcome can only be identified after a long lag, by which time it might be too late.
- It is subject to non-linearity and can lead to large damages, irreversibility and even catastrophic surprises.

That there is a rise in the accumulation of GHG is agreed upon by everyone. What is

uncertain is the extent of climatic impacts such as rise in temperature, rise in sea level or occurrence of extreme events and thereby changes in ecological balances in biosphere. Some expect that in the long term, efforts to contain these impacts and offsetting them would have significant economic costs. However, there are others who say that there are additional benefits in undertaking "hedging strategies" (see box) such as savings of fuel, local pollution, traffic congestion and so on. The uncertainties concerned with the climate change debate here can be classified into the following categories:

1.

Scientific uncertainties regarding the effects of emissions of GHG on climate change characterized by several important variables among many others, viz., mean temperature rise, sea level rise, precipitation changes and changes in frequency of extreme events such as floods, cyclones and draughts. One could also call these uncertainties relating to geographical and atmospheric changes. The interrelationships among these variables for a given level of concentration are also uncertain. These are dealt with by working group I of IPCC.

2.

Impact uncertainties corresponding to each of the above scientific uncertainties where it is not clear how much impacts different levels of climatological variables will have on, say, biomass productivity, eg., that of agriculture and forests, species loss - terrestrial and marine, and other discomfort and damage. These are dealt with by working group II of IPCC.

3.

Economic uncertainties (corresponding to impact uncertainties) concern the effects of Climate Change on national and therefore individual incomes due to physical impacts such as coastal erosion or cost of increased airconditioning. Cline (1992) has elaborated these and calls them as benefits of avoiding climate change. Both the costs and benefits of abatement are uncertain. Costs of abatement could be different for each region and could have different impacts on GDP growth of different nations. However, the uncertainties regarding the costs of abatement measures are less than those associated with the benefits these measures bring. Here again, the same level of geophysical impacts could lead to different economic impacts to countries at different levels of economic development. Several chapters in the present report deal with economic and technological uncertainties, viz., chapters 7 and 8.

4.

Technological uncertainties concern the timely availability (lead times) and cost of reliable

technologies and their impacts on reducing emissions. As shown by Hafele et al. (1981), it takes nearly forty to fifty years for a new energy carier to capture 50% of the market from the time it captures 1% of the market. Judging by this thumb rule, there are not many technologies to look forward to in the very near future. Though many technologies look promising, they have yet to enter in global energy balances. Even if there are many successful demonstrations of carbon free technologies, the ultimate test is to enter the global energy balances, which at present still consist of coal, oil, gas, hydro and nuclear energy[1]. In fact, it is possible that nuclear energy which is a part of the global and national energy balances today, might make an exit without reaching its full potential. Thus, lead times required for transition in energy system are very large. The lead times required for abatement technologies to be effective and extent of abatement possible by each, thus, become important factors in decision making.

2.1.2.1 Relating scientific uncertainties with impact uncertainties:

How are these uncertainties related? If one could structure the relationships among them, decision making can be guided with better understanding rather than getting overwhelmed by uncertainties, and some action paths can become obvious. Scientific uncertainties concerning the changes in climate variables for a given concentration level, can be linked with impact uncertainties as follows. Considering only the temperature variable, figure 2.1 illustrates that for low levels of climate change one could be in the zone of adaptation. Further emissions could lead to higher concentrations, that could increase temperature and increase damages. Say, at Dt=2°C, there could be "discomfort" zone; but, with some positive probability, this zone could mean disaster for some. We refer to disaster as "an event occurring suddenly and causing great damanage or hardship". For example, a small percentage in sea level rise might cause serious damages only to Bangladesh and Maldives but, might not have as much effect on the rest of the globe. On the other hand, we define catastrophe as "a sudden and widespread disaster." This can occur with a very small probability for say a temperature rise of 4°C but with a higher probability with a temperature change of 6°C. ~~This has to be avoided because apparent and hidden costs of global and local irreversible damages and extensive adaptation are high~~. Figure 2.1 shows that as the GHG accummulation increase, the severity of damages could increase.

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[1] Biomass consumed in developing countries in the form of fuel-wood, crop residues and animal dung are not recorded satisfactorily. They provide 10% to 90% of household energy for cooking in many developing countries.

2.1.2.2 Relating impact uncertainties with economic uncertainties:

Now we shift from "damage" to "damage costs" and what they could mean in terms of economic impacts to a country. Damages have different impacts on different countries for three reasons.

I. Impacts themselves may be higher in geophysical terms. For example, for a given rise in global mean temperature, sea level rise in Indian subcontinent could be higher than in, say, North America.

II. Even the same change say, 1°C temperature rise, could have more impact at 25°C average temperature than at location with 15°C average temperature.

III. Even for identical climate change, adapation to climate change imposes greater burden on poor countries than rich countries, i.e., the same amount of adaptation costs say, $1 billion, could have differnt economic impacts due to differences in population, economic resources and technological capability.

When damage costs for adaptation are considered, as figure 2.2 shows the zone for acceptable costs for a poor country compared to a rich country may be much smaller and the disaster zone may be much wider beginning at a modest level of climate change.

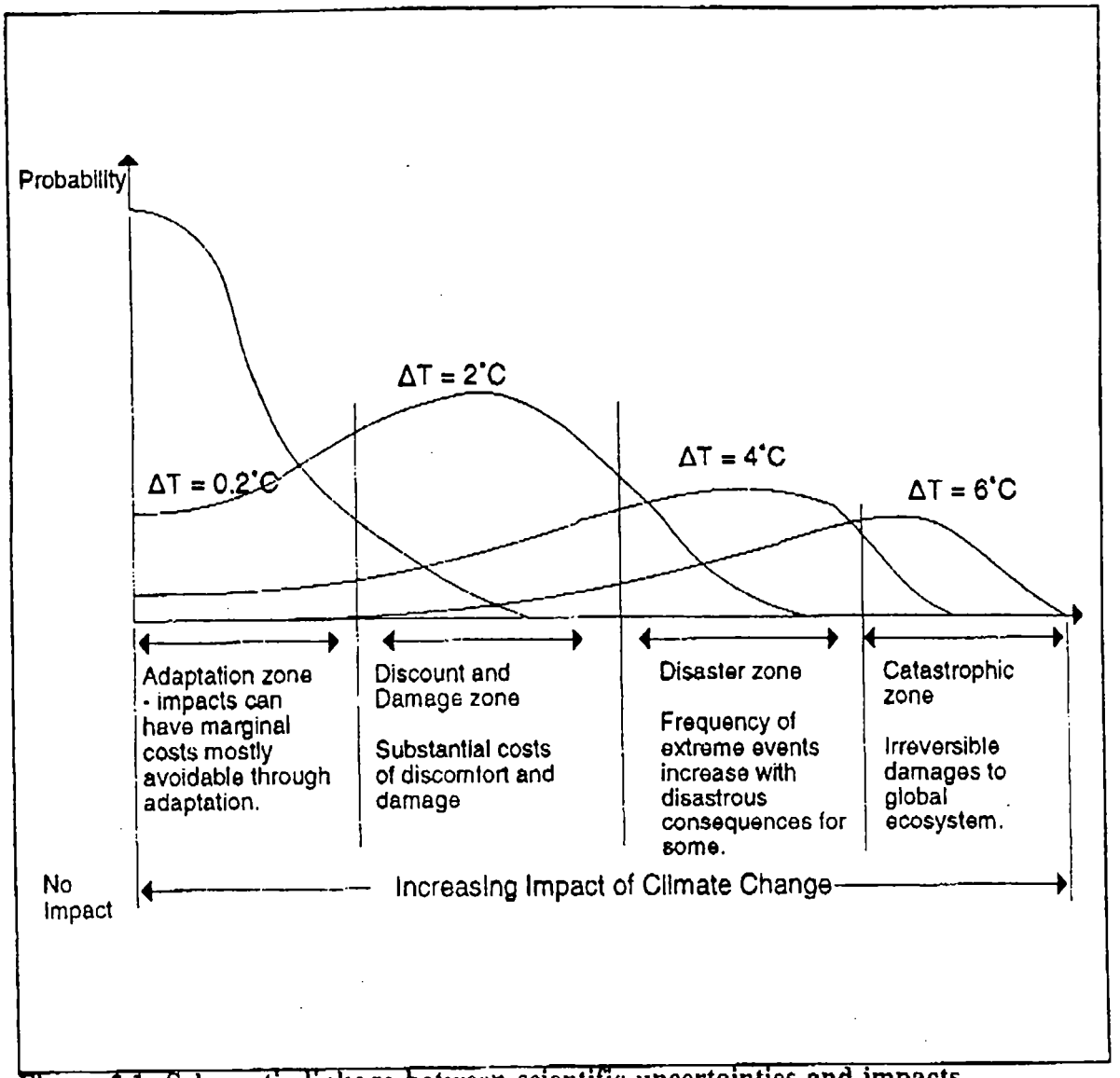
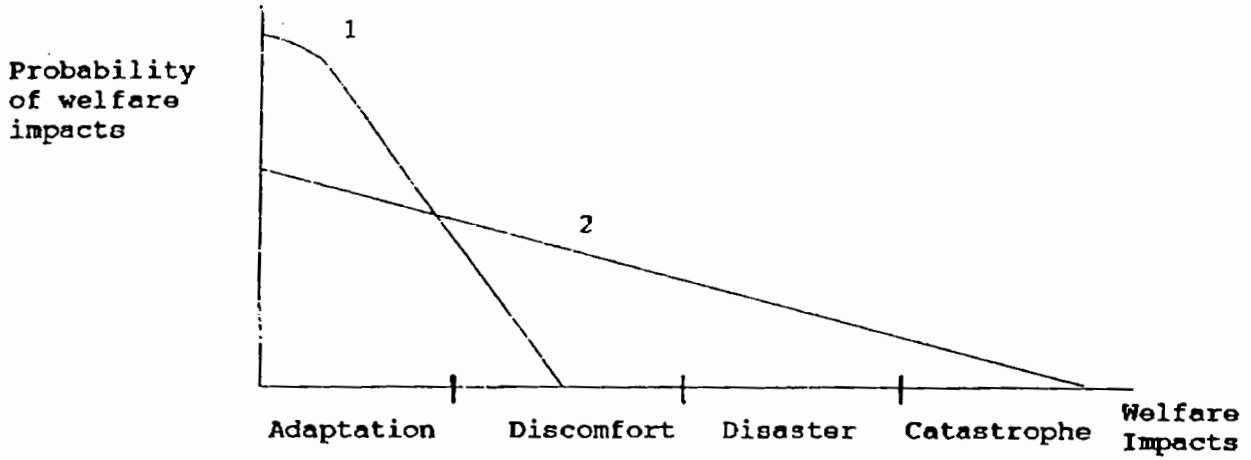


Figure 2.1: Schematic linkage between scientific uncertainties and impacts

Area under each probability distribution curve is 1. At $\Delta t = .2°C$, the probability that there is no or little impact is much larger than at $\Delta t = 6°C$. Reverse is the case for catastrophic zone. Different curves are meant to represent qualitative differences between "small" climate change and "large" climate change, and the range of temperatures corresponding to each curve remains a subject of discussion. Similar relationship may be there for different levels of sea level rise.

DIFFERENT WELFARE IMPACTS FOR THE SAME CLIMATIC DAMAGE : AN ILLUSTRATION



1 : A rich country has more resources to deal with climate change, it can avoid even discomfort and be within adaptation zone

2 : The same level of climate damage can bring economic disaster to a poor country

Figure 2.2

We have assumed that adaptation to climate change imposes greater hardship on poor countries than rich countries for identical climate impacts.

Hence, in this chapter we undertake a detailed analysis of the consequences of various issues and attitudes, such as, equity, poverty, ecocentric approach and discounting, information uncertainty and distributional effects for climate change decision making problem marked by uncertainty.

2.1.3 Scope of the chapter:

This chapter raises the *basic questions* involved in climate change decision problem; it emphasizes the *collective nature of the decisions* to be taken at the international level; it focusses on the various *issues related to climate change decision* such as vulnerability of food production systems, poverty, cost of delay, free riding, valuing common property, inequalities in responsibilities, North-South transfers, and ecocentric views; and it provides the *linkages between various components of the sequential climate change decision problem*. It also discusses various *decision tools* such as the utility based criteria, the nature of uncertainty, risk and non-linearity, the role of time, insurance and portfolio approaches to climate change.

To address the climate change decision problem, one should know what are the questions. Section 2.1 raises all the relevant questions related to climate change decision making and the various uncertainties related to climate change and their interrelationships are also discussed. Section 2.2 gives an overview of the nature and genesis of the climate change decision problem; this section includes topics such as concentrations, absorption capacity, nature of risk and inequalities in responsibilities. Section 2.3 presents factors that affect collective decision making. In section 2.3.1, how and why of collective decision making are analyzed. Various considerations that go into collective decision making such as vulnerabilities, ecocentric views, poverty, and intergenerational equity are covered in section 2.3.2. The implications arising out of collective decision making such as cost of delay, valuing common property, accepting adaptations and North-South transfers are dealt in section 2.3.3. In section 2.4, under the heading of process of collective decision making, we look at the steps involved in iterative decision making, criteria for inter-regional allocation, and North-South co-operation through global policy instruments. The economic notions of uncertainty, risk, bounded rationality, as well as various decision tools are discussed in section 2.5. Finally, in section 2.6, we provide a sequential decision making framework to hedge against impacts of uncertainty and change. This framework is made of three components, namely, decision making paths, mutual insurance decisions, and

2.2 NATURE AND GENESIS OF THE CLIMATE CHANGE PROBLEM LEADING TO THE FCCC

2.2.1 Concentrations not emissions:

The climate change problem is one of increasing concentrations (i.e. accumulation of gases over decades) and not just emissions in a given year (stock and not flows) of GHGs. Of course, to contain the increase in concentrations, one has to worry about the rate of emissions as well. At present targets are being discussed in terms of emission levels, say reaching 1990 level by 2000. However, consequences of each path to 1990 levels have to be worked out in terms of concentrations (Fig.2.3a). While there is a discussion on reporting emissions every year at the Intergovenrnmental Negotiating Committee (INC), the concentration levels as shown in Fig.2.3b, are yet to be discussed. Both shape and area under emission curve are important, since risks are measured in CO_2 -years. Hence, climate change decision problem need to be addressed in terms of concentrations where earlier reductions should be rewarded to account for their more beneficial consequences and to encourage early actions. If we decide to wait for more information without acting, the stock of concentration of the order of 750 billion tons, since pre-industrial times gets larger, passing a larger burden to future generations.

EMISSIONS, CONCENTRATIONS AND CLIMATE CHANGE RISK

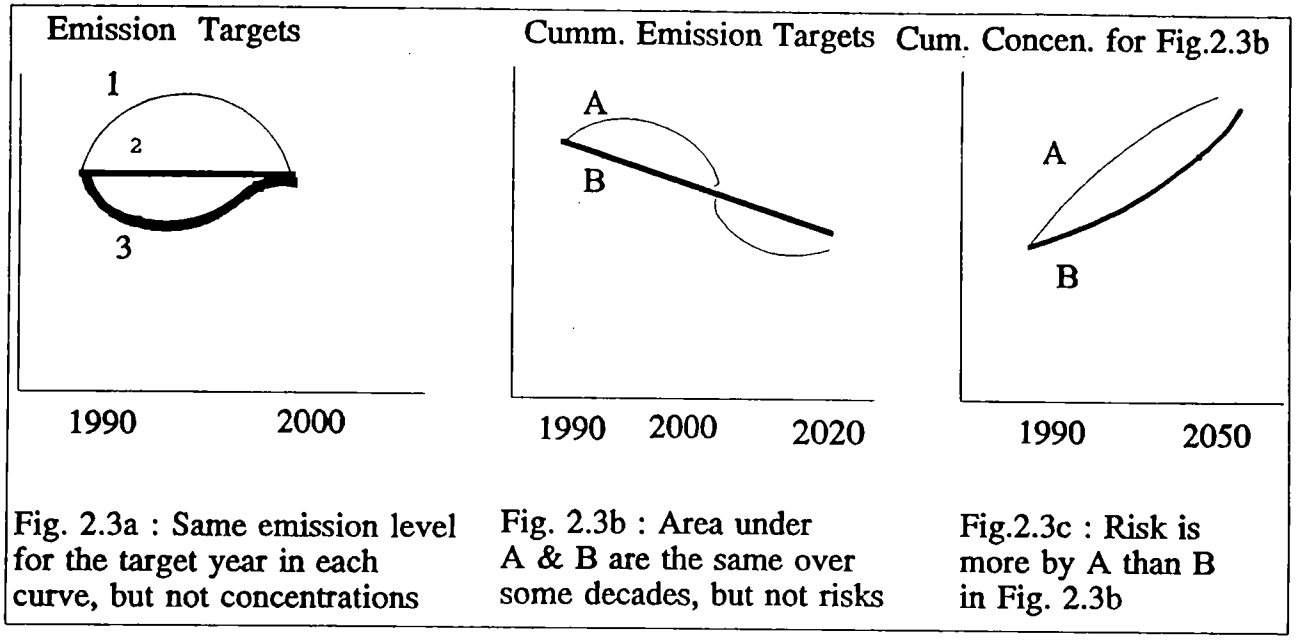


Fig. 2.3a : Same emission level for the target year in each curve, but not concentrations

Fig. 2.3b : Area under A & B are the same over some decades, but not risks

Fig.2.3c : Risk is more by A than B in Fig. 2.3b

In Fig.2.3a, the emission levels in the target year are the same for all paths, but each path has obviously different implications in terms of cummulated emissions. Fig.2.3b shows that the cummulative emission targets are the same for paths A and B - i.e., area under each path is the same. However, as shown in Fig.2.3c, the climate change risk is more under path A than path B due to higher "CO2-years" in the atmosphere. Therefore, earlier reduction should be rewarded.

Figure 2.3

2.2.2 Absorption capacity:

The difference between cummulated emissions and atmospheric concentrations is due to absorption capacity of the atmoshpere. Due to lack of understanding this is often represented as a factor by which one reduces cummulated emissions.

Greenhouse gas emissions are absorbed by forests, oceans, agriculture and so on. Thus, not all emissions end up as concentrations in the atmosphere. While some hold a view that absorption capacity, also known as sinks, may increase slightly with increased concentrations, others consider that this is eroding fast due to denuded forests and polluted oceans. Assuming that about 4 billion tons of carbon dioxide is annually absorbed by the sinks, one implication could be that if humanity lived a lifestyle corresponding to about 0.66 tonne of carbon equivalent emissions per person, per year, there would be no rise in atmospheric concentration of greenhouse gases from current levels. This figure is applicable for the present population levels. According to this principle, those who emit less than this amount may not be considered responsible for climate change effects. In other words, responsibility of marginal damage begins after going above this limit. However, is this the right way to allocate absorption capacity? This is an important issue. While absorption capacity of forests and agriculture could belong to the state in which they are, capacity of oceans is a common global property. There is a need to understand how absorption takes place and how the sink capacity can be distributed.

2.2.3 Nature of risk:

Climate change risk is a trend risk and not a sudden risk, or a random event say as in nuclear accidents, earth quakes or floods. That is, if there is a risk at time t, then, there will be similar risk at time t+1.[2] However, correspondingly there would be a stream of benefits of abatement, i.e., if there is benefit at time t, there will be benefit at t+1 also, and they are additive. This has two implications: once climate change impacts get in motion, it would be difficult to halt them. Corollary of that is, that the problem has to be addressed in a systematic fashion by reducing the trends of growth, i.e., more like gradually decelerating a car, rather than swerving to avoid an accident. Second, higher abatement costs are justified in case of trend risk, as it has stream of benefits for all years starting after a given year, in distant future. That is, abatement avoids adaptation costs not in say, 2025 but for many years subsequently.

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[2]That is, presently, there is 750 giga (billion) tons of carbon equivalent greenhouse gases in the atmosphere accummulated due to human activities. If there is risk at time t, then the risk at time t+1 will be similar.

Therefore, small but regular reductions may be desirable than hoping to reduce suddenly and a lot later, which can be traumatic, if not impossible. It is better to initiate efforts to be on the learning curve which is gradual. If new information suggests that scaling up is not required, one could relax. However, in the meantime due to learning experience, understanding of how to deal with it develops. One could compare this with developing and testing fire fighting systems before the fire breaks, not after. This capability is to be developed as early as possible. As pointed out by Chichilnisky (1994), climate risk is endogenous, collective and correlated. Delay in response is associated with two risks: (a) need to adapt to the changes and (b) irreversible damages. Can irreversible damages, say, by extreme events, be compensated by insurance? The bigger issues such as increased costs and damages due to temperature rise, sea level rise, loss in biodiversity and other unforeseen damages are unlikely to be covered by the insurance industry. Therefore, COP may need to exogenously decide on a risk minimization strategy in terms of concentrations of GHG, which the North could lead. For more deatils, refer chapter on equity.

2.2.4 Common but differentiated responsibilities:

Climate change problem is beset with most difficult problem of inequalities in responsibilities. Annex I continues to emit 70% of CO_2 emissions and has been responsible for 85% of the cumulated emissions from the pre-industrial period and 77% from 1950 onwards. Decisions to reduce would have been easier, if there was equality among nations. Many non-annex I countries have inadequate living standards with insufficient nutrition, provision for safe drinking water and access to sanitation.[3] Nearly, 20% of them do not have even light bulbs. It is not correct to say that everyone emits. In the next 5 decades despite expected rise in South's emissions, concentrations contributed by North would be larger than the concentrations contributed by South, even if North goes back to the 1990 levels and reduces further. Therefore, there would have to be simultaneous trends of the rich (viz., North) reducing and the poor (viz., South) increasing their emissions, to give south the time needed to develop and fulfill basic needs. Here, the North has a stake in South's development. That is, to see that South pursues on path that requires least greenhouse gas emissions for given development goals. If, North's contribution to past and future concentrations are put to zero, South can go on with its development for another century without worrying about the climate problem. This

[3] The non-Annex I countries are not homogenously poor; but, on average their living standards are much below that of Annex I countries. We also note that there are poor in North and rich in South.

point is analyzed in detail in the section on North-South transfers.

2.2.5 FCCC As A Key Element For Decision Making

Some of the features described above are directly or indirectly incorporated in the FCCC. Some may yet guide future negotiations. The following features of Framework Convention on Climate Change (FCCC) are relevant for the decision making framework.

1. Objectives: The ultimate objective is to achieve stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

2. Principles: The parties should protect the climate system in accordance with their common but differentiated responsibilities. The developed countries should take the lead in controlling climate change. The specific needs and special circumstances of developing countries should be given full consideration.

3. Commitment: Developed country parties should take lead to adopt national policies and measures by limiting their anthropogenic emissions of GHGs so as to modify longer term trends. In order to promote progress to this end, each of these parties shall communicate detailed information on measures taken with the aim of returning individually or jointly to their 1990 levels of these anthropogenic emissions.

4. Technology transfer: It also supports technology transfer and training to developing countries by developed countries.

5. Incremental costs: Global Environmental Facility (GEF) would be set up to provide "full agreed incremental costs" to developing countries, when needed.

Keeping these FCCC guidelines in view, we discuss various issues related to climate change decision making in this section.

2.3 COLLECTIVE DECISION MAKING

2.3.1 How and Why collective decision making:

The Conference of Parties (COP) will be the apex forum which makes the collective global environmental decisions for global welfare within the constraints set by equity and efficiency. A conservative choice gives South the space it needs to grow and develop and future generations more options to chose from. However, it can not be too conservative so as to deprive the present generation. There is a hierarchy of decisions involved here.

Climate change means different things to different people. To Annex I countries, it is the cost of abatement, to non-Annex I countries it is the burden of adaptation, and concern for vulnerability, irreversible damages and rise of frequency of extreme events and most of all costlier development. To island states, it is their existence and to oil exporters, it is their revenue loss, if fossil-fuel demand drops. Again, it concerns differently economists and environmentalists. All these concerns need to be voiced in a comprehensive manner.

First stage as pointed out in section 2.1, involves decisions at global level, such as choosing concentration level stabilization and emission growth paths and their interregional allocations. These decisions have to be taken collectively (by the COP). Utility based criteria (see box 2.3, section 2.5.1) would be quite inadequate for this purpose. Global climate change will affect each country differently. Their risks and welfare costs are different. At the same time, those who have to take major abatement actions and therefore bear the costs of abatement are in general different countries from those who are at largest risk from climate change. We do not have a global welfare function that integrates the utilities of different stakeholders. Since global climate change affects every country, each country is a stake holder. In fact, since developing countries are more vulnerable and have contributed little to the pollution so far, they could have unequal rights, and could have more say in this matter. In fact, even in levying income tax, certain limits on taxable income is recognized widely and also progressive income tax. It is seldom that polluters decide what level of pollution could be tolerated particularly when they are less vulnerable to the possible impacts of the pollution. Yet, their difficulties in responding quickly has to be kept in view. In such a situation one can use risk based criteria, discussed later in this chapter. We discuss below the factors to be kept in view while choosing the level of risk.

2.3.2 Factors for collective decision making:

2.3.2.1 Vulnerability of food production systems:

FCCC suggests that ".... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous athropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystem to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner --". Parry & Rosenzweig's study (1994) provides an idea of what is in store for future due to climate change in terms of food vulnerability.

They provide global assessment of the potential effects of climate change on crop yields, world food supply, and regions vulnerable to food deficits. The national yield changes for the climate change scenarios were used as inputs into a world food trade model, the Basic Linked System (BLS), developed at IIASA by Parikh K. et al (1988) and Fisher et.al. (1990). Simulation outputs from the BLS provided estimates of changes in cereal production, food prices and the number of people at risk of hunger.

The study concludes that the world cereal production is estimated to decrease between 1 and 7%, depending on the climate change scenarios used, by 2050. The study also indicates that the impacts would be more severe on developing countries, in comparison with developed countries. With farm level adaptations, reduction in global cereal production is expected to be between 0 and 5%. However, the largest negative changes would occur in developing countries. While, in the North (including China) there would be an increase in cereal production to the tune of 2 to 14% after taking into account the direct physiological effects of CO_2 and the farm level adaptations, there would be a decrease in developing countries to the tune of 6 to 12% even after taking the fertilization effects of carbon dioxide and the farm level adaptations. This loss of production in developing countries, together with rising agriculture prices, according to the study, is likely to increase the number of people at risk of hunger, in the order of 5-50%, depending on the GCM scenario.

Thus, CO_2 concentration levels of double the value of preindustrial values in 2060 may not be acceptable to the South. If 550 ppm is reached in 2060 AD, it is likely that given the long lead times required, stabilization reached by say, 2100 AD, would be much higher and the outcome may be severe.

2.3.2.2 Anthropocentric Vs Ecocentric approaches:

So far, we have viewed climate change decision making purely from the point of homo sapiens. At this juncture we want to emphasize the existence of an alternative viewpoint, viz., that of ecocentricism, which gives adequate, if not equal weightage, to all the living species in the world.

Climate change may affect flora and fauna and their habitats, such as corral reefs and physical environments that are a part of life support system. The earlier IPCC impact assessment indicates substantial pressures on biosphere and biodiversity due to climate change. For example, bleaching of coral reefs is expected. Due to the movement of temperature zones, without the rest of the life support system, species loss on land and sea is indicated. As we mentioned earlier, such a loss of species or damage to biodiversity has been traditionally ignored in the decision making framework. Only recently researchers have started developing tools such as Environmental Impact Assessment to study the value of biodiversity for the humans. Such studies are mostly anthropocentric valuations, carried out to find impact of the biodiversity loss on human recreation, medicines, education, research, chemicals, bio-engineering etc.

An ecocentric view, on the other hand, views homo sapiens as one of the species on the planet earth expected not just to live in harmony and balance with other species but also to share the biosphere (which includes oceans, rivers, atmosphere, etc.) which provide sustenance to other species too. To put it sharply, humankind's abrogation of decision making powers regarding nature is questioned. The ecocentric view proposes to curtail such decision making power. This view extends the ethical stand to include other animals and plants; Equity is not only among human beings but also between humans and other living species.

Though ecocentric viewpoint may seem extreme, it raises one crucial point. The link between the existence of other species and that of the human beings should be kept in mind while making any decisions regarding the activities of humans which would adversely affect the environment and *inter alia* other species.

2.3.2.3 Poverty and Climate Change:

Another important issue while making climate change decisions is that of poverty and the linkages between poverty and climate change impacts. Suppose there is increased occurrence of extreme events such as floods, cyclones, typhones, hurricanes and so on occur due to climate change. Then, in such a situation, it is the poor who are always vulnerable compared to the well off. Take the case of the recent earthquake in India; in this natural disaster, more than 10,000 people died compared to only a few in the earthquake of similar intensity in California.[4] In essence, the threshold level to withstand these impacts would be less for developing countries when compared to the developed ones. In such a case, given that the present accumulation of GHG in atmosphere is due to advanced countries, will they be forthcoming to insure the poor against such calamities?

Large scale out-migration from coastal zones is expected due to sea level rise. Intrusion of sea water in the ground water and changes in temperature can reduce agricultural incomes everywhere. This will create a large number of environmenal refugees. Will they get migration rights (to the North)? Share of GDP from agriculture in total GDP ranges from 16% to 64% in low income developing countries and 12% to 37% in middle income developing countries compared to only 3% of USA (World development report, 1994). Also, the share of population depending on agriculture are of similar proportions in the south. In short, the impact of climate change will differ from region to region and sector to sector.

While the rich can argue about whether to enjoy more now or pay later in the future and if so what discount rate to use, this is unlikely to be a major issue for the poor who are on the margin of subsistence. If a poor country is forced to reduce their GHG emissions or pushed to adapt to climate change without aid or efficient technology, they would have no option but to reduce their current consumption below subsistence level. Rising concentrations of GHG in atmosphere will bring more constraints on their future development. To conclude, since the poor, whereever they are, have a very high marginal utility of income, if required to curtail their GHG emissions in a comparable way to the rich, the poor will bear a disproportionate burden of global warming caused mainly by the lifestyles and consumption patterns of the rich. Any reasonable decision making framework needs to address this primary

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[4] Of course, two earthquakes are never quite comparable. The point, however, is in the Indian earthquake if only the houses were built with modern construction material, even low cost ones, the loss of life would not have been as much. The people could not afford even such low cost modern housing.

concern. Such a concern automatically raises the issue of equitable distribution which we discuss later.

2.3.2.4 Intergenerational equity and discounting:

Climate change problem will affect many future generations because of long life time of GHG. But, whenever cost benefit analysis is used to evaluate long term benefits and costs, as in the case of global climate change, the practice of discounting the future is severely questioned. One set of critics base their criticism on the belief that discount rates place a low weight on future generations. Another group argues that because discount rates dominate decisions relating to the future, one should use low discount rates whenever one evaluates projects with long term implications. This is the position taken in Cline (1992) when he uses a low discount rate ranging from 0 to 2%.

Ethically, generational welfares are to be treated equally. But, future generations could be better or worse off than the present generation depending on the GDP growth rates. In the former case, if the future benefits outweigh the present abatement costs, one would expect that the future generations should pay for the abatement cost. Such an argument is based on the assumption that in the intergenerational welfare function, atmospheric capital (environment space) is substitutable by man-nade capital. This substitutability assumption is highly questionable. If there is no such substitutability between physical and atmospheric capital, one cannot delay abatement actions in favour of setting aside some man-made capital for future generations. Chapter 3 on "Intergenerational equity and discounting" suggests that discounting considerations change if the present generation is richer or poorer compared to the future generation. Most global modelling scenarios (chapter 11 on Integrated Assessment) show that on the average, future generation of South will still be poorer compared to present generation of North even by 2050 or beyond. Thus, global average of all regions can be the reference point for such considerations. Present generation of North could choose discount rate as though global average would be less in future compared to their generation at present, while South can choose discount rate as though the next generation would be richer.

On the other hand, suppose that the future generations are worse off than the present generation. In such a case, what the future would pay for the present abatement will be much less than the cost of abatement. Some argue that intergenerational equity should be dealt with separately as a political decision with ethical dimensions. For a forceful argument of this point

we refer the readers to Schelling (1994), and chapter 3 of thus document.

Not doing anything for the benefit of future generation could be acceptable. But, if the present generation is responsible for the losses of the future, as is the case in the climate change problem, then not doing anything is morally unacceptable. That is, not giving them large inheritance is acceptable, but we should not pass on liabilities. Abatement is not to be looked at as an investment option giving returns in the future but as a liability reduction exercise. Hence, the level of abatement of concentrations could be chosen to minimise climatic impacts on poor and then look for the cost effective ways of fulfilling those commitments. Low levels of discounting could play a role in the later step, but, not in the former.

We have described some of the considerations that go into collective decision making. Having collectively decided the concentration levels and interregional responsibilities, individual countries could formulate their strategies to follow respective emission paths. While deciding who needs to do what, one has to take into account various factors such as responsibility interregional equity, North-South transfers and various policy tools to achieve the required emission reductions.

2.3.3 Implications of collective decision making:

2.3.3.1 Cost of delay and slippages (Free riding through delay):

International negotiations are difficult and take long time. Even if the decisions are taken at international level, it cannot be guaranteed that they will be followed up by people at various social strata. Therefore, slippages may occur.However, in the mean time concentrations mount, if no directions are given. A ortion of every tonne of GHG emitted occupies some environmental space for about 200 years, which is not available to either future generations everywhere, or constrains the development needs of non-Annex I countries. For example, during the nineties, after signing the FCCC, the Annex I countries would emit about 40 to 50 billion tonnes of CO2. This could have been sufficient for South to grow and develop for more than 25 years. In addition, high emissions by one party push the other parties either to adapt or to forego their development.

Therefore, if no decisions can be reached soon, at least it should be agreed that Annex I countries would be liable for whatever concentrations emitted after 1990. That is, whatever the outcome of negotiations, it would hold parties accountable for the cumulated emissions

after 1990 which would be retroactively adjusted against their future share, after negotiations are completed. This would prevent free riding and precipitate some action even while matters are being negotiated. While issues such as past concentrations, population can be discussed later, accepting this principle of accountability after 1990 could lead to prudent behaviour and act as some deterrent to all against wasteful consumption.

2.3.3.2 Valuing Common Property (and Paying for It):

The emissions emitted beyond earth's absorption capacity then test the biosphere's adaptation capacity. This capacity to adapt may be also limited i.e., it is an exhaustible resource. How is the atmospheric resource different from many other exhaustible resources we use every day that include metals, and fossil fuels? First of all, these resources have property rights and they are paid for, each time they are used. "Paying for what you use" is a sound economic principle that should be enforced whenever atmosphere is used to prevent misuse. If one does not have to pay for common property, it encourages appropriation of atmospheric capacity. The user charge should be either paid to others when the property also belongs to them or put in a common pool for future use. Second way it is different from other exhaustible resources is that there are substitutes available or likely to be available for them. This is unlikely to be the case for atmosphere of planet earth.

How does one pay for using atmosphere and to whom? Collective decision is required to decide this. How does one value absorption capacity and adaptive capacity? How does one allocate property rights for both? One can think of several ways.

(a) Consider that those who wish to emit more than their share should pay rent.

(b) Consider that this is a permanent loss and pay damage costs.

(c) If and when property rights are allocated, trade or lease them.

2.3.3.3 Accepting Adaptation:

There is ever increasing reference to need for adaptation. Adaptation ranges from switching to different crops, incurring increased cooling costs to migrating or giving up land rights if they are in the coastal areas. Parry & Rosenzweig (1994) have indicated increased hunger in developing countries which is also one way they adapt. That is, due to delay in abatement, global risks are externalised for which there will be no compensation. In any case, adaptation will be too all-pervasive and costs too difficult to isolate for compensation. Will the North pay for dykes in Bangladesh or give migration rights and compensate for shifting and rehabilitation to people from Maldives?

U.S. estimates for costs to build walls along the vulnerable zones to sea level rise is $130 billion (refer chapter 4). That may be a small share of U.S. GDP, but such measures, even scaling for their coast lines, for say, India, could require very large share of their GDP. Who shall pay India for such a wall? Moreover, one still does not know what would be the environmental impact assessment of such walls. They could also have adverse ecological and economic impacts on coastal zones.

It is said that there may be rise of mean temperature of 0.25 degree per decade. This is sometimes multiplied to get 2.5°C for a century but there could be non-linearity and temperature rise could be more with more GHG accumulations. Moreover, 2.5 degree centigrade mean temperature rise could mean 5.5 degree centigrade rise in the Northern hemishpere due to extensive land areas compared to oceans. Indeed, if this happens, it would be difficult to live in many parts of Indian subcontinent and other populated countries in the mid-east and South Asia and large scale migration may take place. Thus, adaptation costs passed on to others should be internalised in one's actions. It is important to note that marginal damage of one extra degree of temperature is far more serious in the South than in the North, where they may even benefit from that extra degree. Thus, risk tolerance of say, South should matter more than that of North.

Most models developed in the North do not effectively build in the perspectives of the South in adapting to climate change. The resources to adapt often do not exist and the outcome is further human suffering, manifested in, for example, frequent occurrences of the homeless dying from heat stress. South does not have the capacity to adapt except through increased human suffering and is poor enough to have problems of their own. Homeless die of heat stress even today. Finally, adaptation does not solve the problem; it only postpones what more is to

come.

2.3.3.4 North-South transfers:

Several justifications for the North-South transfers are given below. These are not necessarily mutually exclusive. That is, transfers for one may overlap with other. However, these are different ways of looking at North-South transfers[5].

1. Currently there are many countries whose use of environmental space far exceeds their justifiable share of that space. J.Parikh (1993) has indicated that these privilages are worth US $70 billion per year. Also, North's use of environmental space has a temporal characteristic; that is, these emissions will occupy the environmental space for hundreds of years in the future (Smith, 1991). According to the "polluter pays" principle, those who have occupied this environmental space should pay rent for it for their excess use of the global environment to those whose use is below their entitlements. In addition, when the latter need that space, that should be made available to them. (Rent for environmental space).

2. The consumption patterns of the rich countries have put constraints on the development alternatives of the poor countries. Due to the climate change possibility, the poor will be forced to spend more resources for adapting to the climate change problems; this will constrain the resources available for their immediate development priorities.(Compensation for adaptation burden imposed).

3. Those who have emitted more than their share of the absorption capacity of the atmosphere (in per capita basis) and benefitted, are liable to others for the possible damages arising from global climate change. (Liability payments for damages and excess past concentrations).

4. The cost of delay in emission reduction (by the North) in terms of South's foregone opportunities to development is substantial. This will impose many constraints on the way the South decides on policy options regarding issues such as how to generate power, how to use land, and what crops to grow and so on. Hence, North-South transfers of large amounts are needed to compensate South for the development opportunities foregone. (Lost opportunities due to concentrations after 1990).

As against all these, Global Environment Facility (GEF) gets replenishment of US $ 2

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[5]K. Smith (1991) has used a concept of natural debt to address these issues.

billion for three years to address four different global environmental concerns, viz., climate change, biodiversity, international water, CFC reducing to serve Montreal protocal. One could also think of North-South transfers through global policy instruments such as tradeable emission permit regime, joint implementation and so on. We briefly discuss these issues in the next section. The reader can also see the separate Chapter on policy instruments for more details.

Having discussed considerations for and implications of collective decision making, we discuss some theoretical considerations involved in making the national and international decision making in the following section.

2.4 PROCESS OF COLLECTIVE DECISION MAKING

Let us now turn to the process of climate change decision making. In this section, we will first provide a summary of steps involved in iterative climate change decision making problem, criteria for interregional allocation, global policy instruments and consider sequential decision making procedures.

2.4.1 A summary of the steps in iterative decision making:

Necessary elements of collective decision making are linked and brought together with national decision making either directly or preferably through global policy instruments as shown in figure 2.4.

The first step in long-term decision making process is to select concentration level through collective decision making by considering equity of stakeholders, of those stakeholders whose emissions so far have not contributed significantly to the current atmospheric concentration levels. For stabilizing atmospheric concentration of the main greenhouse gas, namely CO_2, at any level between 350 to 750 ppmv calls for significant reductions in the emission trends in the near future. Some alternatives are indicated in figure 2.5. If a very low level is chosen, considerable sacrifice is expected from the present generation. If high level of concentration is chosen, there would be danger of irreversible damages and high adaptative costs. Remember that, if 550 ppm is chosen, it is difficult to go back to 440 ppm, but vice versa is possible.

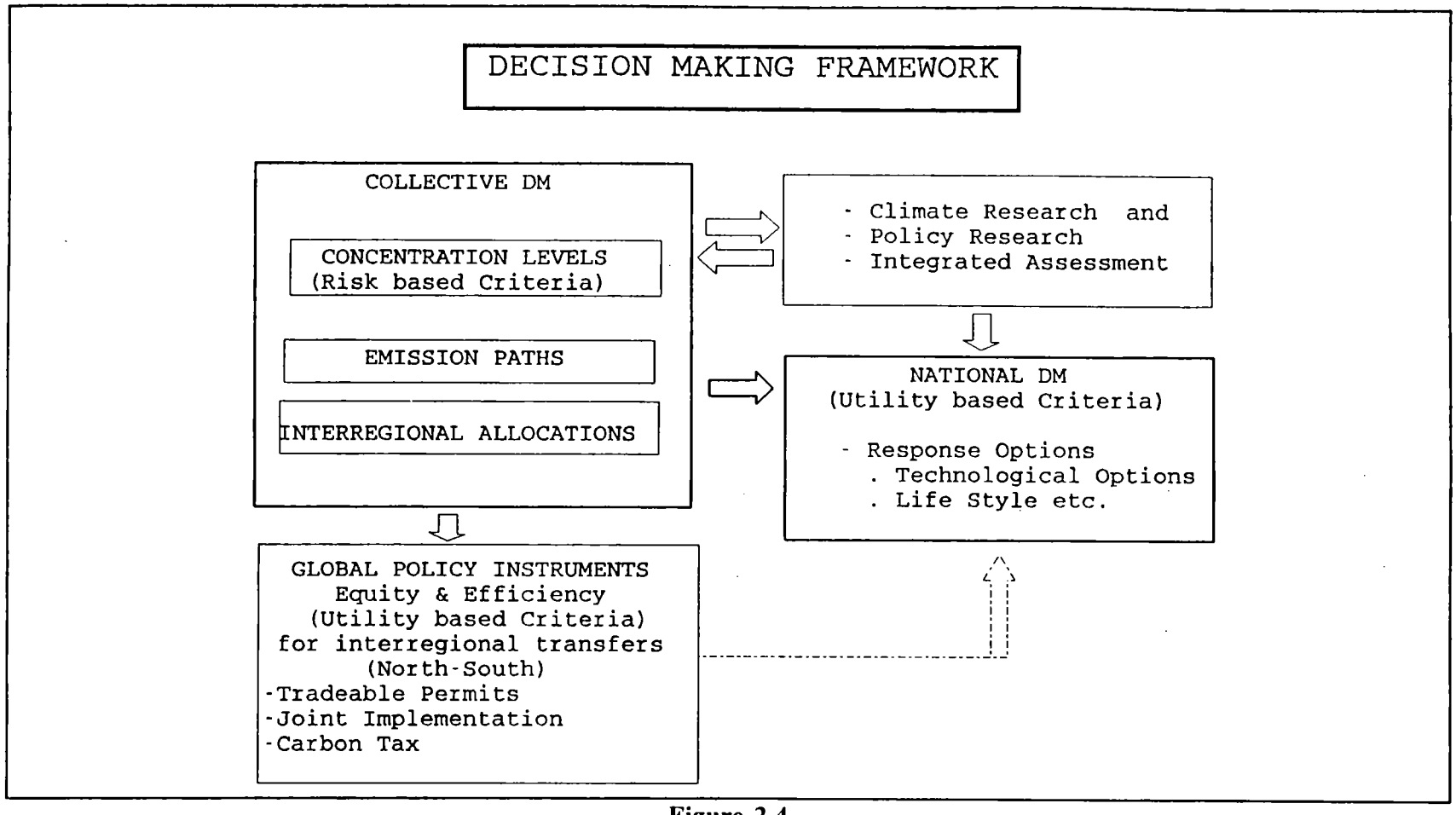

DECISION MAKING FRAMEWORK
COLLECTIVE DM
CONCENTRATION LEVELS
(Risk based Criteria)
EMISSION PATHS
INTERREGIONAL ALLOCATIONS
- Climate Research and
- Policy Research
- Integrated Assessment
NATIONAL DM
(Utility based Criteria)
- Response Options
. Technological Options
. Life Style etc.
GLOBAL POLICY INSTRUMENTS
Equity & Efficiency
(Utility based Criteria)
for interregional transfers
(North-South)
-Tradeable Permits
-Joint Implementation
-Carbon Tax

Figure 2.4

than north. Emissions per GDP are sometimes taken as indication of inefficiency. However, high emissions per GDP can be attributed only partially to inefficiencies in South. High emissions are mainly due to low level of development which requires filling the backlog for infrastructures such as, schools, hospitals, power plants, due to unsatisfied development needs such as health, nutrition, education, lighting, and so on where relatively high share of GDP goes (World Devp. Rep., 1994). This is referred as purchasing power parity. This is comparable to the fact that, growing children need more food per kg. of body weight than adults past fifty. Higher need for new infrastructure building explains high emission per GDP and also calls for higher growth in future. Apart from investment in infrastructure, pricing and valuation of non-tradeables also matter in these calculations. This can be captured by adustment factor for purchasing power parity.

One could think of a time table in terms of limiting emission by Annex I and non-Annex I countries through reduction of emission growth rates.

Illustration of Strategic Decisions to be taken in Sequence

Time Period	Growth rate of emissions (dC/dt)		Rate of change of growth rate (d^2C/dt^2)	
	Annex I countries	Non-Annex I countries	Annex I countries	Non-Annex I countries
Upto 1990	≥ 0	> 0	≤ 0	> 0
1990-2000	$= 0$	> 0	< 0	> 0
2001-2025	< 0	> 0	< 0	$= 0$
2026-2050	< 0	≥ 0	< 0	< 0
Beyond 2050	< 0	≤ 0	< 0	< 0

C : Carbon dioxide emissions

This is only an illustration of the process where Annex I Countries take lead and are followed by non-Annex I countries after some lag. It is a sobering thought that over such a long period, distinction between Annex I and non-Annex I countries may get blurred and countries have to be grouped in terms of per capita emissions below and above the world average.

The discussions regarding future entitlements for GHG emission so far have excluded the historical record of past emissions. Such an omission might be wrong for the following reason. Increases in the concentration of carbon in the atmosphere have taken place over a prolonged period of time. The contribution of North America and Western Europe to the concentration is much greater than their share of current emissions. On the other hand, the

Figure : 2.5

ANEXURE : Figure D

Profiles of Atmospheric CO_2 Concentration Leading to Stabilisation at 350, 450, 550, 650 and 750 ppmv

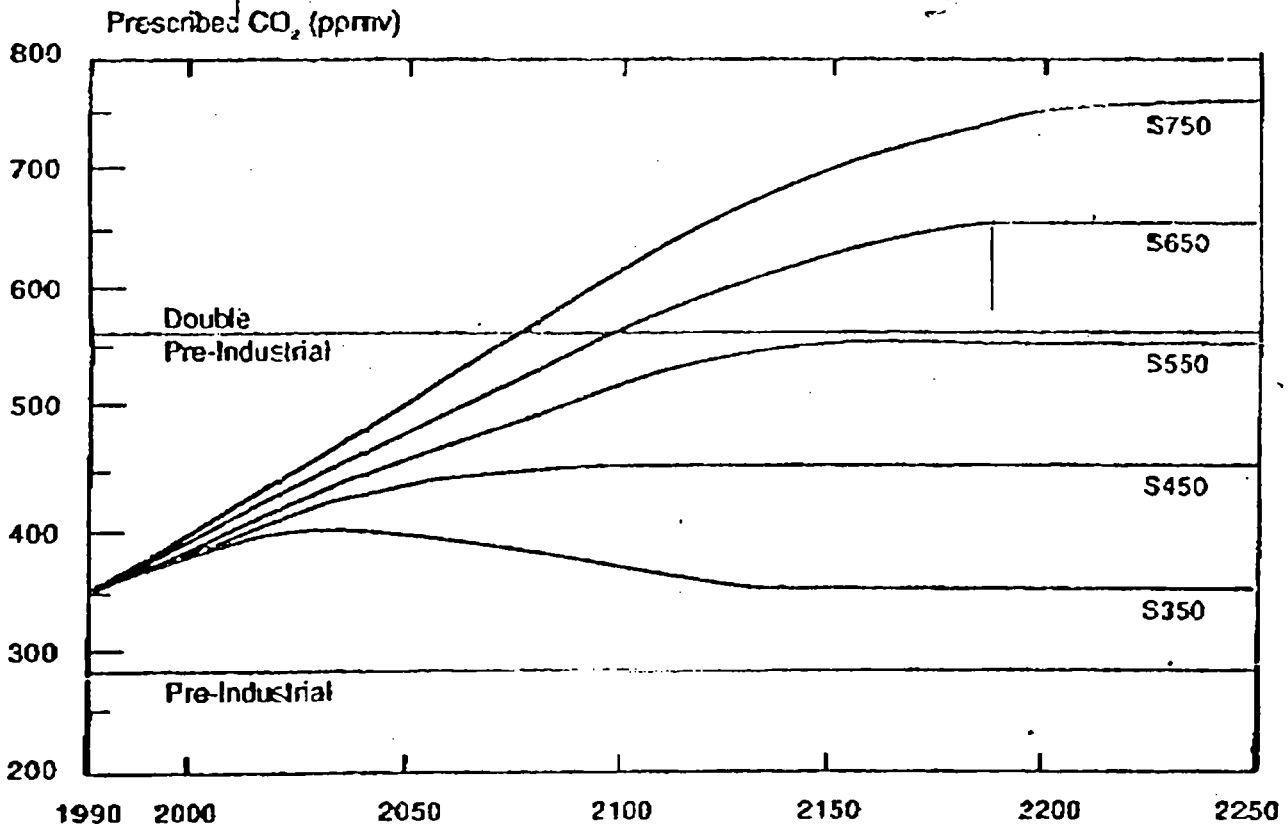
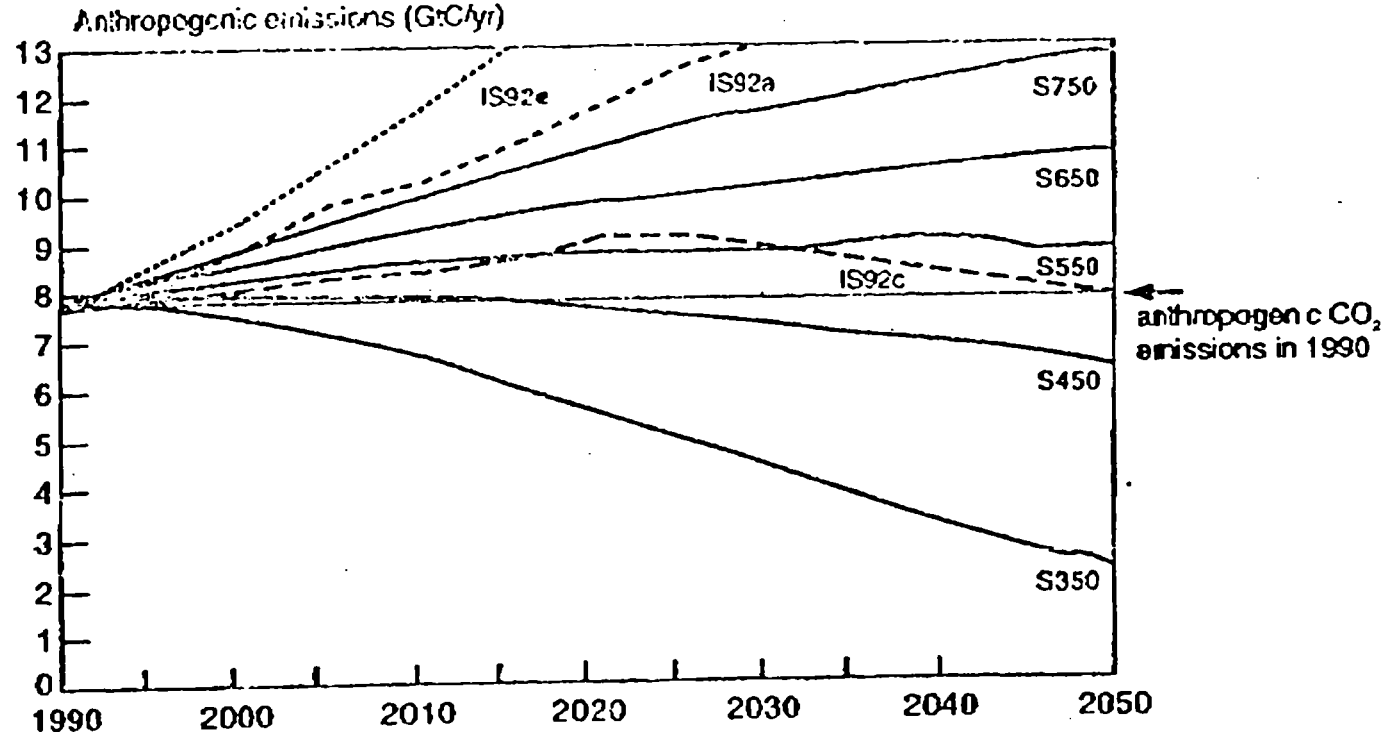


Figure : 2.6

ANEXURE : Figure 1

Comparison of IPCC Emissions Scenarios and Emissions Profiles Consistent with Stabilization of Atmospheric Concentrations of 350 to 750 ppmv



historical emissions from developing countries have been low and hence their share of the overall concentration is also low. The current generation of developed countries are the beneficiaries of resource transfers from past generations. These resource transfers have been possible only due to the exploitation of global environmental resources by their past generations. As a result, the current generation living in the developing countries have the right to claim a part of these resource transfers, or, transfer of emission free technologies, or, right to pollute (for development needs), as environmental resources are common property.

2.4.3 North-South Cooperation through Global Policy Instruments:

Once interregional obligations are decided, one could discuss global policy instruments, which make it possible to reduce the cost burden by either trading emissions or by meeting the obligations jointly or by contributing to carbon tax, which can be used to reduce emissions in-non-Annex I countries. Global Policy is also needed to discuss ways of North-South transfer, either through the above mentioned or other means. These are referred as global policy instruments. They can be selected based on utility (global or national) based criteria. Institutional failures, such as lack of well defined property rights, and distortionary subsidies, always lead to market failures such as gaps between private and social costs of production and consumption activities. As a result of this, producers and consumers do not appreciate the true scarcity value of the resources they use up, such as environmental resources. The emerging pattern of ecnomic growth from such production and consumption plans is usually unsustainable. Economic instruments which are aimed to correct such unsustainable resource use, bridge the gap between social costs and private costs by internalizing all the external costs and risks. The use of economic instruments at the global level to deal with climate change requires special considerations. We emphasize here these, as they relate to some suggested policy instruments. For a more detailed discussion on the policy instruments, refer chapter 10 of this document.

To elaborate, economic instruments such as property rights, pollution taxes, and tradeable emission permits bring about a realignment of resource allocation with the social objectives. Such economic instruments achieve the objective of sustainable growth through (1) providing a corrective to the functioning of the market, (2) encouraging cost minimization, (3) permitting flexibility of use, and (4) adjustability to changing environment. The key to the promise of economic instruments is their ability to harness the power of the market. Economic instruments can be broadly classified into the following categories: (1) allocation of property

rights (ownership rights, use rights and development rights), (2) creating markets (tradeable emission permits, tradeable offsets), (3) economic incentives (emission taxes, subsidies), (4) financial instruments (such as GEF, green fund, location incentives), and (5) liability instruments (liability standards, damage liability, liability insurance).

Joint implementation (JI), Tradeable permits and carbon tax are some of the global policy instruments that lead to economic efficiency but require international negotations. Among these options, JI is already referred in the FCCC and is in the advanced stage of negotiations. Pilot phase of JI is approved by the INC. JI gives opportunity for co-operation between North and South where North can invest in South to reduce GHG emissions, if it is cheaper to do so. South gains in terms of energy efficiency if better technologies are provided. Key question is whether international credit or "offsets" should be given for such efforts. That is, should GHG emissions reduced through JI accrue to the investing country, giving them opportunity to increase their emissions to that extent? If yes, then further negotiations are needed on how much emission reductions through JI can be credited, mode of monitoring and verification.

There are concerns that perhaps JI will delay new technology development or consumption patterns of North will not change. Accountability of global GHG emissions when South does not have limits on the emissions is another concern. Therefore, there is no agreement on the credit issue so far. Even if this is undecided, credits or incentives for the JI in the form of carbon tax rebate can be given internally by North. If carbon tax is not imposed by that country government, then it could permit rebate under some other category such as that of treating JI as a category of R&D expense or charity or other tax deductible expenses. Thus, internal incentives can be given to private entrepreneurs by the Governments in the North. Why should the governments in North do so without international credit? JI can have an immense value in terms of capacity building in South, so that when they will have to reduce emissions, they will be ready for it. They may choose to go for energy efficient mode of development. J. Parikh (1994) shows that if South makes some effort to reduce emissions now, it will reduce pressure on North in future as well. Thus, it could have long term benefits in terms of preparedness of South and reduced global emissions. JI will require monitoring of the projects by certified auditors to account for carbon reduction, especially if international credits are given.

Tradeable emission quotas (or permits) is one way of creating a market for GHG

emissions. A global level of tolerable emissions is set for greenhouse gases and allocated among the nations by some criteria. Tradeable permits scheme on the other hand, give some developing countries the possibility to earn additional foreign exchange for their development till such time that they have surplus permits. Sooner this is done, earlier the benefits. It will also indirectly encourage them to reduce GHG emissions early, unlike JI, which induces them to reduce directly but sporadically. However, on what basis emission permits should be distributed is a thorny issue about which much is written. Though the desirability of distributing permits (quotas) on per capita basis is recognised at least in the long run (Manne and Richels, 1993), population growth in developing countries is an issue of concern. A compromise could be to have the quotas on the basis of the population fixed in the year in which the agreement is reached. This will encourage North to reach agreement sooner and at the same time South does not profit from population growth.

In addition to these options, other forms of co-operation also exist. This could be regional approaches, technology transfer, technology fund or joint technology development. Apart from the North-South co-operation, regional approaches can also be developed keeping in view the common features shared by the regions which may include socio-economic, ecological or meteorological features, viz., temperature, precipitation, solar radiation and so on.

Once the goals and policy instruments are agreed upon, national level DM begins. This strategy will depend on utility based criteria or regulatory mechanisms. Their responses will vary from fuel substitutes, life style changes, technological alternatives, or increasing sinks.

2.5 Economic Formulation of Individual and Collective Decision Making

"Prior judgements that decision makers bring to the problem, and the decision rules they employ, could be far more important in controlling the policy conclusions that they reach than are the results of scientific discoveries."
Dowlatabadi and Morgan, 1992

This section concerns methodological insights and guidance for making choice between a limited range of actions that have attached consequences, and especially establishing a point of convergence between individual and collective decision making. How we think of choice involves issues of rationality and related decision criteria and rules, and is influenced by various factors among which uncertainty comes first.[1] Whereas a key element of the decision making framework to address climate change is the ratified FCCC (which indicates the objective to achieve, namely, the stabilisation of GHGs concentration), providing a steady economic basis to decision making paths and actions to bring about probably constitutes the most important contribution to the negotiating process.

The long term perspective and the globality of climate changes designate uncertainty as a key factor in decision making. Uncertainty is related both to the science and to the economics of climate change. On the one hand, there is a genuine uncertainty of the climate system—which has bounds but which is not quantifiable (Bolin, 1994). For economics, on the other hand, estimates of the costs and benefits of global warming are much uncertain. In particular, the uncertainty of impacts on individual and social welfare seems predominant.

For example, models in science, in economics and in social sciences provide quantitative estimates of effects based on critically important assumptions that openly leave large band of uncertainty in reference to climate change. Lack of knowledge about fundamental mechanisms that equations cannot currently master represents limits to computer models in each domain. It is also true that most models in the North do not effectively build in the perspective of the South in slowing down or adapting to climate change—both in terms of resources and outcomes.

A priori, however, the existence of uncertainty does not mean inaction. Making decision under uncertainty rather implies to filter paths of action and to choose which strategy with which outcome would be best. This can be done at various analytical levels such as economic rationality, utility-based choice criteria and rules, collective decision procedure (the one FCCC brings forth), short run – long run trade-offs, risk analysis, value of improved information, as well as other particular factors af-

[1] Decision analysis also includes a range of techniques such as cost-benefit analysis or multi-attribute utility analysis. Each tool has a methodological foundation in decision theory but is suitable for different purposes. See 2.4.3.2, below.

fecting decision making; among them one can cite attitude, poverty and intertemporal equity.

2.5.1 *Accommodating the supplementary uncertainty caused by climate change*

Cognitive and computational limitations make sense with respect to climate change concerns. Decision making is concerned with these limitations.

Indeed, ignoring climate change would simplify decision making. However, it would be irrational to return to our previous lower level of uncertainty awareness. We thus have to accommodate the supplementary uncertainty caused by possible changes in climate (Caselton and Luo, 1994) and their effects on individual and social welfare.

As a consequence of insufficient knowledge and data, predictions of the rate and extent and timing of climate change and their effects have been made in terms of scenarios rather than in usual probabilistic terms. In particular, this situation reflects a gap between the information that is available on climatic processes and the one that would be relevant to Bayesian inference (the common way to use new information to update beliefs "rationally"), and that is in short supply at present time.

What is the issue? In decision theory, decisions are based on the assessment of alternative strategies and the *valuation* of likely outcomes. The decision process describes uncertainties by means of the concept of "state of nature" (a description of possible "states of the world"—that may be uncertain, as well[2]). Common decision making is served by the Bayesian approach which represents any information or knowledge concerning states of nature by assigning them probabilities. In this respect, the representation of information in the form of conventional, necessarily precise, probability distributions has been systematically developed in the statistical and economic literature since the 1930s.[3]

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[2] To formalise the conditions of uncertainty, it is convenient to refer to Arrow's concept of *state of the world (SOW)*, a description of the world so complete that, if true and known, the consequences of every action would be known. The meaning of certainty is that the agent *knows* the state of the world while that of uncertainty is that the agent *does not know* the state of the world. Uncertainty characterises all activities; "it affects all fundamental variables that determine behaviour, explain choices and bring about decisions" (Kessler, in Edckhoudt and Gollier, 1995).

[3] In decision making under uncertainty and risk, the analyst is provided with precise, either objective or subjective probabilities. When it is not possible to arrive at such a unique probability distribution for an event, one tries to construct it from more fundamental events. Such a procedure is known as the Bayes' rule. Suppose the hypothesis B is true and that an event A has occurred. Then, the probability of hypothesis B under the condition that event A has taken place is given by $\wp(B|A) = \wp(AB)/\wp(A)$. $\wp(B|A)$ is known as the posterior probability and depends upon $\wp(A)$ which is known as the a priori probability. How do we obtain the prior probabilities? If there are past empirical evidences one can obtain the priors from them. But if there is no evidence available to us about, say, whether global warming or climate change of unacceptable level is going to occur or not, then, according to the "principle of insufficient reason", one has to assign equal prior probabilities to all the mutually exclusive events (or to forget about the Bayes' rule if climate change simply does not allow to make prior probability assessments—Heap et al., 1992). In the first case, if new scientific information is forthcoming, one can use that information to update the prior probabilities or beliefs using the Bayes' rule (or shifts and alternatives to the Bayesian scheme—see below) to get the posteriors. In summary, the Bayesian theory yields instructions on how to use new information to update beliefs "rationally" in certain circumstances. In essence, the Bayesian decision theory is subjective expected utility theory.

In view of the climate change concerns, and lack of knowledge and data, we undoubtedly have to address decision situations that go beyond conventional levels of uncertainty. How to treat information sources (these are diverse with respect to climate change, each of which providing only a small component of the total information—IPCC reports provide the most comprehensive assessment in this field), and how to allow probability assignments to which subsets becomes significant.

2.5.1.1 Strong uncertainty

This means that decision making to address climate change appears as a category of decision making which must envisage shifts to the conventional Bayesian scheme (Caselton and Luo, 1994) when confronting the "strong" uncertainties created by climate change.

"Strong" uncertainty refers to situations where chance is included (which by turn designates common uncertainty and risk), but *knowledge is insufficient*—in other words, situations for which probabilities cannot conventionally be defined.

In short, climate change gives rise to a type of uncertainty that might not be straightforwardly reduced to traditional risk. Phrased in economic terms, technological and economic "common" uncertainties (or, "variability"), while including chance, include the prospect of being pleasantly surprised, whereas climatic and biological uncertainties, while including chance, lie beyond our current cognitive and computational capabilities—and (in as far as they are seen as catastrophes) normally imply a downward trend of expected revenue (Price, 1993).[4]

A more sensible distinction would be between situations in which there is some experimental or observational knowledge on the whole system or parts of the system (i.e., conceivable outcomes would be known, but their probability of occurrence would not), and when there is no such knowledge. In the first case, strong uncertainty can generally be dealt with by assessing "subjective" probabilities to the possible states of the world. In the second case, the situation leads to ignorance.[5] From a probabilistic standpoint, one can however argue that the distinction between common uncertainty and strong uncertainty (and so *between risk and uncertainty* as well) is a gradual one, as "objective" probability assessment or statistical inference does not exist.[6] From such a standpoint, a subjective

[4] However, this is not the rule for climate change in as far as it might also represent an opportunity, e.g., for innovation, institutional and technological progress; i.e., it can be used positively whether true or not.

[5] Ignorance basically designates a situation where there is absolutely no information about the unknown state of nature. In the Bayesian theory, ignorance is meant as an informationless prior. Ignorance, and similarly near ignorance, can also be viewed from the perspectives of belief and plausibility.

[6] The distinction is frequently made between risk and uncertainty on the basis of whether the probabilities are

probability can always be formulated "as a bet on a certain event". Under these circumstances, the *condition for making strong uncertainty computable is that agents at least believe that they know, even approximately, the relative frequencies of the states of the world.*

2.5.1.2 Abrupt climate change adds unpredictability to uncertainty and risk

Nevertheless, some controversy exists with respect to probabilities and possible climate changes. On the one hand, the climate change context makes associated risks endogenous (they are affected by our actions) and collective (they are not statistically independent risks) (Chichilnisky and Heal, 1993). For example, circumstances have changed for the insurance industry "in ways that mean traditional practice and the old statistical methodologies are no longer adequate"—"past experience is no longer a safe guide to the far future" (Ayres and Weaver, 1994). On the other hand, strong uncertainty persists with regard to the characteristics of the evolution (rate, abruptness, etc.) of possible climate changes. In sum, climate changes seem to imply a certain degree of irreducible unpredictability beyond the common categories of risk and uncertainty.

On the theoretical side, for example, the important processes influencing the global climate are identified and can be understood at least in principle. Particularly, gases influencing the greenhouse effect are analysed in detail (absorption bands, infrared emissions, diffusion) and so, its anthropogenic modification can be rather exactly calculated. *However, the basic assumptions made in such calculations are that the structure of the climate system remains unchanged.* Especially, atmospheric and oceanic circulation patterns and cloud formation, in many models, are assumed to remain qualitatively the same, at most being quantitatively slightly affected and so contributing to a positive or negative feedback, amplifying or damping anthropogenic climate effects respectively. Easy to understand, that the prognosticated anthropogenic warming is gradual without discontinuities (+0.3 K per decade).

In contrast to this, the picture drawn by the newest ice core results (Anklin et al., 1993) emphasises variability and instability in a surprisingly unexpected way. Not only does the last ice age show a large number of sharp transitions between a glacial and an interstadial climatic regime (what has been known before) but also reveals the last interglacial age (*"Eem"*, 125'000 years ago) as being

known/knowable (risk) or not (uncertainty). In this respect, a risk-like uncertainty (knowable probabilities) is sometimes referred to as "weak" uncertainty. There exist more schemes of distinction between risk and uncertainty though differences can rest on science-philosophical grounds (see Vercelli, 1991, Faucheux and Froger, 1994). An alternative is fuzzy logic. The one application of such logic to climate issues is contained in a paper by Leimbach (1993).

composed of a series of sharp climatic transitions. The largest uninterrupted interval of *Eem* climate optimum (roughly 2K warmer than our *Holocene* level) encompasses only ca. 2500 years and around 20 important abrupt transitions between different climate levels can be observed. The most catastrophical fluctuation yet analysed happened towards the end of the *Eem*, where the climate changed into a glacial regime *within about 15 years*, to make the same abrupt change back to the original warm climate only 70 years later (Anklin *et al.*, 1993)!

The discrepancies between the paleoclimatic observations of abrupt changes and the smooth gradual warming prognosticated by today's models could not be more pronounced. They are the result of the fact that the models simulate climate changes as marginal variations around a stable basic climate mode. That the dynamics of this basic mode could dramatically change, being replaced by a different one, is only beginning to be modelled (eg., Manabe and Stouffer, 1993).

In the framework of the basic properties of non-linear systems with circular causality, small stochastic fluctuations can become important factors influencing the time evolution of a system. As soon as the system approaches a critical value of a control parameter, an unpredictable fluctuation might be the cause triggering an abrupt phase transition into one of several possible nearby states. Even if all the critical values would be exactly known, neither the transition time nor the follow-up state could be predicted due to the "strong" uncertainty coming from stochastic fluctuations and weak causality. Indeed, the main characteristics of the global climate system is its structure consisting of many interlinked feedback-loops, some of which being highly non-linear. Under these circumstances, the most natural behaviour to be expected is not a gradual warming but rather an abrupt phase change, a transition to another climate regime.

It turns out that in addition to the "classical" scenario characterised by gradual warming, two "abrupt change" scenarios can be considered for illustration purposes:

- The "*abrupt global change*" scenario, with a sudden important temperature increase within a short period (within a decade), which seems to be a natural candidate based on theoretical reasons as well as new scientific results. The time point where the abrupt change will take place as well as the amplitude of the step and the regional responses will be unknown, so implying "*strong uncertainty*".
- The "*abrupt regional change*" scenario with sudden important climate changes in certain regions is a possible combination of the above and "classical" scenarios. While the global average temperature increase would be rather continuous and reliable, it would be unknown which region will be

next for what change. We would thus face a "*globally weak but regionally strong uncertainty*".

These perspectives add to the complexity of making decision under uncertainty with respect to climate change. Climate change may be a sudden event. Yet, this does not preclude quantification.

In sum, one can argue that although there is some consensus on the ability to deal with uncertainty and risk through subjective probabilities, some uncertainties and risks associated to climate changes may stay outside the reach of traditional practice. Although this is not the right place to expand "classical" and "abrupt change" scenarios, and although probability distributions should not be attached to such alternative scenarios, subjective probabilities reflecting low probability but great severity are needed (see 2.5.3.3, below). Alternatively, one must be also aware of low probability outcomes (e.g., in the case GHG emissions would in future be captured). This means that shifts to the Bayesian decision theory must be taken into account. To conclude, Baysian decision theory has two limitations with respect to climate change: first the existence of strong uncertainties and, second, the existence of low probabilities attached to large potential damages. Indeed, the search for variations as well as alternatives to the Bayesian scheme for reasoning under strong uncertainty has intensified over the past decades to make reliable inference available from unreliable information, vague, partial and contradictory data (see 2.5.3.2 and 2.5.3.3, below). This stresses that, essentially, uncertainties lead to judgement, and that it is the task of political processes to make judgements.

2.5.2 "Rationalities"

What is choice? On which criteria do individuals make choices in an economic context? Alternatively, do choices with respect to environmental problems convincingly differ from choices in economic situations—which constitute the reference framework in which economic choices apply?

The general picture of the *theory of choice* (equivalently, decision making theory) is as follows. The individual can take a *limited range of actions* that have attached consequences. He or she "has in mind an ordering of all possible consequences of actions". Among the actions actually at hand, "that action is chosen whose consequences are preferred to those of any other available action" (Arrow, 1951). Such situations constitute the reference framework in which economic choices apply.

Central conditions are, for example, a theory of market interactions and clearing as well as any coherent theory of reactions to the economic stimuli (prices, in essence). Discounting, scarcity of the resources, and opportunity costs matter. Assumptions also compose the common economic framework.

For instance, a decision-maker's beliefs can always be represented by a unique probability measure; economic agents are said to be perfectly competent to deal with the difficulty of the processes involved in the decisional situation. Basically, economic situations (and theory) are based on *the consistency of human choice.*

Economic criteria of choice primarily rest upon representations and orderings of consequences of actions by means of the assumption of a *utility function.* Such a utility function renders intelligible with regard to observable situations the ability of the consumers to rank their preferences in a consistent order (in like manner, entrepreneurs will prefer more profit to less if each is equally risky). The assumption of a utility function, therefore, postulates a *consistency* of human choice—in short, rationality. This postulate tells the decision-maker that *the focus is on the decision to reach,* not on the process per se. Verily, inasmuch as individuals are assumed to be perfectly knowledgeable and rational, the most valuable option—in terms of utility, or human wishes—is always chosen (Price, 1993).[7]

Rationality and attached utility-based criteria of choice can still play the same pivotal role in climate change-oriented decision making processes as in economic situations.

However, decision-makers must initially be aware of the following differences. First, with respect to the climate change perspective, choices are of collective and of longer-term view nature—they are no longer individual and fixed choices (for instance, a country individually cannot take abatement measures in so far as emissions in the rest of the world will affect the country in question and the gains from abatement by this country will accrue to the rest of the world). It turns out that a collective decision procedure, based on a "procedural" kind of rationality, must be set up (see 2.5.4, below). Second, choices are not made with respect to a fixed set of alternatives, either. Third, choices are not confined to market related decision situations, but are also concerned with non-market related decision situations (including issues of poverty or fragility of natural ecosystems and species).

2.5.2.1 Utility-based decision criteria

Economists do not assert that human agents are "rational" by definition. Rationality is a law-like refutable statement which "simply means behaviour in accordance with some ordering of alternatives

[7] Simply, it is assumed that in evaluating uncertainty and risk situations, the decision-maker replaces the monetary value of final outcome by the utility (a function) of that one. Therefore, utility can be interpreted as a method "of passing from a more objective level to a more subjective level: that of the amount of satisfaction achieved" (Eeckhoudt and Gollier, 1995).

in terms of relative desirability" (Arrow, 1951, Blaug, 1992). It designates a "*maximization of the expected value of a given utility function* (Savage, 1954; Arrow, 1987).

Subjective arguments are compatible components of the assumption of a consistent utility-maximising behaviour. Expected utility (together with the notion of expected value, the return) is the prime economic criterion for choice. It can take account for risk through various utility-based criteria.

Utility-based criteria mean addressing the maximisation of expected utility (or value—cf. Box 2.5–I). They entail decisions that are based on the valuation of outcomes—wealth levels, time streams of consumption, etc.—(Morgan and Henrion, 1990).

Box 2.5–I: Examples of some utility-based decision criteria
Source: After Morgan and Henrion, 1990: 26

Benefit-cost:	Estimate the benefits and costs of the alternatives in economic terms and choose the one with the highest net benefit.
Maximise multi-attribute utility:	This is the most general form of utility-based criterion. Rather than use monetary value as the evaluation measure, MAU involves specifying a utility function that evaluates outcomes in terms of all their important attributes (including uncertainties and risks). The alternative with maximum utility is selected.
Cost effectiveness:	Select a desired performance level, perhaps on non economic grounds. Then choose the option that achieves the desired level at the lowest cost.
Minimise chance of worst possible outcome *Maximise chance of best possible outcome:*	Political and behavioural considerations frequently dictate the use of such criteria.
Maximum budget (bounded cost criterion):	Set the maximum budget to devote to risk management activity.
Minimise maximum regrets:	Choose measures of "regret" and minimise the maximum regret.
Minimax Loss (Minimax criterion for catastrophic risk):	For each decision alternative find the loss associated with the extreme event. From among these losses find one with the maximum loss and try to minimise it. This is a conservative criterion.
Maximin Gain:	Find the gains associated with each action and try to maximise the minimum of these gains.

For example, if the climate damage is sufficiently great, or the uncertainty of such effect sufficiently strong, it will even pay a poor country to adapt or contribute to slowing down climate change, even at a low level of income. Poor countries have invested heavily in industrial and irrigation projects, thereby sacrificing present consumption to seek higher incomes in the future. In some countries, such as Singapore, people have voluntarily engaged in high savings (45% of income approximately)

even at low present consumption levels to achieve a better life in the future.

The implicit argument is a redistributionist argument based on the higher marginal utility of income at lower levels.

2.5.2.2 *Bounded rationality*

Rational behaviour is a "first approximation" to actual behaviour. Indeed, as soon as one faces either imperfect forms of competition or non-market resources allocation decisions, knowledge requirements radically shift and *exceed those usually required for a pure market framework.* In addition, there might be as many rationalities as there are cultures.

It is anyhow widely accepted that (economic) rationality hypotheses be supplemented by assumptions of a different character (e.g., information-gathering ability and limitation of both knowledge and computational capacity). It is accepted that rationality, obviously, is *bounded* (Simon, 1957, Arrow, 1987). In principle, these cognitive difficulties are connected to decisions that lie beyond individual-related, common economic situations; they relate to decisions that must be reached through *international conventions*, or to decisions that, *independently of the valuation of the outcomes*, are destined to eliminate risks.

As a concept, "bounded rationality" has been coined to name rational choice that takes into account the "cognitive limitations of the decision-maker" (Simon, 1987). Basically, this tells the decision-makers that rationality can be also concerned with *the ways in which the actual decision-making process influences the decisions that are reached* and not only with reaching decisions assuming the maximisation of expected utility, as we are used to consider from a common economic viewpoint.

This concept thus designates a different type of rationality, namely procedural rationality. Incidentally, a decision which optimises co-operation will possibly be in opposition with a decision which optimises the expected value of utility because the latter places the focus on *the decision to reach* while the former places the emphasis on *the decision process in itself.*

2.5.2.3 *Procedural rationality*

The former cognitive limitations may break usual limits on specific information. In the words of Simon, they are almost always limits on the adequacy of the scientific theories that can be used to predict the relevant phenomena (Simon, 1987). Meteorology and atmospheric chemistry, on the one hand, as well as economics, on the other hand, openly leave large bands of uncertainty in reference to

climate change. In addition, lack of knowledge about fundamental mechanisms that equations cannot currently master represents limits to computer models in both domains. These difficulties typically occur with respect to decisions that are taken on a national or international scale *when governments negotiate some form of agreement and countries differ in their economic wealth, reliance on fossil fuels, endowment of alternative resources and technical capabilities.*

Specifically, "procedural" rationality designates the rationality of a decision in terms of the *manner in which it is made* while economic rationality names the *rationality of a decision considered independently of the manner in which it is made* (in the case for economic—equivalently, substantive—rationality, rationality evaluation refers exclusively to the results of the choice, not to the decision-making process in itself—Faucheux and Froger, 1994).

Which kind of theory can better support and explain the decisions at issue under FCCC? Shall we place interest in the decisions to be reached only, or shall we focus attention on the (international) decision procedure as such? Answering to these questions and the like would *command the choice* between economic and procedural rationality frameworks (Simon, 1987). From an economic standpoint, unfortunately, the fact that the manner in which the decision is made—and not the result of the choice—is at issue in the decision evaluation makes the procedural kind of rationality mostly undetermined. This tells decision-makers that procedural rationality should be bounded to the processes of collective decision making, i.e., the steps in negotiating treaties and agreements. We will return to this in subsection 2.5.4., below.

2.5.3 Responses to uncertainty and risk

Getting back to the distinction between uncertainty and risk made on the basis of whether the probabilities are not (uncertainty) or are known/knowable (risk), let's consider how (intuitively) to proceed.

The classical ingredients of a decision problem under uncertainty are a set of feasible acts (A), a set of consequences (C), and a set of states of nature (S). The decision-maker does not know for sure which consequence will result from a chosen act (*probabilities for the events are not known in advance*). The role of the states of nature is to indicate the matching of feasible acts to consequences, thus resolving the uncertainty which relates acts to consequences. This makes states of nature exogenous (uncertainty becomes in like manner exogenous, too) so that probabilities can be computed. As a result, the **decision-makers basically have to assign utilities to the consequences** (utility U assigned

to each consequence c in C) **and probabilities to the states** (probability $\wp$ assigned to each state s in S) (Schmeidler and Wakker, 1987).[8] *In choosing between acts, the decision-makers will elect that one with the highest "expected utility" (or, expected value)—that is, the one with the highest sum of the products of probability and utility.*

A decision making under risk introduces a special formulation of the decision problem to the extent that *probabilities for the events are known in advance*. In other words, the decision problem includes the probability distribution of an act over the consequences. Accordingly, **decision-makers only have to determine utilities of consequences before choosing between acts.**

Yet, this presentation reflects individual election and addresses common economic or technological variability; it is not straightforwardly designed to address unpredictability and judge risks like those climatic and biological possible catastrophes might imply (see 2.5.3.3, below). As a first rough approximation with respect to climate change, the expected utility criterion says that it is possible to retain the notion of expected value (the return) while, with reference to uncertainty decision rules (see below) and efficient risk sharing (see 2.5.2), also taking risk into account.

2.5.3.1 Uncertainty and risk decision rules

One can move from the pure decision criteria that appear in Box 2.5–I to more simple decision rules; i.e., *rules which do not need to elucidate all* possible outcomes and their respective probabilities.

First, approved individual/collective decision rules with respect to *uncertainty* can be outlined as follows (MIT, 1986):

Maximax	The decision maker should opt for that course of action which yields the highest pay-off (net benefits, or whatever) *regardless* of any view taken about which state of nature will occur. It's the optimistic rule.
Maximin (Wald, 1950)	...We should first observe all the minimum pay-offs and then select the highest of these. Amounts to expecting the worst (Price, 1993)—presumably in our case, the failure of technology or substitution to relieve climate change constraints. Decision-makers who employ this criterion are extreme pessimists.

[8] A specific way allowing to cover the case for uncertainty—originally about the availability of resources and about consumption and production possibilities—is the idea of *contingent commodity* introduced by Arrow (1953) and developed by Debreu (1953). This device is added to the current specifications of the commodity such as its physical characteristics and location to make the availability of the commodity contingent on the occurrence of some (uncertain) environmental event such as weather conditions.

Minimax (Savage, 1951)	...We should select measures of "regret" (i.e., the difference between an actual pay-off and what the pay-off would have been if the correct strategy had been chosen). This is a cautious principle and ensures that, if the worst happens, we make "the best of a bad job". Emphasises the cost of making the wrong decision (Price, 1993). ...We should seek to minimise the maximum regrets. ...We should seek to minimise maximum loss (Dowlatabadi and Morgan, 1992).

Second, basic individual/collective preferences towards *risk* can be outlined as follows:

Risk aversion:	Higher expected return is needed as compensation for an increase in risk. A risk averter can be a diversifier and spread his *portfolio* over different assets—or a "plunger" and invest wholly in bonds and money.
Diversifier:	Risk is likely to be the cause of *portfolio* diversification: if risks increase then the diversifiers will move back to holding wealth in the form of money.
Risk lover:	A risk lover accepts a higher level of risk for a given expected return.
Risk neutral:	A risk neutral individual would be indifferent whether or not he or she accepted "fair" insurance. Under risk neutrality, the risk premium is zero.
Cautiousness:	Defined as decreasing risk aversion (Pratt, 1995). The cautious person has no dislike for uncertainty as such, but feels that he or she "can expect to do better in the long run by playing it safe for the present and thus increasing probability that he/she will have the funds available to take advantage of more favorable deals which may arise in the future (Schlaifer, 1961; after Pratt, 1995). Cautiousness is thus derived from risk aversion.

2.5.3.2 Decision analysis techniques

Application of utility-based criteria and rules involve a full range of techniques, each of them being suitable for different purposes. Some are designed to serve as an aid to collective decision making.

One is a balancing of benefits and costs in a Benefit-cost analysis framework. Game theory is one another. Techniques developed by management scientists over the last 10-20 years (which are sometimes collectively referred to as "Soft System Analysis" and include Strategic choice analysis, Robustness analysis, Hypergame theory and a number or others) are other ones (cf. Ríos, 1994). One another grouping of methods for reasoning under uncertainty is Evidence Theory, or defeasible reasoning and uncertainty management techniques (Kohlas et al., 1994). This group concerns the

study of symbolic and numerical methods for the representation and management of incomplete information. Basic research activities cover domains like nonmonotonic logics, fuzzy logic and possibility theory, "surprise" (Shackle, 1967), "imprecise" probability (Walley, 1991), Bayesian networks, Dempster-Shafer theory of evidence (Dempster, 1967, Shafer, 1976; Caselton and Luo, 1994) and "Non-expected utility models" (Yaari, 1987). It attacks, notably, problems related to uncertain, unreliable, vague, partial and contradictory data.[9]

A different conception is the Multi-attribute utility analysis which is suitable for situations where options involve "collections of attributes that are incommensurate" (Keeney and Raiffa, 1976, Morgan and Henrion, 1990). The resulting decision model can avoid the dilemma of converting each attribute to an equivalent monetary value.

Variations to utility-based decision criteria are available. A Cost effectiveness criterion can be used where the value of benefits cannot be estimated—but a choice must be made between alternatives (Morgan and Henrion, 1990). A Maximum budget can be set to devote to risk management activity (bounded cost criterion). Last, measures of "regret" can be chosen and the maximum regrets minimised.

Other methods or tools are thought to help diagnose the *negotiation process* itself, for example, Cognitive mapping, Simulation modelling, Rule-based systems, an Information management (IIASA, 1993). Techniques belonging to decision analysis can be reoriented to serve as negotiations supports as well. One can cite Cross-impact analysis that facilitates the modelling of complex situations or stakeholder analysis which uses information on the position, interest, priorities, and preferences of various stakeholders on a particular issue to facilitate analysis of the range of differences among stakeholders and the potential for coalition formation (IIASA, 1993). Multi-attribute utility analysis techniques have been applied by researchers at IIASA to evaluate coalition building and preference adjustment in the UN Conference on Environment and Development.

2.5.3.3 Addressing strong uncertainty

Under climate changes situations, decision-makers need to pay attention to situations of strong uncer-

[9] An essential aspect of a decision analysis is the ability to combine information from various independent sources. For instance, in the Dempster-Shafer context, if two basic probability assignments (BPA) on the same unknown state of nature are obtained from two different independent sources of information, they can be combined to yield a new resultant BPA. This kind of scheme also allows at specifying probabilities on intervals of the state of nature, leading to a possibilistic specification of probability.

tainty, *which in this matter might not be exactly an exceptional situation but maybe the rule*. In this context, one may choose two different ways.

First, as regards *strong uncertainty*, the approach based on the exploration of the future on the basis of the **use of scenarios** appears as one of the few relatively-useful instruments. This can address mitigation and adaptation to climate changes, the phasing out existing policies, as well as climate and technology research.

Second, in so far as climate change risks can be delineated, the **risk assessment** of potential climate change can deliver probability distributions of the different estimates to policy makers (see Chapter 7, below). On the other hand, in so far as we accept to bet on future events according to a set of possible descriptions of collective risk, it could be natural to allow agents to *trade securities insurance contracts* (see 2.5.2, below).

In sum, an open question is: *are policy makers better served by best guess scenarios than by probability distributions of these estimates* (Shlyakhter *et al.*, 1995)?

These options can be reconciled by drawing distinctions between scenarios that are *probable* (risk situations) and those that are *possible* (strong uncertainty situations). According to Shlyakhter *et al.* (1995), *those risks that fall below a particular threshold of probability*—and thereby are ignored by a particular group or society—are called *"de minimis"* risks. "How societies and governments decide what constitutes *de minimis* risk in particular situations or contexts is largely a matter of political judgement" (Shlyakhter *et al.*, 1995). Although there is no clear definition of a *de minimis* risk, it can generally be seen to be closely akin to a related concept, namely, the *probability of "surprise"*.

The next question is: "At what probability of a serious effect should society take action?" How to compute a *de minimis* risk—equivalently, a probability of surprise? Although many conceptions and definitions are possible, the use by Shlyakhter *et al.* (1995) of the word *surprise* is meant to denote those situations where the true values of a particular uncertain parameter, e.g., climate sensitivity to CO_2 doubling, appear at least 2.6 standard deviations away from its current "best guess" value. For a random variable that is assumed to be normally distributed, the probability that the "true" value is more than 2.6 standard deviations from the current «best guess» is just 1 percent. As Shlyakhter *et al.* (1995) continue, it is interesting to note that public opinion polls suggest that many people are unconcerned about a 5 percent chance of a climate-related catastrophe within their lifetime, although they are concerned about a 1 percent chance of a nuclear accident. They also note that an airliner with a

calculated chance of failure around 5 percent in its 70 year life would not be allowed to fly in commercial service.

Last, qualitative and probabilistic changes relate to the expected value of a single experience. As such, they have "close affinities with the meaning of discounting" (Price, 1993; also cf. Chapter 3).

2.5.4 *Collective decision making*

To discuss the choices of a group rather than of an individual, one can use an index of social welfare as a "utility" function. This fits into the framework of maximising the expected value of a function. The group then makes collective risky investment decisions and insurance decisions by using this function. Though collective decision making is central in economic analysis, many applications are analysed in this way; that is, using microeconomic analogies and inferences.

Specifically, however, a group has possibilities of risk retention that are much greater than that of an individual. "This is partly due to the opportunities of diversification within the group and partly due to the transfer of risk towards the least risk-adverse members (or the richest members if absolute risk aversion is decreasing)" (Eeckhoudt and Gollier, 1995). This is why organisations have always been best suited to undertake risky activities—adapting to or slowing down climate changes is a risky activity by itself due to the existence of strong uncertainties. "Without this diminution of risk aversion in an economy, thanks to the creation of risk pools, many risky projects would not have been undertaken and we would undoubtedly not have known the economic expansion that we have observed over the last two centuries" (Ibid.). In practice and with respect to climate change, applications of collective decision making regard two out of three key rationales this chapter will select: *insurance* decisions (2.5.2) and a policy measures *portfolio* (2.5.3) (the first rationale is time-oriented, i.e., *sequential decision making paths*—see 2.5.1).

Specifically again, 'collective' decision making means the choice of weights for the members of the group. For this reason, the valuation of outcomes will become matter of negociation under a collective decision making framework. Yet, negociation proceeds along a particular procedural scheme, to which we turn now.

As a procedure, collective decision making concerns the processes of co-ordinated decision-making, i.e., the steps in *negotiating* international treaties and agreements, the appropriate weights, decision criteria and/or rules if any, and the particular decision procedure. In this context, 'collective'

decision making should read intergovernmental *"negotiated"* decision making.[10]

2.5.4.1 *Steps in negotiating international environmental treaties and agreements*

Environmental accords tend to be partial and incremental. On the one hand, they tend to be integrated, complex packages of multiple linked issues that are difficult to negotiate internationally. On the other hand, they are made of several steps such as pre-negotiation, negotiation and post-negotiation processes. This is due largely to scientific uncertainty concerning the problems and possible solutions, and the (a priori) need for continued learning about effects and consequences. Partial agreements are also customary because of the political uncertainty in devising fair and equitable approaches at a global level (IIASA, 1993).

Sustained negotiation or post-agreement negotiation are also an attribute of current international environmental negotiations. This is the case, namely, for the UN FCCC, its former Intergovernmental Negotiating Committee (INC) and its new Conference of the Parties (CoP). Post-agreement negotiation can be defined as the dynamic and co-operative systems, procedures, and structures which are institutionalised to sustain dialogue on issues that cannot, by their nature, be resolved by a single agreement. A framework convention or a protocol mechanism often have no clear end-point. A broad framework of principles is agreed to first, followed by additional talks to specify details (IIASA, 1993).

Procedural issues need to be addressed further. It results from a study by IIASA (Sjöstedt, 1993) that the following ones need to be dealt with by practitioners and researchers alike:

- Many new groups and individuals beyond traditional governmental officials are now important participants in the negotiation process.
- The complexity of international environmental negotiations is increasing. Policy makers have linked environmental issues with other important policy concerns, such as development and trade. The implications of these linkages are often not well understood. Ways must be found to develop a common understanding of these linkages.
- Bridging the differences between industrialised and developing countries will be a continuing problem, given their different interpretations of what constitutes fair and equitable solutions.
- New approaches to innovative problem solving need to be found and implemented, perhaps using the assistance of third parties or creative reasoning heuristics.
- New strategies to implement negotiated environmental agreements are needed to reduce national ratification delays and increase the likelihood of compliance (IIASA, 1993).

[10] The choice of the country as decision unit has formal justification in international law. However, this does not solve real world decision making in as far as major energy producers and users are directly involved in it. Therefore the paramount importance of utility-based decision making criteria and rules.

Unlike the processes of pre-negotiation and negotiation, post-agreement negotiation has received little attention from researchers in terms of their procedural rationality. Options can be:

- Involving domestic stakeholders in negotiations from the beginning.
- Modifying the structure of the accords themselves: Clusters of simple, single-issue agreements may be more practical.
- Initiating a new learning process in the post-agreement negotiation process in as far as international problems can be more abstract than local environmental issues.

Post-agreement negotiations present policy makers with the challenge of progressively reframing problems, adjusting strategies and perceptions, and refining solutions (IIASA, 1993).

2.5.4.2 Collective decision criteria

At the world level, decisions cannot be easily based on individual-like utility functions (index of social welfare). In addition, once it is accepted that we have no world sovereignty and no global social welfare function, ***the outcome is a matter of negotiation***. This is the way to address the choice of weights for the members of the group.

How much each country has to say is, however, more a matter of what is than a matter of ethics. The literature on negotiation analysis (Fisher and Ury, 1981; Raiffa, 1982; and others) stresses that each party to an agreement must find himself better off with the agreement, than without. Otherwise he has no reason to agree.

The Conference of the Parties (CoP) will be the apex forum which makes the collective global environmental decisions for global welfare within the constraints set by environmental risk and economic efficiency.

One possibility is to use *collective decision criteria* (or, rights-based criteria).

One another possibility is—in as far as every country has its predispositions in the debate, and there can be no certainty about which position will be vindicated in the passing of time (Price, 1993)—to adopt *traditional criteria for decision making under uncertainty*.

The maximin criterion (Wald, 1950; see also 2.5.3.1, above) amounts to expecting the worst—presumably the failure of energy and technology substitution to relieve climate change constraints—and adopting a policy based on that expectation (Price, 1993).

The minimax regret criterion (Savage, 1951; also see 2.5.3.1) emphasises the cost of making the wrong decision—presumably, in the climate change context, the very high cost of damages as a result

of assuming technological progress which might fail to materialise.[11]

Convention-related principles are still one another possibility. Indeed, the need for an equitable distribution of tasks both at the national and international levels is the cornerstone of the Framework Convention on Climate Change (FCCC). For example, while all the Parties are required to contribute to the collective effort by elaborating a national programme, the application of *the principle of "common but differentiated responsibilities" implies that the industrialised nations should take strong measures*—first by adopting specific national measures to stabilise greenhouse gas emissions, second by promoting the transfer of financial resources, know-how and/or technologies to developing countries, in particular the least developed countries (FCCC, 1992, BUWAL, 1994).

The precautionary principle also belong to the FCCC-related principles. Basically, it is a rights-based criterion. According to FCCC, however, it has been thought to encourage nations and individuals to take early actions to prevent environmental damage even when these actions are not "economically attractive". In this sense, it might look like some *legal or ethical principle*, and consequently be in contradiction with cost-effectiveness demands (that also are requested by the framework convention on climate change!).

2.5.4.3 Decision procedure

The Convention establishes flexible procedures, based on the submission by governments of national communications, in order to ensure that States implement their commitments. These procedures are

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[11] Here are examples of some collective, rights-based criteria (Morgan and Henrion, 1990):

Zero risk:	Independent of the benefits and costs, and of how big the risks are, eliminate the risks, or do not allow their introduction.
Bounded or constrained risk:	Independent of the costs and benefits, constrain the level of risk so that it does not exceed a specific level or, more generally, so that it meets a set of specified criteria.
Approval/compensation:	Allow risks to be imposed only on people who have voluntarily given consent, perhaps after compensation.
Approved process:	Not strictly a decision criterion for analysis, but widely applied in risk management decision making. If all relevant parties observe a specified set of procedures (e.g., under some international convention), then any decision reached will by definition be acceptable.
Liability insurance:	Parties which impose risk might be eligible for liability insurance (added example).

Rights-based criteria have been thought to deal with processes and constrained actions or activities (Morgan and Henrion, 1990). For instance, the *approved process* criterion insists "that all the relevant parties observe a specified set of procedures" such as some internationally signed convention defining a due process (this leads us back to procedural rationality). Some of these criteria are *inconsistent to deal with exogenous, naturally occurring risks* as for instance the *zero risk* criterion which simply does not allow the introduction of the risk. Hybrids of utility- and rights-based criteria are sometimes used.

also designed to allow if necessary to amend the Convention in the light of new knowledge, for example through protocols dealing with specific areas (BUWAL, 1994).

In line with the provisions of the FCCC (Art. 4.2e), industrialised countries must also *co-ordinate* economic and administrative instruments. International co-ordination also helps at avoiding undesirable side-effects such as trade distortions and unwanted impacts on the environment of third countries.

All countries should participate collectively in efforts aimed at solving global environmental problems, based on an equitable sharing of responsibilities. In this respect, increased solidarity between the planet's rich and poor regions is essential.[12] Attention should also be paid to providing financial support to the Central and eastern European nations, in order to encourage their full participation in the work undertaken within the FCCC.

Under FCCC, indeed, the developing countries have no obligation to control emissions and therefore do not need to pay "global carbon taxes". However, if a CO_2 tax is imposed, *efficiency requires that it be imposed on everyone*. Energy efficiency is just as important in poor countries as in rich countries. The issue is exceptionally sagacious: (a) Equity may demand that the proceeds of the tax be remitted to the developing countries; (b) however, there seems to be no objections raised against tradable permits; (c) as a rule, transferable permits *amount to a tax* on emissions *by all countries*.

For example, if India or any other developing country seeks to increase its own combustion, it reduces its sale of permits to the developed countries and therefore loses that revenue; this is equivalent to a tax.[13]

It turns out that *all* countries have to reduce their emissions, at least compared with what they otherwise would do. The growth of non-Annex I countries depends *both* on emission reductions in Annex I countries and on increased efficiency in their own energy usage. Developing countries should not be exempted from the tax—as this would lead to inefficiencies.[14] Instead, they could be

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[12] This argument does not imply that poor countries cannot afford to take any thought for the future. They do, and have to do, though day-to-day adversity can become pervasive, as it is the case in large parts of Africa. This does not means that there is nothing for Northern parties to gain from an agreement, either: a growing prosperous South contributes to the North through international trade and reduces the possibility of environmental refugees and northward migration pressure in general; Northern countries do have moral and humanitarian interests in reducing poverty of some countries; though smaller than likely Southern adverse impacts, there are adverse impacts that the North will suffer too; last, we all have interest in avoiding an irreversible catastrophe.

[13] This example also concerns the problem of decision making at the firm or at the household level (Chapter 8 deals with the process of innovation and technology adaptation by firms and households—see 8.3.1.3).

[14] In addition, one of the major thrusts of environmental economics is that society must internalise the costs of "free" natural resources (the atmosphere). This obligation applies to developing and developed countries alike. The carbon tax is

entitled to an overproportional share of tax recycling. In this respect, however, liability would be impossible for emissions prior to the discovery of the possibility of anthropogenic warming (ca. 1988). Instead, it should be recognised that more GHG efficient technologies are available to developing countries than it was the case when developed countries were in development phase, and that the only path to development is not the one that has been travelled by developed countries (otherwise, it must be acknowledged that developing countries will be the source of most pollution in future years).

In this respect, joint implementation (JI) can be a valuable instrument though controversies—that mainly are political and not economic—still surround the concept. Used in very flexible manner, it would induce additional transfers to the South. Developing countries would not invest in "climate change abatement" but might change their development strategy in ways that are compativle with lower GHG emissions. Left without efficient devices then the South is unlikely to invest in abatement of climate change. This will have to come from the North. Second is cost-effectiveness. Any Northern investment in abatement would be most cost-effective through joint implementation (Chapter 4; Pillet et al., 1993). Last, it now clearly appears to many developing countries that solving the climate change issue is closely linked to future development paths (Villanuova, 1994). So it is in the global interest that North South trade reliable, cost-effective mitigation.

2.6 A Sequential Decision Making Framework to Hedge Against Impacts of Uncertainty and Change

This section concerns the decision making framework for hedging against possible climate changes and related impacts, and especially establishing decision making paths relative to uncertainty and risk, exploring the use of financial markets, and pooling different kinds of policy options.

2.6.1 Decision making paths: Which strategy would be best?

2.6.1.1 Scenario analysis

The decision making framework to address climate change is served by scenario analysis. Scenario analysis is one of the few relatively-useful instruments at hand to look at the here-and-now significance of alternative futures. Uncertainty is indirectly treated; that is, the very existence of uncertainty makes alternative scenarios different, but uncertainty is not incorporated within scenarios.

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one means of doing this.

Within scenarios, therefore, the analysis proceeds as if we definitely had the opportunity to learn the state of the world before taking action—in other words, it proceeds as if all uncertainties are resolved prior to the date at which decisions are taken. Each scenario develops within a certainty-like context.

A decision-making framework is made of a combination of paths that lead to a decision making strategy. Scenarios are no decision-making paths. Acting is a path. Learning is one another path. The best combination of such paths would give the best strategy.

The size of the strategy will depend on the probabilities assigned to alternative outcomes attached to possible states of the world (which can be served by alternative scenarios). The value of improved information (expected value of perfect information) will play a central role.

2.6.1.2 Sequential decision making

Alternative combinations of decision-making paths give alternative characterisations of the decision problem.

One strategy is to proceed as if we definitely had the opportunity to learn the state of the world before taking action; in other words, as if all uncertainties were resolved prior to the date at which decisions will be taken. This decision making strategy can be called a "learn–then act" strategy. Learning comes first. Then, once all uncertainties are more or less resolved, action can be taken.

One another strategy is to hedge against the probability of surprise such as those risks that fall below a particular threshold of probability. Such a strategy can be sequential, proceeding under an "act–then learn" characterisation of the decision problem: decisions are taken (acting) for the years to come without knowing which of the possible states of the world will occur in a sequence of decisions allowing new information (learning) to be incorporated into a complex decision process.[15]

See Figure 2.6—1(a) on which a circle denotes a chance, and a square a decision node.

To illustrate, Box 2.6–I shows hypothetical emissions constraints ascribed to each of the three states of the world under the "learn–then act" procedure (Fig. 2.6–1a).

Figure 2.6–1 shows the decision trees:

(a) for a "learn–then act" decision strategy (learning about damage potential, then acting) and

(b) for an "act–then learn" decision strategy (hedging against damage potential by acting first, then learning about the damage potential, and then acting again).

[15] Hedging is not equal to "act–then learn" as learning does not necessarily take place.

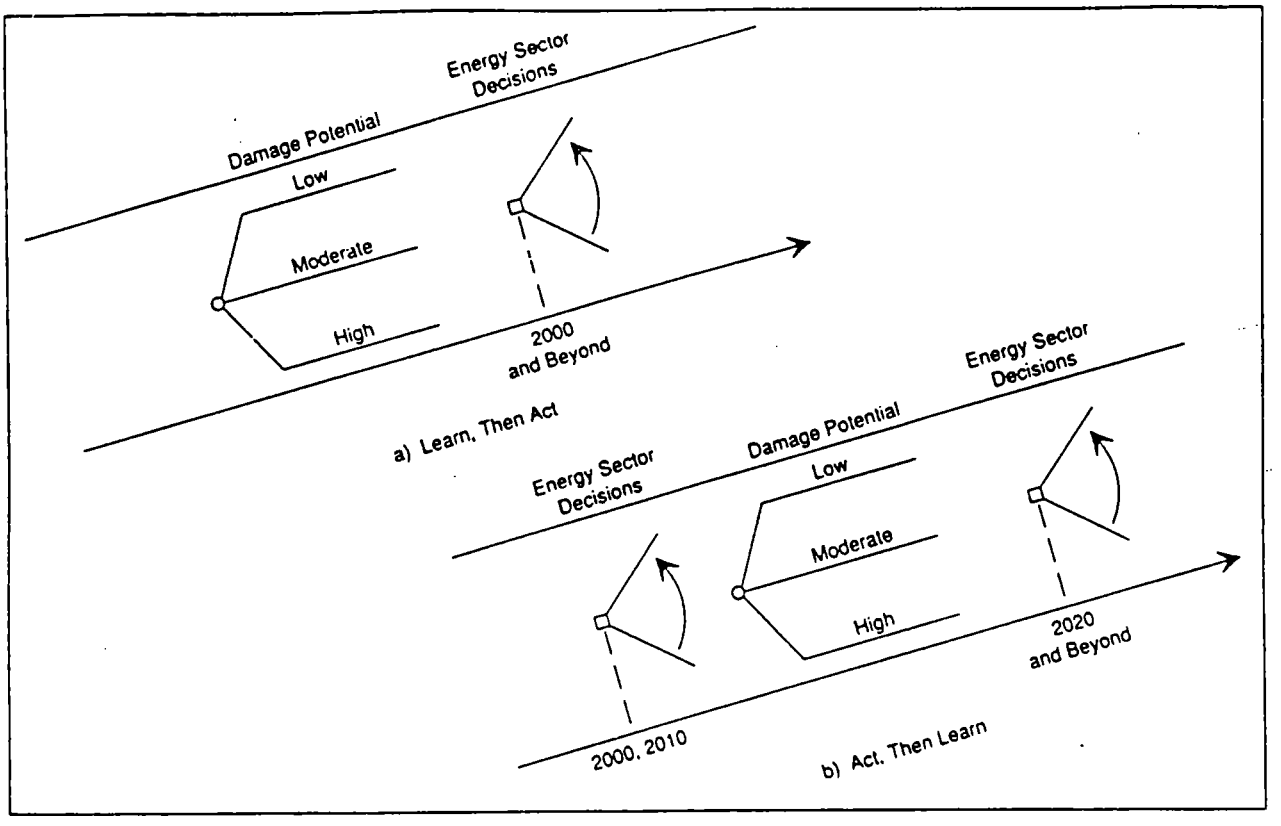

Figure 2.6–1: Alternative decision making strategies
A circle denotes a chance node—a point at which an uncertainty is resolved.
A square denotes a decision node—a point at which actions are required.
Manne and Richels (1992).

Box 2.6–I: Emissions level under "learn-then act" procedure (hypothetical)

Damage potential	Carbon emissions (2010 target)
Low	Unlimited (hypothetical)
Moderate	20% below 1990 level (hypothetical)
High	50% below 1990 level (hypothetical)

Source : Manne and Richels, 1993

If the damage potential proves low, then carbon emissions would remain unconstrained. With a moderate damage potential, the 2010 target would be 20 percent below 1990 levels, and with a high damage potential, the 2010 target would become a 50 percent reduction (incidentally, this might not be possible to be implemented at that time).

Under a "act-then learn" hedging policy, decisions would be taken at discrete points of time separated by intervals of one decade. *It would be assumed that prior to 2020, the energy sector's supply and demand decisions should be made under uncertainty about reaching a consensus on*

carbon limits. From 2020 onward, it would be supposed that decisions would be made after the resolution of uncertainty. Under the "act–then learn" strategy, we would make decisions for 2000 and 2010 without knowing which of the states of the world (low, moderate, and high damage potential) would occur and should select an optimal hedging policy for the emissions levels[16].

A sequential hedging strategy consists of adopting an emissions level that lies between the extreme cases shown by different emissions scenarios, and the size of the hedging strategy will depend on the probabilities assigned to alternative outcomes. To illustrate a case in which the expected value of perfect information (EVPI) would be high, and in which the probability of low damage would be 60 percent and that the probability of a 20 percent reduction 1.5 times that of a 50 percent reduction, then, Manne and Richels (1992) conclude, if controls are required, they are more likely to be moderate than high.

One another example of a sequential decision making is reported by Hammitt *et al.* (1992). According to well publicised works (see also Singer *et al.*, 1991; Manne and Richels, 1991, 1992; IUCC, 1993; Richels, 1994; Peck, 1994), first decisions might be to take those actions where the cost is not high while considering more aggressive-reduction policies (Fig. 2.6–2).

First, energy conservation represents a set of low-cost, quickly implemented policies. To illustrate, if adopted at t_0, energy intensity falls 30% over 20 years (Hammitt *et al.*, 1992). This corresponds to some minimal agreement made of two complementary actions: conserve energy by discouraging wasteful use globally, and improve efficiency in energy use (Singer *et al.*, 1991).

Second, fuel switching represents a more aggressive-reduction policy. It is a set of high-cost, slowly implemented emission-reduction technologies. They are produced by long-lived capital equipment using either emitting or non-emitting technologies (fossil fuel vs. nuclear, solar, biomass). Both have construction periods of about 10 years, and an operating period of roughly 30 years (Hammitt *et al.*, 1992). The motto is: use non-fossil fuel energy sources wherever this makes economic sense (Singer *et al.*, 1991). "The policy decisions are whether to begin substituting non-emitting or emitting equipment, and if so, the rate at which to substitute, specified as the transition half-life, or the time until half the capital stock then operating is non-emitting" (Hammitt *et al.*, 1992).

[16] The period-to-period allocation of carbon emissions is determined so as to maximise the expected discounted utility of consumption (Global 2100 by Manne and Richels, 1992).

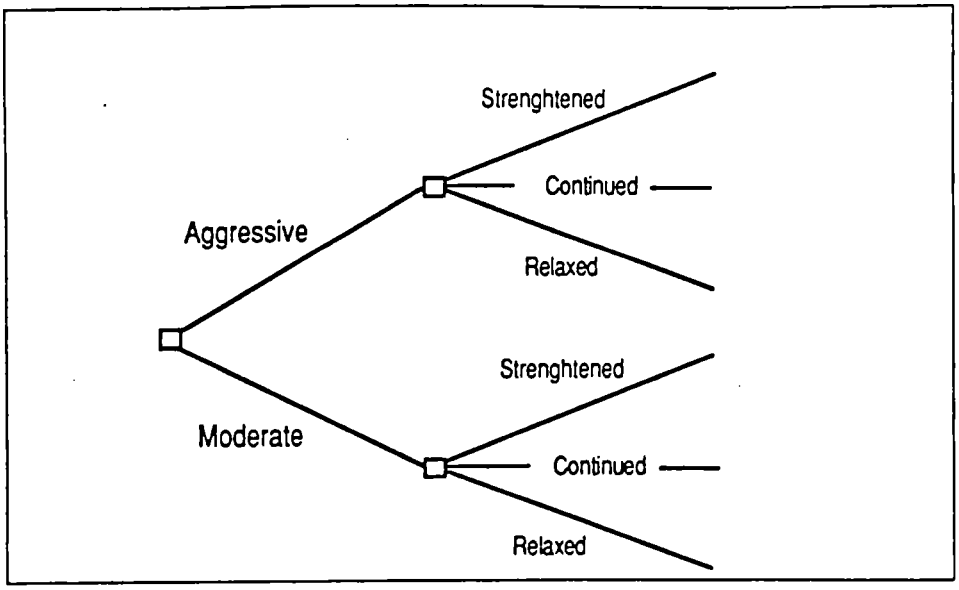

Figure 2.6–2: *Decision tree for sequential policy choice.*
At the beginning of the first period, (1992) either the moderate reduction or aggressive reduction near-term abatement policy is selected. At the beginning of the second period (2002), uncertainties about climate sensitivity and the damages of climate change are substantially resolved and the chosen policy is amended to limit climate change to the "optimal" level. Hammitt et al., (1992).

Hammitt *et al.* consider two near-term policies, aggressive and moderate reduction (Fig. 2.6–2).

Under the aggressive-reduction policy, conservation and fuel-switching are adopted together starting in 1992.

Under the moderate-reduction policy, only the conservation policy is adopted and implemented in 1992. At the beginning of the second period (2002), uncertainties about climate sensitivity and the damages of climate change are thought to be substantially resolved and the chosen policy is amended to limit climate change to some "optimal" level (though this could appear as an irreversible process).

2.6.1.3 Clearing up the uncertainties? The value of improved information

Under a "learn–then act" sequential decision making, the value of new information depends on changes in the probabilities assigned to the (alternative) scenarios before and after the study. "If the probabilities of (alternative) scenarios remain equal, then the value of the study is zero; if, on the other hand, only one scenario can be selected, a study might be worth as much as 100 billion dollars" (Shlyakhter *et al.*, 1995).[17]

[17] Values of situations before and after imperfect or perfect information is received can be computed. When there is risk neutrality, these values also represent expected utility. Suppose that expected results are as follows: (a) without information: +150; (b) imperfect information: +325; (c) perfect information: + 500. This hypothetical example "illustrates a perfectly general result: the value of perfect information (500 - 150) clearly exceeds the value of imperfect information (325 - 150)"; it also indicates that some information—albeit imperfect—is better than no information at all (Eeckhoudt and Gollier, 1995). Hourcarde and Chapuis (1994) have shown that, accounting for climate change related surprises under

Under an "act–then learn" sequential decision making, there is an agreement that uncertainty *cannot be resolved* before a decision is taken. This does not mean that uncertainty is an obstacle for decision making. This means that first, its resolution is at a too high a cost and, second, that maybe it will not facilitate a decision—clearing up the uncertainties could make the greenhouse warming issue more difficult to resolve (Waterstone, 1993). Accordingly, it is for instance assumed that the damage potential will remain unknown until 2010-2020. As a consequence, the appropriate emissions level would be known only well into the second decade of the twenty-first century. The actual level of investment is also influenced by the conflict between the long term nature of the problem (and the time that would be required for resolution of the uncertainties) – and the short term public and private decision makers horizons (sometimes called NIMTOO phenomenon). Today decisions must thus consider the partial disclosing of the uncertainties along with the long-term effects of short term decisions. Sequential decision making can address this point.

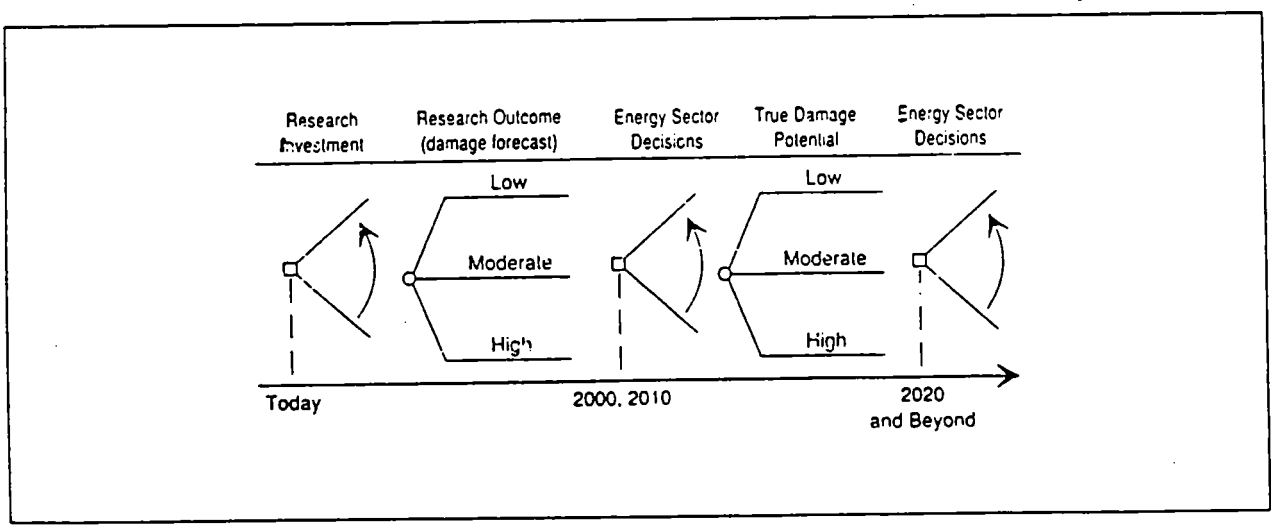

Figure 2.6–3: Decision tree for value of information analysis.
Source: Manne and Richels (1992)

A decision tree reflecting this type of sequential decision making can be adapted from the one in Figure 2.6–1b. Figure 2.6–3 shows this for the energy sector's near-term supply and conservation decisions that must be made with respect to the uncertainty regarding the ultimate damage potential. In this case, the degree of uncertainty is represented by a likelihood table indicating the probability that the damage forecast will be low, moderate, or high—given that the true damage potential is low,

a sequential decision model, a resolution of uncertainty had high value relative to no-regret potentials and technical innovation. Peck and Teisberg (1992) and Manne and Richels (1992) show similar results.

moderate, or high (conditional probabilities; cf. Manne and Richels, 1992).

This representation allows the use of standard probabilistic techniques to incorporate the outcomes of the research program in the decision model (Global 2100, in this case).

Maximum accuracy, or perfect information, would eliminate the need to hedge against surprise. Accuracy of the forecast, however, will not be maximum. We therefore have to accommodate with hedging under imperfect information. In this case, the research outcome will lead to a revision of our beliefs. It will help at modifying near-term decisions.

A sequential decision making strategy made of acting and learning decision making paths would be the best strategy.

2.6.2 Exploring mutual insurance decisions and markets for risk

Insurance is one another way to respond to risks and uncertainty which is worth to explore.[18]

Transferring risk from one agent (country) to another or sharing risk collectively does not make the risk disappear though restrictions can be attached to that kind of transfer. Yet, under what conditions, and why will an agent (country) demand insurance to cover possible climate change damages? Can market evaluate the price of climate change risk? How would the allocation of risk be decided?

Exploring insurance decisions means addressing the problem of determining the economic value of things. In particular, it goes much further than simple knowledge of costs and benefits of climate change; that is, risks. Exploring insurance decisions and, consequently, markets for risks is addressing the possibility of determining the final allocation of these risks. Who bears the economic risk of the possibility of climate changes which is one of the large risks of our modern economies?

In particular, do transfers of risk improve welfare in an economy (or is it instead a 'zero sum game')? It appears from the literature that "the transfer of risk is a potential source of large improvements in economic efficiency and social welfare" (Eeckhoudt and Gollier, 1995).

Insurance markets leave uncovered collective or correlated risks such as the risk induced by

[18] The word 'insurance' is sometimes abused in climate debate. For instance, the insurance premium of, e.g., Manne and Richels (1992) is in fact a risk premium in the Arrow-Pratt sense (the Arrow-Pratt insurance premium describes situations where, because of risk aversion, people are willing to pay more than expected yearly damage), and the insurance scheme of AOSIS is in fact a liability scheme (see below). In addition, one can think that there is no analogue between the impact of climate change and the insurance market because climate change is not an isolated event, and that to control portfolios of insurances requires the risks to be fairly well known. Yet, the insurance industry is currently giving up because of increasing losses that are not indispensably linked to climate change-related natural catastrophes such as a new insurance orchestration must anyhow be envisaged. Simple evidence is given here to decision makers (the approach is purely normative due to the absence, to date, of any applied analysis of climate change insurance scheme). Note that the impacts of extreme events on *property insurance* market and adaptation to climate change by *property insurers* are the concern of IPCC WGII Chap. B9 on "Financial Services" and consequently are out of the scope of this section.

ignorance of the true frequency distribution of harmful events. According to Chichilnisky and Heal (1993), our ignorance of the frequency of the impacts of climate change constitutes a collective risk. This collective risk can be allocated through markets for securities that pay off contingent on that frequency. For the individual risks that remain, it is more practical to use mutual insurance contracts: this is done by having a different individual insurance contract for each possible frequency of impacts.

2.6.2.1 Use of financial markets

According to Chichilnisky and Heal (1993) an interesting aspect of financial markets is that they can provide a natural mechanism for reconciling differences in assessments of the likelihood of important climate changes between countries, and for testing the conviction behind publicly-stated positions. International markets for risks of climate change would also provide an objective test of the seriousness with which countries adhere to their publicly-professed positions on the risk of climate change.

The Arrow-Chichilnisky-Heal idea is then to settle a framework involving securities whose pay-offs depend on which description of the (collective) risk is correct. "Betting on which of several alternative descriptions of the way the world works is correct, is in effect what one does when choosing one research strategy over another. (...) For example, a market for the securities of high-technology firms pursuing different research strategies towards the same goal is a financial market in which these bets are made" (Chichilnisky, 1994).

The trading of climate risk positions from a global ecological-economic viewpoint is amply thinkable. In short, ecological models are energy oriented models whereas economic ones are based on the behaviour of individual agents and groups. Under the case for climate change prospects, the behaviour of the agents contributes to make particular energy profiles to appear and develop, with unknown feedbacks on future economic outcomes (Pillet, 1994).

Under this perspective, one better has to place the focus on the various matching and diverging points that dynamically occur; that is, on what will possibly emerge from such interconnections. This amounts to allowing agents to identify the set of possible descriptions of the risks that humanity faces and to bet on which model of the climate change related risk is correct.

Ecological systems (assets) cannot easily be allocated on the marketplace. Therefore, instead of

either *laissez-faire* or to let suboptimal policies being implemented—which for sure are biased against the ecological-economic long run—, trading climate change risk positions that are contingent on which model of the change is correct would *interlace* systems that basically are highly differentiated ones. In addition, countries would have to express their estimates on global climatic risks through a market commitment and therefore will have to express their true views. If a country sells securities that pay off in the event that climate changes are not serious and buys those paying off if they are serious on terms that do not correspond to its true beliefs, it will suffer a financial loss (Chichilnisky, 1994, Pillet, 1994).

2.6.2.2 Insurability of risks associated to climate change

The insurance issue can also be accorded our attention in contrast with mitigation strategies.

Basically, in view of uncertainties about consequences of carbon emissions, the question is: Is it worth taking costly and disruptive measures to reduce levels of emission far enough to stop the build-up of CO_2 (Chichilnisky, 1994)? Next, should you consistently decide to wait until more is known and better estimates of the consequences are available, would it not be cautious to insure against harmful events even if the chance of their occurring is small and not immediate? Is a trading of risk positions between regions of the world conceivable?

Climate change associated risks are first difficult to quantify (in a classical statistical sense, the probabilities describing them are unknowable). They are then endogenous (once steps have been taken toward reducing climate associated risks), correlated (which demands complex analysis to assess probabilities), and collective (by which the uncertainty about the relative frequency of harmed agents is meant). In principle, however, once frequencies are at least approximately known, actuarial calculations can be set up, and the problem can be conceived as insurable.

For instance, to the extent that carbon emissions lead to uncertainties about climate change and the corresponding damage that such changes cause, it can be said that the uncertainty is induced by the industrial countries (to date), and borne by the world as a whole. The available data also indicates that developing countries are more vulnerable to climate change. Any insurance scheme must take this distribution of causes and risks into account.

The floods of 1993 in the US, in Bangladesch, and in Europe (France, Switzerland) have reminded us of the profound vulnerability of human settlement to climate. There is considerable natural varia-

tion in these phenomena, although climate scientists expect that variation induced by human activity will soon come to except the natural variation.

Box 2.6–2: Natural events and attached insured losses (after Weilenmann, 1994)

Event	Date	Insured Losses (in billion US$)
Hurricane Gilbert	September 1988	0.05
Hurricane Hugo	September 1989	5.8
Winter storms Europe	January/February 1990	10.0
Colorado storms	July 1990	1.0
Hurricane Bob	August 1991	0.62
Hurricane Andrew	August 1992	15.5
Hurricane Iniki	September 1992	1.6
East coast storms US	March 1993	1.6
Midwest floods US	Summer 1993	0.765

Correspondingly, one must bear in mind that before 1989, natural disasters caused by storm events with insured losses greater than one billion dollars were unknown (Weilenmann, 1994). For insurers, the most costly storm event to date has been 1992 hurricane "Andrew" with insured losses of US$15.5 billion (see Box 5.2-II). This kind of *losses* has become more frequent and a potential rise is predicted on the standpoint of the insurance industry (Weilenmann, 1994). However, the causes for that trend are not clear and are not conclusively linked to current "greenhouse activity". They seem to primarily depend upon the increasing concentration of people and insured economic values in areas of high risk although losses in climate related disasters have been increasing since the 60s at a rate 3 times that in earthquakes (Yokohama document, 1994).

2.6.2.3 A market framework to respond to collective risks

Next, what a society believes it to be worth paying to reduce the risk of climate change depends inter alia on two key characteristics of that society: its *degree of risk aversion* and its *discount rate*.

The degree of risk aversion is a measure of how much an individual or group is willing to pay to avoid a risk.[19] The discount rate is an equivalent measure of the value of the future relative to the present (see Chapter 4).

It consequently turns out that different country's positions with respect to measures to restrict

[19] An indication of the degree of risk aversion can be obtained by the following exercise: offer a person the choice between either $0 if a tossed coin comes down heads and $100 if it comes down tails or $50 with certainty. Most people will choose $50 with certainty, even though on average they will get the same by choosing to bet on the tossed coin and they stand some chance of doing better (and some change of doing worse). In fact most people will choose $45 with certainty to a bet on a tossed coin giving $0 for heads and $100 for tails. Suppose that $45 is the smallest amount for which this is true. Then the difference between $45, the reward in the risk less situation, and $50, the average reward in the risky situation, is a measure of the person's risk aversion. *The more risk averse you are, the more you will insure* (Chichilnisky, 1994).

greenhouse gas emissions depend on their discount rates and degrees of risk aversion (even if there were complete agreement about all of the scientific aspects of the global change problem, there could still be disagreement about policy responses). Differences in policy positions could then be attributed to differences in discount rates and degrees of risk aversion rather than, or in addition to, different interpretations of the current scientific evidence.

Yet, different perceptions of the risk involved do not however preclude efficient solutions. Differences in attitudes toward risk could merely lead to the introduction of new markets in which different risk positions are traded, with efficiency gains. Economics is about differences in preferences leading to trade (Chichilnisky, 1994). Betting on climate states could be envisaged, not only because insurance can be provided within a market framework, but basically because there exists an ecological-economic ground for the use of financial instruments in addressing climate change collective risks induced by uncertainty about the overall/regional distribution of adverse effects (Pillet, 1994).

The institutional structure to be developed would use two types of financial instruments in order to deal with the two above-mentioned aspects of the problem. The aim is to obtain an efficient allocation in the face of those risks. One instrument is a *mutual insurance contract* which is tailored to deal with the risks faced on a regional basis by *communities* contingent on the distribution of harmful effects world-wide. The other one is related to *Arrow securities* because we need such securities to deal with collective risks induced by strong uncertainty about the *overall distribution* of adverse effects.

A *mutual insurance contract* is an agreement between parties subject to similar risks that those who are harmed will be compensated by those who are not.[20] In the climate change context, one can think of groups of communities subject to the possible impact of that change, with those unharmed compensating the others. To illustrate, the *Alliance Of Small Island States* (AOSIS) has proposed that an *"International Insurance Pool"* be established to cover climate change impacts. The *Pool* would take the financial burden suffered by affected developing countries and distribute it amongst the industrialised countries. The members of the *Pool* would be divided into two groups. The first group would consist of low-lying coastal countries and small island states that would receive insurance coverage from the fund. The second group would include industrialised countries who would

[20] Examples are agricultural co-operatives of the type recorded in Europe at least since the fifteenth century, and the nineteenth century UK workers' associations and friendly societies. These involved agreements between a group of workers that if one were sick and unable to work, he or she would be compensated by the others.

contribute funds (after IUCC, 1993).

Mutual insurance contracts would mean making transfers, the size of the latter depending on the overall level of prosperity, and the transfer per se being contingent on the overall incidence of negative effects (in the sense of high or low overall incidence of negatives climate change-related events in the population and in ecosystems).

The AOSIS proposal calls for *Pool* contributions to be collected in 2004, ten years after the *Climate Change Convention* enters into force—provided the rate of global mean sea-level rise has by then reached an agreed figure. This ten-year delay has been thought to give the funding countries sufficient time to make their initial investments. If sea-levels have not risen too much by the time the ten-year period expires, a review of conditions would be undertaken.[21]

The *securities* we would need to deal with collective risks induced by uncertainties about the overall distribution of adverse effects would pay out if and only if there were a particular frequency of damage in the world as a whole. This would involve identifying the set of possible descriptions of the risks that humanity as a whole face, which are called here collective risks. Climate-related events such as floods, tropical storms or certain temperature patterns are examples.

Introducing, therefore, securities whose payoffs depend on which description of the risk is correct would allow agents to bet on which model of the risk is correct. A similar financial instrument is already in use to hedge against environmental uncertainties and risks: *CAT Futures* (for *Catastrophe* Futures). This instrument is a security which pays contingent on the frequency of the occurrence of a major weather risk, such as tornadoes in the East Coast of the US, and floods in the Midwest. *CAT Futures* are traded by insurance companies to hedge against their exposure to major climate risks as some sort of reinsurance scheme.

Yet, would insurance companies be able to address global climate change risks? Currently not. A new financial structure has to be set up.

For the insurance industry, which is used to drive fixed, short-term contracts, climate change introduces new circumstances "in ways that mean traditional practice and the old statistical methodologies are no longer adequate". Climate change implies a certain degree of irreducible unpredictability beyond the category of risk-like uncertainties For insurance companies, "past experience is no longer a

[21] Others would say: the island countries would have to contribute some funds to the *Pool*. Note that the AOSIS proposal was presented to the negotiators of the *Climate Convention* but was not included in the final treaty—and that it is closer to a liability scheme than to an insurance contract.

safe guide to the far future" (Ayres and Weaver, 1994). The current trend in the insurance industry with respect to weather events is a clear attempt at modifying the underwriting guidelines by setting restrictions on coverage (exclusions), at setting total exposure limits for a specific high risk zone to avoid the cumulation of risks (for instance the Eastern coast of US, Japan, Australia, low lying coastal areas), or at improving overall risk exposure by selective underwriting.[22]

To conclude, the markets just described can provide a natural mechanism for reconciling differences in assessments of the likelihood of important climate changes between countries, and for testing the conviction behind publicly-stated positions (Chichilnisky, 1994). Accordingly, this could be helpful in advancing negotiations between industrial countries with different perceptions of the risks, such as the US and the EU (also see Pillet, 1994)[23] as well as in correcting the North-South balance between the causes of climate risks (in the North), and the ecological-economic impacts of the risks (which are believed to be more serious in developing countries).

2.6.3 Portfolio Analysis Analogy

Numerous policy measures are available to limit the impacts of climate change. Countries will typically implement several of these policy measures since no one measure is clearly superior. Indeed, the decision-maker's problem is much more complex than the choice of a single action/policy measure to the exclusion of all others. In practice, it is a question of constructing a *portfolio* of actions/policy measures with the goal of best using the opportunities to diversify that are present in the economy.[24]

Although governments will be making climate change decisions for most of the next century, this does not mean that they have unlimited opportunities to adjust the size and mix of their portfolio of climate change policies. The total resources devoted to measures to limit climate change (the size of the portfolio) and the mix of measures implemented (the mix of the portfolio) cannot be changed as often as governments deem appropriate because of lock-in effects as well as other time-, attitude-, and scientific results-related factors. In many cases, instead of making decisions, options will be taken.

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[22] Swiss Insurance Industry, anonymous executive. Pers. com., 1994.

[23] Suppose for example the US believes it most likely that there will be little climate change, and the European Union believes otherwise. Then through the market for securities whose payoffs depend on which description of climate change is correct, the US will naturally sell insurance to the EU. The US would wish to be a seller of securities which pay if climate change is serious, because of its belief that this event will not occur, and a buyer of securities that pay if it is not, because of its belief that this will be the outcome. The EU would be on the opposite sides of these markets. (Chichilnisky, 1994).

[24] This portfolio is not the same as a portfolio of an investor; however, decision makers should envisage the evaluation of the expected return and the risk of that portfolio.

2.6.3.1 *Selecting a portfolio*

In this respect, the key for selecting an optimal portfolio is to understand how the options interact —e.g., better greenhouse information will influence technology development and emission reduction decisions (Manne and Richels, 1993).

In principle, the policy measures/options available to countries to limit climate change and its impacts include:

- technology research aimed at improving the cost-effectiveness of greenhouse gas mitigation technologies such as energy efficiency and non-fossil energy sources;
- joint implementation, technology transfer and other forms of international co-operation to limit climate change;
- phasing out existing policies, such as subsidies to fossil fuels, that reduce welfare and directly of indirectly increase greenhouse gas emissions;
- measures to reduce emissions, or increase sequestration, of greenhouse gases,
- measures to adapt to the consequences of climate change;
- insurance orchestration to hedge against risks revealed by strong/unexpected uncertainties;
- insurance for additional costs incurred due to adaptation.

The specific policy measures available vary from country to country; research capabilities vary, the inefficient existing policies vary, the costs and availability of measures to reduce greenhouse gas emissions vary, the costs and availability of measures to increase sequestration of greenhouse gases vary, the damages due to climatic change and the measures for adapting to these damages vary.

A portfolio manager attempts to get the best return given a level of risk (as derived from a given level of uncertainty of a given type). The appropriate level of risk can be derived from the investor's assets using assumptions about maximising expected value behaviour. The investor can also impose constraints on the portfolio to reflect his or her preferences. Investing some or all of the funds in "environmentally friendly" assets or prohibiting investments in specified industries, regions, or assets for ethical reasons are examples of such restrictions.

Countries likewise will select a portfolio of climate change policies that reflect, at least implicitly, a variety of objectives and constraints. A country may look for the economically optimal portfolio of climate change policies. However, considerations of the impacts of the policy mix on different socio-economic groups, international equity, and intergenerational equity are likely to come into play. These objectives will have different weights and will vary from country to country. The "right" blend of options will include political costs and institutional capacities and is a decision which each

political system must take for itself (countries do not use information; government departments may use information).

2.6.3.2 *No operational model is available*

An operational model to analyse the optimal portfolio of climate change policies for a country is not feasible given the state of our knowledge. But even the sparse information on the expected costs and benefits of some amongst the broad policy options can yield some useful insights.

- Peck and Teisberg (1993), and Manne and Richels (1993) have estimated the value of spending on climate research. It is shown that the expected return is several times the current level of climate research spending. The same analysis could be performed for technology research. To better encounter uncertainty, the main idea is to consider spending on climate research and climate-related technology improvements as an risk premium, and not as subsidies to be randomly allocated. Indeed, the key for selecting an optimal portfolio is to understand how the options interact, e.g., better greenhouse information will influence technology development as well as emission reduction decisions.
- Several researchers compare the costs of unilateral action and international co-operation to address climate change. The analyses consistently show large returns to international co-operation. International co-operation should however contain an instrument by which welfare can be redistributed among nations. If it is not the case, as shown by Pillet et al. (1993), small countries with a comparative advantage in the production of clean commodities and a high emissions reduction marginal cost, might have arguments for doing nothing and thus adopting a free-rider behaviour until a complete international climate agreement is concluded.
- An OECD analysis of the effects of phasing out existing inefficient policies suggested that greenhouse gas emissions would be reduced by over 25% with a net economic benefit. In many cases eliminating existing subsidies is politically very difficult, nevertheless a large net benefit is possible from this policy.
- An emissions reduction supply curve or other analysis of the costs and potential emissions reductions that could be achieved through a wide range of specific measures has been conducted for many countries. Virtually every study shows that some emissions reductions are possible at very low, possibly negative, cost. Many of the measures also yield other environmental benefits such as reductions in acid rain, ground-level ozone precursors, and toxic discharges.
- Adaptation measures that reduce some of the damage due to climate change are available in some countries; building dikes to protect low lying coastal areas from sea level rise for example. Such measures can be implemented where they cost less than the damage that would otherwise occur.
- Climate change insurance contracts and transfers, and trading of risk positions between regions and countries can be referred to face unexpected uncertainties and collective risks.

2.6.3.3 *Three main forms of policy options*

It turns out that three mains forms of policy options dominate current discussions: continued intensive science research to reduce climate and impact uncertainties, development of new supply and conservation technologies to reduce abatement costs, and immediate emissions reductions in order to slow down climate changes. The issue for the "option-taker" is not one of either-or but one of finding the right blend of options. Policy makers must decide how to divide greenhouse spending among competing needs. What portion goes to resolving climate uncertainties? What portion goes to technology development? And what portion goes to immediate abatement of emissions? (Richels, 1994). Using the portfolio analysis analogy, a country must use the available information to decide upon the size of its investment in climate change limitation and on the allocation of that investment across policy measures.

The size of the investment will reflect the country's objectives and its obligations under international agreements (FCCC, 1992). Assume that the country has ratified an international agreement that specifies national greenhouse gas emissions limits. Then the size of its climate change investment reflects the most cost-effective means of achieving the country's agreed emissions limit plus expenditures on research and adaptation measures. In the absence of an international agreement a country may have little alternative but to implement necessary adaptation measures. Since almost every country accounts for only a small fraction of global greenhouse gas emissions, unilateral actions will have only a negligible effect on the pace and extent of climate change. No country, acting alone will be able to appreciably reduce the damage it suffers due to climate change except by implementing adaptation measures. This suggests that all countries have an economic incentive to reduce emissions of greenhouse gas emissions.

At a global level, benefit-cost analyses can help establish an appropriate level of climate change investment. Climate change policy does not involve a one-time choice—or some go/not go type of decision—between distinct, long-term options (do nothing or implement policy "X" for the next century), the types of decisions to which benefit-cost analysis has historically been applied. Since climate change policy can be modified frequently and incrementally, the "option values" of decisions must also be considered (the option value of deferring action on climate change can be interpreted as an insurance premium to cover the cost of damages that may result).

The level of their investment in climate change policy will be influenced by factors beyond the

strictly economic considerations mentioned above. Expected damage to ecosystems, expected sea level rise, potential socio-economic impacts, international equity concerns, intergenerational equity, and economic development strategies based on development of mitigation and adaptation technologies are examples of other considerations that may influence a country's climate change limitation spending.

Incorporating option values into the benefit-cost analyses of the policy measures indicates that some action on climate change is economically justified by every country. No country can be confident that it will not incur damage as a result of climate change. Thus, delaying action to limit climate change is an option that has a cost, at least an insurance premium. Every country has available policy measures that have negative or very low costs after accounting for any associated benefits. Thus every country has some climate change mitigation measures that are economically justified.

Normally, the mix of assets in the portfolio is adjusted so that the risk-return ratio is equal at the margin. As discussed above, only sketchy information is available on the expected costs and benefits of the main policy measures. The variability of the costs and benefits for these broad policy options is not known. Governments can make subjective assessments of the variability of costs and benefits of different policy measures. The risks associated with phasing out existing inefficient programs or implementing energy-efficiency measures are lower that those associated with reforestation to sequester carbon or construction of sea walls. The latter offer only climate change benefits while the former also yield other benefits.

2.6 LINKAGES OF CLIMATE SYSTEM WITH DECISION MAKING FRAMEWORK

In this section, we briefly outline the linakges of decision making framework with climate system illustrated in figure 2.8. Each square is fully discussed by various chapters in this report, so we restrain from elaboration. There are two other working groups on scientific and impact assessments, summary of which have to be reflected also in the decision making. Thus, the framework encompasses outcomes of all the chapters in this report and highlights of the other working groups.

The figure shows that the chain of events start from cumulative emissions of greenhouse gases (square 1 in the figure 2.8). These cumulated emissions may trigger off various possible climate related changes such as change in the temperature, sea level rise, moisture loss, precipitation change and extreme events (square 2). These climate changes would in turn have impacts such as damage to agriculture and fishing, migration of population from the coastal areas, species loss, and scarcity of water and so on, which in turn, will constrain irrigation and hydro power generation (square 3). However, the decision making today has to consider climate changes and impacts that may occur 25, 50, 100 years and beyond and respond to it now by formulating, say, 10 or 20 year strategies that have to be periodically revised. Since we do not know what may be in store, we have to rely on climate change research to say how the situation would look at different time periods. Economic costs of adaptation and irreversible damages for these impacts have to be compared with the abatement costs using various decision tools. Thus research results are fed into collective decision making process, which takes into account issues such as inter-regional and intergenerational equity, ecological and poverty considerations apart from the various country specific factors such as risk tolerance and vulnerabilities (square 4). To assess the impacts and to facilitate the decision makers in designing the specific abatement policies, one can use various decision tools such as decision theory, optimization, simulation, forecasting and more importantly integrative assessment models (square 5).

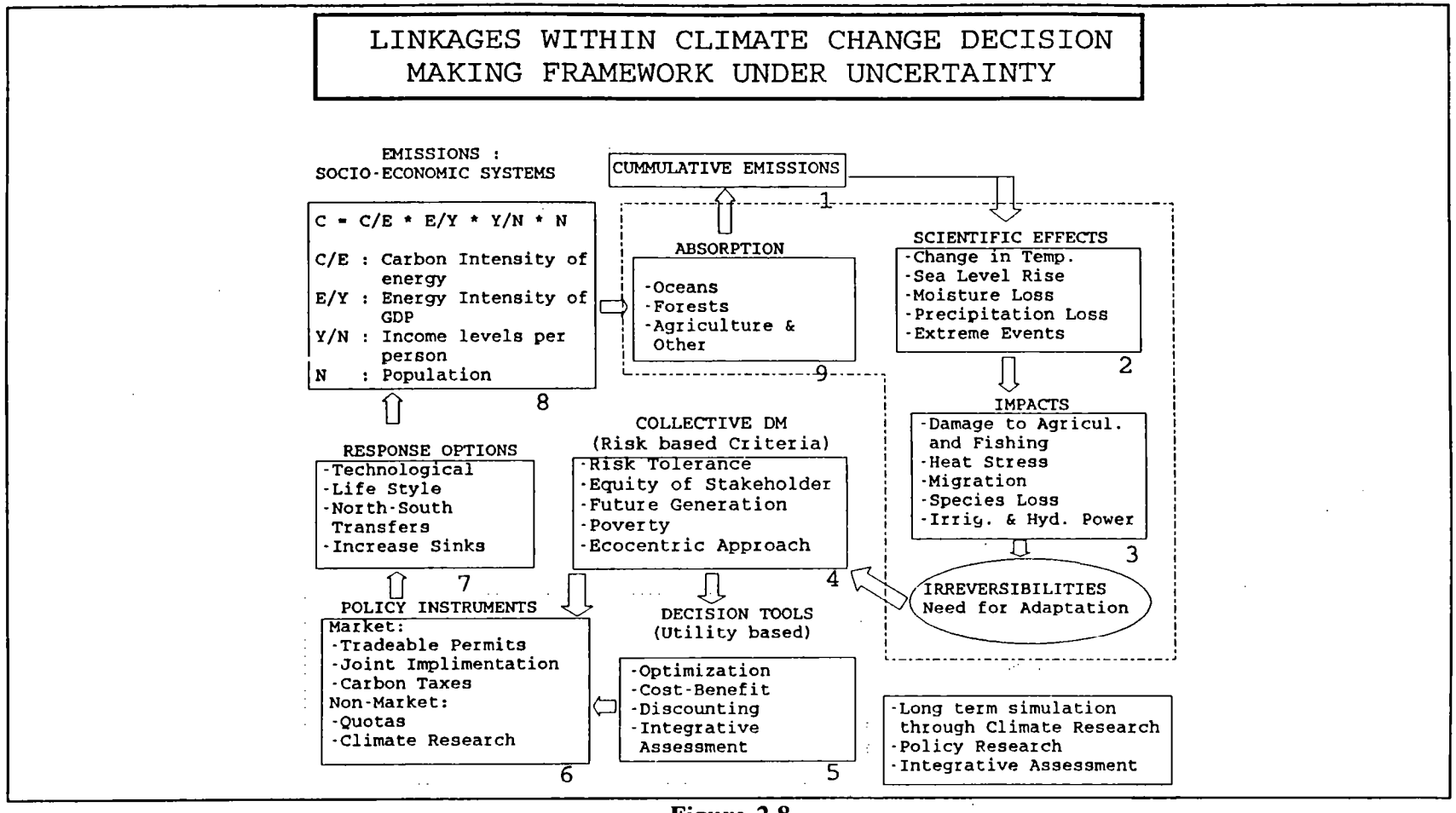
LINKAGES WITHIN CLIMATE CHANGE DECISION MAKING FRAMEWORK UNDER UNCERTAINTY
EMISSIONS : SOCIO-ECONOMIC SYSTEMS
C = C/E * E/Y * Y/N * N
C/E : Carbon Intensity of energy
E/Y : Energy Intensity of GDP
Y/N : Income levels per person
N : Population
8
CUMMULATIVE EMISSIONS
1
ABSORPTION
-Oceans
-Forests
-Agriculture & Other
9
SCIENTIFIC EFFECTS
-Change in Temp.
-Sea Level Rise
-Moisture Loss
-Precipitation Loss
-Extreme Events
2
IMPACTS
-Damage to Agricul. and Fishing
-Heat Stress
-Migration
-Species Loss
-Irrig. & Hyd. Power
3
IRREVERSIBILITIES Need for Adaptation
COLLECTIVE DM (Risk based Criteria)
-Risk Tolerance
-Equity of Stakeholder
-Future Generation
-Poverty
-Ecocentric Approach
4
RESPONSE OPTIONS
-Technological
-Life Style
-North-South Transfers
-Increase Sinks
7
POLICY INSTRUMENTS
Market:
-Tradeable Permits
-Joint Implimentation
-Carbon Taxes
Non-Market:
-Quotas
-Climate Research
6
DECISION TOOLS (Utility based)
-Optimization
-Cost-Benefit
-Discounting
-Integrative Assessment
5
-Long term simulation through Climate Research
-Policy Research
-Integrative Assessment

Figure 2.8

Thus, collective decision making is required to arrive at revised strategies to take into account the new information from climate research, and policy research. This helps to choose the desired concentration levels and emission paths. Allocation of these emission levels among parties requires consideration of current and past emissions, need for development for meeting basic needs and resource endowments and global cost effective criteria. For global cost minimisation, collective decisions are needed to choose among various global policy instruments, such as market based policy instruments, viz., tradeable quotas, carbon taxes, joint implementation, as well as other non-market policies such as setting standards, reduction targets, etc. One can choose a set of instruments or a combination of these instruments to achieve the targets of emission reductions (square 6). This also forms a part of policy research. The choice of a specific policy instrument at national level could be based on a variety of utility based criteria such as cost effectiveness, or cost benefit analysis, which may depend on the discount rate used. The national policy instruments would generate in certain response strategies; these may use ustility based criteria (square 7). The response strategies could be chosen from among portfolio of options such as alternative technologies, changes in consumption patterns and life style, increase in the sinks, etc. These response strategies would again have an effect on the socio-economic emissions (square 8). The emissions of GHG would depend on socio-economic factors such as carbon intensity of energy, intensities of the GDP, per capita GDP and population. Land and forest use patterns also matter, but there may be a decreasing trend of the emissions associated with these. Some of these emissions are absorbed by oceans, forests, agriculture and other related activities (square 9). The fraction of the total emissions which could not be absorbed by the sinks accumulate in the environment over a period of time and leads to cumulation (square 1) completing the cycle. Sequential decision making is required periodically to verify strategies.

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Chapter 5

APPLICABILITY OF TECHNIQUES OF COST-BENEFIT ANALYSIS TO CLIMATE CHANGE

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TABLE OF CONTENTS

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Summary

Cost-benefit analysis has many advocates but also many detractors. Certainly the rather narrowly defined, traditional approaches to CBA, developed originally for project level decision-making with planning horizons typically no more than 20 years, clearly have difficulty in dealing with the very long time frames, and high levels of uncertainty, encountered in the climate change. However, a family of techniques used in decision analysis, that are associated with a more broadly defined CBA approach provides a more promising basis for analyzing climate change issues.

In the introduction we noted that there were four essential questions facing decision-makers regarding climate change: (1) by how much should emissions of GHGs be reduced?; (2) when should emissions be reduced; (3) by what method should emissions be reduced?; and (4) who should reduce emissions?

The first question is answerable by CBA provided costs and benefits could be estimated with adequate accuracy -- the measures whose marginal costs are less than the marginal damage costs should be implemented. Clearly, it matters what perspective is taken: the result will be different if restricted to a consideration of national costs and benefits than if the perspective is global. It is a fundamental result of CBA that the global perspective is the proper one.

The second question is a more complicated one, because it involves judgments about uncertainty. If the marginal damage (benefit) cost were known with certainty, or if future technological advances that might significantly change the marginal cost curve were known with certainty, then the timing of abatement is given by that portfolio of implementation options that maximizes the (deterministic) present value of avoided damage costs (benefits) less abatement costs – a relatively straight forward calculation. But since neither damages nor costs are known with certainty (for example, if fusion technology were to be commercially available at a cost comparable to fossil-fueled technology by 2020 then the optimal timing and structure of abatement actions looks very different than if the date were 2070), extensions of CBA -- such as decision analysis -- are required. As indicated in Section 4 (see e.g. Box 2), recent developments have begun to deal with the question of timing, particularly with respect to the balance between R&D (on both the cost and benefit side) vis-a-vis immediate commitments to emission abatements.

The third question is closely related to the first. As we have seen (for example in Figure 4.2), most attempts to answer question 1 necessarily require consideration of the specific methods that might be used to reduce emissions. A bottom-up, empirical estimation of the marginal cost curve involves analysis of the broad spectrum of possible abatement options, from which marginal cost curves can be derived. Top-down models, typically using national or regional general equilibrium models (recall the results of Figure 4.4), also necessarily require explicit consideration of specific policy or technology options.

CBA cannot itself resolve the fourth question -- which involves equity -- but it does provide a framework for understanding the trade-offs to be made between equity and economic efficiency. CBA, when applied globally, can identify in which countries abatement costs are lowest, since the global perspective identifies all measures whose marginal costs are less than the global marginal benefits (recall Figures 4.5 and 4.6). But how such a program can be implemented in practice involves putting in place appropriate transfer payment mechanisms, the amount and structure of which is a matter of equity.

Nevertheless, despite its many imperfections, CBA (broadly defined) remains the best guide to policy-making for dealing with the essential questions that must be faced in dealing climate change. The CBA approach forces decision makers to compare the consequences of alternative actions, including that of no action, on a quantitative basis. -- and can certainly make a contribution to resolution of the first three of these questions. To the extent that some impacts and measures cannot be valued monetarily (like biodiversity), extensions of the traditional CBA approach, such as multi-criteria analysis, permit

quantitative expression of the trade-offs to be made.

Finally, one should emphasize that the most important benefit of applying CBA is not necessarily the predicted outcome (which is always dependent upon assumptions and the particular technique that is used), but the *process itself*, which forces an approach to decision-making that is based on rigorous and quantitative reasoning.

1. Introduction

In public policy-making, a comparison between the perceived costs and the perceived benefits of an action is routinely made by decision-makers. However, this choice is frequently made on intuitive and qualitative grounds. Cost benefit analysis (CBA) provides an analytical framework that seeks to compare the consequences of alternative policy actions on a quantitative rather than qualitative basis. Indeed, the approach forces quantitative thinking, for its very essence is that costs and benefits must be expressed in a common monetary unit that provides the basis for the tradeoffs. The basic principles are well understood and straight forward: for an action to be justified, the costs of the action should be less than the benefits derived therefrom[1]. If there are several alternatives, then one ought to pick that option whose benefits most exceed the costs.[2]

The objective of this Chapter is to examine how and under what circumstances can CBA make a contribution to the resolution of the central questions now facing decision-makers about global climate change: (1) by *how much* should emissions of greenhouse gases (GHGs) be reduced? (2) *when* should emissions be reduced? (3) *how* should emissions be reduced? and (4) *who* should reduce emissions? CBA can at least theoretically and conceptually answer the first three questions. The fourth question is one of equity, and not amenable to resolution by CBA even in simple, traditional applications not complicated by the complexities of the climate change problem[3].

Section 2 defines more carefully what is meant by CBA: in fact the term has come to encompass a wide variety of specific techniques. We also review the basic concepts. In section 3 we examine the unique features of global warming and climate change as they pertain to decision-making. Section 4 presents a discussion of the application of CBA to the climate change problem in light of these unique features. In section 5 we discuss the key issues: risk uncertainty, irreversibility, valuation, discounting, equity, and multiple criteria.

[1] Indeed, that cost-benefit analysis is appropriate to the analysis of policy options to address global climate change is not universally accepted. A major report recently issued by the US Office of Technology Assessment (OTA, 1993) contains an extensive discussion of how adaptation strategies should be chosen, yet manages to avoid all mention of cost-benefit analysis *per se*. It talks about how one might minimize vulnerability to climate change and about insurance strategies, but avoids the central question of how one might determine the amount of insurance one wishes to buy. Similarly, priorities may be set on non-economic grounds, and CBA could be used in a secondary role (see e.g. Turner, 1991)

[2] Although this needs a little bit of modification in the presence of capital constraints, which may limit selection of the "best" single project.

[3] However, as we shall see later, extensions of CBA *can* help in identifying the *trade-offs* between economic efficiency and equity

2. Cost-benefit analysis

Cost-benefit analysis (CBA) is a generic term that subsumes a wide body of specific techniques. Developed initially as a means to evaluate projects that were limited in scale, geographic extent, and time span, the original techniques have been extended to cover applications of increasing complexity. Traditional project level CBA (see Box 1) is too narrow to be relevant for evaluating climate change issues. However, CBA more widely defined, includes a family of approaches that are useful in this context. For example, cost-effectiveness analysis has been widely used for climate change analysis.

However, in order to evaluate cost effectiveness, it is crucial to clarify how the target is defined, because there are several options in the global climate change context. Most of the recent analyses of the mitigation costs have focused on a target based on future emission levels,[4] such as stabilization of the emission of certain greenhouse gases by a given year. However, it might be more relevant to express the targets in terms of concentrations of atmospheric greenhouse gases at some future time

To change the target for climate policy from emissions to atmospheric concentrations indicates a radically different cost effectiveness strategy. A stabilization of CO_2 emissions at present levels is not sufficient to stabilize the atmospheric concentrations. Richels and Edmonds (1993) have compared the costs of reaching some particular concentration level by year 2100 from alternative strategies. They show that a given concentration level in year 2010 could be achieved at a considerably lower cost path than by stabilizing emissions immediately. The reason is that a more gradual reduction of emissions would avoid the economic shock following a sudden stabilization of emissions, future advanced technologies could be utilized to a larger extent, and sizable abatement costs postponed.

A third possible target, also affecting the cost effectiveness of alternative measures, could refer to the physical consequences of climate change. Apart from the fact that predictions of these consequences are far more difficult to make than forecasts of emissions and atmospheric concentrations of greenhouse gases, the effects of regional differences would have to be included if targets were based on the consequences For instance, whether climate change contributes to sea level rise or to an increase in the frequency of rain storms will be of quite different importance to people in Nepal and Netherlands. In this context, an additional problem arises as to how to assess benefits from abatement of different consequences for different countries

A further refinement of CBA is multi-criteria analysis (MCA), a body of techniques developed to deal with the difficulties of economically valuing certain types of impacts (see Box 1). Indeed, even if one attempted to place economic value on certain impacts -- such as human life -- not everyone agrees that it is *appropriate* Moreover, cost-benefit analysis presupposes that costs and benefits are those perceived by humans -- an endangered species might view the trade-off between threatened habitat and GHG emissions in an entirely different way, and use a different numeraire than money[5].

[4] The degree of emission abatement is reported in such studies in two rather different ways. The first is as a reduction from some baseline -- itself defined as the trajectory of GHG emissions for some postulated business-as-usual scenario. The second is in terms of reductions from some reference year (e.g. "reduce greenhouse emissions to 80% of their 1990 levels, by 2010").

[5] A recent survey of economists and scientists knowledgeable about the climate change problem elicited typical views at the extreme of this spectrum (W. Nordhaus, Expert Opinion on Climatic Change, American Scientist, 82, 45-51, 1994) One respondent argued " the existence value of species is irrelevant-- I don't care about ants except for drugs", while another cautioned that "loss of

Box 1: Techniques of cost-benefit analysis (CBA)

Traditional project level CBA

CBA evolved as a technique to evaluate and compare project alternatives. In the early years of its application, there was little concern with externalities, and the analysis took into account just the direct costs of projects, and the direct benefits. Developed in the industrialized world, market prices provided appropriate guidance on how to evaluate benefits. When the World Bank began to apply the technique to non-market economies, where prices were subject to significant distortions, shadow pricing techniques provided simple corrections. For example, if an oil-importing country kept the domestic price of oil at artificially low levels, CBA requires the use of the border price, not the domestic price, as a basis for valuing oil.

One of the central concepts in CBA is that of discounting, which addresses the fact that costs and benefitsmay not occur at the same point in time. For example, while costly actions to avoid future climate change may need to be taken in the near future, most of the benefits of such actions will occur far in the future. Discounting enables one to take into account the time value of money. In the case of evaluating simple investment alternatives over shorter time horizons (e.g., < 15 years), the use of the opportunity cost of capital as the discount rate to be applied to both costs and benefits, is well established and uncontroversial. However, in the case of complex public policy applications, particularly those whose time horizons are very great, and involving environmental impacts or the depletion of natural resources -- essential characteristics of the global climate change issue -- there is sharp disagreement as to what discount rate is appropriate. This issue is dealt with in Section 5.

Cost effectiveness analysis

As CBA began to be applied to much broader contexts, and particularly to the comparison of alternative *portfolios* of projects and to broad policy choices, the increasing complexity made it desirable to keep the level of benefits constant, and to analyze the problem simply in terms of finding the most effective, or "least-cost" option to meet the desired level of benefits. This has the additional advantage that benefits in some cases do not need to be explicitly valued. For example, in power sector planning, models are applied to identify the capacity expansion plan whose present value of system costs are minimized, given some exogenously specified time path of electricity demand, and some exogenously specified level of reliability. As we shall see below, this is the variant of CBA that has seen the most widespread application to the climate change problem, in which one seeks to identify the least-cost option to achieve given levels of GHG emission reductions, without any explicit attempt to specify what the *benefits* of that level of emission reduction may be.

Multi-criteria analysis

The most basic requirement for the application of CBA is that both costs and benefits can be given economic value. This is typically a two step process: first the costs and benefits must be quantified in terms of the physical measures that apply: and then those physical impacts must be valued in economic terms. Some applications of valuation techniques are likely to be controversial. Putting a value on human health and illness has been a major problem in the practical application of cost-benefit analysis in the past, even in those situations where one can agree upon the levels of increased morbidity and mortality that might be caused by some policy or project. Efforts to place economic value on the loss of biodiversity have been equally difficult. Recognizing this problem has led to the development of so-called multicriteria analysis (MCA) techniques, which are expressly designed to deal with multiple objectives -- of which economic efficiency may be only one of several. MCA is a particularly powerful tool to quantify and display the trade-offs that must be made between conflicting objectives.

Decision analysis

While MCA addresses certain shortcomings of conventional CBA (like valuation problems), it does not necessarily deal more effectively with uncertainty. This complication has led to the development of a further extension of CBA that goes under the general term decision analysis. Here the focus is expressly on how one makes decisions under conditions of uncertainty. These techniques find application in a wide variety of situations, from decision-making in the high risk field of wildcat oil drilling to analysis of financial options. As we shall see below, such techniques provide a rational approach to deal with irreversibility, one of the more important characteristics of the climate change problem.

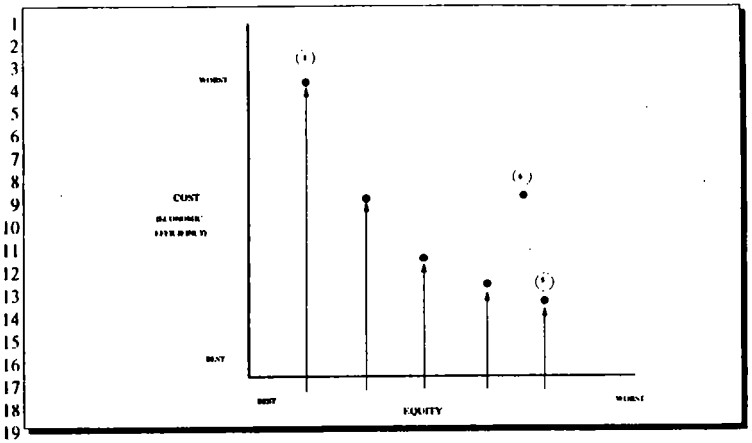

Figure 2.1: Multi-criteria analysis

Such views give further support for MCA-based approaches to decision-making. Similarly, there are concerns that monetized values themselves may be inaccurately estimated, and in any case such values might not reflect welfare. However, the question of who is affected, and how they will perceive the impact, is an issue that needs careful definition in an MCA analysis.

As noted earlier, conventional CBA cannot provide answers about the optimum level of equity in the same way that it provides answers about the optimum level of economic efficiency. But MCA *can* identify the *trade-offs* between equity objectives and economic efficiency, as suggested by Figure 2.1. Thus, the best equity result (indicated by option 1, say an equal per capita sharing of the burden of GHG emission reduction) may have the highest cost; while the worst equity result (indicated by option 5, say based on the present distribution of GHG emissions), may have the lowest economic cost[6]. Nevertheless, even MCA requires a quantification or at least an ordinal ranking of the non economic efficiency criteria, as suggested in the figure. However, even such a non-cardinal ranking may prove problematic when a global issue like climate change requires comparisons across countries and cultures.[7]

More generally, it is increasingly accepted that the pursuit of sustainable development will require recognition of goals related to economic efficiency, social equity, and environmental protection (Munasinghe, 1993). Economic valuation of the impacts of climate change on certain social and environmental aspects (e.g. biodiversity or cultural assets) will be difficult, and MCA related approaches will be needed to make the trade-offs among otherwise non-compensable costs and benefits.

genetic potential might lower the income of the tropical regions substantially". In Section 5 we address the different types of value -- use, option, existence -- in more detail.

[6] But see below for a discussion of the difficulties of making cross-country comparisons of costs.

[7] There may also be some outcomes that are inefficient, i.e. those that lie inside the frontier of efficient points shown on Figure 2.1. Such an inefficient point is represented by option 6. This is discussed further in the presentation of multi-criteria analysis, below.

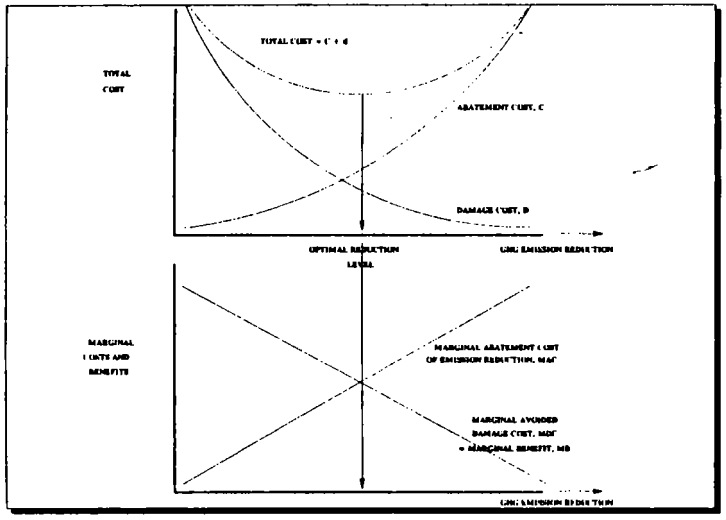

Figure 2.2: Total and marginal costs and emissions reductions.

Basic concepts

An economically efficient policy for emissions reduction is one that maximizes the net benefits, i.e. maximizes the benefits of reduced climate change less the associated costs of emissions reductions[8]. Economic theory provides that emission reduction efforts should be pursued up to the level where the marginal environmental benefits of an additional unit of reduced warming is equal to the marginal cost of emissions reduction. Figure 2.2 illustrates the concepts of total and marginal costs in simplified form -- the marginal costs at any level of emission reduction is equal to the slope of the total cost curve at the same level.

The shape of the total cost and benefit curves reflects the idea of diminishing returns. Each additional unit of emissions reduction will have a higher unit cost: the first 10% reduction can be done cheaply, but the next 10% will cost considerably more, and so on.[9] Thus the

[8] It should be noted that the algebra of cost-benefit analysis can be expressed in many different ways: the cost-benefit ratio, net present value, or the internal rate of return are all different ways of doing the arithmetic. However, particularly in situations involving portfolios of potential actions, and where shortages of capital may constrain the choice, great care must be paid to rigorous application of principles, else different methods can yield different decisions. Maximizing net present value subject to applicable resource constraints is the most useful approach for climate change analysis.

[9] Perhaps the simplest and most intuitive example as to why the marginal cost of emissions reduction increases with increasing levels of reduction is the removal of pollutants from wastewater. The first 60% can be easily removed by a settling basin, that require just a structure. large particles simply settle by gravity. The next 30%, to reach, say 90% removal, requires biological treatment this requires not just a physical structure, but pumps to aerate the water to promote aerobic bacteria. The

abatement cost curve is upward sloping (with increasing slope) as shown on Figure 2.2A. Similarly, the marginal benefit (or avoided cost of GHG damages) falls as emission levels are reduced. The consequences of the foregoing is that the total cost (TC) has a minimum at the point where the slope of the abatement cost curve equals the negative slope of the damage cost curve (or avoided costs).[10]

The foregoing analysis ignores many complications. For example, the emission of a unit of CO_2 may give rise to a varying stream of environmental costs which must be discounted to yield a present value aggregate. The environmental damage function may be discontinuous and non-convex. Abatement costs may change over time, depending on when the technologies are applied -- because of technological progress. Similarly, abatement costs may exhibit economies of scale (e.g. mass production of solar photovoltaic cells), resulting in a marginal cost curve that actually declines beyond a certain point. Finally, the abatement costs are net costs, to the extent that certain technologies (e.g. renewables) may produce other (non-climate related) benefits and costs -- the so-called joint products complication (discussed below).

3. Unique features of climate change

There are several important characteristics that define the conventional context in which CBA is applied. First is that costs and benefits arise within a time span typically no more than 15-25 years, corresponding roughly to the physical life of most projects over which benefits are derived. Second is that the elements of uncertainty are relatively tractable, and can often be characterized by probability distributions.

Most of these characteristics are very different in the context of climate change. The relevant time spans extend to a century or more. The uncertainties are extremely large, and few elements of uncertainty are amenable to characterization as probability distributions. Moreover,

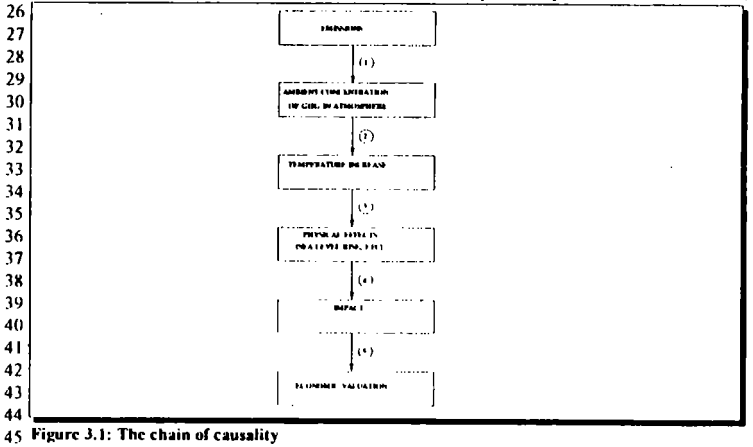

Figure 3.1: The chain of causality

next 5-6% requires chemical treatment, with high operating costs of chemical agents. 100% removal, theoretically possible, would require complete distillation, which is extremely expensive.

the cascaded uncertainty implied in each link of the chain of causality greatly amplifies the total uncertainty in the final outcome, namely the extent of damage caused by climate change.

Figure 3.1 shows the chain of causality. It begins with emissions of greenhouse gases. While the most important of these is CO_2, it should be noted that there are many other gases that contribute to the climate change phenomenon, including methane, and CFCs. While estimates of CO_2 emissions from fossil fuel combustion are fairly straight forward, emissions from other sources are subject to much higher uncertainty. Moreover, the separation of anthropogenic and natural causes of climate change is much more difficult than in the case of other important regional/global pollution issues (such as CFC's or nuclear wastes). Indeed, the calculus of CBA may be significantly affected by natural events such as major volcanic eruptions.

The first link (1) is between emissions and the resultant ambient concentration of CO_2 in the atmosphere. Unlike other pollutants that are subject to complex chemical transformations in the atmosphere,[11] the calculation of the ambient concentration increase that follows from a given increment of emissions of CO_2 is relatively simple. However, because of the role of natural sources and sinks (particularly the ocean), even this calculation is subject to a considerable degree of complexity and uncertainty.[12]

The next link (2), between atmospheric concentration and temperature, is subject to much greater scientific uncertainty. The greenhouse effect itself, i.e. the trapping of incoming solar radiation, is subject to all kinds of additional factors that are highly complex . For example, if temperatures rise, and cloud cover increases, feedback effects involving increased reflection of incoming radiation will complicate the calculation of equilibrium temperatures.

The next link (#3) involves many different components, all of which are to some degree difficult to calculate. For example, calculating the rise in sea level associated with increases in mean sea temperature proves to be far from simple in some cases (as noted in IPCC WGI in the case of the West Antarctic ice sheet). Even more complicated are estimates of how precipitation patterns might change, especially the spatial and temporal distribution of rainfall. Perhaps of even greater concern in the developing countries will be the changes in the patterns of extreme weather events, to which they are particularly vulnerable.

If these physical effects are understood in general terms, quantifying the impacts on the flora and fauna is much more difficult (link #4). Suppose it were possible to predict the change in precipitation and temperature regime for some given region. What can be said about the shifts in vegetation patterns? While general poleward shifts of vegetation and agricultural production zones can be predicted in general terms, quantifying the effect is quite difficult. What is the impact on biodiversity? On wetlands? On the water table? Clearly these are very difficult assessments to make.

[10] Although we show the marginal cost and benefits as linear in emissions reduction in Figure 2, this need not be so. For example, where abatement costs are subject to economies of scale, there might be sections of the MC curve that have a form other than that shown on Figure 2.2. But as noted elsewhere (e.g. Figure 4.1 for the U.K.), empirical studies of the marginal cost curves frequently do exhibit the stylized shapes shown on Figure 2.

[11] The acidity of precipitation is influenced by complex interactions between sulfur oxides, related oxidation products, and NO_x.

[12] For example, the presence of CFCs could affect climate change not only directly through its greenhouse warming potential, but also indirectly by its impact on biota like nanoplankton -- which in turn influence oceanic CO_2 uptake. Similarly, the degree of reliance on fossil fuels would affect CO_2 directly, and CO_2 absorption indirectly -- via the effects of acid rain on forests and biomass.

Finally, in order to estimate the damage costs, one needs to be able to value these effects (link #5). Some valuation tasks will be relatively straight forward: for example, the cost of engineering structures to protect against sea level rise are relatively easy to establish, given the existing experience in this field (in such countries as the Netherlands) Other calculations will be more complex, but at least tractable: as for example, the calculation of increased cooling and decreased heating costs on the energy system , or the impact of increased irrigation pumping requirements associated with drier climates in some regions upon electricity demand But a very large number of potentially important impacts are very difficult to value such as the impacts on forests, wetlands, and biodiversity

Special features

Beyond the degree of uncertainty, what makes the analysis of the climate change problem so different to other environmental analysis problems? The main reasons can be summarized as follows:

GHGs are stock, not flow pollutants:

Many pollution phenomena are relatively short-lived, such that the damages are closely related to the current rate of emissions. This is because the rate at which most pollutants are removed from the atmosphere is relatively rapid (say in the case of particulates by dry or wet deposition). Reducing emissions at major sources will likely have a relatively immediate impact. In the case of GHGs, however, the damages occur as a result of the total atmospheric concentrations at any one time, in other words, are related to the stock of the pollutant, not to the current rate of emissions.[13]

Therefore, in the context of the climate problem, the global climate is a lagged function of the various greenhouse gases. At any point of time, these atmospheric concentrations (which are stock concepts) depend on the whole time path of emission of the greenhouse gases up till the point of time under consideration. Similarly, an increase in current emissions of a greenhouse gas at any point of time will affect the atmospheric concentrations of this gas, and thus the climate, in all future periods.

To calculate the marginal environmental cost of increased current emissions of a greenhouse gas, one must first calculate the physical impact of such an emission increase on the future development of the atmospheric concentration of the gas. This will depend on physical characteristic of the gas, which affect how rapidly an increased atmospheric concentration depreciates. There are large differences between different greenhouse gases, with atmospheric lifetimes varying from some 15 years for methane[14] to more than 100 years for CO_2, N_2O and some CFCs

Once the impact of current emissions of a greenhouse gas on future atmospheric concentrations has been calculated, one can in principle calculate the effect of the increase in current emissions on the future climate development. If one has specified a function which measures the monetary cost of climate change, one may thus calculate the incremental costs, and thus obtain a present value measure of the marginal cost of increased current emissions of a greenhouse gas.

[13] There are of course some exceptions, notably for radioactive wastes, which also have an extremely long life; thus the total environmental risk, and the scale of the disposal problem at any one time, is not so much dependent on current rates of production of nuclear wastes, as on the total stock

[14] The IPCC Sepcial report, 1994, estimates the lifetime of methane at 14.5±2.5 years

It is clear from the description above that the marginal monetary cost of greenhouse gas emissions is a complex concept. Several assumptions of an economic nature must be made, such as the appropriate discount rate and the monetary costs of climate change for the whole future. In particular, the relative importance of different greenhouse gases is much more complex than some simple physical conversion into a common index. In the context of the climate problem, a reasonable definition of the importance of a greenhouse gas relative to, say, CO_2, is the marginal environmental cost of current emissions of this gas relative to the corresponding marginal cost of CO_2. It follows from the discussion above that the relative importance of GHGs depends on a number of economic assumptions which must be made.[15]

Inertia and irreversibility:

Since the emissions of GHGs in any one year represent a relatively small fraction of the total global stock, the system has great inertia. This means that even if all emissions went to zero, it would be decades, if not centuries, before the stock of GHGs become reduced significantly. Therefore, in effect, decisions about emissions reduction become effectively irreversible, at least over the 100-200 year timespan of interest. In other words, failure to reduce emissions in the short to medium term may be irreversible in the sense that once the effects of climate change become apparent, it will then be too late to do anything about it.

Global characteristics:

Most environmental pollution problems are local or regional in scale.[16] The benefits of emissions reductions generally accrue to the same geographic areas as would otherwise bear the costs. The damage associated with GHGs, however, are dependent upon the total global GHG concentration, largely independent of the regional meteorological patterns that usually define the geographic scope of other trans-national environmental problems such as acid rain. Therefore the distribution of benefits of emissions reduction is global, not local. Per contra, even a country that emits no GHGs would incur the damages of emissions by other countries

Geographical distribution of impacts.

Poorer nations are likely to be the most vulnerable to the impacts of climate change, since they lack the resources to protect themselves against sea level rise, extreme weather events, or desertification. For example, the impacts of acid rain tend to be concentrated in richer countries, from emissions in poorer countries or regions (Japan from China[17], Richer West Germany from E. Europe).[18] These richer areas therefore have powerful incentives to promote

[15] See e.g. Hoel and Isaksen(1993,1994) for a further discussion and numerical calculations.

[16] There are exceptions here as well, most notably the phenomenon of acid rain, which is largely a long-range phenomenon often involving emissions in one country, and acid rain damage in another. However, to the extent that lake acidification completely destroys aquatic ecosystems, one could argue that at least some of the impacts are irreversible, although even here the impacts are generally of a fairly local nature. Long time periods may also elapse between the onset of acid rainfall, and to actual visible damage.

[17] For new data on emissions and acid deposition rates in Asia, see *Interim Report, International Collaborative Project on Acid Rain and Emissions Reduction in Asia*, World Bank, Asia Technical Department, September 1993.

[18] To be sure, there are exceptions: for example, to some extent, even the richer countries of Europe among themselves are affected by mutual pollution problems (e.g.acid rain in Scandinavia from the U.K, or the severe water pollution problems in the Rhine Basin involving Switzerland, Germany France and Holland, or the dumping of wastes in the North Sea). However, in most of these cases of international pollution issues involving richer countries, much better institutional mechanisms

emissions reductions programs in the source areas, including the provision of financial assistance.[19] By contrast, in the case of GHG emissions reductions, countries such as the U.S. (where there is the *perception* that the *direct* impacts of climate change on the U.S itself are relatively small), may have less obvious economic motivation to reduce emissions.[20] Considerations of humanitarian solidarity and equity alone will unlikely be sufficient.

Absence of actual impact data:

Unlike almost all other environmental externalities, in the case of climate change it might be argued that there are few directly relevant actual data, and that predictions of physical impacts are based entirely upon the predictions, judgments, and models of scientists.[21] Only once (or if) climate change does in fact occur, will the impacts be known. The evidence of cause-and-effect will be difficult to substantiate, because of the likelihood that, at least initially, changes will be incremental. It should be noted, however, that there does exist a significant body of verifiable scientific theory that underlies the estimates and models of scientists

Non-linearity.

Global climate change is determined by complicated interactions involving a chain of non-linear linkages (i.e. GHG emissions - atmospheric concentration - temperature change - physical impact). Therefore, climate change phenomena and risks are likely to be much more non-linear than the relationship between conventional emissions and more local pollution.

Very long time frame

The very long time frames involved in climate change make some of the normally exogenous variables endogenous. For example, the economic impact of sea-level rise is dependent upon the size of the population living in low-lying coastal areas, which may decrease once a sea level rise becomes evident. The costs of such adaptation mechanisms may be especially difficult to estimate.

4. Cost-Benefit Analysis in the context of climate change

In light of these unique characteristics of the climate change problem, what can we say about the suitability of CBA? How and under what circumstances can CBA make a contribution to the central questions now facing decision-makers: (1) by *how much* should emissions be reduced? (2) *when* should emissions be reduced? and (3) *how* should emissions be reduced?

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exist for addressing their problems (e.g. the EU in Europe) than are available for resolving environmental disputes between rich and poor.

[19] For a discussion of the relationship between economic assistance for restructuring in Eastern Europe and assistance to guarantee desired environmental standards, see e.g. M. Amman *et al.*, Economic Restructuring in Eastern Europe and Acid Rain Abatement Strategies, Energy Policy, p.1187-1198, Dec. 1992.

[20] However, the indirect impacts, for example large scale immigration from Mexico that might follow from agricultural devastation in that country, may ultimately prove to be much more serious for the U.S. than the direct consequences of sea level rise or higher energy bills for air conditioning but such impacts are also very difficult to quantify, and many regard them as speculative. Proper CBA analysis, to be sure, would correct for such distorted perspectives.

[21] In some cases laboratory experiments -- such as growing plants in CO_2-enriched atmospheres -- do of course provide some actual data for predictions

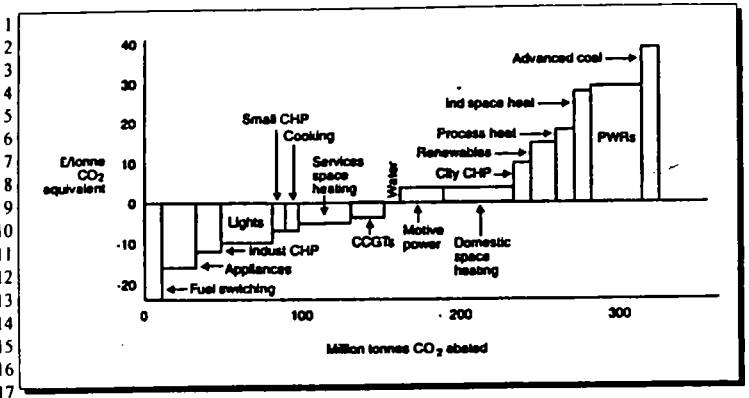


Figure 4.1: The marginal cost curve for the U.K.

The fundamental problem in applying CBA to the climate change problem follows directly from the chain of causality discussed above: while estimating the costs of emissions reduction involves the beginning of the chain, estimating the benefits (or the avoided damage costs) involves the very end of the chain. Since there is some level of uncertainty associated with each of the links, estimates at the last stage of the chain are subject to compound uncertainties which may be very large indeed.

Estimates of the marginal cost curve

Marginal abatement cost (MAC) curves got GHG emission reductions have been derived for many industrialized countries, but for only few developing countries.[22] On Figure 4.1 we show the cost for the U.K., as estimated by Jackson (1991). The curve is derived by a rank ordering of the individual measures considered by cost per ton of CO_2 saved (the height of each block), with the width of each block representing the tons of CO_2 so saved. The shape of the MAC curve, when smoothed, is indeed of the type indicated on Figure 2.2, a result confirmed by many other examples [23] Generally, these studies rely on known or near-term technical options, and ignore effects due to joint products, economies of scale, and capacity building, that might reduce the upward slope of the cost curve. A more detailed disucssion of estimates of the MAC curves is contained in Chapters 8 and 9.

What is interesting in these (and other studies[24]) is the significance of "below the line" options (i.e. MAC is negative but still upward sloping) These are measures that appear to

[22] A recent UNEP review on GHG abatement costing studies concluded "..the state of abatement costing studies in developing countries is wholly inadequate even to draw preliminary conclusions concerning possible costs and the impact of different abatement options. It is a body of analysis which is only just beginning, and which may take many years to mature towards consensus even on very rough estimates and understanding of the key issues (UNEP, *op.cit.*, p. 66).

[23] See e.g. the review of eleven studies by London Economics (1992)

[24] See e.g. J. Moreira *et al.*, 1992 for Brazil; S. Sitnicki *et al.*, Opportunities for Carbon Emissions Control in Poland, Energy Policy, 19,10, p.995-1002, 1992; or P. Meier, M. Munasinghe and T Siyambalapitia, *Energy Sector Policy and the Environment*, World Bank Environment

have negative costs associated with them -- in other words, when these options are implemented, both costs and emissions go down, relative to the reference case.[25] Compact fluorescent lighting, other energy efficient devices, and demand side management measures typically fall into this category, and in developing countries, measures such as reducing T&D losses, or instituting vehicle maintenance programs, also appear here. These, then, are measures that should be implemented in a least cost energy development strategy, even in the absence of any desire to reduce GHG emissions. The fact that they are not implemented reflects either market failures, the influence of powerful vested interests, or other factors, such as high transaction cost (which might exceed the potential benefits)[26]. Indeed, in developing countries, there may be more such "below the line" options because education and information about the availability and benefits of options in this segment of the MC curve is worse than in developed countries.

This issue highlights a practical problem for the Global Environment Facility (GEF). The GEF has been set up as the funding mechanism, on an interim basis, to provide financial resources needed by developing countries to meet the "full incremental costs incurred" in complying with their obligations under the Convention on Global Climate Change.[27] If the GEF is to fund the "incremental costs" of GHG reduction measures, this presupposes that a baseline can be unambiguously defined, against which such incremental costs are to be measured.[28] But

Department, 1993, (for Sri Lanka).

[25] Unfortunately there is some confusion in terminology here. Some (e.g. London Economics, *Economic Costs of Carbon Dioxide Reduction Strategies*. Global Environment Facility Working Paper Series 3, Washington, DC, 1992), use the term "no regrets" to describe policies for which MB > MAC, i.e. for which the marginal benefits exceed the marginal costs. Others use the term only where MAC< 0, i.e. to those options that are "below the line" in the empirical cost curves of the type shown on Figure 4.2 However, since on both the cost and the benefit side there will be some netting out (e.g., to account for joint costs and benefits), the criterion MAC<0 is arbitrary, whereas MAC<MB is well defined

[26] The fact that such "no-regrets options" are in fact observed is much debated. What may be calculated as monetary benefits need not necessarily be regarded as benefits to decision-makers -- there may be other, non-monetary costs involved. The huge subsidies given to European agriculture illustrate the point that more than monetary benefits might be involved. In the case of developing countries, the unavailability of finance may constrain the ability to implement some of these options. For example, until recently, obtaining finance through export credits for power generation expansion has been much easier than financing energy efficiency measures

[27] These methodological problems have been recognized by GEF, who has initiated a research program to find an operational approach for measuring and agreeing upon full incremental costs within the context of the Climate Change Convention: the so-called PRINCE study (Program for Measuring Incremental Costs for the Environment). See K King, *Issues to be Addressed by the Program for Measuring Incremental Costs for the Environment*, Global Environment Facility, Working Paper 8, Washington, DC 1993.

[28] Moreover, another problem here is that the concept of "least cost" as well as the integrated planning process to achieve it, may be quite complex (see e.g. M. Munasinghe, Energy Analysis and Policy, Butterworths Press, London, UK, 1990; P. Meier, Power Sector Innovation in Developing Countries: Implementing Investment Planning under Capital and Environmental Constraints, Annual Review of Energy, 15, pp.277-306, 1990, or E. Crousillat, *Incorporating Risk and Uncertainty in Power Sector Planning*, Industry and Energy Department Working Paper, Energy Series Paper 17, World Bank, Washington, DC, 1989). Such a solution, typically obtained by fairly sophisticated optimization models, may be "least cost" only for a very narrow band of input assumptions; and if these assumptions prove to be different, then an investment program predicated upon the "least cost" plan may ultimately be distinctly non-optimal.

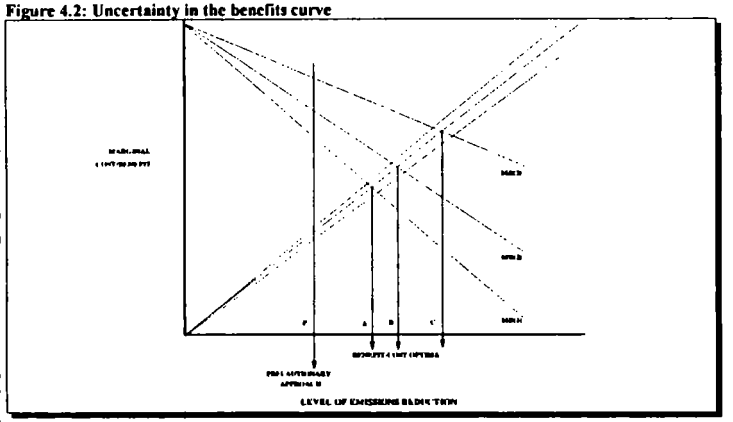
under such a definition, should demand side management programs which have negative incremental costs-- such as energy efficient lighting -- be funded by GEF?[29]

The marginal benefits curve

It follows from the discussion of the previous section that the level of uncertainty in benefits is much greater than the level of uncertainty in the cost curve. The practical implication of this, depicted in Figure 4.2, is that the optimum point of emissions reduction is also subject to significant uncertainty (indicated by points A, B, and C): whether the marginal benefits curve is MB1, or MB2 or MB3 has a much greater impact on the location of the optimum point of emissions reduction than the much smaller uncertainties in the marginal cost curve. Therefore, with such wide uncertainty about the economic optimum, CBA may not be very helpful. On the other hand, a "precautionary" level of emissions reduction, at P, has a very high probability of at least meeting the criterion that MB>MC.

In fact, there exist few if any estimates of the benefits curve, and most of the estimates that do exist are not much more than single point estimates for some presumed level of GHGs in the atmosphere. Table 4.1 shows some estimates of the GDP impacts of climate change (whose avoidance represents the benefits of abatement. A complete discussion of benefits estimates is provided in Chapter 6.

Figure 4.2: Uncertainty in the benefits curve



[29] In the words of King, *op.cit.*, "...How can the adoption of apparent win-win solutions be stimulated? Such solutions are sometimes referred to as negative incremental cost projects because they are economically viable in their own right. The dilemma arises because these projects are often not being funded. On the one hand, if the GEF restricts itself to those projects that have positive incremental cost while the bulk of negative incremental cost options remains unfunded, it risks becoming irrelevant to the main solution to the global environmental problem. On the other hand, providing grant finance for economically viable projects effectively makes a net transfer to the country, which is not the purpose of new and additional funding; worse, it provides a perverse incentive to potential recipient countries to delay economic reform. (p.17)"

Table 4.1: Estimates of the impact of climate change [billions of 1988 dollars]

	U. S.				Global	
	Nordhaus	Cline	Fankhauser	Other	Fankhauser	Other
Heavily affected sectors						
agriculture	1	15.2	7.4	1.2	39.1	12.3
coastal areas	10.7	2.5	2.3			
energy	0.5	9				
other sectors						
wetlands and species loss		7.1	14.8			
health and amenities		8.4	30.3			
other	38.1	11.2	12.1			
total	50.3	53.4	66.9			
total as % of output (GDP)	1	1.1	1.3		1.5	2.8(a)

Blanks denote not available (a)from Nordhaus's survey of experts Sources: Nordhaus(1991), Cline(1992), Fankhauser (1992), for agriculture under "other" Reilly and Hohnmann, 1993.
Source. Nordhaus (1994), p.369.

A number of estimates for the industrialized countries (especially the well-known work of Nordhaus for the U.S.) suggest that the economic impact of climate change on the industrialized countries is quite small. However, Nordhaus, as well as others, are quick to concede that such results may not apply to developing countries, where typically much larger shares of national income are in agriculture, and much of it in subsistence farming in marginal areas where even small changes in climate may have devastating effects, and where the ability of the farming population to adapt may be very small indeed.[30] The types of human settlement most vulnerable to climate change are concentrated in developing countries, including low-income communities, residents of coastal lowlands and tropical islands (such as coastal Bangladesh, or the Maldives), populations in areas already significantly affected by desertification, and the urban poor in squatter settlements[31].

[30] This is likely to be true even though higher CO_2 concentration itself may promote plant growth.

[31] For further discussion, see e.g. J. T. Houghton *et al* (Eds) *Climate change--The IPCC Scientific Assessment.*, World Meteorological Organization and the United Nations Environment Program, Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 1990; or L. B. Lave and K. Vickland, Adjusting to Greenhouse effects: the Demise of Traditional Cultures and the Cost to the USA, Risk Analysis, 9, 283-291, 1989. However, as also noted by Nordhaus (1994), the fertilizing effect of atmospheric CO_2 is a particularly strong mitigating factor for Agricultural nations, particularly where water is a limiting factor while the extent and quantitative importance of CO_2 as a fertilization agent are controversial, the balance of the evidence is positive (Nordhaus, 1994, p 369)

Unfortunately, to date, most of the discussions of impacts of climate change on the developing countries have been qualitative in nature,[32] and there is an urgent need for more quantitative estimates for developing countries. According to a recent GEF survey of country studies[33], there are now almost as many studies underway on effects as on mitigation , but it is difficult to ascertain how many of these studies, most of them now underway, will result in the sort of quantitative information necessary to construct an impact cost curve. Certainly none of the studies and papers published to date for developing countries contain quantitative estimates of the type derived by Nordhaus for the US.[34]

Measuring costs and benefits

Most of the work on the benefit (avoided cost) side, and much of the work on the cost side, assumes that the relevant measure by which to evaluate options is loss of GDP. This raises a separate set of questions about the extent to which GDP, (or loss of GDP growth) is the appropriate measure.[35] It is well established (Weitzman, 1976, Brekke, 1994) that GDP is not a welfare measure per se, but rather a convenient way to aggregate goods and services which clearly contribute to welfare. Nevertheless, Figure 4.3 summarizes some of the estimates that have been made for GDP impacts; Chapter 9 discusses such estimates in more detail.

Thus it is well recognized that GDP is an imperfect proxy for social welfare. One recent Norwegian study (Alfsen, Brendemoen and Glomsrod, 1992) showed significant differences in cost-effectiveness of different policy options for GHG emissions reduction policy when consumer surplus effects were also included in the analysis[36] These effects have found to be significant in developing countries as well, as shown by Meier *et al.*(1993) in the case of Sri Lanka (see Table 4 2)

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[32] see e.g. the discussions of P. Glieck, Climate Change and International Policies: Problems Facing Developing Countries. Ambio, 18, 6, p 333-339, 1989, or R. K. Pachauri, *Global Warming: Impacts and Implications for South Asia*, Tata Energy Research Institute, New Delhi., 1991).

[33] J. Fuglestvedt *et al.*, *A Review of Country Case Studies on Climate Change*, Global Environment Facility, Working Paper 7, Washington, DC, 1994. This report identifies 39 studies (or elements of studies) focused on inventories of GHGs, 48 studies of effects, and 46 studies on mitigation.

[34] For example, in a report prepared by the Tata Energy Research Institute for the India Ministry of Environment and Forests, the Chapter on Adaptive Strategies for India in the Perspective of Climate Change, which elaborated the impacts associated with given levels of sea level rise and mean temperature, was entirely qualitative in nature, and no cost estimates were attempted. (TERI, *Report on Global Warming and Associated Impacts*, Report to the Ministry of Environments and Forests, January 1991). Similarly, neither Volume on Climate Change published by the Asian Energy Institute (Pachauri and Behl, (Eds), 1991), nor the country studies conducted by UNEP (Reported in UNEP, 1992) contain any county specific estimate of costs associated with specific levels of GHG accumulation in the atmosphere. ADB is currently sponsoring a multi-country project in Asia that is attempting to establish costs of potential effects.

[35] There are several related issues. For example, should one use nominal exchange rates, trade-weighted rates, or purchasing power parity rates in making cross-country comparisons of costs or impacts?

[36] Consumer surplus impacts have been vigorously debated in the United States in terms of how to evaluate the costs and benefits of demand side management (DSM) programs. For example, Hobbs(1991) shows that some programs may have positive benefits under a simple "least cost" criterion from the utility perspective (avoided supply costs exceed program costs to the utility), but have negative benefits when changes in consumer surplus are taken into account

Table 4.2: Impact of welfare losses of GHG abatement options in Sri Lanka
(in $/ton of avoided carbon)

	no coal	wind	CFL
supply cost impact	16	67	-472
consumer impact	10	66	-66
total	26	131	-538

source: Meier , Munasinghe, and Siyambalapitiya, *op. cit.*, 1993.
notes: negative numbers indicate a *benefit*
CFL= compact fluorescent lighting

Of course, the magnitude of such impacts is a function of how much of the technology is adopted, how soon, and what discount rate is used. The effect of a single 25Mw wind plant will obviously be much less than if a 300 Mw wind farm displaces an imported coal plant in the near-term. Generally, what these results do underscore is the need for great caution when interpreting the so-called costs of GHG-emission reductions attributable to specific technologies.

Equally important are the concerns over the extent to which conventional measurements of GDP growth take into account the depletion of natural resources ("Green Accounting"). For many developing countries this is a particularly important issue, and there is a growing literature suggesting that conventional accounting substantially overstates GDP growth: the corollary is that estimates of GDP impacts of climate change that *fail* to take into account changes in the rate at which natural resources are depleted, or in environmental impacts, may be understating the true effect.[37]

Some of these problems are evident from the numerical estimates. On Figure 4.3 we display the results of recent studies of the impact of emissions reduction strategies on loss of

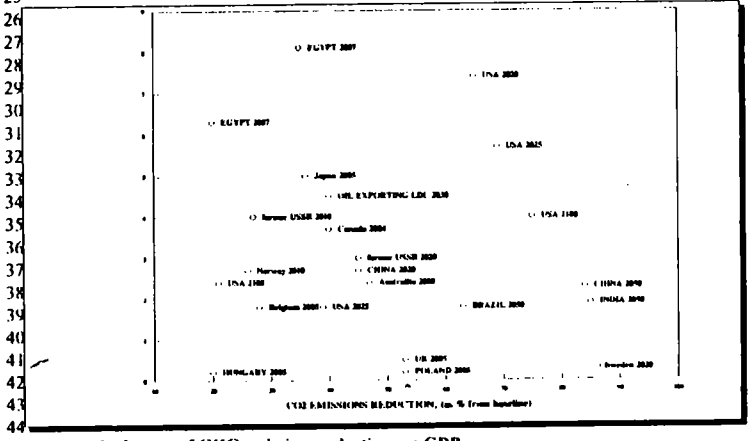

Figure 4.3: Impact of GHG emissions reductions on GDP

[37] The question of "green accounting" is one of valuing and aggregating marketable and non-marketable goods (see e.g., United Nations (1993), or Munasinghe *et al.*, 1995). The many

GDP[38] As is evident, these impact estimates show considerable variation. even so, none of these estimates reflect "green accounting", and only one takes into account joint products.[39] Most of these studies are national studies. Many researchers argue that unilateral action by the US or by OECD countries are likely to be less effective than global action, and that unilateral actions are likely to exaggerate the impact on GDP.[40] However, these studies also neglect the benefits of the development of advanced technologies in the market economies, which could then be more quickly adapted in the developing world.

Traditional CBA basically relies on a partial equilibrium framework which takes a large number of parameters, including prices, as given. For questions relating to climate change, (whose consequences may have major effects on prices), the more far-reaching and inclusive general equilibrium approach is appropriate. For this reason, computable general equilibrium models are widely used in climate change studies.

The joint products problem

A related question concerns the joint benefits and costs of emissions reduction. Options that reduce GHG emissions may also provide significant changes in other pollutants whose impacts are of a quite different scale. For example, the substitution of renewable energy technologies for coal will reduce not just CO_2 emissions -- a *global* benefit -- but also SO_2 and particulate emissions that bring a reduction in *local* environmental damages. On the other hand, the increased use of renewable energy technologies (such as hydroelectric generation), which also reduce CO_2 emissions, may also impose new and different local environmental *costs* (such as loss of biodiversity associated with reservoir inundation).[41]

Estimates of the importance of joint benefits and costs vary widely (in part because valuing the costs and benefits of other environmental impacts may be subject to similar difficulties of valuation and scientific uncertainty as for GHG emissions), but most lie in the range of 1 to 10$ of additional benefits for every dollar of benefit from GHG emission reduction.[42] A recent Norwegian study (Alfsen, Brendemoen and Glomsrod, 1992) indicated

different proposals for "green accounting" reflect the difficulties involved. Rather than speculate about valuation, or poorly founded proxies for non-marketable goods, MCA provides an alternative approach.

[38] These results are for studies that estimate both emissions reductions and GDP impacts relative to some baseline, i.e., relative to the trajectory of emissions in the absence of the policies followed. For many countries, particularly the developing nations, even significant reductions from such baselines may still imply increases in the absolute quantity of GHGs emitted. Other studies report results in terms of GHG emissions in some future target year, relative to emissions in some prior year (e.g. 2010 emissions 10% less than 1990 emissions).

[39] S. Glomsrod, H. Vennemo, and T. Johnson, *Stabilization of Emissions of CO_2: a Computable General Equilibrium Assessment*, Central Bureau of Statistics, Discussion Paper 48, Oslo, Norway, 1990.

[40] For further discussion see UNEP, *op.cit.*, p.72. Studies that have examined the question of unilateral v. multilateral approaches include Proost and van Regemorter (1990) for Belgium, and Edmonds and Reilly (1983) and Rutherford (1992).

[41] Additionally one might note that, while the environmental risks of current technologies are fairly well established, those that apply to new technologies -- including some that are sometimes proposed as solutions to the climate change problem (such as fusion, or new nuclear reactor cycles) -- are less certain.

[42] For example, if we use the externality values suggested by the California Energy Commission ($26/ton for CO_2, 14,483 $/ton for NOx, $7,425$/ton for SO_2, and $57,620$/ton for TSP), then estimated benefit of reducing electricity demand by 1 mwh is 23$ for CO_2, and 74$ for the reduction

that when the joint products of carbon reduction were taken into account (reduction in environmental damages to forests and lakes, health damages, reduced traffic congestion, road damage etc.), then such benefits go a long way toward compensating the economic loss measured as reduction in GDP.[43]

Adding the benefits of reductions in conjoint pollutants to the MB measure is one possibility. The other is to subtract theses benefits from the MC measure. Since most of such benefits go to the country that bears the costs of abating the CO_2 emissions, while the benefits of less CO_2 emissions go to all countries, it follows that the preferred approach is to adjust the marginal cost curves

The aggregation problem

We now turn to the matter of implementing policy. Consider first Figure 4.4, which depicts the situation faced by some country. Its marginal cost curve is upward sloping, in the manner discussed above, it begins with negative values (the "no regrets" or "win-win" options) again in the manner indicated earlier.

Suppose Figure 4.4 depicts the situation for an industrialized country, say the US. Suppose that indeed Nordhaus is correct in his estimates that the benefits to the US are rather small. If MB_1 were true, then the optimal policy would be only to implement the win-win policies -- demand side management, more efficient end-use devices, economically efficient pricing, and the like. If MB_2 were true, for the US perspective, then perhaps only small emissions reductions are warranted. We assume, of course, an appropriate adjustment for the

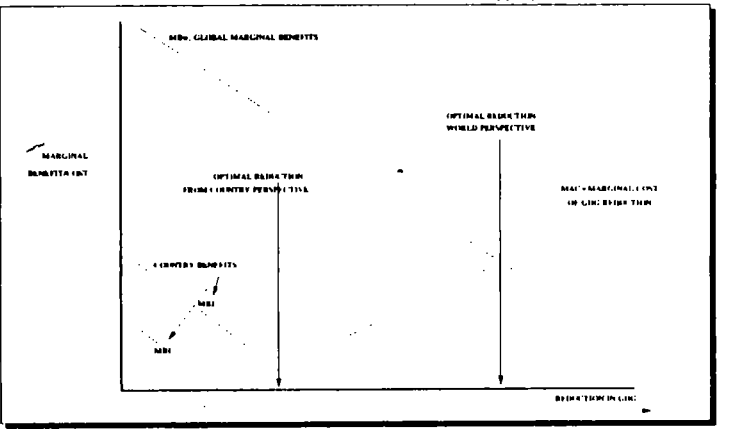

Figure 4.4: The marginal cost and benefits curve for an industrial country

of NOx, SO_2 and TSP, i.e. a ratio of 3 to 1. (Assuming emissions rates for a coal-fired power plant meeting New Source Performance Standards.

[43] For example, in one alternative (the "Treaty Alternative"), loss in GDP was estimated at 3.1 billion Kroner, and the loss of private consumption at 2.6 billion, however joint product benefits were estimated at 2.4 billion (with a range of 1.0-3.8billion) (Alfsen, Brendemoen and Glomsrod, 1992, p.28).

valuation of the benefits of the reduction of joint costs.

However, the benefits to the rest of the world of emissions reductions are likely to be much higher: and hence the curve MB_w lies as shown, far above the MB_1 and MB_2 curves. Therefore, when global benefits of emission cost reductions are taken into account, the optimum level of emissions reduction shifts to the right, as shown. How one persuades decision-makers in the US (and in other industrialized countries) to take a global perspective is the main question.[44]

Consider now the situation for a developing country (Figure 4.5). Again the global benefits curve lies far above the curve for an individual country. Evidence from empirical studies suggests that a far larger portion of the MC curve is in the no-regrets zone. Several multi-country studies point to the same result.[45]

In the case of developing countries, it is the GEF mechanism that provides the means for shifting the level of emissions reduction undertaken by any specific country to the right. But in what range does the GEF mechanism operate? Conceptually, it should operate in the range CD, i.e. provide funding only beyond the optimal level from the country perspective. But since the MB curve is so difficult to determine, operationally, an easier definition is for GEF to operate in the range BD; i.e., from the conventional "least cost" point that would normally apply, and in which any benefits, even locally, from GHG reductions are simply taken as zero. For example, wind plants would not normally lie in the least cost expansion path for an electric utility (if environmental externalities are valued at zero); GEF provides the mechanism to fund such technologies. Yet in fact, GEF has also funded projects in the range AB -- such as the energy efficient lighting project in Mexico.[46]

The difference between optimal level of reduction from the national perspective, and that from the global perspective, lies at the heart of the practical problem of implementation. A related but different issue -- related to equity -- concerns one of the premises of CBA, namely that sunk costs and past actions are not relevant. Yet developing countries argue that in the

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[44] In Figure 4.4 we have drawn, for clarity, only a single marginal cost curve (MAC). It is quite possible, however, that different countries will also have different marginal cost curves (although the differences in costs are likely to be smaller than the differences in benefits).

[45] For example, studies by Burgess 1990) and by Larsen (1993) address the impact of eliminating price subsidies: they estimate the level of reduction in GHG emissions by application of assumed price elasticities to the difference between the subsidized and unsubsidized price. Burgess uses the difference between actual average cost of electricity and the estimated long run marginal cost (LRMC), applies an assumed long run price elasticity of -1, and estimates the reduction in GHG emissions for eleven countries, including the USA, China, India, and some small developing countries such as Tanzania and Peru. Not surprisingly, the bulk of the total carbon emission savings of 124 million tons/year (mtpy) come from coal fuel savings, of which India accounts for 11.9 mtpy, China 26.6 mtpy, and the USA 85.4 mpty. Larsen does the same analysis but from the perspective of *fuel* prices, applies estimated own- and cross-price elasticities for the different fossil fuels to the difference between an appropriately adjusted border price and the domestic subsidized fuel price, and, more significantly, includes the countries of the former USSR and Eastern Europe. In this analysis, the former USSR (917 mpty) and Poland (105.2 mpty) dominate the results; indeed, the combined estimated impact in India (54 mpty), and China (45.4 mpty) together is less than that for Poland.

[46] GEF has recently introduced the term "Type I project" for those in which operate in the range AC (i.e. for which national economic benefits are greater than national costs), and "type II project" for those in the range CD, (i.e. for which national economic benefits are less than national economic costs, but the global benefits are such that the project is justified under GEF criteria). For further discussion, and arguments for why GEF should give priority to type II projects, see e.g. D. Anderson and R. H. Williams, *The Cost-Effectiveness of GEF Projects*, Global Environment Facility, Working Paper 6, Washington, DC., 1993.

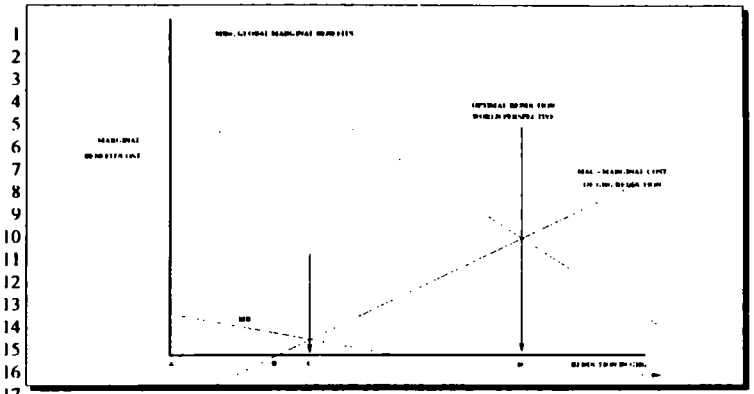


Figure 4.5: The marginal cost and benefits curve for a developing country

case of the climate change problem, past emissions are relevant, because it is the industrial countries, not the developing countries, that have accounted for the bulk of the man-made GHGs present in the atmosphere.[47]

Systemic evaluation. The above results for Sri Lanka also points to the importance of systemic evaluations: the cost per ton of avoided emission for both wind and the no coal option are much lower than those estimated by others, for the exact same technology (see Table 4.3). The answer, of course, lies in the fact that the incremental cost of, say, wind power, depends upon what technology is being substituted: and these will be very different from case to case. For example in Sri Lanka, imported coal baseload plants largely determine the future system expansion cost. This is much more expensive than in India, which has available relatively large quantities of low cost domestic coal. Similarly in the generic cost estimates made by GEF for no coal options, the presumed substituting fuel is domestic oil or gas, not imported oil (as is the case for Sri Lanka). The point is that there likely exist very large, country-specific variations in the estimates of the cost of GHG emissions abatement through given technologies. Joint costs and benefits that are local in nature will very likely vary even more from place to place.

Table 4.3: Comparisons of cost estimates for CO_2 abatement. [In $/ton of CO_2]

	study type	wind	no coal
Sri Lanka	systemic, single 300Mw windfarm	67-131	16-26
GEF	generic	116-223	45-89
India	supply cost	150-600	

Sources: For Sri Lanka, Meier, Munasinghe and Siyambalapitiya, *op. cit.*; for India J. Hossain and C Sinha, *Limiting CO_2 emissions in the power sector of India*, Energy Policy, Oct. 1993, p.1028. Generic estimate from London Economics, *Economic costs of carbon dioxide reduction strategies*, GEF Working Paper Series 3, Washington, DC, 1993.

[47] See, e.g., M. Munasinghe, Sustainable Energy Options for Developing Countries, World Energy Council Journal, 1, Dec. 1991, p.69-87.

Another way of making the same point is by noting that single point cost estimates for many technologies can be quite meaningless, because the supply curve for even an individual technologies is not flat. For example, in the previously presented GHG emission cost curve of Figure 4.1 (for the UK), "renewables" is shown as a single block, with a single marginal cost. Yet as shown in a recent study of wind and hydro for India[48], the supply curves have the expected classical upward sloping shape as illustrated on Figure 4.6 for the supply cost of windfarms in India. Such static cost curves neglect the counter-argument that in a more dynamic analysis, cost may decline due to economies of scale and technological advances.

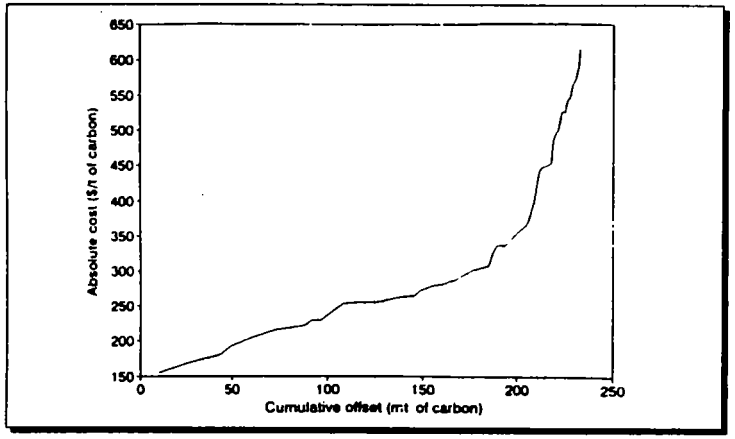


Figure 4.8: supply cost curve for windfarms in India

source: J. Hossain and C.Sinha, Limiting CO_2 emissions in the power sector of India Energy Policy, Oct. 1993, p.1028.

5. Issues

Risk, uncertainty and irreversibility

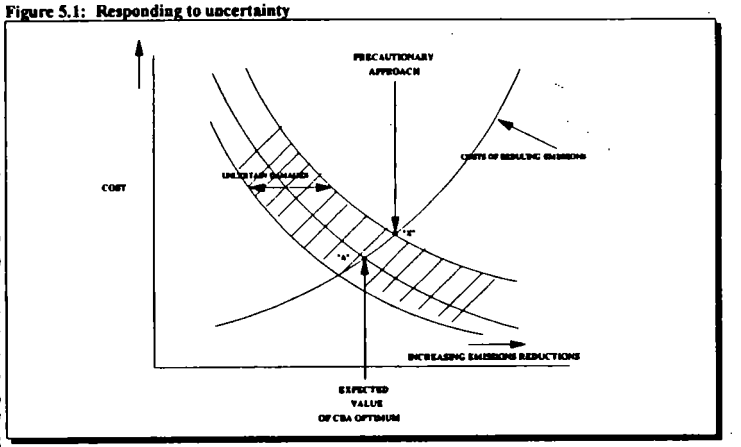
Our knowledge about how anthropogenic emissions of greenhouse gases affect global temperature, what kind of effects a change in global temperature may have, and how efforts to mitigate climate change may work is clearly restricted. How different greenhouse gases react in the atmosphere are not fully understood, and exact predictions of the average increase in global temperature will have different regional effects which are exceedingly difficult to foresee, even if the effect on the average temperature were taken as given. There is also considerable uncertainty about the economic and social effects of abatement measures, which are decisive for the costs and benefits of the measures.

One cannot, therefore, evaluate climate measures without taking these uncertainties into account. On the other hand, acknowledgment of vast uncertainties should not lead to an inert

[48] J. Hossain and C. Sinha, *Limiting CO_2 emissions in the power sector of India* Energy Policy, Oct. 1993, p 1028.

attitude, but rather to develop rational strategies for how to act under uncertainty. Economic analysis under uncertainty aims at developing strategies for decision makers that face uncertainties in their future costs and benefits. The uncertainty in the outcome of a variable is often described by a probability attached to each possible outcome. In some cases the probability distribution is objectively presented, in which cases one normally talks about risk. More often, subjective probability distributions are assumed, in which cases one talks about uncertainty.

Figure 5.1: Responding to uncertainty



In Section 4 we noted that the level of uncertainty in the benefits curve is greater than the level of uncertainty in the cost curve (recall Figure 4.1). Figure 5.1 illustrates the practical consequence of uncertainty in a different way. If cost abatement and damage functions were known with certainty, or if in the absence of risk aversion, one were to use expected values of the uncertain cost abatement and damage functions, then the optimum degree of emission reduction is as shown at "A". However, given uncertainty in the damage function, risk aversion leads one to a precautionary approach – at "X" – which requires more stringent emission reductions, lying to the right of the expected value point "A", and roughly determined by the intersection of the cost curve and some notional upper envelope estimate of the damage function. (There may also be some uncertainty with respect to the emissions reduction cost curve).

The attitude towards risky outcomes is often expressed in terms of a risk premium, which is the minimum compensation required to accept a lottery with expected return x to a certain return of x. Such a premium may be required because the decision maker prefers certain to uncertain outcomes, but may also occur if the net benefit of his investment is non-proportionate in quantity. For instance, suppose a country commits itself to reduce emissions by 100 tons, and considers two alternative measures. One alternative reduces emissions by 100 tons with certainty. The other measure has a 50 percent chance of reducing them by 100 tons. Even if the expected reductions are equal, it is evident that a decision maker will prefer the certain

alternative unless the uncertain alternative is considerably less costly, as there is a chance of having to impose additional measures if unlucky. Assessments of the uncertainty involved in the analysis of climate change may therefore be of great importance to decision making.

However, given the uncertainty it is also important to emphasize that some actions will be less attractive than others. The mirror of the above argument is that some actions may be acceptable even with negative net expected benefit if they reduce the uncertainty. One way to do so is to spread the risk among several measures. Then, if one fails to meet its expected target, another may satisfy the achievements that were expected. The total risk would thus be lower than if all efforts were concentrated on one single measure.

One is scarcely able to account for all the uncertainties involved when analyzing climate change. In some cases it may be equally difficult to assess a probability distribution of a variable as a single expected estimate. Ignorance about certain effects of a measure indicate that they should be left out of the analysis. However, CBA may be of great help to decision making even when limited to effects on which reasonably well-founded value-estimates can be provided.

One issue that has attained a lot of interest in the literature of environmental economics is the problem of irreversible decisions under uncertainty. The reason is that environmental effects, such as climate change are regarded as irreversible. If the effects turns out to be worse than expected, the world is stuck with a permanent, perhaps unwanted, climatic change, which clearly is worse than if the climate could be reestablished after such a change.

In order to incorporate the cost of irreversible effects in the CBA, a vast amount of information is required -- such as how the uncertainty evolves over time. Such information, is rarely available, but we may assume that increased knowledge about climate change will narrow the range of uncertainties in the future. If so, it has been shown that one extra cost of irreversible effects is the so-called quasi option value. This value can be interpreted as the value of keeping future options open, and suggests that decision makers follow flexible strategies when faced with uncertainty.

The strategy that leaves most future options open is, however, difficult to determine. Investing in abatement of climate change opens possibilities for increasing emissions at a later stage if the effects turns out to be less serious than expected. On the other hand, it reduces the potential use of adaptation. In addition, it is difficult to predict the effect of increased knowledge, especially whether the outcomes become more certain. When dealing with many of the effects of climate change, ignorance is perhaps a more appropriate concept than uncertainty. Increased knowledge may change ignorance to uncertainty, but the range of possibilities will not necessarily narrow for that reason.

In applying CBA to the global climate change problem, and in particular to the evaluation of alternative policies to optimize net benefits, there are several major sources of uncertainty that need to be considered[49]:

1. Uncertainty over the actual rates of emission.[50] Most of the many studies cited earlier make assumptions about current and future rates of emissions in some "business-as-usual" case as a starting point. Current CO_2 emissions from fossil fuel use may be reasonably well known, but the level of uncertainty increases as one considers levels of

[49] This is a partial list. Other problems include the assumption that non-carbon based materials are benign with respect to the GHG problem; uncertainty concerning natural sources; and uncertainty over the spatial distribution of physical impacts.

[50] See IPCC (1994), Chapter 6 for further discussion on uncertainty in future emissions.

possible fossil fuel use in the more distant future[51], the impact of deforestation[52], or the emissions of other GHGs such as methane.[53]

2. Uncertainty over the costs of emissions reduction. Again there are significant differences between estimating the costs in electric utility systems (relatively well known for conventional technologies) and those elsewhere, particularly for reforestation.

3. Uncertainty about scientific linkages. As already noted in section 3, there exists a chain of scientific uncertainty (see Figure 3.1). The extent to which these uncertainties can be resolved by further research is itself subject to uncertainty (especially in light of the previously noted fact that by its very nature, *ex ante* verification of models by actual data is difficult. Thus it is unclear that similar arguments invoked in the context of other environmental problems have validity for global climate change. For example, the argument that further research was necessary on an understanding of atmospheric chemistry, or of the chemistry of lake acidification , or of the exact nature of the damage mechanisms on forests., before very costly efforts are undertaken to control SO_2 and NO_x emissions, did at least have the merit that data on the actual damage of acid rain could be found.

4. Uncertainty in valuing the costs and benefits of the physical impacts. Here there may exist quite large variations in the level of uncertainty: for example, evaluating the cost of protective dikes to protect against sea level rise, or of estimating the opportunity cost of inundated land is subject to significantly less uncertainty than estimating the impact on agriculture, or on biodiversity.

5. Uncertainty about the assumptions underlying policy options. For example, a number of studies have estimated the impact on GHG emissions of eliminating subsidies on coal, or on electricity, using assumed values of price elasticity.[54] General equilibrium models require all kinds of assumptions about the elasticities of substitution, whose actual values used in the numerical simulations are either based on historically estimated elasticities, or upon the judgment of the modeler. In either case there is uncertainty about the extent to which such values match actual behavior.

6. Uncertainty over the effectiveness of policies. For example, the proposition that a certain level of carbon tax will in fact result in the hypothesized fuel substitution makes a number of assumptions about the functioning of markets. As noted earlier, the very fact that many apparently "no regret" options are not being implemented suggests a higher level of market imperfection than economists like to admit, and/or substantially higher transaction costs or discount rates.

7. Uncertainty about joint benefits and costs: As noted earlier, joint benefits and costs may be a very significant factor in evaluating options for greenhouse gas abatement. However, these joint benefits and costs are also subject to significant uncertainties (and also measurement problems).

[51] One need only remember how dramatically growth rates and energy/GDP ratios changed in the decade following the 1973 oil crisis to recognize the hazards of such forecasts.

[52] This issue is made more complicated by the fact that much deforestation is presently driven by the need to expand pasture land, which in turn implies higher methane emissions from livestock.

[53] For a full discussion of uncertainty in emissions, see e.g. Ebert and Karmali (1992).

[54] See note 46, *supra*.

The application of valuation techniques is difficult even where the impacts themselves can be quantified with relative confidence. But in the case of global climate change, however, uncertainties in economic valuation techniques may be significantly smaller than the *scientific* uncertainties that surround the impacts of increasing concentrations of greenhouse gases. Advocates of immediate mitigation action to reduce emissions argue that even if the probability of some of the important impacts are unknown, and subject to great uncertainty, they are not zero. Low probability, high impact events are especially complex to model, and may also elicit counter-intuitive public reaction due to extreme risk-averse behavior (e.g. nuclear accident). Further, the process of climate change, once underway, will be irreversible (at least during a period measured in centuries), and the damages which may result are so catastrophic, that action may be warranted even in the absence of more precise scientific knowledge about the impacts.

A good analogy is a nuclear power plant accident. The Chernobyl incident notwithstanding, the risk of catastrophic accident is extremely small. But the cost of a major accident is undoubtedly very large. Both the probabilities[55], as well as the cost of the impacts, are very difficult to estimate. But even if one could agree on appropriate values to use, and one were able to calculate an expected value, decision-making on the basis of the expected value may still not reflect the preferences either of the public or of decision-makers. The consequences of even an extremely unlikely event may be perceived as so undesirable (especially in the case of extreme risk aversion), that "normal" decision rules may simply not be viewed as appropriate. In other words, cost-benefit analysis must deal not just with expected values, but also with risk preferences of the decision-makers, and those they represent.

The traditional and simple way of incorporating uncertainty considerations in CBA has been through sensitivity analysis. Using optimistic and pessimistic values for different variables can indicate which variables will have the most pronounced effects on benefits and costs. While sensitivity analysis need not reflect the probability of occurrence of the upper or lower values, it is useful for determining which variables are most important to the success or failure of a project (Dixon *et al.* 1988). Indeed decision-makers often assign (even if only implicitly) probabilities to the various outcomes. Admittedly, the sheer magnitude of the costs of catastrophic climate change will make the sensitivity analysis problematic.

One might note that for certain types of uncertainty, something akin to risk insurance is available in the form of futures and options markets. For example, one can hedge against uncertainty in the future price of oil by transactions in the oil futures markets, but their efficient functioning depends upon there being some balance between those who are buyers of oil (who are primarily interested in protecting themselves against a rise in the price), and sellers of oil (who are interested in protecting themselves against a fall in the price of oil). (See Box 2)[56].

Finally, extreme uncertainty might also influence the nature of the economic instruments employed for policy purposes. For example, a price-oriented mechanism (such as a carbon tax) which limits economic dislocation might be preferred over a quantity-based mechanism (such as tradable permits) in a situation where there are both uncertain control costs and an uncertain environmental response (see Lave and Gruenspecht, 1991).[57]

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[55] The US Nuclear Regulatory Commission has made repeated attempts to establish probabilities for specific kinds of accidents through a technique known as fault tree analysis. Despite the appearance of scientific rigor, the resultant probability estimates remain highly controversial. For examples of the use of cost-benefit analysis by the US NRC, see e.g. Mubayi *et al* (1991) or Abrahamson *et al.* (1989).

[56] Precautionary expenditures may also be influenced by aversion to catastrophic risks. A recent example is the hundreds of billions of dollars per year spent in the U.S to avert soviet nuclear attack.

Box 2: Applications of decision analysis

Option analysis: In conventional CBA analysis, the usual decision rule is to take some action if the expected benefits exceed the expected costs. Depending on the degree of irreversibility present, a more appropriate rule is to take the action when benefits exceed costs by an amount at least equal to the value of the forgone option. Suppose some investment depends upon some assumptions that are subject to great uncertainty -- such as future world oil prices. If one makes some investment decision that is largely irreversible -- such as building a large hydroelectric power project -- then one loses the flexibility associated with waiting to learn more about the factors that affect oil prices. Preserving that flexibility has some economic value, namely the so-called option value. In financial and commodity markets such options to buy (and sell) are traded, with option prices determined by the market itself. But option value theory is now being applied to other fields involving capital intensive investments -- such as power generation.[1]

In applying these concepts to the climate change problem, there are of course many key differences. First, in one sense the problem is exactly opposite to that faced, say, by the power sector. In climate change, one loses flexibility if one does *not* make short-term investments to reduce GHG emissions. Second, unlike in the financial and commodity context, there is no marketplace to set the value of the option.[2]

Decision analysis and hedging strategies: Among the early attempts at applying decision analysis to the climate change problem are those of Manne and Richels,[3] who have developed an approach for determining the optimal hedging strategy. The paradigm they use is that of a portfolio of insurance options:[4] what combination of insurance should be bought, if indeed any at all? "...what portion goes to R&D to resolve scientific uncertainties? What portion goes to the development of new supply and conservation technologies to reduce abatement costs? And what portion goes to immediate abatement of emissions? Particularly they focus on the value of information[5] how much accuracy is needed in climate modeling and impact assessment? Clearly, with *perfect information*, the best course of action can be charted immediately, and there is no need to hedge bets. Manne and Richels conclude that the need for precautionary near-term emissions reductions is inversely related to the sustained commitment to R&D to develop better climate information (which reduces the need to hedge against an uncertain and potentially hostile future). However, given the inherent predictive uncertainty of climate change, (and in particular the reliability of indicators), the limitations of such approaches need to be recognized.

[1] See e.g. E. Crousillat and S. Martzoukos, *Decision-making under uncertainty. An option valuation approach to power planning.*, Industry and Energy Department Working Paper, Energy Series Paper 39, World Bank, Washington, DC, 1991. This study reviewed power sector investment decisions in Costa Rica, Hungary and West Africa. For a general review, see Dixit and Pindyck (1994)

[2] A marketplace might of course emerge if a tradable emissions permit system were to be instituted. Chao and Wilson (1993) outline a means of using option values to quantify the flexibility associated with the purchase of a tradable emissions permit instead of fixed capital investment in control technology.

[3] See e.g. A. S. Manne and R. Richels, *Buying greenhouse insurance: the economic costs of carbon dioxide emission limits*, MIT Press, Cambridge, MA, 1992

[4] L. Lave (*Are economists relevant? The efficiency of a carbon tax*, in Dornbusch and Poterba (Eds) Climate Change Economic Policy Responses, MIT Press, Cambridge, MA, 1991) notes that the concern about global climate change is not merely concentrated in the rich nations, but in the upper income groups in those nations, these are the same groups that voluntarily purchase insurance to protect themselves against other losses-health, flood, earthquake. Persuading poor people to buy flood or earthquake insurance is exceptionally difficult even in the developed countries.

[5] The value of information under uncertain conditions is a concept much used in the private sector. For example, in oil exploration, before drilling a wildcat well -- a very expensive proposition -- the question arises as to how much ought to be spent in much less expensive prior survey work: general magnetic surveys, or more expensive seismic surveys? Neither yields perfect information. For details of how such decision-theory models are applied in this field, see e.g. Newendorp (1976).

Valuation

The robustness of a cost-benefit analysis depends critically on how reliable the values attached to each item are. The prices of marketable goods and services express social values as long as the goods in question are not rationed and there are no externalities.[58] For non-marketed goods and services, such as many environmental services, values have to be estimated in order to aggregate costs and benefits and obtain an overall evaluation of choice of policy. Estimated prices may depend on the methodology chosen to create them, and one should therefore interpret results which include such prices with caution.

One reason why avoiding climate change may have a value is that climate change will cause a change in economic activities. Sea level rise will force people to move, more turbulent weather conditions may increase the need for rebuilding of damaged materials etc. A second reason is that people attach subjective values to the climate where they live, to some extent reflected in the notions of "good" and "bad" weather.

However it is difficult to assess these values. To simplify somewhat, one may base an estimate on the anticipated costs of achieving a certain target at observed market prices, for instance the minimum abatement cost of attaining the same level of greenhouse gases emissions as a previous year. Alternatively, one may estimate the willingness to pay for reaching such a target. In neither of the cases, however, would one be able to assess the equilibrium price, or the value. The choice of approach might therefore be strictly decisive for the conclusion, for instance if pollution that causes severe damage (high willingness to pay) could be avoided by low costs.

Valuation of environmental effects in CBA may be helpful in attaining cost-effective decisions. However, the valuation should be based on a reasonably well founded methodology. Speculative assumptions will not contribute to decision making. A measure which yields negative net benefits according to an analysis may be worthwhile to accept if effects that are assumed to be positive but not explicitly valued in the calculation are well documented. Decision makers will normally manage to consider more than one measure simultaneously. CBA usually simplifies the decision by aggregating several effects, but there is no necessity for all effects to be aggregated into one single measure.

There are several fundamentally different types of costs and benefits that must be addressed, each of which requires somewhat different approaches to quantification and valuation:

1. Mitigation actions taken *before* the actual impacts are observed. These are primarily a matter of emissions reductions, or of removing GHGs through reforestation.. The vast majority of the applications of cost-benefit analysis have addressed the question of how

[57] Perhaps there is a possible role of financial markets for insuring (and pricing) environmental risks (just as utilities can insure or self-insure against environmental damages caused by accidents at plant sites), but since the damage estimates related to climate change are very difficult to assess, the opportunities for such a approach seem limited, even if the probability of occurrence could be estimated more accurately.

[58] If prices of marketed goods are distorted (e.g. due to arbitrary taxes and subsidies), it will be necessary to use shadow prices -- usually the set of economic opportunity costs or efficiency prices -- to determine the set of opportunity costs or efficiency prices -- to determine their correct economic value (for details, see DasGupta *et al.*, 1972; Little and Mirrlees, 1974).

best to achieve given levels of emission reduction reductions. Valuation issues generally do not arise in this category.

2. Costs of mitigation actions taken after impacts become apparent. These will necessarily occur in the future, and would be undertaken only if (1) climate change actually does occur, and (2) that climate change does in indeed result in specific impacts. The cost of dikes to prevent inundation of coastal areas is a typical example in this category: based on actual experience (such as in the Netherlands) the cost of such mitigation actions are relatively easy to establish.[59] Climatic engineering options also fall in this category, such as painting roads and roofs white, or putting particles into the stratosphere. Again there are few valuation issues here.

3. Costs (and benefits) of Adaptation. Society will adapt with varying degrees of pain to many of the impacts of climate change -- indeed, society has already adapted to changes in climate that have occurred over the past 1000 years. For example, climate change will affect crop yields, and result in poleward shifts in cultivated land. Some areas will gain, and some will lose, which becomes an equity issue (between regions and countries) as much as a cost issue. Estimates of net losses for U S agriculture, for example, suggest a tolerable impact for the *U.S.* as a whole, but significant regional variations.[60] Some of the costs of adaptation will vary, depending on ex-ante actions (e.g. more agricultural R&D expenditure to develop drought or saline resistant crops).[61]

4. Costs (and benefits) of non-adaptation. In some cases, adaptation may not be possible, and/or the cost of mitigation may be higher than the loss incurred in its absence. For example, in some areas, the cost of construction of dykes may be far higher than the value of the land lost to coastal flooding, in which case the relevant cost to be estimated for purposes of CBA is the value of the land lost.

It is thus in the third and fourth of these categories that valuation issues arise. Table 5 1 lists the specific categories of impacts that may be encountered as a result of global climate change.

Conceptually, the total economic value (*TEV*) of a resource consists of its use value (*UV*) and non-use value (*NUV*).[62] Use values may be broken down further into the direct use value (*DUV*), the indirect use value (*IUV*) and the option value (*OV*) (potential use value)[63] One needs to be careful not to double-count both the value of indirect supporting functions and the value of the resulting direct use. One major category of non-use value is existence value (*EV*) Thus

[59] It should be noted that the distinction between a mitigation measure and an adaptation measure

[60] "Preliminary results suggest that although US crop production could decline, supplies would be adequate to meet domestic needs" (EPA, *op.cit.*, 1989, p.93). It might well be pointed out, however, that this reflects the very narrow perspective of the study U.S. grain exports represent a significant supply of food for developing countries, and were the U.S. surplus to decline, developing countries may well be concerned about the use of food exports as a political weapon.

[61] Particularly difficult to value is the cost of forced adaptation and population movements -- a problem already encountered in cost-benefit analysis of the impact of large reservoirs where significant numbers of individuals must be forcibly re-located.

[62] For further details, see Munasinghe (1993), Pearce and Warford (1993).

[63] The issue of option values and irreversibility in CBA has received increasing attention in the literature, starting with Arrow and Fischer (1974), and more recently by Chichilinsky and Heal(1994)

TEV = UV + NUV

or

TEV = [DUV + IUV + OV] + [NUV]

Table 5.1: Potential impacts to be valued (for the U.S.)[1]

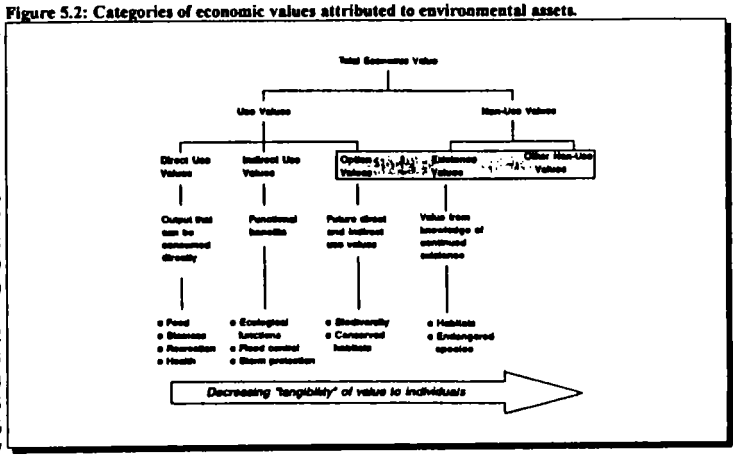
Systems	Potential Impacts
forests/ terrestrial vegetation	migration of vegetation reduction in inhabited range altered ecosystem composition
species diversity	loss of diversity migration of species invasion of new species
coastal wetlands	inundation of wetlands migration of wetlands
aquatic ecosystems	loss of habitat migration to new habitat invasion of new species
coastal resources	inundation of coastal development increased risk of flooding
water resources	changes in supplies changes in drought and floods changes in water quality+hydropower production
agriculture	changes in crop yields shifts in relative productivity and production
human health	shifts in range of infectious disease changes in heat-stress and cold-weather afflictions changes in fertility due to stress
energy	increase in cooling demand decrease in heating demand changes in hydropower output
transportation	fewer disruptions in winter transportation increased risk for summer inland transportation risks to coastal roads
also considered in EPA study	
air quality	
other impacts not considered in OTA or EPA studies	
weather-related damages	damages related to changes in the frequency and severity of extreme weather events like storms.
amenity value	
construction industry	

[1] Systems and potential impacts as listed in OTA, *op.cit*, p.15.

Figure 5.2 shows this disaggregation of TEV in schematic form. Below each valuation concept, a short description of its meaning and a few typical examples (based on a tropical rainforest) of the environmental resources underlying the perceived value, are provided. Option values and non-use values and existence values are shaded, to caution the analyst concerning some of the ambiguities associated with defining these concepts -- as shown in the examples, they can spring from similar or identical resources, while their estimation could be interlinked also. However, these concepts of value are generally quite distinct. Option value is based on how much individuals are willing to pay today for the option of preserving the asset for future (personal) direct and indirect use (see Box 2). In the context of uncertainty, quasi-option value is said to define the value of preserving options for future use in the expectation that knowledge

will grow over time -- about the potential benefits or costs associated with the option (see Pearce and Turner, 1990, and Fisher and Haaneman, 1987). This approach may be quite relevant, given the great uncertainties associated with climate change. Existence value is the perceived value of the environmental asset unrelated either to current or optional use, i.e., simply because it exists. A variety of valuation techniques may be used to quantify the above concepts of value.[64]

Figure 5.2: Categories of economic values attributed to environmental assets.



The basic concept of economic valuation underlying all these techniques is the willingness to pay (WTP) of individuals for an environmental service or resource, i.e., the area under the compensated or Hicksian demand curve.[65] As shown in Box 3, valuation methods can be categorized according to which type of market they rely on, and by considering how they make use of actual or potential behavior.

[64] For a recent overview of techniques suitable for valuing environmental costs and benefits, especially in developing countries, see Munasinghe (1993).

[65] Problems of measurement may arise because the commonly estimated demand function is the Marshallian one -- which indicates how demand varies with the price of an environmental good, while keeping the user's income level constant. In practice, it has been shown that the Marshallian and Hicksian estimates of WTP are in good agreement for a variety of conditions, and in a few cases the Hicksian function may be derived once the Marshallian demand function has been determined (Willig, 1976, Kolstad and Braden, 1991). What people are willing to accept (WTA) in the way of compensation for environmental damage, is another measure of economic value that is related to WTP. WTA and WTP could diverge (Cropper and Oates, 1992). In practice either or both measures are used for valuation.

Box 3: Taxonomy of valuation techniques

TYPE OF BEHAVIOUR	TYPE OF MARKET: conventional market	implicit market	constructed market
	effect on production	travel cost	artificial market
Based on actual Behaviour	effect on health	wage differences	
	defensive or preventative costs	property values	
		proxy marketed goods	
Based on intended behaviour	replacement cost		contingent valuation
	shadow project		

Effect on Production. An investment decision often has environmental impacts, which in turn affect the quantity, quality or production costs of a range of productive outputs that may be valued readily in economic terms.

Effect on Health. This approach is based on health impacts caused by pollution and environmental degradation. One practical measure related to the effect on production is the value of human output lost due to ill health or premature death. The loss of potential net earnings (called the human capital technique) is one proxy for foregone output, to which the costs of health care or prevention may be added.

Defensive or Preventive Costs. Often, costs may be incurred to mitigate the damage caused by an adverse environmental impact. For example, if the drinking water is polluted, extra purification may be needed. Then, such additional defensive or preventive expenditures (ex-post) could be taken as a minimum estimate of the benefits of mitigation.

Replacement Cost and Shadow Project. If an environmental resource that has been impaired is likely to be replaced in the future by another asset that provides equivalent services, then the costs of replacement may be used as a proxy for the environmental damage - assuming that the benefits from the original resource are at least as valuable as the replacement expenses. A shadow project is usually designed specifically to offset the environmental damage caused by another project. For example, if the original project was a dam that inundated some forest land, then the shadow project might involve the replanting of an equivalent area of forest, elsewhere. *Travel Cost.* This method seeks to determine the demand for a recreational site (e.g., number of visits per year to a park), as a function of variables like price, visitor income, and socioeconomic characteristics. The price is usually the sum of entry fees to the site, costs of travel, and opportunity cost of time spent. The consumer surplus associated with the demand curve provides an estimate of the value of the recreational site in question.

Property Value. In areas where relatively competitive markets exist for land, it is possible to decompose real estate prices into components attributable to different characteristics like house and lot size, air and water quality. The marginal WTP for improved local environmental quality is reflected in the increased price of housing in cleaner neighborhoods. This method has limited application in developing countries, since it requires a competitive housing market, as well as sophisticated data and tools of statistical analysis.

Wage Differences. As in the case of property values, the wage differential method attempts to relate changes in the wage rate to environmental conditions, after accounting for the effects of all factors other than environment (e.g., age, skill level, job responsibility, etc.) that might influence wages.

Proxy Marketed Goods. This method is useful when an environmental good or service has no readily determined market value, but a close substitute exists which does have a competitively determined price. In such a case, the market price of the substitute may be used as a proxy for the value of the environmental resource.

Artificial Market. Such markets are constructed for experimental purposes, to determine consumer WTP for a good or service. For example, a home water purification kit might be marketed at various price levels, or access to a game reserve may be offered on the basis of different admission fees, thereby facilitating the estimation of values.

Contingent Valuation. This method puts direct questions to individuals to determine how much they might be willing-to-pay (WTP) for an environmental resource, or how much compensation they would be willing-to-accept (WTA) if they were deprived of the same resource. The contingent valuation method (CVM) is more effective when the respondents are familiar with the environmental good or service, and have adequate information on which to base their preferences. Recent studies indicate that CVM, cautiously and rigorously applied, could provide rough estimates of value that would be helpful in economic decision-making, especially when other valuation methods were unavailable.

Source: Munasinghe (1993)

Valuation techniques obviously need to be selected with some care, and in particular one must recognize that a particular valuation technique may not necessarily capture the entire value. For example, if the replacement cost approach is being used to value the loss of forest area being inundated by a dam, it would likely capture only the *use* value. The value of biodiversity loss involved in the loss of primary forest, or a developed ecosystem, may not be included.[66]

We note that these valuation techniques have been developed for more conventional environmental impact analysis, and would require significant modification and/or careful interpretation when applied to global climate change (e.g. long-term intergenerational impacts, biodiversity loss, welfare comparisons across cultures, or where there are wide gaps between gainers and losers, etc.). Nevertheless, whatever may be the difficulties, the importance of valuation remains, and the development of better techniques should be viewed as an important item in the overall climate change research agenda. Certainly ignoring an impact because it cannot be satisfactorily valued carries high risk, and is one of the reasons for the use of MCA (see below).

Discount rate

We noted in the introduction that CBA requires a very specific and explicit way of dealing with time. The first principle is that past (or "sunk") costs are ignored, based on the premise that since past decisions cannot be changed, they have no bearing over decisions regarding the efficiency of resource use that are to be made in the present or in the future.[67]

The second principle is that a discount rate is applied to future costs and benefits to yield their present values. The issue of choosing an appropriate discount rate has been discussed in the context of general CBA for many years (Dasgupta et al. 1972, Harberger 1976, Little and Mirrlees 1974, Sen 1967). The long term perspective required for sustainable development suggests that the discount rate might play a critical role in intertemporal decisions concerning the use of environmental resources (Lind and Arrow 1982). We briefly discuss below, several key issues relating to discount rates – the topic is dealt with more fully in Chapter 4.

Compared with most other economic investment decisions, the time perspective of measures aiming at mitigation of climate change is considerably longer. Cline (1992) suggests a 200 - 300 years time horizon for climate policy decisions, while investments in economic activities seldom need more than a 25 years horizon. This makes assumptions about how the economic and the environmental systems will develop, and the discounting of values that occurs in the future critical to the evaluation of measures.

The discount rate denotes the social opportunity cost of capital. It reflects total social benefits if one unit of present output is withdrawn from consumption and instead is invested (for instance in production or abatement). The criteria for optimal social and economic development is that the marginal total benefits from the different investments should be equal regardless of what the investments are aiming at. In other words, the social discount rate

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[66] Contingent Valuation methods in particular are somewhat controversial, and need great care in their application to produce credible results.

[67] One needs to take note also of the fact that this principle is also not universally accepted, particularly by political leaders. The principle that "past sacrifices ought not to be in vain" is frequently invoked as relevant to present decisions. Indeed, in the climate change debate, developing countries correctly note that it is the developed countries who are largely responsible for the present levels of GHG in the atmosphere, and that this past behavior *is* relevant in the search for equitable solutions in the future. However, these observations point to the *equity* dimension of the problem, and do not affect how one ought to seek the economically efficient options.

should be equal for all investments. If not, it would be possible to reallocate resources and attain a higher social benefit without any cost. Thus, the discount rate expresses a condition for dynamic (or intertemporal) efficiency.

The discount rate also provides a signal to decision makers who evaluate single projects or measures to take decisions in accordance with dynamic efficiency (over time). Even if one accepts the requirement to apply the same discount rate for marginal projects within a given time period, there are many potential optimal levels of the discount rate. This level depends, *inter alia*, on the social preferences about present versus future consumption which may be reflected by an intertemporal welfare function. The formulation of this function has been the subject of an extended debate in which questions about intertemporal comparisons as well as current welfare contributors have been raised.

It is worth emphasizing that although externalities related to climate change will affect the social rate of discount, it is not sufficient to merely adjust this discount rate in order to take full account of climate change in a CBA. One must include also the "price" of the environment, which may increase substantially over time. As a consequence, future impacts from climate change may be quite important to present day decisions, even in "discounted terms": A five per cent increase in the price of the environment will fully counteract the effect of a five per cent discount rate.

To conclude, discounting is necessary in order to compare costs and benefits at different time periods. Attempts to avoid discounting or to apply a different discount rate for climate measures than other investments will inevitably result in an inefficient policy. However, it is difficult to pick out the correct level for the optimal social rate, as there are no practical observations of such a rate. Furthermore, discount rates may depend on the future scenario that is assumed, and could vary over time – in particular very long term discount rates may be lower as economic growth rates saturate and decline.[68]

CBA and Equity

The benefits and costs of climate change mitigation strategies may accrue to different countries (and to different regions within larger countries). How one reconciles these differences is therefore one of the central dilemmas facing policy-makers: and the equity issues involved are discussed in some detail in Chapter 4.

Thus, while CBA can provide answers on who should engage in how much abatement based solely on the criterion of maximizing economic efficiency, it must be recognized that some deviation from the global least-cost solution as obtained by CBA may have to be accepted in order to get international agreement. As indicated earlier on Figure 2.1, there will likely be a trade-off between equity objectives and economic efficiency: CBA can help define the trade-off curve, but it cannot provide an answer to what combination of economic efficiency and equity is necessary to get international agreement. However, whether there is a trade-off between equity and efficiency (and the properties of this trade-off) depend upon what policy instruments are available. For example, if one permits side-payments (of some kind) between countries, the efficient allocation of emissions across countries is independent of the equity issue.

Several concerns shape equity perceptions and the ability to obtain international agreements Effective action to control climate change is dependent on a degree of international agreement. Therefore a first obstacle to whatever mechanism might be agreed upon is national sovereignty – to what extent will sovereign nations subject themselves to enforcement actions

[68] For a discussion, see Munasinghe (1993).

by others? Even simple agreements for joint implementation of projects involving two countries have run into difficulties (see below).

The second obstacle is the heterogeneous nature of the effects of greenhouse warming. Although the most widely cited measure of climate change is the average increase in global temperature, climate change affects different countries differently. In addition, the costs or response measures and their economic implications vary greatly among countries, particularly as a function of the level of development. Therefore the perceptions of benefits of global cooperation will differ greatly.

A third obstacle is posed by strategic incentives. If some countries take the lead and set up a greenhouse gas agreement, others have an incentive to free-ride and abstain from joining, as they cannot be excluded from the benefits such an agreement creates. If countries act selfishly in this way, few will become party to an agreement. Most countries will therefore not cooperate and no general agreement will be reached even if all countries were to benefit from it. (This is the well known prisoner's dilemma from game theory).[69] Some argue that the overwhelming historical contribution to the build-up of GHGs from developed countries constitutes an "environmental debt", that cannot be conveniently ignored using the traditional "sunk cost" approach. If past contributions to GHG emissions are considered from an equity viewpoint, establishment of appropriate side-payment mechanisms from developed to developing countries, including financial assistance and technology transfer, could facilitate the more enthusiastic cooperation of developing countries in climate change mitigation efforts.

The question of joint implementation illustrates the limits of CBA in this regard. The motivation for joint implementation is a straight forward result of CBA. If a country -- say the U.S. -- decides to make an effort to reduce GHG emissions, and if reductions can be obtained at lower costs abroad, then the US should initiate projects in other countries in order to minimize overall costs (Aaheim, 1993). The receiving country has nothing to lose if the additional cost of such a joint implementation project is covered by the investing nation. Yet many countries and organizations have reacted with skepticism, for reasons that are political, and based on equity concerns, rather than on economic efficiency. The reasons include the mistrust of the true willingness of the industrial countries to mitigate climate change; the belief that the ultimate reduction in GHGs under such a regime would be negligible; and the suspicion that joint implementation gives industrial countries an opportunity to "buy themselves out of their problems" at the expense of the developing countries.[70] Indeed, some developing countries fear that joint implementation investment might partly substitute for traditional forms of financial and donor assistance, and that such agreements might preclude the right of future generations to emit GHGs.

Brazil and other countries have advanced a further reason for host country skepticism of joint implementation projects, namely that Annex I countries to the Rio Convention would invest in all of the low cost/high return projects, and thus non-Annex I countries required to curb emissions would find the cheapest and best options already taken up. Such an extension of

[69] However, for a criticism of this argument, see e g. Brown (1992), who points out that some European countries have already taken unilateral action to reduce greenhouse gases, in hopes that others will follow. Moreover, other game-theory paradigms have been proposed for modeling international environmental negotiations: for example, Carraro and Siniscalo (1992, 1993) propose a "chicken game" framework belonging to the class of coordination games.

[70] For a discussion of these issues, and a discussion of how CBA can make a contribution to the evaluation of such projects, see Aaheim (1993). Concerns about "market justice" and related considerations are outlined in Rose (1990).

non-Annex I parties' commitments, to higher income developing countries has recently been proposed by Australia at INC 10.

Multicriteria analysis

Even the staunchest advocates of cost-benefit analysis would concede that economic efficiency (or economic value) is not the sole criterion in setting public policy, and that policy-makers rightfully need to consider a broader set of objectives. Unfortunately there is much confusion about what constitutes a coherent set of objectives. Table 5.2, taken from a major EPA study, lists the criteria suggested there as constituting the basis for selecting public policy; the authors go on to note that the first four criteria listed -- flexibility, urgency, irreversibility and low cost-- "...would generally be given the highest priority". Note that many of these criteria overlap with each other, and economic efficiency is among them!

Table 5.2: Criteria for choosing a strategy

1. Flexibility
2. Urgency
3. Low cost
4. Irreversibility
5. Consistency
6. Economic Efficiency
7. Profitability
8. Political feasibility
9. Health and Safety
10. Legal and administrative feasibility
11. Equity
12. Environmental quality
13. Private v. Public sector
14. Unique or critical resources

Source: EPA, *The Potential effects of global climate change on the United States*, EPA-230-05-89-050, Washington, DC, December 1989, p.390.

Simple applications of CBA tend to focus only on economic efficiency. However, in more recent extensions, traditional CBA concepts are embedded in MCA, that expressly allows more than one objective, and expressly addresses risk and uncertainty -- thereby providing an integrating mechanism for most of the criteria listed. Multicriteria analysis techniques first gained prominence in the 1970s, when the intangible environmental externalities lying outside conventional cost-benefit analysis (CBA) methodologies were increasingly recognized. It also met one objective of modern decisionmakers, who preferred to be presented with a range of feasible alternatives -- as opposed to one "best" solution. MCA also allows for the appraisal of alternatives with differing objectives and varied costs and benefits, which are often assessed in differing units of measurement.

Thus, upon closer examination of the criteria listed on Table 5.2 , criteria 1, 2, 3, 4, 5, 6 can all be treated by modern decision-analysis: indeed, questions of timing (urgency), flexibility (or robustness), capital constraints ("low cost") are all central elements of the approach. Criterion 13 is really part of 6 (in the text the authors of the EPA report amplify the criterion as follows: "Does the strategy minimize governmental interference with decisions best made by the private sector" ?). Furthermore, modern valuation techniques permit substantial parts of Criteria 9 and 12 to be included in the economic analysis as well. As conceded by the EPA

report (p.393), "if the principal costs and benefits can be quantified in monetary terms, economic theory provides a rigorous procedure for making trade-offs between present and future costs, and for considering uncertainty, profitability, and most of the other criteria".

There is also a need to separate the basic goals of public policy -- such as economic efficiency and equity -- which surely have primacy, from implementation issues such as legal and administrative feasibility, which are generally secondary. The premise of CBA analysis is that one looks first at the primary objectives, and then asks how much of the primary objectives one may have to sacrifice to achieve practical implementation. This principle has become accepted in many areas of policy-making. For example, the starting point for setting electric utility rates is to calculate the economically efficient tariff (based on marginal costs), and then make adjustments to protect low income groups (through lifeline rates, special provisions for disconnection in the event of non-payment, etc.). The essence of the approach is not that non-economic issues are ignored, but that the trade-offs between economic efficiency and equity (or indeed other objectives not readily monetized) are explicitly quantified and displayed in such a manner that decision-makers are made aware of how much of one objective is traded off in the interests of the other.

Indeed, one of the advantages of MCA is that it forces political decision-makers to look at the trade-offs between their major objectives, rather than attempting to boil down everything into a single number, particularly where valuation techniques may be controversial. Nowhere is this more important than in valuation of human life.[71]

The application of MCA methods involves the following steps:

1. Selection and definition of attributes, say A_i, $i=1, \ldots N$, selected to reflect important planning objectives. While the two major relevant attributes in the context of the global climate change problem are cost and GHG emission reductions, we have already noted that strategies to control GHG emissions may have other side-effects, some positive, and some negative, which may also difficult to value, and which might therefore require additional attributes (such as, for example, for biodiversity)
2. Quantification of the levels A_{ij} of the i attributes estimated for each of the j alternatives. In this quantification, full consideration must be given discounting issues, for non-economic and economic attributes alike . At this stage of the analysis, trade-off curves are powerful tools to communicate with decision-makers: they are particularly relevant in a situation, such as the climate change problem, were the quantification of benefits may be difficult, and where decision-makers must act largely on the basis of trading-off short-term costs against certain levels of GHG emission reduction.
3. Determination and application of a decision rule, which amalgamates the information into a single overall value or ranking of the available options, or which reduces the number of options for further consideration to a smaller number of candidate plans. Where amalgamation is contemplated, attribute levels are first translated into a measure of value, $v_i(A_{ij})$ (also known as the attribute value function). [72] This is sometimes combined with a

[71] Differential valuation of human lives is strenuously opposed by some: if a U.S. life is worth $1.5million, then so is everyone else. On the other hand, when making comparisons of per capita GDP, economists are increasingly turning to purchasing power parity adjustments in an attempt to make more valid comparisons of economic level. MCA avoids these difficulties by removing judgments about the value of human life from the domain of technical assessment, into the domain of political decision- making, where making such judgments properly belong.

[72] MCA deals with attitudes toward risk and uncertainty at this stage by the use of multi-attribute utility functions, which explicitly capture attitudes toward risk (see Keeney and Raiffa, 1976; Keeney and Wood (1977) for an application in water resource planning; or Keeney and von Winterfeldt (1987) for application to electric utility planning).

normalization procedure usually on a scale of zero to one (in which the lowest value of the attribute value function is assigned zero, the highest one). Subsequently weights w_i for each attribute must be determined to arrive at the overall amalgamation.

Trade-off curves are a particularly useful tool for analysis of energy-environmental policy options. Figure 5.3, taken from a recent study of options for greenhouse gas (GHG) emission reductions in Sri Lanka (Meier, Munasinghe and Siyambalapitiya, 1993), illustrates the essential concepts. The figure is a plot of two attributes -- GHG emissions and total system costs -- for the technology options identified on Table 5.4. Each point represents a perturbation of the reference case, defined as the official 1993 basecase capacity expansion plan of the CEB.

The *trade-off curve* is the set of options that are not dominated by others (sometimes referred to as the "non-inferior set"). These are the options that are "closest" to the origin, and therefore represent the "best" set of options that merit further attention.[73]

Several useful concepts arise here. First is the concept of *dominance*.[74] PFBC (a clean coal technology) is said to dominate the options in the sector shown, namely FGD, wind and *FGD. PFBC has better costs and better (lower) GHG emissions, and is thus preferred over these options under both criteria. If only these two attributes mattered, then there would be no reason to select any of the dominated options in place of PFBC.

Another perspective is gained by dividing the solution space into quadrants with respect to the reference case (Figure 5.4). The options that fall into quadrant III are the "win-win" options, which are better than the reference case in *both* attributes. In this case, mini-hydro, energy efficient refrigerators, T&D system loss reduction and compact fluorescents all fall into this quadrant, providing both cost and emission gains. Such win-win solutions were mentioned earlier, in Section 4, in connection with the empirical estimates of the MAC curves (e.g. Figure 4.2): these "below-the-line" options in the MAC curves are equivalent to the options in quadrant III of a multi-attribute analysis. [75]

Finally one should note that MCA leads to *implicit* valuations whenever two options are compared. For example, in the case of Figure 5.4, a decision-maker who prefers option "Y" ("max hydro+no coal") to point "X" ("NoCoal+lowSoil") makes an implicit valuation of the concomitant reduction of GHG emissions in terms of the increased costs (i.e. equal to the slope of the trade-off curve between X and Y, about 200$/ton of CO_2)[76]

[73] We note also that the trade-off analysis and surfaces will be much more complex as the number of attributes increases.

[74] Decision analysis distinguishes among several types of dominance -- such as strict dominance and significant dominance -- see e.g. Meier and Munasinghe (1994) for an application of these concepts to environmental decision-making.

[75] In general, of course, the trade-off curve may extend into quadrant II; and quadrant III may contain fewer, or need not contain any solutions at all.

[76] However, because of the presence of joint products -- each represented by a different dimension in the multi-dimensional trade-off space -- such valuations that look only at two dimensions need to be interpreted with some caution.

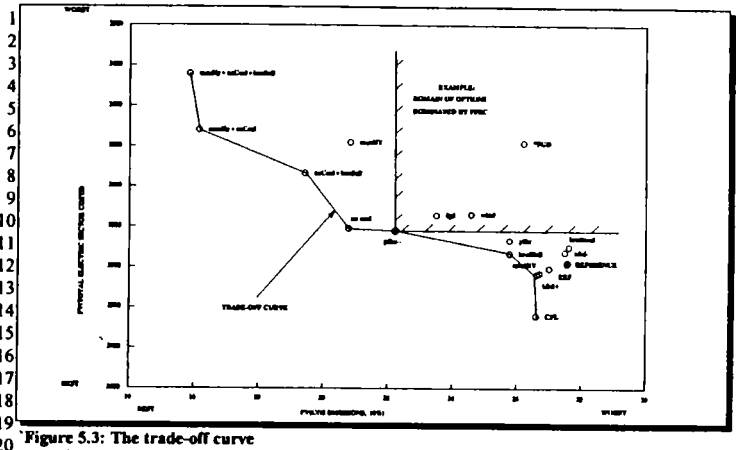

Figure 5.3: The trade-off curve
source: Meier, Munasinghe and Siyambalapitiya (1993)

Table 5.4: Technology interventions for GHG emission reductions

option	comments	symbol
wind energy	305 Mw total	**wind**
mini-hydro		**minihy**
DSM: energy efficient refrigerators		**EEF**
DSM: compact fluorescents		**CFL**
T&D loss reduction	10% T&D loss goal (in place of 12%) by 2000.	**TD+**
	12% goal delayed to 2003	**T&D-**
max hydro	builds both reservoirs in the Upper Kotmale project; 144Mw high dam version of Kukule.	**maxHy**
clean coal technology	pressurized fluidized bed combustion-combined cycle units, assumed for all coal units after 2000:	**PFBC**
	with pessimistic capital cost assumptions	**PFBC--**
clean fuels	use imported low-sulfur residual oil for diesels (0 5% S by weight rather than 2.5%S).	**low S oil**
	use low sulfur (0.5%) coal (rather than 1% S coal)	**low S coal**
FGD systems	model free to chose optimal generation mix; coal plants must have FGD systems	**FGD**
	FGD systems forced onto basecase solution	****FGD**
no coal	model free to choose least-cost combination of diesels +hydro	**noCoal**

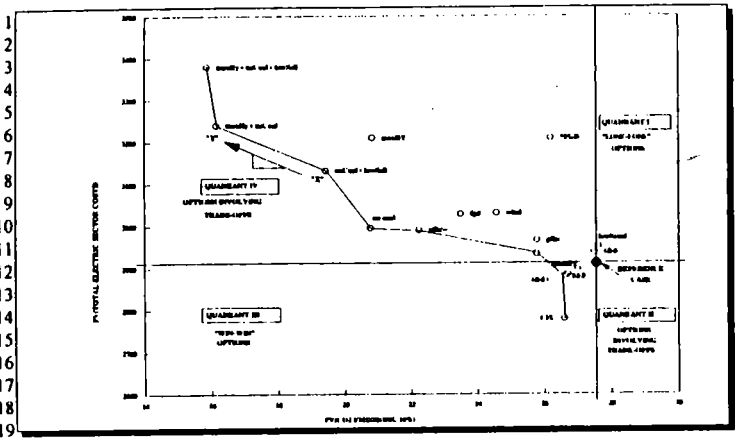

Figure 5.4: "Win-win" options
source Meier, Munasinghe and Siyambalapitiya (1993)

5 Concluding Remarks

Cost-benefit analysis has many advocates but also many detractors. Certainly the rather narrowly defined, traditional approaches to CBA, developed originally for project level decision-making with planning horizons typically no more than 20 years, clearly have difficulty in dealing with the very long time frames, and high levels of uncertainty, encountered in the climate change. However, a family of techniques used in decision analysis, that are associated with a more broadly defined CBA approach provides a more promising basis for analyzing climate change issues.

In the introduction we noted that there were four essential questions facing decision-makers regarding climate change: (1) by how much should emissions of GHGs be reduced?; (2) when should emissions be reduced; (3) by what method should emissions be reduced?; and (4) who should reduce emissions?

The first question is answerable by CBA provided costs and benefits could be estimated with adequate accuracy -- the measures whose marginal costs are less than the marginal damage costs should be implemented. Clearly, it matters what perspective is taken: the result will be different if restricted to a consideration of national costs and benefits than if the perspective is global. It is a fundamental result of CBA that the global perspective is the proper one.

The second question is a more complicated one, because it involves judgments about uncertainty. If the marginal damage (benefit) cost were known with certainty, or if future technological advances that might significantly change the marginal cost curve were known with certainty, then the timing of abatement is given by that portfolio of implementation options that maximizes the (deterministic) present value of avoided damage costs (benefits) less abatement costs -- a relatively straight forward calculation. But since neither damages nor costs are known with certainty (for example, if fusion technology were to be commercially available at a cost comparable to fossil-fueled technology by 2020 then the optimal timing and structure of abatement actions looks very different than if the date were 2070), extensions of CBA -- such as decision analysis -- are required. As indicated in Section 4 (see e.g. Box 2), recent developments have begun to deal with the question of timing, particularly with respect to the balance between R&D (on both the cost and benefit side) vis-a-vis immediate commitments to emission abatements.

The third question is closely related to the first. As we have seen (for example in Figure 4.2), most attempts to answer question 1 necessarily require consideration of the specific methods that might be used to reduce emissions. A bottom-up, empirical estimation of the marginal cost curve involves analysis of the broad spectrum of possible abatement options, from which marginal cost curves can be derived. Top-down models, typically using national or regional general equilibrium models (recall the results of Figure 4.4), also necessarily require explicit consideration of specific policy or technology options.

CBA cannot itself resolve the fourth question -- which involves equity -- but it does provide a framework for understanding the trade-offs to be made between equity and economic efficiency. CBA, when applied globally, can identify in which countries abatement costs are lowest, since the global perspective identifies all measures whose marginal costs are less than the global marginal benefits (recall Figures 4.5 and 4.6). But how such a program can be implemented in practice involves putting in place appropriate transfer payment mechanisms, the amount and structure of which is a matter of equity.

Nevertheless, despite its many imperfections, CBA (broadly defined) remains the best guide to policy-making for dealing with the essential questions that must be faced in dealing climate change. The CBA approach forces decision makers to compare the consequences of

alternative actions, including that of no action, on a quantitative basis. -- and can certainly make a contribution to resolution of the first three of these questions. To the extent that some impacts and measures cannot be valued monetarily (like biodiversity), extensions of the traditional CBA approach, such as multi-criteria analysis, permit quantitative expression of the trade-offs to be made.

Finally, one should emphasize that the most important benefit of applying CBA is not necessarily the predicted outcome (which is always dependent upon assumptions and the particular technique that is used), but the *process itself*, which forces an approach to decision-making that is based on rigorous and quantitative reasoning

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Environment - climate change

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

MEMBER

February 15, 1995

Dear Erik:

This is a quick response to your February 14 inquiry. The basic procedure that we advocate involves converting risks (benefits and costs) into certainty equivalents, and then discounting those certainty equivalents at the risk free rate. Thus, you are perfectly correct that costs and benefits may not be treated symmetrically--the risk premia may well differ--but they would still be discounted at the same rate.

I hope this answers your question.

With best wishes,

Joseph E. Stiglitz

Erik Haites
IPCC
145 King Street, West
Suite 1002
Toronto, Ontario M5H 3X6
CANADA

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

145 King Street West, Suite 1002, Toronto, Ontario M5H 3X6 CANADA
Tel: (416) 369-0900 Fax: (416) 369-0922

cc: RS SM

MEMORANDUM

TO: Chapter 4 Writing Team

FROM: Erik Haites

RE: Multiple Discount Rates?

DATE: February 14, 1995

My limited understanding of finance theory is that each cost stream should be valued using a discounted rate that reflects its own risk. If this is correct, shouldn't mitigation costs and benefits of reduced climate change damage be discounted at different rates? That raises the question of the appropriate values of the discount rates for different cost and benefit streams, which is the principal subject of the existing text. My sense, however, is that the existing text focuses on the value of the appropriate discount rate for the benefits stream. A, presumably shorter, discussion of the appropriate value of the discount rate for the cost stream would be useful. If the discount rates for the cost and benefit streams differ, it would be interesting to note that all of the available benefit-cost studies use the same discount rate for both the cost and benefit streams.

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Post-it™ Fax Note 7671E	Date Feb. 14	# of pages ▸ 1
To Joseph Stiglitz	From Erik Haites	
Co./Dept.	Co.	
Phone #	Phone #	
Fax # (202) 395 6958	Fax #	

MEMORANDUM

COUNCIL OF ECONOMIC ADVISERS

October 11, 1994

Enviroment
Climate
Chron

TO: JOE STIGLITZ

FROM: MIKE TOMAN MAT

SUBJECT: WEEKLY WRAPUP (A few things that have happened in the last week that may end up involving you, or at least it seemed important to keep you informed)

(1) **Climate Change, Post-2000 Assessments**: Both substantive and scheduling issues are on the table. The substantive issues involve what kinds of "pricing" options for GHG control to include in the draft report currently due in December. The scheduling issue is how quickly to move on analysis and discussion of such options (in particular, now versus in November). There is a lot of disagreement among the four agencies making up the IAT working group (OSTP, NEC, OEP, NSC) on these points. I have said that we want a wide range of pricing options in and are not too concerned about a short delay in moving the report forward. There will be a lot of discussion on this in the next day or so, and a Deputies' meeting of the IAT working group -- probably at the end of the month -- to review the bidding and to decide how far and how fast the Admin is willing to go in considering pricing options.

(2) **Environmental Justice**: The language on definitions and standards (now referred to as "guidance") that Alan went over with you when the White House Counsel's Office was concerned now appears to be held up in an intramural squabble at DOJ. Moreover, it will not be sent to the EJ Advisory Council, whose first meeting is October 24-25; and there is some uncertainty about when it will be circulated at all. My concern is that the whole EJ debate could go off the rails without the principles in place to keep people focused on criteria. I will keep you posted.

(3) **Endangered Species Act/Austin**: you may have heard that Babbitt apparently overrode the Fish and Wildlife Service on their plans to "list" endangered species *habitat* in Texas. While this does not directly affect either enforcement of habitat protection requirements (under Section 9 of the ESA) or the specifics of the Section 10 mitigation banking plan in Austin, it seems to raise questions in practice about ESA issues will play out. Again, I'll keep you posted. (I foolishly asked someone in the VP's office who Alan had interacted with on this earlier if they had any plans to be involved at this point. I hope my political sensitivities start to develop more quickly.)

(4) **Odds and ends**: I got a panicky call from someone at EPA's Air Office claiming an 11th hour budget threat to implementation of the SO_2 trading program. I passed this on to Laura in your absence, since it seemed to me that there was a legitimate policy issue *if* the threat was real. She was going to call Browner to see what was going on; I don't know what developed after that.

MEMORANDUM

COUNCIL OF ECONOMIC ADVISERS

Environment
Climate Change

APRIL 14, 1995

MEMORANDUM FOR: LAURA TYSON
JOE STIGLITZ

FROM: ~~MIKE TOMAN~~ MAT

SUBJECT: CLIMATE POLICY ANALYSIS POST-BERLIN

Issues

As you may know, one of the main outcomes of the Berlin Conference of Parties meeting was an agreement among the industrialized (so-called Annex I) countries to engage in a process over the next two years that will lead to agreement on a new, post-2000 "aim" for greenhouse gas emissions control and "means" for achieving the goal.[1] The next international meeting of the parties will be in October, at which time countries will have to start establishing agreement on the process and its goals. To prepare for this, the US will have to exert some considerable effort between now and October.

At a meeting last Wednesday of the Climate Change Management Committee,[2] there apparently was considerable discussion of what we need to do to be ready by next October.[3] There apparently was considerable interest in having NSC chair a fairly analysis-intensive interagency process to look more carefully at post-2000 baseline emissions in the US and the potential for reducing them through various measures (presumably including international "joint implementation"). My understanding is that after some initial staff-level preparation by NSC, there will be another higher-level meeting **sometime next week** to begin (and maybe end) figuring out what to do.

Two related questions arise in this context. (1) If NSC does undertake this process, what role should the CEA and NEC play and how should they seek to play it?

---

[1]This agreement was a plus for the US in that other Annex I countries wanted to move much faster, but the lack of progress in broadening the discussion on actions to include developing countries was more disappointing. In climate parlance, "aim" refers to a target for emissions; our current aim (under the Climate Change Action Plan) is to return our emissions to 1990 levels by 2000 (we aren't making it for a variety of reasons, but no one else seems to be either). "means" are just that -- policies, technologies, incentives, and so forth.

[2]CCMC is the interagency steering committee for discussing a variety of climate change issues; it is chaired by CEQ.

[3]Sally attended the meeting; I did not. I have not had a chance to discuss the meeting with Sally; my information comes from other participants.

(2) What is the status and fate of the current, Presidentially-mandated post-2000 study that NEC, CEQ, OSTP, and NSC co-chair and in which CEA has been very active.

Background

The current post-2000 process has not been very successful, and we are nowhere near a final report despite the fact that we are more than three months past the Presidential deadline. There are several reasons for this. Most basically, there have always been deep divisions among the participating offices and individuals. From the NEC/CEA standpoint, we have been consistently thwarted in our efforts by some of the other participants to present an economically sound characterization of climate issues or discussion of policy options. Some of the other participants have had little incentive to behave otherwise given their access to or control over the international process and their constituency needs. These divisions have never been brought to a head and resolved at the co-chair level, in part because of staff-level miscues but also because of inattention or alternative interests by some co-chairs. Related to and compounding these woes has been a mixed bag in terms of agency cooperation in providing policy analysis support.

Parallel to but largely separate from the post-2000 process, NSC has run a process of their own to develop policy positions and options for use in the international negotiations and discussions. These have focused largely on political defense and advancing an agenda for more rapid international dissemination of lower-emission technology.

Analysis and Options

With respect to CEA and NEC roles in any new process, the options are to participate pretty fully, participate in a more limited way by trying to exercise quality control, or do nothing. With respect to the current post-2000 process, the options are to try to produce some kind of product on which the new process would build or simply sweep everything into the new process.

The answer to the question of how much to participate in a new process depends crucially on how that process is organized. Most people would agree that the current process with multiple chairs has not worked very well, and that has led some to concluded that having NSC alone chair a new process is the best outcome. I would submit that not being on the wrong side of good climate change policy is important enough,[4] and opinions among offices differ enough, that there is much to be said for a multi-chaired process provided the chairs work aggressively to address and settle their differences. An alternative that would still be workable is an NSC-chaired process that explicitly recognizes the authority of the economics and technology offices in developing, managing, and screening the quality of conceptual and policy discussions. If the process is simply one of reacting to NSC-prepared positions that have been developed with cooperative

[4]There are of course many other things competing for our time, and we should not commit resources to this at the expense of failing to adequately engage in other crucial policy debates.

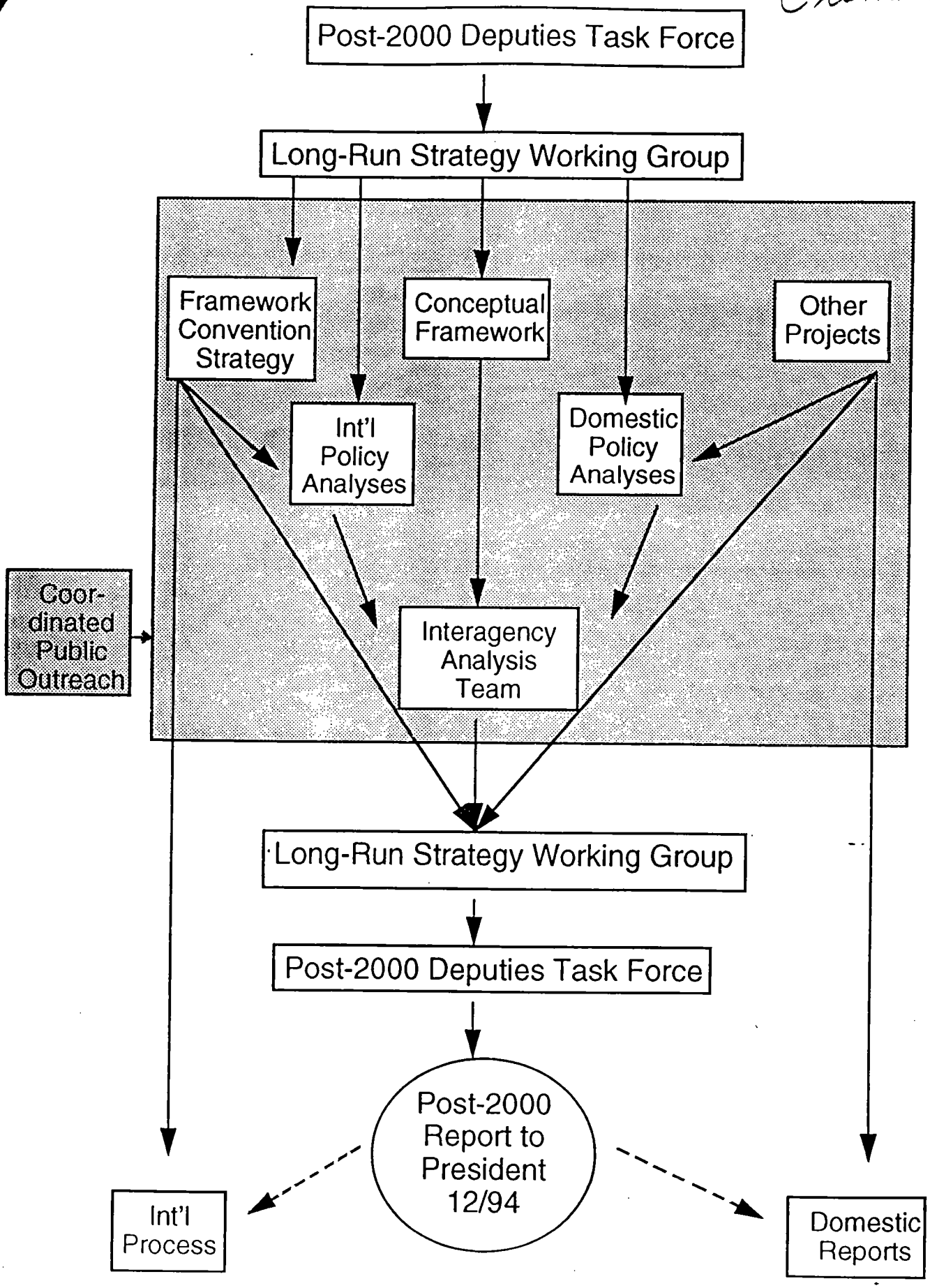
agency participants, there is much less for the economic offices to gain and much more for them to lose.

As for the current post-2000 process, there is little positive momentum in the system for succeeding in generating even an interim report. Yet there are some important ideas about how climate change should be addressed in principle, as well as some useful concrete policy analysis, that should not be lost. If the new process were to accord the economic offices a real opportunity to shape the outcome, one could agree easily to folding in the current work. If, on the other hand, NSC basically plans on going its own way in the new process, we should fight hard to make sure the good ideas in work to date are not lost by issuing an interim statement of findings.

In any event, I would urge you to engage in the meetings on this subject that are likely to occur over the next couple of weeks, as plans for the future are developed. Please let me know if there is any other information I can provide. Thanks.

Environment - Climate Change

CLIMATE CHANGE POST-2000



United States Department of State

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

Washington, D.C. 20520

cc: SES (W/O Attach)

September 2, 1994

S/C
AIC

TO: IWG/GEA Principals

FROM: David A. Colson DAC
Acting Assistant Secretary, OES

SUBJECT: Agency Clearance of the U.S. Climate Action Report

Attached for final agency clearance is a copy of the Climate Action Report. We have incorporated suggestions received during the review process and expect that it is now in final form. As Principals on the IWG/GEA, we ask that you:

- let us know immediately should you find any errors that may have been overlooked; and
- ensure that this document has the full and final clearance of your agency.

Please send notification of clearance to:

Daniel A. Reifsnyder, Director
Office of Global Change, Room 4333
Department of State
Washington, DC 20520-7818
Tel: 202-647-4069
Fax: 202-647-0191

by **COB Thursday, September 8**. If we have not heard from you by that time, we will assume that the Report has been cleared and will proceed with the production schedule timed to enable us to meet our commitment to submit the document to the INC by September 21.

We appreciate the valuable assistance your agencies have provided throughout this project. We believe that the document we present to the INC will be exemplary and indicative of our level of commitment to addressing the threat of climate change.

Joe will be on vacation

cc: AR

The Post-2000 Deputies Task Force meeting has been rescheduled for Tuesday, August 9 from 2:00pm to 3:20pm in Room 180-OEOB. The agenda, you received yesterday, remains the same. If you had not called to be cleared in for the previously scheduled meeting please do so by calling 456-5373.

Re: Climate Change...

EXECUTIVE OFFICE OF THE PRESIDENT

Washington, D. C.

FAX TRANSMITTAL COVER SHEET

DATE: 04-Aug-94

TO: JOE STIGLITZ

SUBJECT: POST-2000 DEPUTIES TASK FORCE

FROM: MARGARET P. SMITH (202) 456-5373
ECONOMIC AND DOMESTIC POLICY

If there are any problems receiving this transmission, please call the sender, or (202) 395-7370.

Joe will be on vacation

The Post-2000 Deputies Task Force meeting scheduled for 4:00pm today has been cancelled. Tentative plans are to reschedule for Monday, August 8. You will be notified of the exact time and day.