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DATE: 12/28/94

NUMBER OF PAGES: 04

FROM: Prof. José Goldemberg

TO: Joe Stigglitz

FAX: (001-202) 395-6958

MESSAGE:

Dear Joe,

I came across a very interesting remark made by Hannah Arendt on progress and intergenerational equity ("Reflections on Violence" in First Anthology - 30 years of the New York Review of Books Edited by R.B. Silvers, B. Epstein and H.S. Hederman) which is relevant to our OVERVIEW chapter.

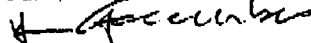
The central point dates back to Kant in his famous article of 1787 "Idea for a Universal History with Cosmopolitan Intent" given in the quote

"It will always remain bewildering ... that the earlier generations seem to carry on their burdensome business only for the sake of the later ... and that only the last should have the good fortune to dwell in the [completed] building!"

What Hannah Arendt does not quote is the final sentence of Kant in his discussion of the "Third Principle". What he says is that

"the bewilderment disappears when one realizes that human beings are rational animals - all mortal - but the human species is immortal and should attain a complete fulfillment of its attributes" (I'm translating from a portuguese version of Kant's article)

Yours,


José Goldemberg

¹ Kant, "Idea for a Universal History with Cosmopolitan Intent", Third Principle.

EDITED BY
ROBERT B. SILVERS, BARBARA EPSTEIN, AND REA HEDERMAN

THE FIRST ANTHOLOGY

30 YEARS OF
THE NEW YORK REVIEW
OF BOOKS

unswerving loyalty to Progress with a no less strict refusal to look upon History in Marxian and Hegelian terms, which alone could justify this belief.)

THE NOTION THAT there is such a thing as Progress for mankind as a whole, that it is the law which rules all processes in the human species, was unknown prior to the eighteenth century and became an almost universally accepted dogma in the nineteenth. The same idea both informed Darwin's biological discoveries, whereby mankind owed its very existence to an irrepressible forward movement of Nature, and gave rise to the new philosophies of History, which, since Hegel, have understood progress expressly in terms of organic development. Marx's idea, borrowed from Hegel, that every old society harbors the seeds of its successors as every living organism harbors the seeds of its offspring is indeed not only the most ingenious but the only possible conceptual guarantee for the sempiternal continuity of Progress in History.

To be sure, a guarantee which in the final analysis rests on not much more than a metaphor is not the most solid basis to erect a doctrine upon, but this, unhappily, Marxism shares with a great many other doctrines in philosophy. Its great advantage becomes clear as soon as one compares it with other concepts of History—such as the rise and fall of empires, the eternal recurrence of the same, the haphazard sequence of essentially unconnected events—all of which can just as well be documented and justified, but none of which will guarantee a continuum of linear time and hence a continuous progress in history. And the only competitor in the field, the ancient notion of a Golden Age at the beginning, from which everything else is derived, implies the rather unpleasant certainty of continuous decline.

There are, however, a few melancholy side effects in the reassuring idea that we need only march into the future, which we can't help doing anyhow, in order to find a better world. There is, first of all, the simple fact that this general future of mankind has nothing to offer the individual life, whose only certain future is death. And if one leaves this out of account and thinks only in generalities, there is the obvious argument against progress that, in the words of Herzen, "Human development is a form of chronological unfairness, since latecomers are able to profit by the labors of their predecessors without paying the same price,"¹⁷ or, in

¹⁷ Alexander Herzen is quoted here from Isaiah Berlin's introduction to Franco Venturi, *Roots of Revolution* (Grosset and Dunlap, 1966).

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Reflections on Violence

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the words of Kant, "It will always remain bewildering... that the earlier generations seem to carry on their burdensome business only for the sake of the later... and that only the last should have the good fortune to dwell in the [completed] building."¹⁸

However, these disadvantages, which were only rarely noticed, are more than outweighed by the enormous advantage that Progress not only explains the past without breaking up the time continuum, but can also serve as a guide for action into the future. This is what Marx discovered when he turned Hegel upside down: he changed the direction of the historian's glance; instead of looking toward the past, he now could confidently look into the future. Progress gives an answer to the troublesome question: And what shall we do now? The answer, on the lowest level, says: Let us develop what we have into something better, greater, etc. (The liberals' at first glance irrational faith in growth, so characteristic of all our present political and economic theories, depends on this notion.) On the more sophisticated level of the Left, it tells us to develop present contradictions into their inherent synthesis. In either case we are assured that nothing altogether new and unexpected can happen, nothing but the "necessary" results of what we already know.¹⁹ How reassuring that, in Hegel's words, "nothing else will come out but what was already there."²⁰

I don't need to add that all our experiences in this century, which has constantly confronted us with the totally unexpected, stand in flagrant contradiction to these notions and doctrines, whose very popularity seems to consist in offering a comfortable, speculative or pseudo-scientific, refuge from reality. But since we are concerned here primarily with violence I must warn against a tempting misunderstanding. If we look upon history as a continuous chronological process, violence in the shape of war and revolution may appear to constitute the only possible interruptions of such processes. If this were true, if only the practice of violence would make it possible to interrupt automatic processes in the realm of human affairs, the preachers of violent actions would have won an important point, although, so far as I know, they never made it. However, it is the function of all action, as distinguished from mere behavior, to interrupt what otherwise

¹⁸ Kant, "Idea for a Universal History with Cosmopolitan Intent," Third Principle.

¹⁹ For an excellent discussion of the obvious fallacies in this position, see Robert A. Nisbet, "The Year 2000 and All That," in *Commentary*, June 1968, and the ill-tempered critical remarks in the September issue.

²⁰ Hegel, *Vorlesungen über die Geschichte der Philosophie*, pp. 100ff.

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FAX COVER SHEET

DATE: December 15, 1994
TO: Dr. Ray Squitieri
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FROM: Prof. Akihiro Amano
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NUMBER OF PAGES: 1 (including cover page)

Thank you very much for your facsimile of December 14. It is a neat and nice summary. I have no further comment except that the first line of para. 7 seems to be read "Issues of efficiency and equity can be . . ."

Best regards.

Sincerely yours,



TO: Joe Stiglitz, CEA

In Vienna, Eric Haites asked our chapter to choose the most important points from the Scope chapter, and summarize them in 1 to 1 1/2 pages for the Technical Summary. I requested contributions from the other authors, and received them late last week from Amano and Saha; Goldemberg will weigh in after he sees our draft. Attached is my edit after going through the submissions.

I'm sending these out to the other authors this afternoon, asking them to respond by Friday. Please look this over and make additions and comments as appropriate.

Ray Squitieri

**FACSIMILE COVER SHEET
OFFICE OF ECONOMIC POLICY**

DATE: 14 DEC 94

NUMBER OF PAGES TO FOLLOW: 1

FAX TO: JOE STIGLITZ
CEA

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Indira Gandhi Institute of Development Research

DR. (MRS.) JYOTI K. PARIKH
Senior Professor

Ref: IPCC/JKP/94/-HH

December 12, 1994

Dr. Joseph Stiglitz
Council of Economic Advisors to the
President of the United States
Old Executive Building
Pennsylvania Avenue
Washington D.C.
U.S.A.

202 395 6947

Dear Joe,

Kirit and I were disappointed as we could not meet you at IIASA. We could have settled much of this over a glass of wine.

Now that our report is moving in its final phase, I am more concerned that our report is acceptable to others and not about differences among us. So from now on, we have to think of us as authors of the IPCC report to face our readers, who will be from North and South. In addition, there will be environmentalists who will expect some positive outcome, since they are the pressure groups who initiated the FCCC process and made sure that heads of state attend it. While we need not get pressurised by them as such, we have to recognise that environmental concerns have entered many persons utility function and there is a willingness-to-pay for environment which is manifested in large amount of expenditure incurred, equipment bought, parks preserved, NGOs formed and time spent. While we have looked into the cost issue there is a need to balance it with "willingness-to-pay" as well. For example, they may prefer to consider "no-regret" as the one which minimises concentrations. Even EEC was willing to pay some time ago.

Climate change means different things to different people and our report should recognise it. To Annex 1 countries, it is the cost of abatement, to non-Annex 1 countries, it is the burden of adaptation, concern for vulnerability, irreversible damages and rise or frequency of extreme events. To island states, it is their existence and to oil exporters, it is their revenue loss, if fossil fuels demand drops. Again, it concerns differently economists and environmentalists. All these concerns need to be voiced in a comprehensive manner in our IPCC report. Many facts have to be looked at so as to be acceptable to a large number of people, if not all.

With this general background, I would like to answer your specific concerns. Although, according to IPCC procedures, I could have given small remarks in side columns, I plan to give a detailed reply to you because you are special to us, Joe. (And it is not because you are now connected with the White House. But we want you to visit IGIDR again!) In any case, some of the remarks will be taken care of as we have decided to rewrite a few portions and others have also raised similar questions.

Secondly, I might explain that to some measure "earlier" chapter 2 (of which first 28 pages are written by me), was in response to the earlier draft of chapter 1 which provoked me. The revised chapter 1 is moderate but it also needs a few modifications, which perhaps are also suggested by others. Therefore, now in the revised chapter 2, I do not need to counter-balance it as heavily as I did. In fact, in the revised version of chapter we will have a section on North-South cooperation and regional approaches. Since there is a feeling that scope chapter ought to be based on what is in other chapters, we could support some of your ideas on technology funds etc. in this section.

In case you find my views "radical", I might tell you that when I did not agree that "population is an asset and not a liability" I was told, I have been too long at IIASA! I have written a paper on "North-South cooperation through joint implementation". I have also written a book on "Planning for Demand Side Management in the Electricity Sector" where I have not even mentioned the issue of climate change because I think some of these steps are worthwhile doing ourselves anyway. Though, if the developed countries could help financially and technologically, the process could speed up. I do not believe in subsidy for electricity, but I think kerosene subsidy is required for a few decades for certain income groups. I have hinted in chapter 2 that when non-Annex 1 countries cross certain per capita levels, they may have to join the efforts of abatement. This may perhaps be questioned by the Governments of non-Annex 1 countries who have high emissions such as NIC, oil exporters and so on. I have even worked on statistical value of life and given a number for Bombay! Thus, there is more on the other side of me and you may find my views in the centre when the IPCC review process is over. Our reports have to balance these. In fact, others have not reacted as sharply about the chapter 2 and some IPCC lead authors have praised it, especially developing countries and some European countries and Japan. Though, as always, those who like it tell you privately and those who have problems, voice their views publicly.

You will receive another communication about how we took care of your comments by the end of this month as I am also involved in chemotherapy

With warm regards from both of us.

Yours sincerely,



Jyoti Parikh

MEMORANDUM

COUNCIL OF ECONOMIC ADVISERS

NOVEMBER 23, 1994

TO: SALLY KANE
JOE STIGLITZ
RAY SQUITIERI

FROM: MIKE TOMAN

SUBJECT: BROAD COMMENTS ON IPCC WG III SCOPE AND
DISCOUNTING PAPERS

I have not had time to prepare more detailed comments, but with Vienna approaching I wanted at least to convey three broad sets of comments.

(1) Exhaustible Energy Resource Economics

I continue to think that care is needed in distinguishing exhaustible from depletable resources. It is well established that basic comparative statics/dynamics results for the exhaustion case do not necessarily carry over when there is only economic exhaustion. This point comes up several times in the scope chapter (pp 10, 28, Figure 3). Do these arguments apply with Ricardian scarcity as opposed to Malthusian scarcity? Are there similar concerns in assessing the dynamics of intertemporally efficient carbon taxes?

(2) Discounting and Intergenerational Equity

The construction of an ethically neutral discount rate based on the elasticity of marginal utility and the growth of per capita consumption is well established and definitely should be made. There is, however, another argument that also has intellectual respectability and avoids the ad hoc separation of efficiency and equity inherent in the first approach (see p 13 of scope chapter). Rather than constructing a quasi-Rawlsian thought experiment involving intergenerational contracting, imagine that the current generation has to determine resource allocation decisions, including preservation of resources for the more distant future, and its motivations include general concerns about the future health of the planet as well as narrower bequest motives involving their own families. The issue then becomes a social choice problem in which individual marginal rates of substitution between individual consumption and environmental preservation come to the fore. These marginal rates of substitution affect the social imputation of a shadow price to future environmental degradation. Discounting can occur at the social rate of time preference, but the valuation of future environmental impacts could act to offset the impact of

discounting if preferences are for this outcome. This approach does not repeal Arrow's theorem, but it does move the intergenerational problem onto ground that is more familiar from the standpoint of welfare economics. In particular, one could imagine carefully defined valuation studies to elicit intergenerational marginal rates of substitution, though I in no way underestimate the empirical problems here.

As something of an aside, Kerry Smith wrote a series of articles a number of years ago in which I believe he argued that the intergenerational rate of discount for valuing intergenerational public goods could vary with the nature of the goods and the specification of the numeraire. This stuff seems very relevant to the discounting chapter, but I don't think there has been much follow-up in the economics literature.

(3) Sustainable Development

The discussion here could stand some beefing up. There has been a lot of literature on this subject over the past few years that is not reflected in the discussion (a problem that also arises to an extent elsewhere). First, Solow's "classic" statement of the issue is only one definition, and not necessarily the best one. The Brundtland definition actually is somewhat broader in that it is more agnostic on what the text refers to as "specific egalitarianism" (more on this below). As for justification of the Solow-type criterion, it does *not* require a Rawlsian criterion. Asheim has shown that certain abstract principles of fair intergenerational distribution imply a criterion of *nondeclining* utility, which captures the spirit of sustainability without implying stasis or stagnation. The nondeclining utility criterion also has been studied extensively by Pezzey.

The question of intergenerational equity is only half of sustainability. Another issue is the degree to which other forms of capital accumulation (including skills and technology) can compensate for economic degradation over time. The scope paper states that concerns for specific endowments cannot be reconciled with individualistic notions of well-being (p 30). I vigorously disagree. If substitution possibilities are limited enough, then necessarily individuals will be concerned about the quantities of limiting factors in the wealth portfolio. The relevance of this ultimately is an empirical matter, notwithstanding our standard assumptions of substitutability in conceptual models. The discounting paper (p 2) argues that *some* environmental effects can be offset by other capital accumulation, but this begs the question of whether climate change or other irreversible global changes might be more than "some."

I hope these comments are useful; I'll try to provide more detailed remarks as time permits.

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Mr James Bruce) depending which fax goes
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21 September 1994

Dear Jim/Eric

Scope Chapter/Contribution on Equity

I have attached herewith my contribution on the Equity issue for the Scope chapter, as discussed with Jim.

I am not quite satisfied with it, but in view of Ray's urgent request and the need for him to incorporate the ideas by next week, I prefer to call it a day so as not to change the time table, with an assurance that I shall go through the next revised draft very attentively.

Please ensure that my submissions are copied to the members of the members of WK group I, specially Joe and Ray. I hope that my submissions dated 19th September reached you safely and have been copied to Joe and Ray.

My papers do not seem to fax through easily somehow.

Cheers

Ruby

Ruby Saha

Please note that I got only
1 page of the Draft Policy
Makers' Report. Try to fax me
on (230) 212 42 40 as far as
possible.

7 pages
altogether

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To	Joseph Englitz	From	Eric Haites
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Equity: A Key Consideration

Why Equity?

The far-reaching consequences of climate change which originate from an unequal and inequitable use of the global commons by some nations that overconsume and live unsustainably at the expense of others, including their unborn generations, raises considerations of a different order beyond the purely economic. They urge a strong focus on equity issues.

For the first time in recorded history, economic activity has manifestly reached consequential dimensions, in terms of physical and biological impact upon the planet, through a process of development which has been one-sided, the North having used and still continuing to use most of the global environmental resources and the South bearing most of the risks, being vulnerable to the physical, chemical and biological effects of climate change, on factors which are *already* precarious, like food production and living conditions.

Wealth and Basic Needs

The sharp chasm between wealth and poverty across the world constitutes one of the most pervasive differences in global welfare. Half the world's population is classified as low-income with an average income of US \$ 359 *per capita* whilst the 12.6% of the world's population in the high-income countries have an average income of more than *sixty times* this level.

Activities of the poor that result in greenhouse emissions are mostly those that relate to *basic needs*, whilst those of the rich tend to be dominated by overconsumption and unsustainable living.

The welfare impacts of cutbacks on greenhouse gas emissions would differ greatly according to the level of personal wealth.

There is a need to link in within the above concept the principle of *basic needs* introduced by several individuals in the 1970s, amongst them, Graciella Chichilinsky, not only to rethink development patterns so that they would be consistent with environmental constraints, but also to ensure that the basic rights of every individual to a minimum utility *making it worth living* are not infringed.

Sovereign Equality of States

A basic tenet of international law is the sovereign equality of all States. Each State has jurisdiction over its territory, within which it has the right freely to choose and develop its political, social, economic and cultural systems. This includes the right to develop its own policies and laws regulating the exploitation of its natural resources.

Carbon Emissions:**A Case of Damage Beyond National Jurisdiction**

States have the sovereign right to exploit their natural resources pursuant to their own environmental and developmental policies *subject to the proviso* that they bear the responsibility of ensuring that activities within their jurisdiction do not cause damage to the environment of other States or areas beyond the limits of national jurisdiction.

By overexploiting the atmosphere of the planet, the North has transgressed areas beyond what could equitably be within their allocation. The atmosphere of the planet is not a private good, but an international public good which is not "rival" in consumption and the allocation of which must be the same for all.

The atmosphere has served previous generations and is expected to service the unborn generations in an intertemporal context. The reason why such over-exploitation has remained unnoticed until the present has been due to the hidden nature of the phenomenon to the human eye, the time lag in scientific information as well as the still greater timelag in the dissemination of this information to the public at large. *The public in the South is still largely unaware of the threat of climate change.* Furthermore, areas such as the high seas, the outer space beyond territorial airspace are considered *global commons* in respect of which the rights and obligations of States are defined by separate legal regimes and not by national jurisdiction. Enforcement is therefore extremely precarious.

Intergenerational Justice

Climate change and future policy implications will have substantial impacts on the distribution of welfare between different generations as well as a differential regional impact, depending upon the vulnerability of the Region.

If policies are implemented to reduce the risk of global warming, the burden of abating emissions of greenhouse gases will fall more on present generations whilst the benefits from not having to adjust to climate changes will be incurred by future generations.

On the other hand, if climate policies are not implemented, the future generations will bear the burden whilst the present generations will benefit from continued use of fossil fuels. It is necessary to formulate operational guidelines that would support a more equitable intertemporal distribution of welfare.

An equitable distribution of welfare over time is provided by the Brundlandt concept of sustainable development to the effect that the present generation should not make such changes in the present resource availability so as to reduce future generations' possibilities to achieve a comparable well-being. This concept has far-reaching implications on intertemporal justice.

The weakness in intergenerational justice within welfare economics comes from the use of discounted welfare criteria to maximise value across time. Discounting the future leads to undervaluing future environmental assets. Discounted cost benefit analysis is not adequate to evaluate long lived environmental projects and the preservation of infinite streams of utility must be given due consideration in economic analysis.

Equity Among Countries

Issues of international equity are clearly related to a variety of differences between countries. Wealth and consumption have already been referred to above. Another important dimension of difference relates to the degree of contribution to climate change.

The patterns of emissions - historical, cumulative, current and projected - are being presented subsequently in the text. The *per capita* emission rates highlight the dominance of North emissions associated with what is considered in the South as *the unsustainable Northern lifestyle*.

Conversely, critiques from the North tend to focus upon the gross emissions, with population as a causal factor. 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, but conversely, this clearly reinforces the case for developing countries' *leapfrogging* strategy.

Whatever the past and current responsibilities, it is also clear that the developed countries on their own will not be able to control climate change and the full collaboration of the developing will be required. This in itself is not an equity issue, but the distribution of effort and payment will be.

Other dimensions of difference between North and South include the differences in capabilities as well as priorities. The South will need to cope with climate change on top of other *major constraints* being experienced with

development generally, such as debt service, education, malnutrition, population, governance, environmental catastrophes.

Then, there would also be the question of differential impact of climate change. Small island states and lowlying deltaic regions are a particularly vulnerable group in the light of the obvious irreversibility of sea level rise, but also their heavy dependence upon natural resources that would be affected by climate change and traded commodities that may be adversely affected under global warming conditions.

Likewise, many specific countries differ in their endowment of resources and would be adversely affected by efforts to mitigate climate change, in their current reliance to exploit such resources. We refer here to the coal and oil producing countries and the countries endowed with forest reserves.

Equity among countries will lead to extensive debates subsequently within the text, but we could at this stage *signal* some major developing country issues like abnormality of the burden, limited capacity for resilience, limited responsibility for the buildup of Greenhouse Gases, the dominance of developed country research, need to avoid environmental colonialism and distort existing aid arrangements.

also risk, absence of insurance

Equity - An Undercurrent of the Framework Convention

Principles of equity in respect of climate change strongly permeate the United Nations Framework Convention on Climate Change, signed by 155 States and the European Community at the Rio Conference in June 1992 and are a strong indication of the awareness of all States of the strong *inequity issues* arising from the overexploitation of the atmosphere and the *good faith* with which States are prepared to address the problem.

Definitions of Equity Within the Framework Convention

Considerations of equity permeate the Convention thoroughly (the basic principles (Art 3), the developed country commitments (Art 4.2) and the financial mechanism (Art 11.2)). In common language, equity means "the quality of being fair and impartial" or "something that is fair and just".

Science cannot prescribe what would be equitable under the Climate Convention, but it is the responsibility of Science to illuminate the meaning of equity and clarify the choices that the Parties will have to make.

Several broad traditional definitions of equity such as parity, proportionality, priority, classic utilitarianism as well as Rawlsian distributive justice, exist, which define the distribution of burdens and the allocation of benefits. In

practice, however, when societies try to achieve equity, they do so in nuanced ways.

Does the Convention give a concrete lead as to the ultimate undertone of its likely eventual practical implementation?

Seen in its entirety, the Framework Convention does provide a substantial context for the interpretation of equity in designing measures to achieve its objectives.

These include prominently the concept of intergenerational equity. Many sections deal with equity between regions and countries, including immediate action to be taken by the developed Parties, equitable nature of financial contributions, equity among developed countries, equitable procedures, the conditions as well as the physical and time-limits within which equity should be achieved.

The Convention notes that developed countries have been and are responsible for the largest share of greenhouse gas emissions and that the share of greenhouse gas emissions from developing countries will grow. Developed country Parties are required to take immediate action to limit greenhouse gas emissions.

The Framework Convention also singles out categories of Parties for special consideration and notes the particular vulnerability of countries endowed with vulnerable ecosystems or economies dependent upon the production, use or exportation of fossil fuels. It also creates obligations and mechanisms for the transfer of resources and technologies from developed country Parties to developing country Parties to assist them deal with the adverse effects of climate change.

There is therefore already a significant context within the Convention for addressing Climate Change within an equitable framework.

The Role of Equity in International Disputes Concerning Natural Resources

It is relevant to examine the role of equity in a range of international disputes concerning natural resources. Farhana Yamin (FIELD, July 1994) has spelled out some principles which may be relevant to the climate change context, these including, in particular, the following principles:

- equity does not involve distributive justice;
- equity cannot compensate for the inequalities of nature;

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- equity does not necessarily imply equality;
- equity requires the consideration of all relevant factual and legal considerations;
- equity implies a duty on States to refrain from engaging in inconsistent conduct *vis à vis* other States; and
- equity entails the principle of good faith that requires States to enter into *bona fide* negotiations to resolve their differences.

Ms Yamin emphasises the *critical* importance of *good faith* negotiations entailed in the last principle, in the context of the Framework Convention that provides a legal process, consisting of institutions and procedures, to resolve disputes between Parties concerning the interpretation and application of equity.

The Need for Illuminating Factual Information in the Application of Equity

Precise factual information will be required in the application of equity in the Climate Change context. The speed with which the Climate Convention was negotiated meant that not all issues could be conclusively addressed and negotiations would be vital if the Parties are to resolve their differences in the further development of rights and obligations to protect the climate system in a fair and equitable manner.

Some of the areas which will require further clarification will include *inter alia* the implementation and enforcement of common responsibilities; the allocation of differentiated rights and responsibilities between present and future generations; the allocation of differentiated rights and responsibilities between members of the present generation represented by State Parties to the Convention; and the basis of legal entitlement for limiting use of the climate system which can be seen as a common and valuable natural resource.

The application of equity requires the consideration of all factual circumstances, including technological and scientific ones, considered legally relevant to a particular question.

The IPCC is required to play an eminently illuminating role in providing information about these factual circumstances.

IPCC Workshop on Equity and Social Considerations in the Climate Change Issue,
Nairobi - 18th-23rd July 1994

The Dilemma of Small Islands States and Other Coastal Areas in the Developing
World:

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*Please note that views and opinions expressed are personal and do not commit the
Mauritius Government for whom the Author works.*

Abstract

*Positive progress on the further development of policy measures and instruments within
the Framework Convention on Climate Change will depend on the political resolve to
integrate equity as well as efficiency objectives into the Programme.*

*Small island States and low-lying Coastal areas are becoming increasingly vulnerable
to the negative impacts from the higher stormwater baseline that is occurring with
sealevel rise. Concomitant with this phenomenon, extreme events are expected to
become increasingly more important.*

*These countries already face a daunting challenge in attempting to establish priorities
for the many social and economic problems they undergo and they certainly have not
got the financial capacity to respond adequately to the threat of sealevel rise. In
addition, such countries have made very small contributions to the Global emissions.*

*Equity and social considerations will require a higher priority in the further evolution
of the Implementation of the Framework Convention on Climate Change.*

It is a great honour for me to present this paper in front of such a distinguished
audience.

I feel that it is a very great responsibility too to convey to the international audience the
dilemma of those Small Islands States and that of the deltaic areas which in my
opinion constitute, along with the desertification-threatened areas, those areas likely to
be most vulnerable to Global Warming.

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Being heavily oriented towards the Coast, they are not only vulnerable in physical terms, but also in terms of socio-economic activity. At the same time, in view of their relatively small economies, costs of adaptation would be prohibitive.

The low-lying nature of deltaic areas such as Bangladesh on the Nile Delta renders them particularly vulnerable to sealevel rise. These areas are among some of the most densely populated areas of the world.

The vulnerability of both categories of areas to sealevel rise is not contested. Both categories are already encountering many problems arising from the unsustainable use and unrestricted development of coastal areas and resources, itself often the result of population pressure, poverty, survival and ignorance. Both areas already undergo from time to time the onslaught of significant caused by climate variability such as cyclones and monsoons, all these being independent of the climate change issue, but which the latter could exacerbate.

Climate Change and the Coast

The Conference Report of the World Coast Conference (IPCC, Preparing to Meet the Coastal Challenges of the 21st Century, April 1994) states the following in respect of Climate Change and the Coast:

"climate change and climate variability are likely to aggravate the impacts of unsustainable development of coastal areas and resources. In turn, these impacts will further exacerbate the vulnerability of coastal areas to the consequences of climate change and associated sea level rise"

In its First Assessment Report, the IPCC Report predicted a global mean sea level rise of 3-10 cm per decade. This rise is more than 3 times faster than that experienced over the last 100 years. Even with actions to limit emissions, some rise in sealevel is still predicted, due to some lags in the overall system.

The IPCC 1992 Supplement did not revise the 1990 Report's estimate of sealevel rise.

It is a fact that those who are searching for the sealevel rise issue find that more impact assessment reports highlight the warming issue and not the sealevelrise issue. The sealevel rise issue tags on as an additionality.

However for small islands and lowlying Coastal areas, sealevel rise constitutes an irreversible threat in view of the existing relativity of the areas of activity and infrastructure to existing sealevel.

Whilst there is scientific uncertainty regarding the the timing and regional impact of Global Warming and numerous scenarios are being worked out to determine who would be the likely winners and likely losers, there is no doubt about the specificity and vulnerability of small Ocean Islands and Coastal areas lying largely just a few metres above sealevel. They would all be losers.

The scope for productive activities on islands is limited and is predominantly monoculture, alongside with traditional fishing and some tourism. The biggest assets of those islands are their large EEZ areas which the Law of the Sea has conferred upon them, but it is noted that most of these countries lack the capacity of surveillance for these areas which are in practice being exploited by the larger nations.

Multiple use of resources upon small islands impinges upon limited land as well as water resources and creates serious competition between different landuse options, including those areas which need to be protected such as catchment areas, wetlands and other coastal ecosystems, parks and forested areas. This threatens biodiversity. By reason of their isolation, small islands are characterised by a high degree of endemism and species get rapidly threatened.

The lowlying nature of deltas make them particularly vulnerable to sealevel rise. The sheer problem of deltas relates to their size, the large numbers of population that dwell on them and the galloping rate of increase that is occurring now. Bangla Desh is an example of a country where, when river floods occur, this can affect 65 percent of the country at one time (IPCC Response Strategy Working Group 1992: Global Climate Change and the Rising Challenge of the Sea). In late 1970, storm surges killed approximately 300,000 people in BanglaDesh and reached over 150 kilometres inland.

Natural flooding and the resulting sedimentation can enable deltas to keep pace with sea level rise. However, the construction of dams and other flood-prevention structures, without proper EIAs in the past, reduced sedimentation in deltas, accelerating erosion and subsidence.

Primary Impacts

The primary impacts of sealevel rise would, in either of those areas, be on physical property and the economic activities and ecological systems astride the coast. Sea level rise would result in increased loss of valuable coastal land, damage property, cause increased flood related deaths, affect coastal ecosystems and also eventually lead to loss of territorial seas.

Research also suggests that extreme events may become more frequent as a result of increased ocean temperatures which would change the frequency, duration and intensity of tropical storms. Inundation of coastal areas is already common during tropical storms and any increases in the extent or frequency of inundation may render numerous heavily populated areas marginal or uninhabitable.

Sealevel rise would increase the severity of storm related flooding and the higher base for storm surges would be an important additional threat in areas where hurricanes and tropical storms are frequent.

Secondary Impacts

Beyond the primary impacts of climate, secondary effects would occur, some of which would be even more complex than the primary ones. A very sensitive impact would be on the hydrological resources, where the low coral islands have almost absolute dependence on underground water, found in the freshwater lens below.

Equity and Social Considerations:

Abnormality of the Burden

The review of the vulnerability of Small Islands and Coastal States as spelled out in the foregoing sections bring out the disproportionate and abnormal burden (*including quasi-annihilation in the case of the atoll islands*) that such areas would undergo as part of the impact of Climate Change and Sealevel Rise. The prospects are likely to be irreversible. I have not found anything contradicting this in the Scientific Reports.

No Capacity for Resilience

Countries with larger surface areas and higher elevations can offer higher prospects of resilience and adaptation. In small ocean islands, the degradation of water supplies through saltwater intrusion can alone dictate the end of any sustainable prospects for present, let alone future generations. Large deltaic areas in developing Regions have a different limitation for resilience. Their economic resilience is weak and impacts, when they occur, are wide-ranging.

Problems of Capability

There is also the question of differentiated physical capability to deal with the problem. In view of the dimensional aspect of the problem, retreat is quasi-impossible in our subject areas, and provided aquifer supplies remain sustainable, the question of adaptation may be evoked. But the costs implications of such options, *the scope of which has been given earlier*, would be beyond the reach of most of the countries involved.

Limited Responsibility for Buildup of Greenhouse Gases

The small ocean islands and the developing coastal states have had little to do with the processes that are causing an accelerated warming of the atmosphere. Their consumption patterns, since times immemorial, have been modest, often on survival lines, and have nothing to compare with the consumption patterns of the North.

Dominance of Developed Country Research

The research and the examples in the IPCC Working Reports are dominated by the scientists of the developed economies who command an articulate voice at interanational forums. Active participation kindles interest and brings together policy makers and scientists, a process which, in the environmental field, is normally absent among the small nations where politicians are more concerned with the problems of governance, survival, job creation, food security and so forth.

Symbolic Representation of Developing Countries

There is a commitment to the participation of the developing countries in the IPCC process, but this participation has been, is and will remain largely symbolic. The developing country research capability, specially that of the small island countries is extremely limited.

Management of Information

Whilst large sums have been committed towards Global Warming research by the developed countries - the powerful environmental lobby facilitates the release of substantial funds for massive research programmes on Global Change, but does not necessarily guarantee that money will be pumped into endangered areas outside their national boundaries, a full international process has merged towards the submission of voluminous Reports as part of the First IPCC process. It is inequitous that the special problem of these areas is not specifically highlighted in most reports.

The figures also assume a smooth transition to a state with double CO₂ concentrations, as estimated by mid-range equilibrium GCM modelling studies, but it is unlikely that, for the small island states and the deltaic areas like Bangla' Desh, the transition will be that smooth. Extreme events like flooding or drought, taking into consideration the flooding trends of Bangla Desh and the drying trends of Africa, that have already claimed millions of lives, are more probable with considerable human and financial costs.

The cost to the Mauritian economy, which is relatively robust compared to other small island states, of Cyclone Hollanda which struck the island in early 1994 is estimated to have amounted to approximately 3% of GDP. On account of vulnerable infrastructure (such as overhead electric cables), each extreme event is potentially capable of significant disruption.

For low atoll islands dependent on aquiferous hydrological resources, the onslaught of storm surges would annihilate the long term possibility of continued sustainable living - the loss of a complete cultural identity - what market valuations can be placed on the same?

Additional case studies of vulnerable areas have been initiated this year as part of World Coast Conference 1993 and profiles for selected areas at risk are published in the Conference Report which was published in April 1994.

Following examination of the profile for Mauritius, with which the author is familiar and which the author believes is *underestimated*, it is felt that more complete studies, with very rigorous indicators for global comparison need to be undertaken.

However, the Global Vulnerability Analysis does state that because of regional differences in regimes of storm surge events, the risk of flooding risk due to sealevel rise is greater than average for some areas including the coast of the Carribean and other small island states. It is also confirmed that the global costs for basic protection works would constitute a substantial part of GNP for Indian Ocean and Pacific Islands.

Policy Instruments: their Pace

The unquestioned commitment of the industrialised countries to ecological security is being seriously compromised by the slow pace with which they are introducing limitation measures on greenhouse gases. This speaks of little or no concern for the vulnerability of the small innocent and fragile nations which have been at the receiving end of actions that have "exhausted" the Global Commons. The prolonged delay itself is also an open flouting of the precautionary principle which the Convention advocates.

Inter-Generational Issues:

The bulk of world population, as projected in the future, would occur in the developing world. Agenda 21, Chapter 17, suggests that up to three-quarters of the world's population could be living within 60 km of the shoreline by the Year 2020. World Bank experts suggest that two-thirds of the population of developing countries (3.7 billion) is expected to be living along the coast by the end of this century.

Any evaluation of such action will need to consider the evolution of energy policy and planning in the developing countries. Any energy transition and major efficiency measure will require major resource transfers to deflect existing policy paths towards more environmentally acceptable options.

Emphasis on No-Regrets Policies:

A climate of solidarity will pave the way for the bringing in of no-regrets policy measures like energy conservation. Energy pricing may eventually play an important role in containing and reducing the problem.

"Recent World Bank studies show that getting energy prices right makes good economic as well as environmental sense.." (B. Larsen and A. Shah, Proceedings of the Tsukuba Workshop of IPCC WG III, p 34)

Avoidance of Environmental Colonialism:

It is also important that any resource transfers effected in connection with Joint Implementation measures are not accompanied by a novel attitude of environmental colonialism.

Avoidance of Distortion of Existing Aid Arrangements:

The transfers associated with Joint Implementation in developing countries should not displace existing aid arrangements which, in the normal order of things, are helping to shape social and economic policies and move countries out of the survival stage. They should be seen clearly as an *additionality*, arising ,

"from the mutual desire on the part of two equal partners to come to some agreement" (T. Jones, OECD, Proceedings of the Tsukuba Workshop of IPCC WG III, P 212)

and without any sense of gift. In the same above - mentioned paper, Jones also speaks of the risks of *cream-skimming* by the developed country partner, who would "pick off" the cheapest abatement option, leaving the developing countries to pay a higher price later on when they begin to abate themselves.

Emphasis on Energy Efficient Technologies:

It is essential that the significant development paths of the developing countries be steered towards more sustainable practices than presently possible with inefficient technology.

The developing countries should be given the opportunity to leapfrog into more energy efficient technologies, as a fundamental ingredient in the process of economic development (Goldemberg, Jose in *The Regions and Global Warming*, ed by Schmandt and Clarkson, 1992, Oxford University Press, P 235).

If this is properly conducted, the growth and further development of the developing countries will become less of a threat to the future stabilization of the atmospheric composition. The technical and financial resources must come from the developed countries.

Larsen and Shah, "Energy Pricing and Taxation Options for Combatting the Greenhouse Effect", Proceedings of the Tsukuba Workshop of IPCC WG III, 1994

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"A rise in sealevel would (i) inundate and displace wetlands and lowlands, (ii) erode shorelines, (iii) exacerbate coastal storm flooding, (iv) increase the salinity of estuaries and threaten freshwater aquifers and otherwise impair water quality, (v) alter tidal ranges in rivers and bays, (vi) alter sediment deposition patterns, and (vii) decrease the amount of light reaching ocean bottoms" (P 6-1 IPCC Impacts Assessment Report , 1990).

Such areas are furthermore currently exacerbated by population growth, competition for resources, including freshwater, land and human capability resources, degradation of the environment, problems of governance, food security, health care as well as mitigation of disasters often caused by unfavourable weather conditions and made more difficult on account of poor infrastructure.

Taking into consideration *on the one hand* the vulnerability, smallness and weakness of the economies involved and the lack of involvement in the cumulation of processes which have led the world to this quasi-irreversible situation, and, *on the other hand*, the disproportionate burden of the potential impacts of Global Warming on these areas, it is obvious that there are strong equity considerations that arise in the management of information, let alone the sharing of responsibilities over this new phenomenon affecting the world.

We shall go a bit deeper into the predicament of Small Islands and Other Coastal Areas in the next Section.

Predicament of Small Islands States and Other Vulnerable Coastal Areas:

The needs and aspirations of human beings in small island states, and other vulnerable developing Coastal Areas - including responsibilities to future generations - are no different from those of the larger developed countries. They all aspire to food security, a home that would provide shelter from vagrancies of the weather and other importunities, job satisfaction, a higher level of economic development, leisure as well as a sustainable future for their offspring.

Specificities

The specificities of these areas are such that the problems being faced in the pursuit of sustainable development are already complex and are being increasingly compounded under the prospects of climate change and sealevel rise.

So far as our islands are concerned, smallness of size is also magnified by the fact that many of the Island States are not made up of single islands, but of several small islands, sometimes a considerable distance apart.

The islands are generally characterised by a narrow resource base, excessive dependence towards international trade and hence excessive vulnerability in respect of external markets; distance to market problems, including high costs of freight; population density which increases pressure upon land for housing and other productive activities.

With the current problems of overpopulation and multiple use of resources, freshwater resources are already available below sustainable limits. Changed temperature and rainfall patterns as well as higher evapotranspiration would reduce the amount available for recharge, resulting in even more marginal conditions for sustainable development.

Agriculture would be another of these areas of complex impact. The 1990 IPCC Impacts Report had the following to state in respect of sugarcane:

"A probable area of impact in the Tropics will be on sugar production, reducing further the value of the sugar cane crop in tropical countries relative to the success of sugar beet (C3) in the temperate zone..."

More carbon dioxide, higher temperatures, the seasonal distribution of rainfall, extremes such as droughts or storms would affect development factors whilst indirect effects would occur through reduced land availability and hydrological resources. Such factors would shift spatial patterns in the long run and affect competitiveness.

The subject areas we are dealing with are also no different from their Northern counterparts in that there is major infrastructure along the Coastal areas in the form of ports, urban development, Coastal roads, tourist resorts. Such infrastructure is however of much lower specification than their Northern counterpart and is also badly maintained. They will be increasingly under risk, requiring increased rehabilitation costs after every storm.

The capacity of small islands and their economies to absorb the impacts of irreversible events is *much smaller* than in the case of larger areas.

Neither have lowlying developing states like Bangla Desh got the capacity to adapt to sealevel rise.

The practical and cost considerations are as follows:

A dilemma facing Majuro Atoll in the Marshall Islands is determining the source of the necessary materials for raising the land surface (The Rising Challenge of the Sea, IPCC, 1992, P16). The next problem is costs: protection in Majuro against a 0.3 m rise in sealevel would cost 1.5 to 3.0 times the present GDP.

The total estimated costs for protecting the Maldives is set at US\$ 1 billion. Maldives has already started evacuating residents from four islands because the resources for protecting all the islands are not there. - and, taking into consideration the likelihood of impending threat, proactive measures should be considered as of now, but the incremental costs of many adaptive measures are beyond the capacity of most of the developing nations - as is starkly evident in the other additional burdens falling upon these nations.

In the light of the above, the added prospects of loss of land and greater vulnerability through climate change and sea level rise are of *very grave concern* to the small islands and other lowlying areas *already constrained* by limited development perspectives.

The above review brings us to the further consideration of equity issues:

The strong economies have commanded the most articulate voice in the previous IPCC process and they obviously still do in the current process, the developing countries, specially the island nation ones being confronted by problems of capacity building of their own.

Island issues have been generally brushed aside in the IPCC Working Papers. Were it not for the immediacy of the problems of the atoll islands, in respect of which the Maldives and the South Pacific islands have taken the initiative to mobilise international interest, perhaps there would have been no coverage of islands at all, except for some passing references to Fiji, well documented upon by Nunn, (1988).

Is there a trend towards Management of Information? A carefully worded Report intended for the US Congress in March 1990 promoted the idea that,

"Whilst there is general agreement among scientists on the current state of understanding of climate processes and on the degree of reliability of current models for projecting climate change, there is less agreement on whether current information, with its uncertainties, can and ought to be used as a basis for policy" (Morrison R, CRS Report for Congress - Global Change and the Greenhouse Effect: Prediction and Uncertainties, March 1990).

It is noted that whilst the Report spells out

"confidence in the direction of sealevel rise as well as the generally greater risks for poor countries, which largely depend on natural ecosystems and lack resources to insulate themselves from climatic shifts, than for wealthy nations,"

there is no mention in the Report of the problems of survival of either small island nations or deltaic states and the differential impacts that the Global Change poses. Is this a careful omission ?

Inequities in Costing Climate Change:

Numerous attempts have been made in the recent past to quantify the impacts of climate change as a basis for calculating optimal policy responses and some such attempts suggest that the costs may be rather modest and insufficient to justify such abatement effort at present.

Michael Grubb (The Costs of Climate Change: Critical Elements, Paper to the IIASA Conference on the Impacts, Costs, and Possible Benefits of Measures to Limit Climate Change, IIASA, Laxenberg, October 1992) has rightly pointed out that such estimates suffer from important limitations because they do not *inter alia* make valid extrapolations from industrialized to developed countries and ignore the possibility of major and costly surprises arising from the sheer complexity of the system.

Most studies estimate the costs of climate change as one percent of GDP, but this figure was extrapolated from studies based on the robust economy of the US, where much of the economy is not vulnerable to climate change.

It is evident that the equity and social issues raised here would relate not only to the present populations, but also to the unborn generations of the areas we are discussing.

Issues and Recommendations:

A highlight of the major issues and recommendations which emanate from this review would be as follows:

Low Priority on the Agenda

Whilst Small island nations and lowlying deltaic states in the developing world have more to lose from climate change than thmost of the rest of the world, such issues are clouded by other problems of immediate survival, such as poverty, hunger, governance, disease as well as economic development. Moreover, they are not in a position to finance adaptation measures. The specific dilemma of these vulnerable areas and the financing of response strategies do not seem to feature as a high priority on the Agenda for implementation.

Scope for Redress:

Action to mitigate the impacts on the areas subject of my talk would comprise measures to reduce the concentration of GHG emissions on the one hand and on the other hand, financial resources to provide adaptive measures.

The Menu of Instruments:

A host of policy instruments, *economic, regulatory as well as other programmes*, are being debated, with respect to their feasibility and cost effectiveness. Numerous complex issues are arising, such as free riding, leakages, tax incidence, timespan. It is important that the debates be not overstretched beyond the intention of the original policy i.e. to reduce emissions in the most cost efficient and equitable manner.

The question of who should pay for reducing emissions is a separate one from questions of what type of reductions are most urgent and where they can be readily and most inexpensively implemented. Most cost-effective measures to reduce greenhouse gas emissions will be in developing countries, in part, because income constraints have often resulted in relatively inefficient process being used (Ali M. Azimi, Proceedings of the Tsukuba Workshop of IPCC WG III, Jan 1994, p 319).

Need for International Cooperation:

There is no escaping from the conclusion that if the world is to reduce Greenhouse Gas emissions, developing countries must all be active participants in the process and to that end, a climate of solidarity *based on social and economic considerations* as well as *differentiated responsibility for priority action*, with developed countries taking the active lead, with concrete initiatives.

Developing countries need to be won to that cause. Although they also stand to be losers if they do not comply, they perceive, *and rightly so*, their immediate survival problems to be their immediate priority and that the GHG problem has to be resolved by the Nations that were responsible for it.

Resource Transfers:

Action by developing countries will require transfer of technology and financial resources from developed countries as provided for by the Framework Convention.

Conclusions:

International cooperation to address climate change in a fair, equitable and cost-effective manner is essential. We live today in a threatened world.

The increased concentration of Greenhouse Gases in the atmosphere is the legacy of the industrialized nations, in their quest for aggressive industrial development.

Certain areas, like Small Island States and other low-lying areas are coming under immediate threat, but the issues of such areas do not feature as a priority on the Agenda.

There should be greater commitment to remedial action from the industrialized countries, in keeping with the wording as well as spirit of the Framework Convention on Climate Change, in terms of both financial and technology transfers.

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Overview

Those who signed the Framework Convention for Climate Change moved for the ultimate environmental goal within a context not only of economic efficiency, but also social equity, a clear priority being

"to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner"(Article 2 of the Framework Convention on Climate Change, United Nations, 1992).

The latter can only occur if certain standards of equity are respected, specially as regards those nations least able to help themselves and least responsible for the root source of the problem, itself an economic development process which has widened considerably the developmental gap between the the developed and the developing world.

Those standards are well spelt out in the Convention, which acknowledges that

"the largest share of historical and current global emissions of greenhouse gases originated in developed countries,"

and calls for the widest possible cooperation, precautionary principles, intergenerational fairness as well as cost effectiveness, without any disguised restriction on international trade and within a context of differentiated responsibilities with developed countries taking the lead.

Furthermore, Principle 3 spells out that,

"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."

The inadequacy of the response to date to the social equity objectives spelled out, two years back now, speaks eloquently of the need to *reactivate the debate*. I shall illustrate my point from the example of the Small Island Developing States and the lowlying developing deltaic States.

Our Subject Areas

The Small Islands States of the world comprise over seventy states of vibrant communities of various cultural origin that operate at varying levels of economic performance. By reason of their size and their activities, their entire geographical areas are considered as Coastal Zones.

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yield (Pareto) efficient outcomes, under appropriate conditions (perfect competition, no externalities, etc.). The distributions of income which they yield, however, have no special merit; that is, they do not, in general, maximize any particular social welfare function. It is a well recognized function of government to intervene in the distribution of income, e.g. by establishing programs for the very poor. By the same token, the intertemporal distribution of welfare that emerges from the market will not, in general, maximize any particular social welfare function discussed in the preceding section. While it is a legitimate function of government to intervene to change the intergenerational distribution of welfare, there is no presumption that the government has in fact intervened so that the observed resource allocations are those that maximize intertemporal social welfare.

In general, the market rate of interest--the relative price of consumption of one generation in one year of its life to consumption in another year--has nothing to do with the SRTTP. In standard life cycle models, even with no technological progress and an economy in steady state, there would be no discounting for society's purposes. Nonetheless, the market rate of interest will be positive in any efficient equilibrium under certain reasonable assumptions about utility functions (such as individual impatience and zero bequest motive; Diamond, 1965). In such models the market rate of interest would thus always overestimate the SRTTP.

Under some special conditions, with governments intervening with non-distortionary taxation to optimally redistribute income across generations, then observed market rates of interest will accord with the SRTTP. But these are highly specialized conditions. (See Stiglitz, 1985, Pestean, 1972))

Some economists have argued that a zero or very low pure time preference is "lower than would be consistent with observed real interest rates" (Nordhaus, 1992b); and that such a low rate of time preference would imply that society is seriously underinvesting (Nordhaus 1993). This analysis is based on the premise that there should be a close relationship between observed market rates of interest and SRTTP, a conclusion which is valid, as we have seen, only under highly restrictive conditions. Moreover, real returns on treasury bills in the United States--the closest approximation to a risk-free rate of return available to consumers--has averaged only .3% over the past 60 years. As for the underinvestment argument, it would seem inappropriate to counsel against action in the area of global warming policy just because there are other areas in which additional social investment also might be worthwhile undertaking (Cline, 1992).

weak
argument

3.4 Producer or Consumer Interest Rates?

There is a large literature which has debated whether, for small changes in consumption levels, observed rates of interest provide

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replace with interest
Section 3.4

Chapter 3

Discounting,
1 *Intertemporal Equity and Discounting Economic Efficiency*
questioned

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3.1 Introduction

This chapter concerns the methodology for comparing effects at different points in time, and especially establishing trade-offs across different generations. How we think of these trade-offs involves issues of intertemporal equity. This issue is a matter of philosophy (and for some, religion and morals) because it involves reaching judgements about what is fair or just. The issue is also a matter of economics, because comparisons across time are appropriately judged in the light of changing standards of living over time as well as opportunities for productive investment.

3.1.1 Importance of the Discount Rate

The discount rate is the analytical tool economists use to compare economic effects that occur at different points in time. Identifying the proper discount rate is probably the single most important analytical step in economic analysis of global warming. It is also the most profound ethical question, since it inherently confronts present pain of abatement cost against damages suffered by future generations if no action is taken.

The issue of choosing an appropriate discount rate has been discussed in the context of general cost-benefit analysis (chapter 5) for many years (Dasgupta et al. 1972, Harberger 1976, Little and Mirrlees, 1974, Sen 1967, Stiglitz 1982). 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).

The emission of carbon dioxide causes effects likely to persist on a time scale of centuries. IPCC (1990a) estimates that the first half-life of CO_2 is 50 years and the second half-life another 250 years (with the decline to $1/e$ taking 120 years). In the absence of policy intervention carbon dioxide concentrations could continue to rise for the next 300 years, given current fossil fuel resources (Sundquist, 1990). Global warming thus poses unusual problems for economic analysis, which more typically considers issues with time scales of only a few decades at most.

The usual formulation for discounting over time involves exponential growth of the discount (or value-shrinkage) factor. Thus, one unit of consumption that arrives t years from today is equivalent to the fraction $1/(1+i)^t$ of one unit of consumption



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Dear Colleague:

We realize that you requested a copy of all chapters of the Working Group III Second Assessment Report. However, Chapter 2: *Decision Making Framework to Address Climate Change* and Chapter 5: *Applicability of Benefit Cost Analysis to Climate Change* have ~~not~~ been received to date. We have been assured that these chapters will be arriving within a day or so, and we will forward copies to you immediately.

Our sincere apologies for any inconvenience that this unfortunate delay may have caused.

Sincerely yours,

Erik F. Haites

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Re: Review of the Draft Chapters of Second Assessment Report

You are invited to review the enclosed draft chapter(s) of the Working Group III Second Assessment Report. If you wish to offer comments on the draft chapter(s), please read the attached information carefully.

THE DEADLINE FOR RECEIPT OF COMMENTS IS NOVEMBER 25, 1994.

The function of the IPCC is to produce "reports on the assessment of available scientific information on climate change.. written in such a way as to address the needed of policy-makers and non-specialists". All IPCC reports are subject to both peer and government review before they are published.

It is important that social and economic issues related to global warming, including those of particular concern in developing countries, be adequately addressed in the WG III report. If the body of published work from the industrialized countries is the only one thoroughly covered in our assessment, we would fail to present a truly global picture.

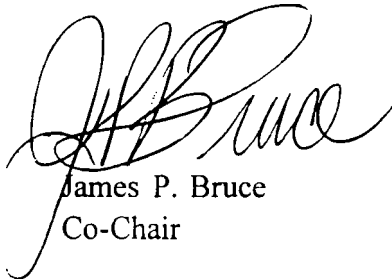
As part of your review, please ensure that key issues of importance to both developed and developing countries are adequately addressed. These issues include:

- recognition of the regional social, environmental, and economic benefits of existing eco-systems and ways of life that are threatened by climate change and sea level rise.
- the disproportionate burden borne in developing regions of the potential impacts of global warming and costs of adaptation. This is evident in the case of climatically related natural disasters, and in agriculture, water resources, tourism, and other economic sectors.
- the uneven distribution of proportional costs of climate change mitigation measures.

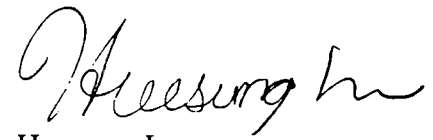
In early September, the lead authors restructured the report. A revised list of chapters is attached. The enclosed chapter(s) should cover the topics of most interest to you. If you want to review additional chapters, please contact the Working Group III Technical Support Unit at the above address.

If you would like a copy of the Working Group III Work Plan to provide a context for your review, please contact the Technical Support Unit.

Sincerely yours,



James P. Bruce
Co-Chair



Hoesung Lee
Co-Chair

Information for Reviewers of the draft chapters of the Working Group III Second Assessment Report

Role of IPCC Assessments

The function of the IPCC is to produce "reports on the assessment of available scientific information on climate change...written in such a way as to address the needs of policy-makers and non-specialists".

IPCC reports consist of two components:

- a Summary for Policy Makers which focuses on those key issues which, on the basis of current scientific understanding, IPCC believes should be addressed in the political arena; and
- a Chapter which critically examines and summarizes available scientific and technical information relating to research and understanding of the subject. While it should avoid complexity wherever feasible, and should not attempt to be a scientific 'text book', this document must allow assertions and conclusions appearing in the Summary for Policymakers to be traced back to the international scientific literature.

The IPCC Review Process

The peer and government review processes are very important steps in the adoption of every IPCC report. You, the reviewer, are being asked to play an important and active part in the evolution of the final version of this document. Please review the draft report and identify parts of the draft text that you believe are particularly good or that do not accurately represent the scientific and technical literature.

Review comments which express agreement with draft text, particularly where the issue is a complicated or sensitive one, are positively encouraged. This helps to avoid the danger of important text, which may be widely but silently accepted by most reviewers, being adversely altered in response to one or two critical comments. Reviewers are also asked to suggest, wherever possible, a few critical comments. Reviewers are also asked to suggest, wherever possible, *solutions* to errors they find rather than simply flagging them.

All comments submitted by reviewers are logged by the WG III Technical Support Unit before being passed (without identifying the reviewer) to the lead authors for assimilation in to the draft report. Final disposition of review comments is the

responsibility of the lead authors in consultation with the Working Group III Bureau. In recognition of the important part played by reviewers their names will be listed in an appendix to the final, published report.

Nature of this Draft

This draft is circulated for scientific review. *Reviewers are asked to concern themselves only with the specific aspects of the draft, and not with typographic, spelling or purely editorial matters.* Editorial work to unify style and correct typographical and other text-related errors will come at a later stage in the process.

Timetable

In general, it greatly helps the whole process if review comments are submitted as soon as possible.

The last date for receipt of review comments is **Friday, November 25.**

Submission of review comments

Enclosed with this letter is a pro forma 'Cover sheet for review comments'. Please use this as a master copy for photocopying. It will greatly ease the handling of your review comments both by the Technical Support Unit and by the lead authors if you use separate cover sheets for comments relating to different parts of the chapter(s).

All review comments should be sent to:

Erik Haites
IPCC WG III Technical Support Unit
145 King Street West, Suite 1002
Toronto, Ontario M5H 3X6
CANADA

After logging each submission, the TSU will pass comments directly to the lead authors. To avoid confusion, please do **NOT** send a copy of your comments to the lead authors.

IPCC WGIII Second Assessment Report

Cover sheet for review comments

Reference no

(to be inserted by WGI Technical Support Unit)

Part I. Reviewer

Name	Affiliation (country or organization)
------	---------------------------------------

Part II. Comment (use one cover sheet per substantive comment)

Summary of substance of comment (preferably no more than one sentence)	Date of draft:
	Chapter:
	Section:
	Line nos:
Number of pages attached to this cover sheet:	

Part III. This space is for use by WGIII Technical Support Unit

Action taken by WGIII TSU	Date Received:
	Handled by:
Action taken by Lead Authors	
Additional comments	

**WORKING GROUP III
SECOND ASSESSMENT REPORT
PROPOSED REPORT STRUCTURE**

Summary For Policy Makers

1. Scope of the Assessment
2. Decision Making Framework to Address Climate Change
3. Equity and Social Considerations
4. Intertemporal Equity and Discounting
5. Applicability of Benefit Cost Analysis to Climate Change
6. The Social Costs of Climate Change: Greenhouse Damage and the Benefits of Control
7. A Generic Assessment of Response Options
8. Key Determinants of Abatement Costs
9. Estimates of Abatement Costs
10. An Assessment of Greenhouse Policy Instruments
11. Evaluation of the IPCC IS92 Emissions Scenarios*

* Not being circulated for review at this time.

Influence of Extreme Events

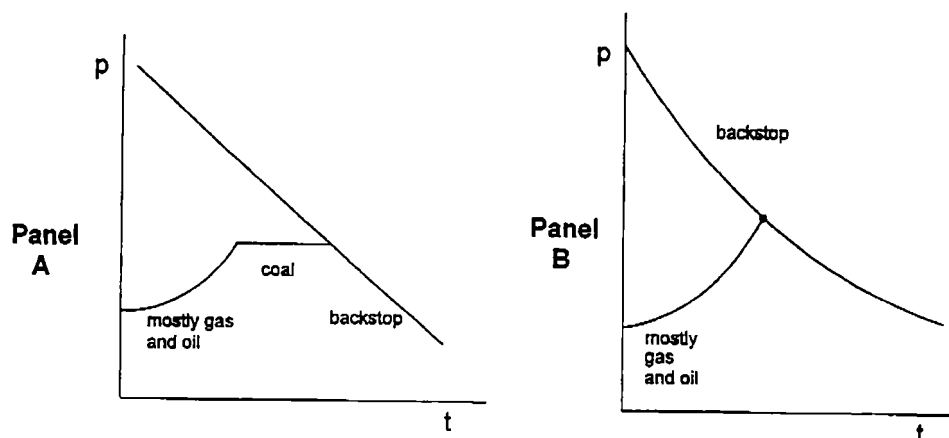
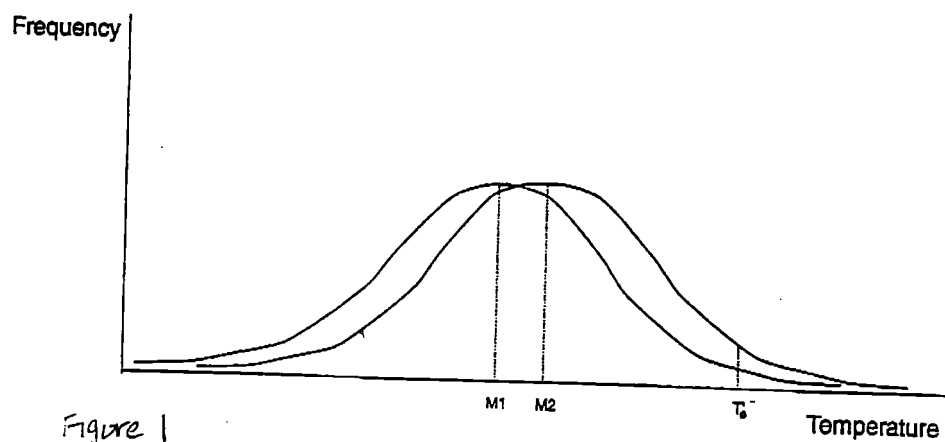
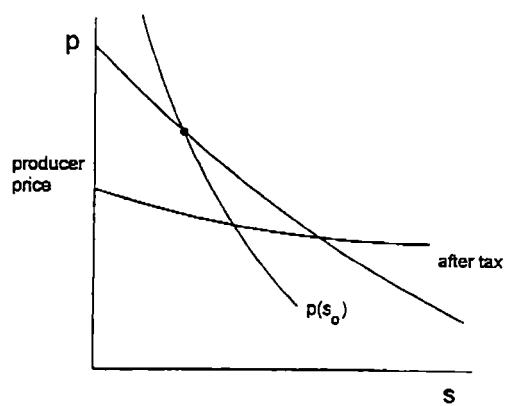


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1.1 INTRODUCTION

In recent years, atmospheric emissions of greenhouse gases have risen significantly. Concentrations are currently about 25 percent greater than at the beginning of the Industrial Revolution. If current trends continue, concentrations will double from pre-industrial levels by the end of the next century and, if unchecked, continue to rise thereafter.

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

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

Climate change impacts are likely to vary dramatically from country to country. A rising sea level might threaten some small island states. Countries with large coastal cities such as Brazil or Bangladesh will face higher adjustment costs than landlocked countries such as Bolivia or Bhutan. Changes in ocean currents could lead to the cooling of some regions (such as northern Europe and Newfoundland), even as other areas face warming. A warmer climate is likely to mean less rain in some areas, at the same time that other areas face a greater threat from floods. A warmer climate might also mean greater temperature differences, which could increase the number and intensity of storms¹. Further, an increase in extreme events could increase the social consequences of climate change; for example, an increase in the number of days of extreme heat would disproportionately influence agricultural yields.

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

The commitment of resources to mitigate climate change may rest on one of two arguments:

1. We have only one planet. Some changes are largely irreversible, and may occur rapidly. Prudence calls for avoiding a large-scale experiment with the planet. Thus, avoiding climate change lies beyond normal economic calculus, on the plane of a fundamental value.

Even if this view is adopted, economics has much to contribute to the discussion, for we still must address the question of how to cost-effectively reduce emissions and preserve the atmosphere.

2. The potential exists for large, sudden, irreversible non-linearities with major effects on the economy, particularly the economy of certain countries or regions.

If this view is adopted, economics will likewise be required.

This chapter, and others in this Assessment Report, makes use of the findings of Working Groups I and II, and is conducted within the context of the Framework Convention. That Convention makes clear that there

remain important open questions that will have to be addressed by subsequent negotiations, such as the adequacy of national commitments. At the same time, this chapter takes the Framework convention as a political document, recognizing that particular terms of the agreements reached by international negotiation may or may not accord with accepted scientific research; that for instance, the agreements may or may not have provided the basis of a cost-effective approach to mitigating climate change. It is hoped that the findings of this chapter and the assessment report more broadly will enhance an understanding of the costs and consequences of alternative actions, and will provide the scientific basis for ongoing negotiations.

1.2 FEATURES OF CLIMATE CHANGE

Climate change could impose a variety of impacts on society. IPCC Working Group II analyses these impacts in detail. They include effects on agriculture², forests³, water resources⁴, the costs of heating and cooling⁵, the impact of a rising sea level rise on low-lying coastal areas⁶, and a possible increase in storm damage. Although most attention to date has focused on negative impacts, some impacts will be positive. Beyond these tangible impacts are a variety of intangible impacts⁷, including damages to existing ecosystems and the threat of species losses⁸.

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

Large uncertainties. While scientists agree that greenhouse gas emissions are rising, they do not agree about the mechanism linking concentrations, temperature, and well-being. Further, although scientists agree that some warming will occur, they do not agree on the speed of change, or the ultimate amount of change (IPCC 1992, 1994). In addition to these uncertainties, social scientists do not agree on the size of behavioral responses to climate change policies.

Nonlinearities and irreversibilities. Nonlinearities occur when changes in one variable cause a more than proportionate impact on another variable. For example, some have suggested that even a modest increase in atmospheric greenhouse gas concentrations could, beyond a certain point, trigger a substantial increase in temperature. Alternatively, even a modest increase in average temperature might significantly increase weather-related agricultural losses because, for many crops, extra days of extreme heat severely limit yields. In Figure 1, if the threshold temperature for crop damage is T_m , then even a small increase in the mean temperature, from $m1$ to $m2$, may greatly increase the number of days above the threshold, represented by the area under the curves to the right of T_m . Irreversibilities are changes that once set in motion cannot be reversed, at least on human time scales. "Runaway warming" that some have hypothesized is an example. Some oceanographers have expressed concern that warming might disrupt the deep cold-water current of the North Atlantic Conveyor, responsible for much of the oceans' carbon uptake. Once disrupted, this current might not revert to its original position for centuries¹⁰.

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

Slow pace of change. Every country has made large capital investments in its cities, farms, ports, etc. Some of this investment cannot be changed without large costs: low-lying port cities, for example, cannot be rebuilt without substantial additional costs. For other investments, the cost of change will be small; the cost of switching from one annual crop to another will be small if the temperature increase is on the order of 0.2°C to 0.3°C per decade, as climate scientists now expect (IPCC 1994).

Time lags. Atmospheric concentrations, rather than emissions, determine the amount of warming that occurs. Concentrations change much more slowly than emissions, meaning that affected nations might not have enough time to prevent warming damage or to mitigate economic impacts after the effects of climate change become evident. The combination of time lags in the climate system and uncertainty about effects requires taking action before unambiguous information emerges about timing and magnitude of climate effects.

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

Regional variation. Impacts are likely to vary greatly both within and among countries. Some countries and regions will suffer from warming; others will benefit. Some cold countries will benefit from a reduction in heating costs and an increase in the length of growing seasons; some warm countries will see a drop in yields from agriculture and forestry. For the world as a whole, the net effect at any time will be the sum of local effects at many points on the globe, some positive and some negative; analysts have no simple way to estimate this sum.

Multiple gases of interest. Increases in radiative forcing (heat trapping ability) depend on the concentration of all greenhouse gases, not just CO₂, even though most economic modeling to date has limited itself to CO₂. Because different greenhouse gases have different atmospheric lifetimes, analysts have devised weighting schemes to make different gases commensurate¹¹.

Importance of net emissions. Because greenhouse gas concentrations depend on net rather than gross emissions, changes in forests and other carbon sinks must be taken into account¹².

On a priori grounds, there is no reason to believe that greenhouse warming should have in the aggregate, either positive or negative effects. Indeed, studies twenty years ago suggested that global cooling rather than warming might have a negative effect. It seems unlikely that the earth is somehow endowed at this moment with the optimal temperature. Nonetheless, global warming would certainly result at least in short-run adjustment costs.

1.3 CONTRIBUTION OF ECONOMICS

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

Going beyond this fundamental idea is a large body of work, originally done in other areas of economics, that may be applied directly to the study of climate change; this includes work on risk, dynamics, sequential decision making, public goods and externalities, taxation, and general equilibrium.

1.3.1 Risk

The uncertainties associated with climate change are large. In the past thirty years, much new economic research has focused on rational responses to risk, including three areas important to an understanding of climate change:

1.3.1.1 Portfolio Theory

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

Numerous policy measures are available to reduce risks to future generations from climate change. Four have dominated discussions in recent years: 1) immediate reductions in emissions to slow climate change; 2) R&D on new supply and conservation technology to reduce future abatement costs; 3) continued research to reduce uncertainties about how much change will occur and what effects it will have; and 4) investments in actions to assist human and natural systems to adapt to climate change if it occurs. Other choices include agreements for one country to fund emissions reductions in another country (joint implementation), technology transfer and other forms of international cooperation; and phasing out existing policies, such as subsidies to fossil fuels, that reduce welfare and directly or indirectly increase greenhouse gas emissions.

A well-chosen portfolio of climate change investments will yield greater utility to society for a given cost than any one option undertaken by itself. At issue is how to choose the portfolio of policy measures best suited to

Risk and Uncertainty

Uncertainty arises when a decision can lead to more than one outcome.

Expected return or expected value of a decision is the amount an observer would expect to receive as a consequence of a decision, often expressed in monetary terms.

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

Risk premium is the increase in expected value required to compensate a person for assuming a given risk.

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

each country's circumstances, and to adjust the portfolio over time in response to new developments.

Governments will be making climate change decisions for most of the next century. This means that they will have many opportunities to adjust the size (total resources) and mix (choice of measures) of their portfolio of responses.

1.3.1.2 Insurance

One item in the portfolio of possible responses is insurance. Several concepts bear critically on insurance as it applies to climate change: risk aversion, risk premium, and certainty equivalent.

That individuals and societies are *risk averse* means that they are willing to pay something to reduce the risks they face. If society as a whole is risk averse, some investments -- for example, in climate change mitigation -- with a negative expected return should be undertaken if they reduce the probability of a loss, or the costs of adaptation.

The magnitude of those expenditures depends on (a) society's degree of risk aversion; and (b) the magnitude of the risk. Thus, the *risk premium*--the extra amount that society is willing to pay to reduce a risk--is small if the stakes (say, the maximum loss) are small. An investment of a dollar is justified if it reduces the loss of expected utility by more than a dollar, and not if it reduces the loss by less than a dollar. Thus, results reported below focusing on the expected loss of GDP from climate change do not directly address the risk premium issue. If, for some society, there is a potential loss of 10%, even though the average loss is 3%, then the *certainty equivalent* loss will exceed 3%. A dollar investment that reduces this certainty equivalent loss by more than a dollar should be undertaken; such an investment could either reduce the average loss, e.g. by reducing the probability of the loss occurring (through mitigation actions) or reduce the variance of the loss. For example, some actions the reduce extreme losses will have more than proportionate returns.

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

One consequence of this analysis is that the *no-regrets* policy advocated, for instance, during the Bush Administration within the United States, was not an adequate response to the threat of global warming. One wants clearly to undertake all actions which reduce greenhouse gas emissions at zero or negative costs. (Whether, or how many, such actions is discussed later). But a prudent response to the risk of greenhouse gas warming is to go beyond the no-regrets policies to some policies which actually incur net costs.

In the context of climate change, insurance means two things:

Transferring risk, as when a homeowner pays an insurance company to assume the risk of fire damage; and

Actively responding, as when a business takes steps to reduce the probability of a fire, burglary, or other adverse outcome.

1.3.1.3 Active response

A business takes actions against particular risks to reduce the total risk of its portfolio. As described in the

discussion on portfolio theory, active responses to climate change can take four forms: 1) immediate reductions in emissions; 2) R&D to reduce uncertainty about the timing and consequences of climate change; 3) R&D on new supply and conservation technology; and 4) investments in actions to facilitate adaptation to climate change if it occurs. Several researchers have independently confirmed the value of successful R&D on carbon-free energy sources¹¹; others have confirmed the value of R&D on other uncertainties that will be important in climate change decisions.

1.3.1.4 Transferring Risk

Insurance markets, for the most part, do not reduce overall risk¹⁴, but rather transfer risks from those who are less able to bear the risk to those who are more able to bear the risk, and by spreading the risk among a large number of individuals, reduce the aggregate impact of the risk. The large differences in regional impacts noted earlier suggest the potential for an insurance market. This holds, irrespective of who pays the cost, because wealthier individuals and countries are better able to bear risk¹⁵, and because many countries likely to be most adversely affected will be developing countries of the South, while many of the countries least affected (or positively affected) will be the industrialized countries of the North, who could provide insurance for effects of climate change that might fall harder on the South.

Losses associated with climate change are likely to be both correlated and large, compared to losses absorbed in a single year by the commercial insurance industry. The long term nature of climate change insurance also raises the problem of contract enforcement: will contracts signed today be enforceable tomorrow? Will the insurers be around to pay claims 50 or 100 years from now? (Even in the industrialized countries, private markets may be inadequate to insure against losses from a major national disaster today.) These considerations suggest that private markets may not be able to provide insurance against climate change, and argue for international action to establish insurance markets, perhaps with government reinsurance. Should such an insurance market be established, careful attention will have to be given to ensuring that the insured parties engage in appropriate adaptation actions, mitigating the losses that might be associated with any greenhouse gas warming.¹⁶

1.3.2 Dynamics

The problem of greenhouse gas warming involves additions to concentrations resulting from net emissions over extended periods of time. Inherently, the analysis must focus on issues of dynamics. Dynamic analysis involves three stages: the dynamic processes involved, the trade-offs, and judgments concerning those trade-offs.

Dynamic analyses have lead to important insights. For example, atmospheric concentrations and therefore temperatures depend on the total amount of greenhouse gases emitted over a period of years. A given concentration target can be achieved by a variety of emissions time paths. Time paths that provide for the economical turnover of existing capital stock and time to develop low-cost substitutes will be less costly. This suggests large potential gains from flexibility in timing of emission reductions¹⁷.

1.3.2.1 Kaya Identity

The driving forces in carbon dioxide emissions can be seen in the following identity (Kaya 1989):

CO ₂	=	CO ₂ /E	E/Q	Q/L	L
carbon dioxide		carbon dioxide	energy	output	population
emissions		emissions per	per unit per		
		unit energy	output	capita	

or, expressed in rates of change:

$$d \ln CO_2/dt = d \ln CO_2/E /dt + d \ln E/Q /dt + d \ln Q/L /dt + d \ln L /dt$$

that is, the percentage rate of change in carbon dioxide emissions is equal to the rate of change in carbon dioxide emissions per unit energy plus the rate of change in energy requirements per unit output plus the rate of change in output per capita plus the rate of change in population¹⁸.

This identity clarifies different approaches to reducing emissions. For a developed country with a stable population, as long as increases in emissions/output efficiency (emissions per unit energy times energy per unit (GDP) keep pace with labor productivity, CO₂ emissions will not increase. Because of the substantial potential for energy efficiency improvements, this seems feasible for most developed countries. Many opportunities exist for increasing end-use efficiency, represented by the first term on the right-hand side, for example from cars to public transportation, from less to more fuel efficient cars and homes. Fuel switching (for example, from coal-based electricity to oil, gas, hydroelectric, wind, and geothermal), represented by the second term, also offers the potential to limit CO₂ emissions in many countries.

On the other hand, population increases will boost emissions, unless per capita output drops or energy efficiency increases in an offsetting way. For many developing countries with rapidly growing populations pressures for economic development will make it difficult to direct capital to greenhouse mitigation.

Developed countries and developing countries are following different paths. Though developed countries (including Annex II countries) contribute more than half of total world greenhouse gas emissions today, developing country emissions are growing much faster. Without some means of controlling developing countries' greenhouse gas emissions, world emissions cannot be controlled (Manne and Richels 1992).

On two essential issues evidence is currently limited: (a) to what extent will improvements in energy efficiency require net increases in investment beyond the resources saved from reduced energy usage, i.e., to what extent is there a trade-off between growth and emissions reduction? Order-of-magnitude calculations suggest the presence of only limited trade offs, at least for the near term; (b) do the developing countries have the institutional capacity to achieve the desired increases in emissions efficiency?

1.3.2.2 Non-renewable resources, backstop technologies, and emission reduction strategies.

Though in principle the atmosphere is a renewable natural resource, the longevity of the greenhouse gases and the relationships between stocks and flows mean that for practical purposes, it may be better treated as an exhaustible natural resource, but one where welfare depends not just on the flow out of the stock, but on the stock itself¹⁹.

The central problem with natural resources, whether renewable or not, is *timing*. Renewable natural resources such as fisheries possess a maximum sustainable rate of exploitation. The harvest cannot long exceed this maximum rate without depleting the stock, and ultimately reducing the harvest. Corresponding to the sustainable flow rate is a steady-state stock. If, initially, the actual stock exceeds the steady-state stock, then, for a while, the flow can exceed the maximum sustainable flow. The question is how to distribute this excess over time. Even when the stock is at the sustainable level, in times of emergency, it may be desirable to exceed the maximum sustainable flow. For a renewable resource, this can be done, though only at the expense of decreased levels of flows in future years²⁰.

Timing of reductions in greenhouse gas emissions should reflect differences in costs, discounting (to evaluate

those costs), and risk. If technological change will make future emissions reductions much less costly, some reductions should be postponed. With high discount rates, the costs borne by future generations will carry less weight. With considerable risk, non-linearities, or irreversibilities, risk aversion suggests a strategy of early mitigation.

The theory of non-renewable resources has a second set of lessons for climate change policy. There are four broad categories of energy sources: coal, gas and oil, biomass and non-carbon sources. Gas and oil are exhaustible natural resources; hence the amount of total emissions from these sources is limited. With exhaustible natural resources, the question is not how much will be consumed, only when²¹.

Figure 2 depicts the development process for an economy, in three phases. In the first phase, the economy relies on non-renewable resources; in the second, on coal; in the third, on backstop technologies-- e.g., biomass combined with non-carbon sources. The switch points depend on rising energy prices and improving technology, which lowers the costs of the backstops. The figure shows alternative long run scenarios. In panel A, the price of the backstop technology falls sufficiently slowly that for a time, the economy relies on coal. In panel B, the price of the backstop technology falls fast enough to eliminate the intervening stage of primary reliance on coal.

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

From this perspective, conservation of gas and oil is an important part of a risk strategy, for it provides insurance against the possibility of delayed arrival of backstop energy sources.²² This, in turn, has important implications for the "leakage" debate, which asks whether, in the event that the North imposes carbon taxes but the South does not, the South's response will largely offset emission reductions made in the North. It is also possible that lower prices for gas and oil will induce China and India to decrease their reliance on coal, thus possibly producing "negative" leakages. But to the extent that occurs, the "insurance" provided by greater conservation of oil and gas is eliminated, and it is this insurance which should be an essential part of the dynamic strategy. If the backstop arrival is delayed, then the earlier fuel switching by China and India will yield no long-run benefits; while if the backstop arrival is early, the whole issue is largely moot. Leakage needs to be looked at not from a static perspective, of what occurs in a single year, but from a dynamic perspective, corresponding to the long run nature of the global climate problem.

1.3.3 Sequential Decision Making

This chapter has treated two of the essential features of global warming, risk and dynamics. In fact, risk and dynamics interact in several ways, with important implications for the design of policy.

First, information will become available over time, both about the nature of the problem and the efficacy of alternative policies. Moreover, economic circumstances will change: the change in the relative price of oil, for example, has a first-order effect on emissions. Thus, *mitigation needs to be viewed as part of a sequential decision making strategy* with periodic revisions in response to additional information; figure 3 illustrates the progression from a single decision to multiple decisions over time²³. Some have interpreted the phrase *sequential decision making* to mean making climate decisions now for the next 100 years. Rather, the goal is to identify short-term strategies in the face of long-term uncertainty. The next several decades will offer

opportunities for learning and mid-course corrections. The relevant question is not, what is the best course for the next 100 years, but rather, what is the best course for the next few years, knowing that a prudent hedging strategy will allow time to learn and change course?

1.3.3.1 Value of information

Better information leads to better decisions. Because of limits to current knowledge and the high cost of being wrong in either direction, the value of better information about climate change is likely to be great. Most studies of the value of information assume that in the absence of better information, an optimal policy under uncertainty will be adopted. In actual practice, however, lack of good information may lead policy makers to extreme policies (such as "do nothing" or "control everything"). If suboptimal policies would be chosen with incomplete information but better policies would be chosen with better information, the value of improved information may be many times higher than estimated using the standard assumptions of optimal decision making under uncertainty²⁴.

1.3.3.2 Option value

The presence of uncertainty along a dynamic path creates an option value, the value to preserving options. In the context of climate change, the term has been used in two different ways. One stresses the irreversibilities of climate change; mitigation expenditures preserve options of avoiding adaptation expenditures. The other stresses irreversibilities in investment, and the costs of premature turnover of capital.

1.3.4 International Public Goods

The atmosphere is an international public good. A pure public good (Samuelson, 1954) is a good with two properties: the marginal cost of an additional individual using the good is zero (*non-rivalry*), and the marginal cost of exclusion--of stopping an individual from enjoying the good--is prohibitive (*non-excludability*).²⁵ The atmosphere shares both characteristics. If the atmosphere is improved as a result of reduced greenhouse gas emissions, then all are affected. If, as a result, global warming is thwarted, all benefit²⁶. The atmosphere is an *international public good* in that atmospheric concentrations are the result of combined actions by all countries.

Different countries will be affected differently, so that the benefits of avoiding greenhouse gas warming will differ from country to country. Further, some actions will affect simultaneously local atmospheric conditions (providing local public goods) and greenhouse concentrations. For example, actions that reduce urban driving improve local air quality and at the same time reduce greenhouse gas emissions²⁷.

1.3.4.1 International externalities

CO₂ emissions can also be viewed as an international externality: actions by one country affect other countries through global warming.

1.3.4.2 Property rights

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

1.3.4.3 Paying For An International Public Good: Principles and Approaches

Once one views mitigation of climate change as a global public good, the issue arises, who should pay for the public good? This is a standard question within public finance, a question that every country faces internally in determining who should pay for the public goods it provides. Who should, for instance, pay for pollution within a country?

Economists generally agree on several principles:

First, *concerns about equity should be separated from concerns about efficiency*, though ultimately they are intertwined. An implication of this principle is that because pollution is a social cost of production (and consumption), everyone should be made to pay the full social costs of the pollution they generate. Thus, if there is a social cost to a unit of emissions of greenhouse gases, that cost is the same no matter who produces the emissions. All should pay the full social costs of their actions, whether rich or poor. In this perspective, corrective (Pigouvian) taxes should be imposed uniformly.

Second, *it is inappropriate to redress all equity issues through climate change initiatives*. While climate change should not aggravate disparities between one region and another, neither does it provide a vehicle to remedy these disparities.

Economists agree less about the framework for deciding the burden of financing mitigation and adaptation. At least three approaches have been proposed to determine how the burdens of taxation should be shared. One approach looks at *benefits*: just as those who benefit from private goods must pay for them, those who benefit from a public good should be made to pay for them. The principle has some force when large differences in preferences exist within any income class; providing a particular public good benefits some of those individuals more than others, creating inequalities in the absence of benefit taxes. A major problem frequently encountered, particularly for pure public goods, is that it may be difficult to determine who benefits. It is in general possible to ascertain the *economic benefits* of mitigation, and these are likely to be quite unequally distributed. But this principle, by itself, does not fully determine who should bear the costs: appropriately designed mitigation strategies will produce a surplus of benefits over costs, which must somehow be divided.

The second approach looks at *ability to pay*. It is often held that richer countries (or individuals) should pay more than poorer ones. But this principle does not answer the question of how much extra should they pay.

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

Public Goods and Externalities

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

Public good: A public good has two properties: the marginal cost of an additional individual using the good is zero, and the marginal cost of exclusion--of stopping an individual from enjoying the good--is prohibitive. Lighthouses are public goods: when lighthouse services are provided to one person, others may enjoy the same services without cost.

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

to the poorer countries, or that the weight of the tax be borne by the richer countries¹⁸.

Yet a different approach holds that social scientists as such have nothing to say about these ethical issues. Coase [1960], for instance, approaches the problem of externalities by emphasizing (a) the importance of assigning property rights, so that, in the absence of bargaining costs, an efficient solution can be obtained¹⁹; and (b) that the outcome is independent of how property rights are assigned²⁰.

A simple approach that yields efficiency but does not require redistribution (and is thus consistent with the two principles enunciated above) entails coordinated tax rates so that all countries face the same energy prices, with each country retaining the revenues thus generated²¹. The net cost of such a tax (ignoring the benefits from reduced greenhouse gas emissions) will, in general, be smaller for poorer countries, as a percentage of their national output: the burden of the tax is progressive, even though the tax is levied at the same rate in all countries²².

Accounting for past damages Some have argued that because the North has been the major contributor to current levels of greenhouse gases, it should bear most of the costs of mitigation. The "polluter pays" principle, as it is sometimes called, says that costs should be borne not in proportion to benefits, but in proportion to contribution to pollution. The general principle that individuals and firms should pay for the full social costs of their actions has been discussed above in the context of economic efficiency. Arguments for the polluter pays principle do not rest on efficiency. However, to promote efficiency incentives must be prospective (forward looking), not retrospective. No incentive effects attach to imposing charges based on *past* actions. Whether to charge nations that contributed CO₂ to the atmosphere is an issue of ethics, not efficiency.

Economists have cautioned that there might not be an ethical basis for the polluter pays principle²³. Were the polluter pays principle to be applied, the developing countries might eventually pay far more of the mitigation costs than under the other principles described earlier. Greenhouse gas concentrations have increased by 25% since the Industrial Revolution. Taking as an end point a doubling from pre-industrial concentrations, most of the increase will occur in the next 75 years; over that time, developing countries will contribute more than half of all greenhouse emissions.

Population Policy Population policy and allowances for differences in population represent one of the most unsettled areas in public finance theory, and the most troubling area for normative approaches to the distribution of the burdens of mitigation. Should, for instance, families with larger families pay lower taxes (at given levels of income)? Current perspectives emphasize family size as a choice and note the congestion externalities associated with increased population²⁴. These perspectives argue that families with many children should face, if anything, higher taxes; this is counterbalanced by a "child-oriented" equity position, concerned that such policies disadvantage children in large families. These issues carry over to the international arena.

One perspective argues that each country should, under a pollution permit scheme, be given the same pollution permits per capita (or that poorer countries should be given more pollution permits per capita.) But critics worry that this would provide inappropriate incentives: since the pollution permits have market value, it encourages an increase in population. Moreover, say critics, the plan is inequitable: population growth is a major source of environmental degradation in general, and such a policy rewards those who do least to get their population under control.

Combining concerns about equity and efficiency may entail a mixed system: pollution permits would be issued on the basis of current population levels, but would not increase with changes in population (or would increase only slightly)²⁵.

1.3.4.4 Enforcement

Both externalities and public goods need a legal framework within which the problems they pose can be addressed. Without compulsory taxation, there is an incentive for each individual to be a free rider, though there is some empirical evidence that the free rider effect may not be as significant as economists have previously assumed (Bohm, experimental evidence). In the absence of compulsory taxation, externalities can only be addressed with well defined property rights (Coase 1990)¹⁶ and a legal system that enforces compensation for externalities.

Though in many areas, great strides have been made in the development of an international rule of law, problems are likely to face any system for enforcing climate change agreements. Several alternatives have been proposed, each raising political or economic concerns. No consensus now exists about the relative desirability of these alternatives, though it is clear that some sort of international judicial process will be required to determine and enforce compliance¹⁷.

1.3.4.5 Knowledge

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

This suggests the need for an international agreement to fund basic research and subsidize applied research, particularly in energy-related technologies for the developing countries. There need not be a central funding agency, nor a central directorate determining which research should be undertaken. But need be some mechanism for sharing information about research undertaken, and for ensuring that the fruits of this research are made freely available.

1.3.5 Efficiency

Analysts agree that any actions responding to climate change should be cost-effective. With some exceptions noted below, issues of efficiency and equity can be separated¹⁸: no matter who bears the cost of emission reductions, reductions should occur where their cost is lowest. Because of the low energy efficiency in many developing countries, many have proposed that the major effort at the emission reductions be concentrated there.

Mechanisms for reducing emissions equitably and efficiently, including joint implementation, tradeable permits, and coordinated tax policies, are discussed below and in chapter * * *. All of these mechanisms, however, attempt to confront all individuals and producers in all countries with the same cost of emissions. Emission control is an international public good: the atmosphere doesn't care which country reduces emissions. Just as efficiency in the production of steel or any other commodity requires that all consumers and producers face the same price, so too with emissions. Uniform prices can be achieved either through coordinated energy taxes or through tradeable permit requirements; but unless the rules are applied in a systematic way to both developed and developing countries, emission reductions will be inefficient.

Partial participation in an international emissions reduction program, however, may actually increase world

emissions. The growth of international trade has resulted in important links between the developed and less developed countries, and the total effects of any policy undertaken in the North can only be evaluated in terms taking into account the systemic responses, including responses from the South, as discussed under "General Equilibrium," below¹⁹.

1.3.5.1 Bankable permits

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

One way to provide for intertemporal efficiency within a tradeable permit scheme is to allow banking of permits, i.e. using fewer permits in one year and more in another. Establishing a bankable permit system would also address some of the important North-South equity issues. Some developing countries have expressed concern that less aggressive mitigation strategies that will leave a greater burden for the future. Any bankable permit scheme must be accompanied by assurance of future compliance; countries borrowing from the bank would guarantee repayment, perhaps by providing collateral equal in value to the expected future cash value of the tradeable permits borrowed.

1.3.5.2 Exchange/risk efficiency.

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

1.3.5.3 Comprehensiveness

Efficiency also requires that the cost of reducing all greenhouse emissions be minimized. This principle implies that any mitigation program must include all greenhouse gases (taking into consideration their heat-trapping potentials and atmospheric lifetimes²⁰), and must include carbon sinks.

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

1.3.6 General Equilibrium

General equilibrium theory, a cornerstone of economic research over the past century, demonstrates the advantage of looking beyond first-stage effects. It offers two important insights for climate change analysis. First, the various parts of an economic system are interrelated, and perturbations to one part have ramifications

for other parts, which may be quite distant. Second, when all of the reverberations are taken into account, the net effect of an action may be markedly different from the initial (and intended) effect.

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

If different countries have different obligations to reduce greenhouse emissions, different implicit tax rates will result. This will interfere with world economic efficiency--decreasing world real output--possibly with little effect on total greenhouse gas emissions. For example, the most energy intensive activities--such as aluminum production--may well relocate to developing countries¹.

While many of the energy-economy-carbon models described in subsequent chapters attempt to estimate the magnitude of carbon leaks, most are based on standard international trade models, in which the location of production of various goods and machines is fixed (Whalley and Wigle, 1992)². Thus, estimates of carbon "leakages" are based only on commodity substitution³. But allowing for relocation of industries -- as would occur in the very long run, the time span of interest for an analysis of global warming--then leakages may well exceed 100%. At the current time, no consensus exists among economists on the magnitude of long-run leakages.

1.3.6.1 Intertemporal Substitution

General equilibrium issues also arise when production can be shifted from one period to another. For example, in a partial equilibrium analysis, a tax on gas or oil raises the price of the fuel taxed, thereby reducing its consumption, and thus associated emissions. But an exhaustible natural resource like gas or oil has, over the long run, by definition an inelastic supply (ignoring for the moment extraction costs, which, in the case of gas and oil, are small relative to the price). The general theory of incidence argues that when a commodity is in inelastic supply, a tax affects the price, but not the level of consumption. That is, *when all countries impose a tax on gas or oil, the price of oil falls, by an amount just equal to the tax*. The full incidence falls on producers; as a first approximation, *the level of consumption--and thus the level of emissions--remains unchanged*. This provides a first approximation. Obviously, if the tax is large enough, the price will fall below the cost of extraction, and supply will be reduced. Moreover, in the case of exhaustible natural resources, taxes may affect the timing of consumption of the oil and gas (Stiglitz, 1977, 1979, ... , 1993)⁴.

1.4 EQUITY

Because climate change is an international public good, it raises issues of equity: who should bear the costs of damages or of mitigation expenditures, among nations, and among generations? The Framework Convention on Climate Change explicitly recognizes equity as a factor to be considered, beginning with intergenerational equity. Some claim that curtailing greenhouse emissions now will serve the cause of intergenerational equity by shifting the burden of abatement to the current generation, while allowing the benefits of a more stable climate to accrue to future generations. Those holding this view often criticize the practice of discounting future environmental benefits as leading to an undervaluing of environmental amenities.

Some developing countries have claimed that climate change is an example of the unequal and inequitable use of the global commons by the industrialized countries, accusing the North of living unsustainably at the expense of the South. They point to the sharp differences in wealth across nations. Some developing country spokesmen claim that poor countries' greenhouse emissions should not be constrained because their emissions relate to basic needs, while rich country emissions result from overconsumption and what they label the unsustainable Northern lifestyle.

1.4.1 General Issues

There is no consensus among either economists or philosophers about the appropriate ethical responses to the changes that would come with global warming. Should, for instance, owners of resources be compensated for the losses that they incur as a result of mitigation actions and the consequent change in prices or values? Most economists would argue no, for several reasons. First, in many cases, the ownership of the wealth was not a reward for productive activity, merely an accident. It was not because country X did something that it had \$200 billion worth of minerals or oil beneath its territory. Many would say that these random allocations of wealth have actually contributed to world inequality, and that eliminating a part of these windfall gains would, from the perspective of an egalitarian social welfare function, be welfare-increasing. Second, the problem is not that these actions are taking away value from assets that by right should be there; rather, until now, these resources have simply been overpriced, not fully reflecting the social costs imposed by their use. In this view, actions to discourage overuse would simply rectify a previous mistake.⁵

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

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

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

Many of these impacts will be capitalized. Thus, the value of land in more temperate climates will rise, and

the value in more extreme climates will fall. (Similar points can be raised, of course, about the costs imposed by climate change itself.) This capitalization effect has both favorable and unfavorable implications. In the long run, those living in colder climates will consume less heating fuel but at (probably) a higher price, leaving them on balance about where they started. Energy prices will rise and land rents will fall in an almost fully offsetting way. On the other hand, current owners of land will bear the full brunt of the present discounted value of all future increases in taxes (or the tax-equivalent cost of regulations designed to reduce energy utilization.) As a result, unless policy changes are introduced gradually, there may be dramatic changes in land values, and the consequent effects on financial institutions and the economy as a whole can be significant. Offsetting these effects, to some extent, is the *anticipation effect*: property owners do (or should) anticipate some of these changes¹⁰.

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

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

Benchmarks. The earlier discussion of equitable distribution of the burdens of responding to greenhouse gases, employing generally accepted principles of public finance, avoided the concept of benchmarks, which have played an important role in international negotiations. Indeed, the "obligations" assumed under the Framework Convention obligates the developed countries to return emissions to 1990 levels by the year 2000. One justification for this form of obligation is that it gives some sense of equity. The difficulty of the task for each country was gauged by its 1990 emissions; requiring each to keep within that target appeared to impose a proportionate burden on each. It was a rough sense of equity, because no attention was paid to the relative incomes of developed countries and therefore no attention was paid to the implied tax rate.

But in a more fundamental sense this criterion can be criticized as inequitable. It pays no attention to past efforts at achieving energy efficiency, nor to other circumstances that might affect the implied tax rate. For instance, a country which, during the preceding ten years, had made every effort to increase energy efficiency and switch consumption to less energy-intensive commodities would face the burden of reducing its emissions still further. Because the marginal cost curve for emissions reductions rises steeply beyond a certain point, the implied tax rate would be considerably higher than for a country that had previously encouraged overconsumption of energy, for example by energy subsidies. For the second country, achieving the emission targets might require only eliminating the energy subsidies, a policy with an implied negative tax rate. For a similar reason, countries with large endowments of hydroelectric power may find it relatively difficult to meet an emission target of this form.

Public finance theory has focused extensively on "second-best" policies, recognizing the difficulty of achieving first-best objectives of either economic efficiency or distributive justice. In this context, the central issue is whether there exist alternatives to benchmarking, setting target emission reductions in relation to past emissions. When the U.S. government recently issued tradeable emission permits, for example, it took account of emission

reductions already achieved. Benchmarking reflects information that would not be reflected in a simple criteria, such as a particular emission level per unit population or GDP. Thus, a strong case can be made for including benchmarking, if not in the final allocation of permits (obligations), at least in the transition rules.

1.4.1 Intergenerational Equity

Efforts to control greenhouse emissions will provide benefits primarily for our grandchildren and their descendants. We face a difficult task in estimating and judging what aspects of climate and environment they will value and how best to preserve those aspects for them. If we take aggressive action to limit climate change, they may regret that we did not use the funds to push ahead development in Africa, to better protect the species against the next retrovirus, or to dispose of nuclear materials safely. Chapter 2 (* * *) addresses directly the most important issue in intergenerational equity: choice of an appropriate discount rate.

1.4.2 Within-country Equity

While most discussions of equity and climate change have so far focused on North/South issues or on issues between one country and another, issues of equity within a country are also important, and indeed play a central role in the political debates about appropriate responses to climate change. Most policy recommendations involve large within-country losses for certain groups. For instance, any policy leading to less use of coal, and lower producer prices for coal, will lead to large losses for coal mine owners and workers. These issues also arise among countries: countries with large coal deposits will find the value of their natural wealth eroded, and quite naturally will be less enthusiastic about international agreements having that consequence.

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

1.5 ECONOMICS OF POLICY ACTIONS

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

1. What actions would improve economic efficiency *and* reduce net greenhouse gas emissions? How much emission reductions could be achieved by these means?
2. Beyond these zero-cost options, what are the most cost-effective methods of reducing greenhouse gas emissions? What does the cost curve look like? What are the alternative policy measures, and how do they compare?
3. What are the essential ingredients of an adaptation strategy, and to what extent will market forces, on their own, provide the appropriate adaptive responses?

1.5.1 Zero-cost Options

A variety of inefficiencies in the energy sector--many of them government induced--would, if eliminated, increase economic efficiency and reduce greenhouse gas emissions at the same time. How large is the reservoir of conservation opportunities? Proponents of the two major approaches to the question have debated this point for more than a decade. *Top-down models* extrapolate observed behavior into the future. *Bottom-up models*, combine engineering analyses to estimate costs with economic models of individual choice. Top-down models generally show significant costs to reducing greenhouse emissions in the future⁴¹. Bottom-up, or technology-specified models, have been used to show the existence of significant reductions in the cost of energy as new low emissions technologies are adopted. Some proponents of bottom-up models argue that emission reductions can be achieved at essentially no cost, seemingly repealing the long standing economists presumption that there is no free lunch⁴².

Much of the disagreement turns on empirical estimates. Virtually all economists agree that government actions induce important inefficiencies. Many economists identify important market failures that could give rise to inefficiencies within the private sector itself. The next two sections will examine each of these effects.

1.5.2 Government Reform

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

1.5.2.1 Removing Energy Subsidies

Energy subsidies induce inefficient energy use, reducing the total output of the economy as well as increasing CO₂ emissions. These subsidies are especially prevalent in developing countries⁴³. Shah and Larsen (1991) estimated world energy subsidies in 1990 to have been \$230 billion, calculating that their elimination would

reduce global carbon emissions by 9 1/2% in addition to improving allocative efficiency thereby generating a welfare gain in subsidizing countries. Burniaux *et al.* (1992) obtained similar results using the GREEN model, concluding that the elimination of all existing distortions on energy markets would yield an increase in world real income of 0.7% per year in addition to cutting world emissions by 18% in 2050. (Dean 1994) Likewise, Unterwurzacher and Wirl (1991) estimated that raising energy prices to world levels in Poland, Hungary, and Czechoslovakia would reduce carbon emissions from those countries by 30%.

1.5.2.2 Property Rights Reform

One responsibility of governments is to define property rights and enforce contracts. Ill-defined property rights encourage overconsumption of resources. A clearer definition of property rights could be particularly important in helping to decrease deforestation, for example, while improving economic efficiency. Uncertainties about *future* property rights may also contribute to economic inefficiency. Thus, for example, in developing countries where large forests are owned by a few large landowners, excessive deforestation may result from landowners' fear that their tenure will be limited.

1.5.2.3 Administrative Reforms

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

Some nations are revising their national accounting measures to account for natural resource depletion and use of environmental non-market assets. Such a revised measure of national wealth would make the economic versus environmental trade-offs implicit in some policy decisions more readily quantifiable. It would discourage deforestation and the rapid depletion of other natural resources, including fossil fuels. While these amendments may cause national income, as conventionally measured, to fall, national income as measured more broadly would increase⁴⁴.

Pricing of government produced electricity. Many governments price electricity not at the market price but at the cost of production. Economists generally recommend that electricity, like any good, be priced not at its cost of production, but at the competitive price. In countries with a mix of plants, this means that electricity from all sources should be priced the same--at the highest marginal cost of production⁴⁵.

1.5.2.4 Regulating Non-greenhouse Externalities

Many activities producing greenhouse emissions also generate pollution of other types. For example, fossil fuel combustion releases conventional air pollutants; rush-hour auto use contributes to road congestion. Taxes, congestion pricing, or tradable permits can correct these market signals, resulting in lower emissions of both greenhouse gases and other pollutants. Some reforms, such as congestion pricing, also reduce the need for roads and other physical capacity.

1.5.2.5 Special Problems of Economies in Transition

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

While these problems are largely of governments' making, the remedy is likely to rely on a combination of public and private actions: effective environmental regulation, elimination of government-caused price distortions, and an economic environment in which foreign and domestic investment can enhance the efficiency (including energy efficiency) of the economy. For example, many analysts believe that cutting methane leakage from gas pipelines will yield both high economic and cost-effective reductions in greenhouse emissions.

1.5.2.6 Examples of Efficiency-Increasing Policies

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

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

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

Subsidized Parking: In some industrialized countries, many employers provide parking to employees at no cost or lower-than-market cost, thus lowering the relative price of commuting by car relative to public transportation. A distortion arises when governments tax income spent on public transportation, but not income implicit in the parking subsidy.

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

Subsidized trucking: Studies suggest that virtually all road damage is caused by heavy trucks, which pay only a portion of the expense of building and maintaining the road system. Many countries thus subsidize trucking compared with rail or barge transport, probably increasing greenhouse emissions¹².

1.5.3 Market Failures and Government Responses

Economists agree that governments can adopt policies to increase economic efficiency at the same time that they reduce greenhouse emissions. There is less agreement about whether, *given market prices*, firms fail to take advantage of all of the energy efficiency opportunities available to them. This controversy underlies the bottom-up versus top-down controversy treated at greater length in Chapter 3. Engineers have identified a host of seemingly profitable actions that would also save energy. Economists are generally skeptical, however, that firms are leaving large amounts of money on the table, and even if they are, that the government would be in a better position than firms to identify profit-making opportunities.

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

Information dissemination. Acquiring information is costly; providing and disseminating information has many features of a public good (Stiglitz 1988, Romer 1990, Arrow 1990). In the absence of government intervention, there will be too little production and dissemination of information. This is particularly true for information with widely dispersed impacts, as opposed to information about, for example, the production of certain chemicals, which is primarily of value to a few companies¹³.

Moreover, both theory and evidence support the view that markets, on their own, do not provide an efficient level of disclosure of information¹⁴. Indeed, some evidence indicates that markets may try to obfuscate relevant information¹⁵. This provides the rationale for laws that in many countries require disclosure of interest rates and other consumer-relevant information, including appliance energy consumption.

Bureaucratic structure, limited scope of attention. In recent years, economic and organizational theory¹⁶ has emphasized that large organizations are not, in general, run by owners; that the managers, even with the best designed incentives, do not in general maximize the firm's market value; and that one of the principal scarce factors within an organization is time and attention¹⁷. How managers direct their attention has much to do with what the firm does¹⁸. The information disclosures noted in the previous subsection, as well as a number of other government programs focusing on energy efficiency in consumer products, electric lights, and motors, help focus management attention on energy efficiency. The marginal managerial time required to make efficient energy decisions may be small and focusing attention on this issue--when information is being freely provided through government and other sources--may thus yield private returns well beyond these slight marginal costs.

Returns to Scale and System Effects (network externalities): Some technologies might be economically attractive at a large scale of production, but not on the much smaller scale on which they might initially be adopted. Other technologies exhibit dynamic scale economies: unit cost falls over time as a function of the cumulative output of firms or industries. Technology "networks" may also affect diffusion rates. For example, cars and trucks fueled with electricity, natural gas, methanol, etc., require a refueling infrastructure, which itself competes for resources with the conventional fuel infrastructure already in place¹⁹.

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

Capital market imperfections. A major explanation of the difference between best-practice and actual-practice technology is that bottom-up models often compute cost-effectiveness using a discount rate substantially lower than the cost of capital calculated by firms²⁰. Studies of implicit discount rates consistently show that households and firms use discount rates substantially above the long-term government market rates of interest.

Two explanations have been offered: 1) Risk: Interest rates facing firms and households reflect the risk premium that lenders require to compensate them for the probability of default. Firms often use discount rates that include a risk premium to reflect the riskiness of projects; 2) Capital constraints: Individuals and firms often

face rationing in capital markets, both for credit and equity. Recent research has provided a rationale for this rationing based on the fact that information is imperfect and costly.⁶¹

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

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

Economists emphasize that an analysis of the costs and benefits of a project must separate four issues: timing, risk, capital constraints, and information. Discount rates are only to be used for timing. Risk should be treated by converting costs and benefits into certainty equivalents, then discounting costs and benefits for each year at the relevant discount rate.⁶² Higher risks should not result in higher discount rates.⁶³ Similarly, capital constraints should be reflected in the shadow price of capital, not in the discount rate.⁶⁴ Because of limited information (and a version of the "winners' curse"⁶⁵) firms often require threshold rates of return significantly greater than the market rate of interest. In doing so, they may confuse time and information risk: that is, the rules of thumb firms use to evaluate investments may sometimes lead to market inefficiencies, including perhaps in the area of energy-efficient technologies.

Even were firms to follow the economist's guidelines, in the presence of capital constraints, market outcomes would not, in general, be socially efficient (i.e., they are not constrained Pareto optimal.) There may be significant discrepancies between social and private returns to investment (even apart from the externalities associated with greenhouse gases or technological diffusion.) This provides part of the rationale for possible government interventions in capital markets.⁶⁶ Though these capital market imperfections imply that there is no presumption that market allocations are efficient, there is no consensus that they lead to significant underinvestment in energy-efficient technologies in particular.⁶⁷

1.5.4 Innovation

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

In the absence of intellectual property rights, firms would have no incentive to innovate. With standard patent terms, firms are not able to appropriate all the returns to their innovative activity. Setting the optimal patent life involves balancing off the inefficiencies resulting from the exercise of monopoly power during the duration of the patent (static inefficiencies) with the increased incentives for innovation.⁶⁸ Largely because innovators seldom appropriate all of the returns to their innovation, there is a general consensus that markets provide insufficient incentives for R & D; and the greater the spill-overs, the greater the undersupply.⁶⁹ Since the spill-overs are likely to be greater the more basic the research, this suggests a role for government in subsidizing basic and near-basic research.

Still, there is a general consensus among economists that the patent system provides a better basis of financing applied research than does a system of government grants, largely because of difficulties government has in picking those most likely to produce high returns. The question is, is there any reason to believe that any market

failures, in terms of insufficient level of innovation, are worse in this area than in other areas, i.e. are there any special grounds for arguing for government R & D subsidies, *provided the government has corrected energy prices to reflect the externalities generated?* Obviously, in the absence of such corrections, market incentives to provide energy saving innovations will be distorted, just as market incentives to adopt energy saving technologies are reduced⁷⁰. (Tradeable permits have similar effects to corrective taxes, since firms will value reductions in emissions from new technologies, since such reductions will require them to purchase fewer permits.)

Innovation is important, because it provides perhaps the best opportunity for low-cost methods of reducing emissions. Several studies have confirmed the impact of accelerated deployment of advanced energy technologies on the future rate and timing of anthropogenic climate change⁷¹.

1.5.5 Carbon Taxes and Tradable Permits.

The general market failure associated with greenhouse gas emissions is that firms and households are not charged for their externality. Economic efficiency requires all agents in the economy pay for the full marginal social costs of their actions. There are two broad instruments by which this can be done, carbon taxes and tradeable permits.

A tradeable permit scheme involves a determination of the total level of permits and a distribution of the initial allocation. Emission levels for any firm or household are limited to the number of permits they hold. The initial distribution may be performed through a variety of methods, such as an auction or allocation according to historical emissions levels (i.e. "grandfathering"). Once the permits are distributed among the companies being regulated, a market is set up wherein the companies may buy and sell the permits according to their plants' individual need to emit. The cost of production then includes not only the costs of conventional inputs, but also the costs of additional permits to offset additional emissions. Plants whose cost of mitigation is low will find it relatively easier to abate pollution rather than to buy permits. Plants with higher costs of mitigation will have a greater preference for buying permits than for abating pollution. The price of the permits, which are artificially created scarce resources, is determined by the market. With the use of tradable permits, companies have an incentive to improve the efficiency of their production, thereby reducing their emissions level, as they can sell excess permits on the market and generate revenue.⁷²

While permits thus create a marginal cost of production related to the marginal emissions, carbon taxes impose a tax directly on the marginal emissions. Both systems thus force producers and households to face the true social costs of their actions⁷³.

An essential problem with tradeable permits--and at the same time, one of its core advantages--is the initial allocation of permits, both across and within countries. Imposing carbon taxes can have large distributive consequences. While a system of grants can largely offset these distributive consequences, such offsetting grants might well not be made. Providing tradeable permits equal to existing levels of emissions seemingly makes no firm or household a loser. But granting permits in that way represents effectively a grant of money (such permits have monetary value) in a way which may not well accord with standard ethical principles. For instance, a firm which has been a good citizen, and already taken aggressive action to reduce its emissions, would get fewer permits. Not only does this seem unfair, but anticipation of granting permits in this way would, accordingly, have strong adverse effects on emissions. Some developing countries have asked, should the North be given higher levels of permits, simply because it has, in the past, been the chief source of greenhouse gases?

That a tax has large distributive consequences, while presenting a political impediment to its introduction, is not necessarily an argument against it. Why should the fact that firms or individuals have failed to pay the full

social costs of their actions provide them a greater entitlement? On the contrary, one might argue that they should pay more now because they paid less earlier.⁷⁴

Once one recognizes that the distribution of permits across countries will, inevitably, be decided by some principle other than current levels of emissions, then it becomes clear that both taxes and tradeable permits will have distributive consequences. *An agreement among countries to impose uniform corrective taxes, with each country retaining its own revenue, would have little redistributive consequences across countries and the burden of the tax would, as noted earlier, likely be progressive.*

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

1.5.5.1 A Double Dividend?

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

At least three objections have been raised to this idea. First, conceptually: rationalizing the tax system by reducing the most distortionary taxes is certainly a worthy goal, but should not be confused with imposing a carbon tax; neither implies the other. Second, empirically: if the (compensated) labor supply elasticity is relatively low, then the dead-weight loss from the labor tax is low, and the commensurate welfare gain is reduced. Third, politically: if carbon tax revenues are used to offset the deficit, rather than to reduce taxes on labor and capital, then the carbon tax acts more like an ordinary tax increase, increasing distortions from taxation to pay for budget items with a lower return than the extra burden imposed. The gains to total welfare (reductions in dead-weight loss) depend on the welfare losses associated with these other distortionary taxes, as well as the cross-elasticities of demand between carbon and other taxed commodities⁷⁵.

Even though carbon taxes may have a positive effect on economic welfare, they can at the same time have a negative effect on *measured* economic growth, since those measures typically do not include the value of environmental degradation. Researchers differ on the size of the loss. The wide spread in the numerical results, however, should not obscure agreement among researchers on a number of important points. All models used in the major comparison studies to date have projected: first, that intervention would be required to achieve the emissions targets; second, that the size of the required tax increases with the stringency of the carbon limit; and third, that the size of the appropriate carbon tax varies over time, even for the same emissions or concentration target⁷⁶.

The studies show a marked variation in GDP losses across models. For example, stabilizing emissions at their 1990 levels is estimated to reduce U.S. GDP by .2% to .8% in the year 2010 - roughly a \$20 billion to \$80 billion loss for that year. Estimate of the costs of reducing emissions by 20% below 1990 levels in the year 2010 range from .9% to 1.7% of GDP⁷⁷.

1.5.5.2 Energy Taxes

Energy taxes must be viewed as "second best" taxes in that they do not directly tax the externality, carbon dioxide emissions.

While carbon taxes directly penalize the externality generating activity, less targeted alternatives, such as energy taxes, may be politically more acceptable. Carbon taxes reduce emissions first, directly, by moving up the demand curve; second, indirectly, by encouraging consumers to switch to less carbon-intensive energy sources. (On the other hand, energy taxes work through the first path, by reducing total energy consumption. But to the extent that certain kinds of energy, like hydroelectric, have, at least in the short run, a relatively inelastic supply, a major impact will be on oil, gas, and coal; and to the extent that oil and gas supplies are best described by a model of an exhaustible natural resource, with relatively low extraction costs, most of the supply reduction will occur in coal. Thus, indirectly, there will be a considerable amount of switching, through the indirect effects.

1.5.5.3 Tradeable Permit Markets.

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

1.5.5.4 Combining taxes with tradeable permits

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

1.5.5.5 Intertemporal patterns of taxation

If the target is the long-run atmospheric concentrations of greenhouse gases, then climate change damages will be approximately the same for emissions in any particular year, although the optimal carbon tax must be adjusted for differences in costs, discounting, and risk⁷⁸.

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

Figure 3 shows the dynamics of exhaustible resources. S denotes the total available stock of gas and oil. S_t represents the amount of stock left in the ground, a function of the "backstop" price. Imposing a uniform emission tax lowers the cut-off price, and flattens the price curve. The effect on current price depends on how

close the current stock is to economic exhaustion (S_0). Given the currently high levels of rent, it is probable that the net current effect on producers is to *raise* the producer price, not lower it. Thus, short-run leakage effects will be the opposite of that predicted in many models.

1.5.6 Regulatory Approaches

Although economists have long argued for the use of economic instruments for environmental management, governments have so far relied on command-and-control regulations almost exclusively, either by requiring a specific control technology, or by regulating inputs or outputs. For example, Corporate Average Fuel Economy (CAFE) standards in the U.S.A. require automobiles to meet certain mileage standards; U.S. electric utilities are required to employ stack-gas scrubbers to remove sulfur.

Proponents of the traditional approaches often claim that these approaches "force" technology, with less redistribution than forcing technology through taxes. Thus, if automobile makers are required to attain a certain mileage standard, they will meet the standard; on the other hand, gasoline taxes might have to rise significantly to reduce fuel consumption by the same amount.

Evidence for this claim of technology forcing, however, is not convincing. In several well-known cases, when industry has failed to meet the applicable standards, the regulators have withdrawn the standard in the face of unacceptably high economic costs. The very advantage of technology forcing -- one large club instead of the subtle and continuous incentives provided by market forces -- often proves its undoing.

Countering this possible advantage are several distinctive disadvantages. First, command-and-control regulations do not in general result in economic efficiency, since those in one sector face implicit or explicit incentives at the margin that differ from those in other sectors. Second, the particular features of most command-and-control approaches exacerbate the loss in efficiency, and some cases, even results in deleterious environmental effects. Thus, for example, CAFE standards may actually increase greenhouse emissions: more miles per gallon means a decrease in the marginal cost of driving, and hence raises the number of miles driven. Note that this effect does not arise when higher gasoline prices increase fuel efficiency. And any realized reduction in emissions costs far more than necessary⁷⁹. Moreover, command-and-control regulations provide no incentives for exceeding the given target, even when doing so might result in little additional cost⁸⁰.

Command-and-control regulations that focus on inputs and technology rather than outputs have the further disadvantage of not directing research toward meeting performance objectives at least cost. For instance, when scrubbers are required, research will be directed at producing scrubbers at least cost, rather than reducing emissions at least cost. Hence, a dynamic inefficiency is added to the obvious static inefficiencies.

Finally, because of the nature of the regulatory process, traditional regulatory designs are more likely to be captured by special interest groups⁸¹.

1.6 SUSTAINABLE DEVELOPMENT

1.6.1 The Concept of Sustainable Development

The concept of sustainable development can be viewed as a particular manifestation of the issue of intertemporal equity. Within developed economies, the classic statement of the meaning of sustainable development has been provided by Solow: sustainable development requires that future generations be able to be at least as well off as current generations.⁸² The central implication of sustainable development is that *any environmental degradation should be offset by increases in capital stock sufficient to ensure future generations at least the same standard of living*. Sustainable development does not preclude the use of exhaustible natural resources, but requires that any use be appropriately offset.

Within the economics profession, the concept of sustainable development has not received universal assent. It can only be justified by means of a Rawlsian social welfare function, and that social welfare function is not widely accepted. In particular, the implication of that social welfare function that there is no less to the worse off individual, no matter how small, which would be justified, regardless of the increase in *everyone else's welfare*, no matter how large, is neither intuitively plausible nor consistent with reasonable axiomatic structures.

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

In many developing countries, however, Solow's definition would not be viewed as acceptable, since it seems to place no weight on their aspirations for growth and development. Formal models analyzing optimal development paths using a min-max (Rawlsian) criterion would, of course, focus exclusively on the welfare of the less developed countries. But the prescription would be simple: it would call for massive redistribution from the North to the South. Even if there were limits on the transfers, it would suggest that all of the costs of mitigation--including those occurring within the South--be borne by the North. But it would, at the same time, imply that the South actively engage in mitigation, so that efficient mitigation could be obtained.

Any Pareto-efficient development path (including any reasonable definition of sustainable development) must have this property of efficient mitigation. Thus, the level of mitigation should be set based on eventual target of greenhouse gas stabilization and implied levels of *world* emissions (without regard to where those emissions originate.) The magnitudes of actions required to attain those levels of world emissions will, of course, depend on the rates of growth of the less developed countries as well as increases in energy efficiency among the developed countries.

Specific Egalitarianism. A more stringent notion of sustainability (a generalization of the concept of specific egalitarianism) requires not just that future generations be as well off as the current generation, but that their endowments of particular goods--especially environmental assets--be at least as large. Such views cannot, in general, be reconcile with individualistic notions of well-being, and thus have not been generally accepted among social scientists.

1.6.2 Implications of Sustainable Development for Developing Countries.

The concept of sustainable development is often broadened to include an examination of specific policies. In this context, "sustainable" often takes on the meaning of "long run inefficiency." Thus, agricultural policies that lead to a long run decline in land productivity, even though they may lead to a short run increase in productivity, are sometimes referred to as "unsustainable," with the suggestion that the long run losses more than offset the short run gains, at any reasonable discount rate. Many of the discussions of unsustainable growth thus focus on policies which are clearly statically or intertemporally inefficient, for example, large energy subsidies, which encourage energy inefficiency.

1.6.3 Sustainable Development and the Risks of Climate Change.

Climate change imposes special demands on the ability to achieve sustainable development. A rapidly or unpredictably changing climate can disturb orderly economic development plans. Shifting agricultural production regions, for example, can result in the diversion of capital resources that would have been available for other more productive uses. The costs of mitigation and adaptation may take resources from necessary consumption, and may crowd out investment that would make sustainable development possible. Responding to climate change increases the uncertainty and the cost of achieving sustainable development. At the same time, as stated earlier, sustainable development does not mean that all resource stocks remain unchanged; an increase in capital stock can substitute for a decrease in other resources.

Developing countries face particular burdens; their development is likely to be the most affected by the risks of climate change. Many potential environmental consequences--such as rising sea levels--will particularly affect developing countries simply because of their location. Since agriculture is the sector most likely impacted by climate change, and since agriculture's share of GDP is much larger in developing countries than in developed countries, climate change is most likely to impact less developed countries. Moreover the South is more likely to be adversely affected than the North (which might actually benefit from slight global warming). At the same time, the less developed countries often lack the financial and technical resources to respond. Further, many developing countries rely heavily on fossil fuels either for export earnings or for energy consumption, and thus would feel the impact of fossil fuel restrictions. Hence, carbon taxes and other emissions constraints would weigh particularly heavily on the two largest developing countries, India and China, both of which have large coal deposits⁴¹.

1.6.4 Sustainable Development and Growth in the Developing Economies

Population growth is expected to contribute to pollution of water, air, soils, in addition to problems of deforestation, and loss of biodiversity. The world's population is growing at the rate of 1.7% per year, down from its peak of 2.1% per year in the late 1960's (World Bank, 1992). Under the World Bank's base case projection, world population would stabilize at 12.5 billion sometime after 2050, more than double the current total, with 95% of the increase in developing countries. Declines in fertility rates depend on the availability of contraceptives and family planning information, on education, particularly for females, on the standard of living, and on a social safety net.⁴²

Population pressures and economic development will result in greater energy use, which in turn will increase CO₂ emissions. The consumption of commercial energy in developing countries is rising rapidly and will soon dominate growth in energy consumption--and thus CO₂ emissions--worldwide. In 1985, the developing countries contributed 19% of worldwide carbon emissions. By 2020, they are expected to contribute *** % of a larger total (IPCC 1994).

Developing countries also contribute to net increases of greenhouse gas emissions by deforestation. In recent years, deforestation, nearly all from developing countries, has contributed significant amounts of carbon dioxide emissions. Afforestation of open land is one of the most promising options for the sequestration of CO₂ from

the atmosphere.⁴³ Even though afforestation's contribution to carbon absorption is ultimately limited by land area and growth rates, it could postpone the increase of CO₂ concentration as well as check erosion and land degradation in general in many areas of the developing world⁴⁴.

1.6.5 Implications for Climate Policy

The Framework Convention on Climate Change implicitly recognizes that climate change is an international public good in calling for the nations of the world to take actions to reduce greenhouse gas emissions. Three-quarters of present-day emissions have their origin in developed countries where one-quarter of mankind lives. The remaining three-quarters of the world population contributes only one quarter of present-day emissions⁴⁵. Atmospheric concentrations of CO₂ have increased by about 25 percent since the beginning of the Industrial Revolution. But the increase to date will be dwarfed by the increase expected to occur over the next several decades.

Whatever has gone before, the real problems are those to come. Resolving such problems will require a combination of efforts to reduce emissions in developed countries, whose emissions have been largely stable for 20 years, to allow for moderate growth of emissions in developing countries, which is unavoidable. The introduction of cost-effective energy-efficiency measures proved to be one of the important factors in reducing aggregate energy intensity (the ratio of total energy consumption to GDP) in the OECD after 1973⁴⁶. Many studies indicate that developing countries can follow a similar path, allowing them to "leapfrog" the path followed by the industrialized countries⁴⁷. This strategy is slowly becoming current policy in a number of developing countries and the basis of the actions of some international agencies, including the Global Environment Facility⁴⁸.

1.7 ENDNOTES

1. While not dispositive, evidence that property damage claims from such natural disasters have risen at three times the rate of those from earthquakes is suggestive.

2. A warmer climate would directly affect the temperature-sensitive sectors of the economy: agriculture, forests, and fisheries; and construction. Because of the risk of drought, arid and semi-arid regions are likely to be most vulnerable to warming. A warmer climate may also encourage insect populations; this, in turn, is likely to decrease agricultural yields in some regions. On the other hand, increased CO₂ concentrations increase photosynthesis and the effect of water consumption in controlled settings, and may also do so in farmers' fields, increasing crop yields.

A warmer climate would hurt agriculture in some regions and help in others. Recent global studies find that Northern temperate regions could benefit, particularly for small increases in temperature, but low latitude areas could lose. The global studies show significant losses from climate change alone that are significantly offset by the direct beneficial effects of higher ambient levels of carbon dioxide on plant growth. Reilly, et al. (1994?) calculate that global agricultural production will increase for global mean warming of up to 2°C. Most analysts expect that agriculture can adapt without significant added costs for the world as a whole (although some regions will suffer greater-than-average losses), in part because of crop shifting and other adaptation by farmers, and because of the moderating influence of trade in international commodity markets (Ausubel, 1990; Rosenzweig and Parry, 1994; Reilly, Hohmann, and Kane, forthcoming; Kane, Reilly, and Tobey, 1992). Some have concluded that world agriculture would, on balance, benefit from warming of up to 2°C (Reilly 1993).

3. A warmer climate implies both a poleward movement of forests and changes in forest composition. The result would be to increase boreal forests and, by a smaller percentage, to decrease tropical forests. On balance, doubling CO₂ concentrations would modestly reduce both standing biomass and forest area (Sedjo and Solomon, 1989). Some analysts also calculate an additional temporary decline in forest cover during the transition to a warmer climate (EPA, 1989); this decline could last for several hundred years, as more forest death occurs on southern edges than additional growth occurs on northern edges. Higher CO₂ concentrations might also increase tree growth, partially offsetting direct losses from warming.

4. Some analysts conclude that a warmer climate would significantly reduce water supply (Gleick, 1987). Most climate models now predict hotter and drier weather for the mid continents (IPCC, 1990a). If this occurs, the downward pressures on water supply will be intensified by upward pressures on water demand.

Because of the key role of local conditions, further generalizations are difficult. River basin runoff is the difference between precipitation and evaporation plus absorption (IPCC, 1990a). Hence small variations in these three terms--each of which depends on the accuracy of regional climate forecasts--can make a large difference in the runoff.

5. A warmer climate implies reduced heating costs and greater cooling costs. At least for countries in temperate and cool climates, this would move the population-weighted average temperature closer to the ideal indoor temperature. Nordhaus (1991) finds that warming of approximately 3.0°C in a 1981-sized U.S. economy will increase electricity costs by \$1.65 billion and decrease heating costs by \$1.16 billion (1981 dollars), resulting in net costs of \$0.49 billion. Rosenthal, Gruenspecht, and Moran (1994) find that global warming results in a net benefit to the U.S. economy. Cline (1992) finds net costs of \$9.9 billion.

6. Global mean sea level appears to have risen 10-20 cm over the past century (Warrick, Oerlemans *et al.*, 1990). The IPCC has projected a warming-induced rise in mean sea level of 21 to 71 cm by 2070 (IPCC, 1990a), sharply reduced from estimates of 3 to 8 m. made in the early to mid-1980s (Schneider and Chen, 1980; Hoffman *et al.*, 1983; Hoffman *et al.*, 1986). The current "best estimate" for mean global sea level rise by 2030 under "business as usual" is 18 cm (Warrick, Oerlmans *et al.* 1990; Raper *et al.*, 1990).

A rising sea level could inundate some small island nations, flood some low-lying coastal cities (e.g. in Bangladesh), damage coastal farmland, and contaminate water supplies (IPCC, 1990a). More severe storms would accelerate coastal erosion and affect aquifers, intensifying problems existing today. Warmer oceans might damage coral reefs, a natural defence for some coastal areas. To account for the costs of protective measures, the costs of defending the world's developed coastlines against a 1 m rise over the next 100 years have been estimated to range from 0.01% for the former USSR to 0.74% for Indian Ocean small islands, with a world average of 0.028% of GNP per annum (IPCC, 1992).

7. Some analysts have found tangible costs to be small, and believe that the justification for costly and more restrictive actions rests on intangible costs (Nordhaus, 1993), which remain poorly quantified. Intangible costs include migration, comfort, health, leisure activities, urban infrastructure, and air pollution (Fankhauser *date*, Cline (1992). A warmer climate would improve human comfort in cold areas, and in the winter generally, while decreasing comfort in warm areas. Mearns *et al.* (1984) calculate a threefold increase in heat waves for a 1.7 degree C rise in U.S. mean temperature. It is not yet clear whether net comfort will rise or fall for a given rise in temperature.

8. Both the natural rate and human contribution to the process of species loss are difficult to estimate (EPA, 1989). It is even more difficult to predict the effects of climate change on species distribution. Uncertainty about the timing of changes in climate, the duration and type of environmental changes that would be caused by climate changes, and the combination of human and environmental driving forces would influence species diversity make the long-term projection of species change highly complex. Moreover, while some species may have difficulty adapting to climatic changes, opportunities for other species may open up. Population pressures have added to pressure on ecosystems, particularly in the third world. Climate change may exacerbate these damages, particularly in Africa, where environmental degradation has been particularly pronounced during the last 15 years (UN, 1989).

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

10. Recent ice core data from Greenland points to earlier temperature rises of several degrees occurring within a few decades (IPCC 1994); reasons for these sudden changes are still not understood, but might have come from changes in deep ocean currents. The other side of this debate holds that on the whole the biosphere is homeostatic or self-correcting; this "Gaia hypothesis" compares the biosphere to a living being; once moved away from equilibrium, self-correcting forces naturally move it back to equilibrium (Lovelock, *date* ***).

11. Scientists do not agree on how to measure the warming potential of different greenhouse gases (IPCC, 1992). Although global warming potential (GWP), endorsed by the IPCC, is a useful concept in formulating comprehensive approaches to greenhouse mitigation policies (Stewart and Wiener, 1990), some analysts

have recently criticized the concept on the grounds that GWP implicitly sets the opportunity costs of an increment in radiative forcing equal for all periods in the future (Schmalensee, 1993). If all greenhouse gases had the same rate of decay, then this problem would not arise.

12. Although forests cannot be expanded indefinitely, and thus increased carbon sequestration is not a permanent solution to increasing greenhouse gas emissions.

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

14. This is not quite true: fire insurance companies, by requiring commercial buildings to install sprinklers, do reduce the overall level of losses.

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

Insurance contracts may also be created because of differences in judgments concerning the probability of the insured event occurring. This suggests the potential of an important principle to be invoked in future international negotiations/agreements: countries that believe that the risks of climate change are low, and are therefore seemingly unwilling to take strong actions to mitigate these risks, ought to be willing to provide insurance against climate change at low cost (since it has, from their perspective, an actuarially low value). (See below for a discussion of problems of enforce.) (Heal and Chichilnisky **date, reference**: earlier, Stiglitz ** date ** on social risk bearing.)

Insurance markets, if appropriately designed, would have one further advantage: some of the losses associated with climate change are easily avoidable, e.g. construction of durable ocean-front houses. Insurance firms work hard to mitigate the losses that are incurred. Either the insurance should be based on exogenous events (e.g. not on the dollar losses incurred, but on the rise in the sea water), or the insurance companies should be given broad discretion to require the insured to undertake actions to mitigate losses.

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

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

18. Alternatively, the Kaya identity may be written

Growth rate = growth rate - decline in energy - emissions

of CO₂ emissions of output per unit output per unit energy use

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

19. That is, for conventional exhaustible resources, there is a stock, S. Welfare depends on flows out of the stock each year:
 $U(S_1 - S_0, S_2 - S_1, \dots, S_{t+1} - S_t, \dots)$, where S_t is the stock at the end of period t.

Here, welfare depends directly only on the stocks, though indirectly, through the effects on consumption, on emissions, which affect the change in stock:

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

20. Even when the flow exceeds the long-run sustainable level, it will not be optimal to reduce the flow instantaneously, unless -- or even when -- there are zero costs of adjustment.

21. This is not quite correct, since price affects incentives for exploration, and some marginal wells would not be drilled if oil prices fall too low.

22. For analyses of market and optimal responses to uncertainty about the arrival of backstop technologies, see Dasgupta, Gilbert, and Stiglitz [] and Dasgupta and Stiglitz [].

23. An essential determinant of sequential decision making strategies is the speed of response relative to the timing of relevant information. Suppose, for example, that countries could quickly adjust emission levels in response to new information on climate change impacts. Then the optimal sequential decision making strategy would probably not include much expenditure on insurance (e.g., early mitigation). In practice, however, lags in reducing emission levels are likely to be significant; and even if they were not, atmospheric concentrations respond only slowly to changes in emissions.

24. For a treatment of this issue in the context of climate change, see Manne and Richels, 1992; Peck and Teisberg, 1993c; Nordhaus, 1993.

25. Although for counter examples to the received wisdom see Coase (1990).

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

27. Although there may also be trade-offs: reducing those gases that contribute most to local pollution may sometimes be at the expense of increased emissions of greenhouse gases.

28. This kind of optimization problem was first studied by Edgeworth, *Mathematical Psychics* (). The importance of incentive effects for the analysis of distributional issues was first emphasized by Mirrlees (1971) and Fair (1970). There are, obviously, important incentive effects: if the LDCs were able to classify any expenditure that had some effect on mitigation as a mitigation expenditure, with the cost borne by the developed countries, they would have an incentive to undertake excess expenditures of this type. The GEF (Global

Environmental Facility) directly addresses this issue, by only providing funds for incremental costs, that is those costs that go beyond what would have been the efficient level of expenditures ignoring the public good benefits of greenhouse gas mitigation.

29. The importance of the assumptions of the absence of transactions costs, including the presence of perfect information, has only gradually come to be recognized. See Farrell [], or Stiglitz [1988] for an elementary textbook treatment.

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

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

31. For small taxes, these are "compensated" taxes, and have no welfare effect, though they have a substitution effect, and therefore do reduce pollution.

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

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

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

34. This effect was emphasized in early work on the economics of population policy; see, e.g. Edgeworth [1868].

35. It is possible to design allocations of trading permits which (i) on average, impose no net burden on developing countries (thus conforming to the ability to pay principle); (ii) provide those economies which are growing faster per capita with commensurately greater permits, thus imposing no net drag on economic growth, provided the economy exhibits an increase in fuel efficiency at least equal to the average of fast growing LDCs; and (iii) rewards those economies which are able to reduce greenhouse gas emissions faster than benchmark, either through

greater control of population growth, through larger increases in energy efficiency, or through switching from higher to lower carbon fuels.

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

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

37. See Abreu [].

38. Coase (1960), in his discussion of externalities, emphasized the separability between efficiency and equity issues. Though there have been several important qualifications to Coase's conjecture, emphasizing the importance of public goods, imperfect information, and transaction costs (see Farrell [], Stiglitz [1988]), still, the basic insight remains applicable here.

39. These concerns are not just theoretical possibilities, as the following two examples illustrate. Assume that the North imposes high energy taxes, but the South fails to do so. Energy intensive industries, such as aluminum, migrate from North to South. But energy efficiency in the south is much less than in the north, so that the total energy used to produce a ton of aluminum could increase substantially. While economic efficiency would call for locating energy intensive industries where energy efficiency is greatest, a system of partial controls would result in energy intensive industries being located where energy efficiency is lowest. Similarly, the reduced energy consumption by the North will result in lower *producer* prices of oil and gas, leading to increased consumption of energy in the South, partially offsetting any energy conservation induced in the North.

40. The precise manner in which this should be done is a relatively technical matter. To the extent that there are large differences in atmospheric lifetimes, then the relative weighting of different greenhouse gases should change over time, since the "shadow price" associated with effects on relative concentrations at different dates will differ.

41. Similarly, if the developed countries restrict forest cutting, the price of lumber may rise, inducing the developing countries to cut down more of their own trees. While total carbon sequestration may not increase, environmental and economic efficiency will decrease if, as some researchers have concluded, hardwood forests in the less developed countries may be the least desirable ones to cut down from an ecological or economic perspective (Edmonds and Reilly, 1983).

42. Only a few models take into account international capital flows. Thus, most models do not address issues of industry relocation (McKibben and Wilcoxon, 1992).

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

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

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

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

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

47. Top-down models estimate that for developing countries there exist low-cost options to reduce emissions in the near term, but eventually costs would exceed 1 to 2% of GDP (EMF 1993). For economies in transition, because of historical inefficiencies and energy subsidies, there exist large opportunities to reduce emissions at little or no cost. For developing countries, problems of informal economies make hard estimates difficult, but the cost of stabilizing emissions would likely be large enough to cut into economic growth.

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

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

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

Standard accounting procedures require that firms, in an attempt to present an accurate account of "true income," take account of depreciation. GDP measures gross output; it does not take into account depreciation, either of natural or physical capital stocks. The reason is simply that it is hard to get accurate measures of depreciation.

Net national product does take into account depreciation, the change in capital stock. And it is this account which should be most subject to criticism, since it accounts for changes in the physical capital stock, but not in other capital assets, in particular, environmental assets and natural resources.

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

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

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

Environmental assets--such as air quality--present another set of problems, because there are not market prices to value the asset. Dynamic optimization problems of the kind described earlier can be used to calculate shadow prices. How sensitive these shadow prices are to specific assumptions remains to be investigated.

Accounting systems do not, however, have to aggregate all information together. Just as information about longevity and other indicators of well being (see below) serve to complement information from national income accounts concerning standards of living, so too can information about physical environmental measures be used to complement information from the extended national income accounts.

51. Full utilization of non-fossil fuel energy sources, taking account of other environmental impacts.) For example, when hydroelectric power generation, which does not increase greenhouse emissions, can be cost-effectively expanded without other environmental effects, it should be done.

Eliminating Regulations Impeding Efficient Energy Utilization. Many, perhaps most, countries have a host of regulations which increase energy use as they impede economic efficiency. For instance, the United States has had a policy of restricting oil exports to Alaska. Whatever the merits of that policy, it has forced Japan to import oil from Indonesia and Saudi Arabia. World oil transportation costs have thus been greatly increased, at the expense of the American economy. Another example of government reform, included in the US' Action Plan (1993), encourages efforts to expand and improve natural gas markets through continued regulatory reform. These reform efforts include guidelines to allow greater natural gas use in the summer in coal- and oil-fired power

plants.

Land Use Policy. While most attention directed at mitigation has focused on the energy producing and using sectors, there are complementarities between those sectors and policies undertaken in other parts of the economy. Perhaps the most important set of such policies concerns land policy. All governments have policies which directly and indirectly affect patterns of land utilization. Land utilization, in turn, affects transportation costs, heating costs, and cooling costs. Until now, governments have paid little attention to the implications for land use of a variety of policies (such as road networks), and little attention to land use policies for energy consumption. For instance, the construction of major highways into large cities has led to the growth of suburbia. Not only has this growth increased total travel time, the structure of the development has been inimical to the development of effective public transportation networks, contributing further to the overall energy utilization. A variety of tax, expenditure and other policies (such as, in the United States, the superfund program) has led to vast unoccupied holes in the center of major cities, contributing further to the inefficiencies in land use.

52. Consider the following thought experiment: compare an optimally designed road system which only carried cars; and contrast that with an optimally design road system which also carries trucks. The incremental cost of carrying trucks is, in most countries, much larger than the proportionate share of the cost they bear in gasoline taxes and other fees.

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

54. This issue has been addressed in several papers. See, in particular, Stiglitz [1975, 1984] and Grossman [1981].

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

56. The standard reference in the organizational literature is March and Simon. Economic theories emphasizing the non-value maximizing behavior of managers include the works of Baumol [], Marris [], and Leibenstein []. The principal agent literature [Ross, 1973, Stiglitz, 1974] provided the informational micro-foundations for understanding the divergences of interests. See Stiglitz [1988]. A more recent overview is provided by Stiglitz [] and the symposium in the Journal of Economic Perspectives.

57. This key point, while noted in March and Simon's [1958] original work, was elaborated upon by Radner [] and Hannaway [].

58. The facts that time is a scarce commodity and that decision making in large organizations is decentralization do not in themselves constitute a market failure; they do not prove that resources are not efficiently allocated given the real constraints facing society, which include time. However, Greenwald and Stiglitz [1986, 1988] have established a very general theorem showing that when information is imperfect and costly, market equilibrium is, in general, not (constrained) Pareto efficient. Thus, there is no *presumption* concerning the efficiency of the market economy, even in the absence of the kinds of externality and public goods problems that are associated with greenhouse gases. For a more extended discussion, see Stiglitz [1994].

One of the main insights of recent advances in the economics of information is to provide a sound

micro-foundations for these theories of the firm. And indeed, the importance of the limitations on the availability of information, and the consequent importance of attention directing efforts applies to individuals as well as to organizations. Some studies have suggested that the limited success of the special tax provisions in the United States designed to encourage savings (IRA accounts) was primarily due to the competitive efforts of banks to recruit these accounts, and the attention which savings got as a result.

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

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

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

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

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

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

61. For a survey, see Jaffee and Stiglitz []. The basic theory of credit rationing was developed in Stiglitz and Weiss [1981] and the theory of credit rationing is developed in Greenwald, Stiglitz, and Weiss [1984] and Myers and Majluf [1984].

62. This generally accepted methodology is, for instance, reflected in the guidelines issued by the Office of Management and Budget in the United States for the evaluation of projects and regulations. The applied literature does not address the question of whether this procedure is appropriate in the presence of certain types of time and risk non-separabilities.

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

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

65. See Wilson. Though the original discussion of winners curse focused around bidding in auctions, it has subsequently come to be applied to a range of other market phenomena. See, e.g. Stiglitz [].

66. For a discussion of the role of the state in capital markets, see Stiglitz [1994].

67. In some industrialized countries, energy efficient home mortgage lending may help correct the problem. Lenders generally set criteria for the maximum loan amount based on the borrowers' ability to repay, which in turn depends on income and wealth. The fact that a particular expenditure which would enhance efficiency and reduce utility bills is not given special attention. Energy efficient mortgages provide funds to households to make energy efficiency enhancing investments intended to pay for themselves, i.e. result in reduced utility bills equal to or greater than the interest payments. With capital constraints, builders may have an incentive to trade off initial capital costs for higher maintenance costs (lower energy efficiency). Building codes specifying minimal levels of energy efficiency and full disclosure of expected life cycle energy costs may help address these market distortions.

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

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

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

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

- a. advanced fossil fuel technologies
- b. advanced liquified hydrogen fuel cells
- c. advanced hydrogen fuel cells without liquified hydrogen
- d. low cost biomass
- e. accelerated rate of exogenous end-use energy intensity improvement

Combined, the energy technologies reduce annual emissions from fossil fuel use to levels that stabilize atmospheric concentrations below 550 ppmv (i.e. double the concentration prior to the Industrial Revolution). The tax rate, assumed to apply globally, used was the marginal cost of stabilizing fossil fuel carbon emissions in the reference case. With values reflected for only carbon dioxide emission reductions, the cost of global

emission reductions grow from approximately \$35 (US) Billion in 2005 to \$230 (US) billion per year in the year 2095. With advanced fossil fuels, low cost solar electric power, low cost fuel cell vehicles, the present discounted value of adding low cost biomass fuel to the energy technology bundle is almost half a trillion dollars (US). The present discounted value of the advanced energy technologies taken together is \$1.8 trillion (US).

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

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

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

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

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

In the case of greenhouse gas emissions, the time horizon for adjustment is sufficiently long that many of these uncertainties become less important. If the tax rate initially chosen yields too high a level of emissions in one year, it can be increased, and the net impact of the erroneous initial estimate on global warming (or the total cost of achieving a given level of atmospheric concentration) will be negligible. In any case, as the earlier discussion on sequential decision making has emphasized, there is likely to have to be continued revisions in either tax rates or permit levels.

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

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

74. For a discussion of the polluter pays principle, see above.

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

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

76. Two main studies provide insights into the root of the variance in estimates of the economic effects of carbon taxes: The Energy Modeling Forum Study (12) and the OECD comparison project. In each case, sophisticated sensitivity analyses are run by standardizing key economic assumptions along with use of common reference case scenarios of reductions. The magnitude of the effect on economic growth will depend both on assumptions concerning the effect of carbon taxes on savings and labor supply, and the induced investment to offset the higher energy prices. If higher energy prices do not lead to much capital substitution and if the cross elasticity with savings and labor are low then the likely effect on economic-growth will be small.

OECD Project on Economy-Wide Cost Estimates of Carbon Taxes:

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

There is significant variation in tax rates and costs for the same amount of emissions reduction among models due to differing assumptions regarding several key considerations. Several factors explain the differences between model results. The most important factors are:

- The degree of substitution between fuels - the ease with which producers and consumers can switch from high-carbon content fuels to low-carbon content fuels;
- Expectations about future energy prices and taxes;
- The speed of emissions reduction;

- The way in which revenue is recycled;
- The treatment of the removal of energy subsidies; and
- Assumptions regarding backstop technology and a host of other technical and economic factors.

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

The required carbon taxes and associated costs vary significantly across regions in all of the models. This indicates that the same proportional reductions in emissions across all regions would give rise to very different costs in different regions and would thus be globally inefficient - with great potential for savings in the global cost of reducing emissions through the use of emission trading between countries or regions (see section 1.5.2.1) or a global carbon tax.

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

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

Energy Modeling Forum Project 12 (Impact of Carbon Emission Control Strategies)

A recent study at Stanford, the Energy Modelling Forum Project - 12, examines the cost of reducing CO₂ emissions (Energy Modeling Forum, 1993). A diverse group of economic models, employing common assumptions for selected numerical inputs, were used to analyze a standardized set of emission reduction scenarios. In all, 14 top-down models participated in the study.

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

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

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

The modelers generally used taxes based on the carbon content of the fossil fuels in order to achieve a prescribed emissions reduction. The magnitude of the tax provides a rough estimate of the degree of market intervention that would be required to achieve the carbon emissions target. Estimates range from \$20 to \$140 per ton for the carbon taxes required to hold emissions at 1990 levels in 2010. Estimates of the carbon taxes required to reduce

emissions by 20% below 1990 levels in 2010 range from \$50 to \$330 per ton.

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

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

The overall impact of a carbon tax will depend not only on the size of the tax but also on the uses to which the revenues are put. In the standard EMF scenarios, it was assumed that tax revenues will be redistributed in a neutral manner (i.e., without affecting the marginal tax rates). There are, of course, numerous ways in which tax revenues can be used. These include: reducing budget deficits; reducing marginal rates of income, payroll, corporate or other taxes; granting tax incentives to preferred activities; or increasing the level of government expenditures. The costs of the tax will vary widely depending on how the revenues are recycled.

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

79. CAFE standards, which apply to each producer's fleets, imposes different shadow prices on each producer. Thus producers that might have a comparative advantage in making small cars are encouraged to expand into large cars. The imposition of CAFE standards thus intrudes on the underlying economic forces associated with industrial organization. To be sure, there are ways of enhancing the economic efficiency of regulatory systems--such as tradeable CAFE standards--but even with these improvements, the regulatory structures impose unnecessary economic costs to achieve given emission reductions.

80. Indeed, the "ratchet effect," a commonly observed phenomena in the command and control economies (Stiglitz, 1975; Weitzman, 19) leads firms to just satisfy the target.

81. Two examples from the United States Clean Air Act: 1) the requirement that coal-burning power plants install stack-gas scrubbers even if they burn low-sulfur Western coal; 2) the mandates for ethanol in reformulated gasoline.

82. Different observers have defined sustainable development in different ways. The Brundtland Commission (1987) offered this interpretation:

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

The Interamerican Development Bank (date) suggested this definition:

Development that distributes the benefits of economic progress more equitably, protects both local and global environments for future generations, and truly improves the quality of life.

Both of these statements can be viewed as informal statements of the definition proposed by Solow.

83. Because most developing and transitional economies are still in the initial stages of establishing their economic infrastructure, it is difficult to calculate the costs of CO₂ mitigation (Pachauri and Khanna, 1993; see Kononov, 1993 for transitional economy example). As a result, the cost of several mitigation measures which appear to be low in the short run could, in fact, result in very large costs in the longer run. If a particular action results in reduction of CO₂ emissions at low direct cost, but over a period of time slows down the alleviation of poverty, it could lead to large positive costs in the long run, for the following reasons: First, poverty and population growth have a strong and positive correlation; second, deforestation for fuel and fodder is also intensified by high levels of poverty (Pachauri and Khanna, 1993).

84. Experts disagree over the future trend in population growth in developing countries. Recent declines in growth rates have shown that less developed countries are not going through the classical demographic transition that took place in industrialized countries over the last century. The World Bank, for example, in its 1992 World Development Report stated "declining fertility rates associated with these projections should not be taken for granted. They are rapid in historical context, they imply substantial progress in education and income opportunities for women and they will require a doubling in real terms of annual expenditure on family planning programs from \$4 billion (US) to \$8 billion (US) during the 1990's." This view has received widespread support. See, e.g., Bongaarts (1994) who calls for even greater extension of family planning programs beyond the traditional contraceptive information, services, and supplies typically provided. A study by Robey *et al.* (1993) examines the decline in fertility rates in many developing countries. They find that throughout the developing world, birth rates have declined by one third since the mid-1960s: women formerly had six children on average, but today they have four. They cite evidence that birth rates in the developing world have fallen even in the absence of improved living conditions. The decrease has also proceeded with remarkable speed. Developing countries appear to have benefited from the growing influence and scope of family-planning programs, from new contraceptive technologies and from the educational power of mass media.

85. Significant variation exists presently among the many cost studies. However, it is clear that significant opportunities exist for cost-effective reductions in net carbon emissions via sequestration. Table 1 compares the results of several cost studies of carbon sequestration, organized by forest type.

While some of the variation among these results can be explained by variations in methodology, much of the difference among the studies stems from differences in underlying assumptions. Among the key differences in assumptions that contribute to the considerable uncertainty in the precise costs and potential role for sequestration of carbon are: land, establishment, and maintenance costs; carbon uptake rates; transactions costs; and the choice of discount rates.

86. Even with the broad range of uncertainty that presently exists, there appears to be significant opportunities for carbon sequestration as an element of a carbon emissions reduction policy. It is likely that afforestation could contribute as much as 10⁹ tonnes to a reduction in global net annual carbon emissions. When forest management and agroforestry practices and biomass energy technologies are included in the technological response options, the potential contribution of managed forest ecosystems rises to above 2x10⁹ per year (Hall *et al.*, 1993; Dixon *et al.*, 1994). Afforestation on a large scale also opens up the possibility of greater diversification in electricity generation. Recent technological advances in wood gasification coupled with aeroderivative gas turbines increases the potential for the replacement of fossil fuels by biomass in power generation, depending on various economic factors and local circumstances.

87. Table 2 historic CO₂ and methane contributions by region (Grubb 2 Sept. 1994).

	Past contribution, 1800-1988 in %

	Industrial CO ₂	Total CO ₂	CO ₂ + CH ₄
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
Oceania	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 & MdEast	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

88.E.D. Larson, M.H. Ross, and R.H. Williams, "Beyond the Era of Materials," *Scientific American*, vol. 254, no. 6, pp. 34-41, June 1986; A.K.N. Reddy and J. Goldemberg, "Energy for the Developing World," *Scientific American*, September 1990, pp. 111-118.

89.Edmonds et al. 1994; Energy Modeling Forum 1993, section 1.6.4; "Costs" chapter of this report.

90.Programs such as the "Golden Carrot" appliance program in the U.S.A. and Sweden are leading to the adoption of cost-effective energy efficient lighting fixtures, refrigerators, washing machines, etc. Such programs usually are more successful when changes in equipment are introduced either to conform to new environmental regulations or to replace obsolete equipment. Some developing countries are moving toward the same policies. Moreover, evidence shows that multinational corporations based in the U.S.A. or Western Europe are not exporting pollution when establishing subsidiaries in developing countries, but are instead adopting state-of-the-art environmental controls. Reductions in trade barriers and increased world trade tends to work in the same direction (U.N. Environment and Development Branch, U.N. Center for Transnational Corporations, "Options to Increase Transfer of Environmentally Sound Technologies to Developing Countries on Favorable Terms," New York, 1991, 89pp.

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DECISION MAKING FRAMEWORK TO ADDRESS CLIMATE CHANGE

IPCC WORKING GROUP III WRITING TEAM II

CHAPTER 2

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2.1. INTRODUCTION

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 followed 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, sovereignty 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 concerning 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%.

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 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 the 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 uncertainties of climate change decision making are characteristically 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 for a very long term and differently,
- Any wrong decision made now can only be identified after a long lag, by which time it might be too late. (Distributional/regional effects)
- It is subject to non-linearity and can lead to large damages, irreversibility and 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 benefits in undertaking "no regret strategies" such as savings of fuel, pollution, traffic congestion and so on. The uncertainties concerned with the climate change debate here can be classified into the following categories:

- 1 1. scientific uncertainties regarding the effects of emissions of GHG on climate change
2 characterized by four important variables among many others, viz., mean temperature rise,
3 sea level rise, reduction of moisture, coastal erosion and draughts one could also call this
4 uncertainties relating geographical and atmospheric changes. The interrelationships among
5 these variables are also uncertain.
- 6 2. Impact uncertainties corresponding to each of the above scientific uncertainties where it is
7 not clear how much impacts different levels of climatological variables will have on, say,
8 biomass productivity, eg., that of agriculture and forests, species loss - terrestrial and marine,
9 and other discomfort and damage costs eg., cost of increased airconditioning. Cline (1992)
10 has elaborated these and calls them as benefits of avoiding climate change.
- 11 3. These physical impacts will also translate into economic impacts but the extent and nature of
12 these is uncertain. "Economic uncertainties" concern the effects of Climate Change on
13 national and therefore individual incomes. Both the costs and benefits of abatement are
14 uncertain. Costs of abatement could be different for each region and could have different
15 impacts on GDP growth of different nations. However, the uncertainties related to the costs
16 are less than those associated with the benefits. Here again, the some level of geophysical
17 impacts could lead to different economic impacts to countries at different levels of economic
18 development.
- 19 4. Technological uncertainties concern the availability (lead times) and cost of reliable
20 technologies and their impacts on reducing emissions. As shown by Hafele et al. (1981), it
21 takes nearly forty to fifty years for a new energy carrier to capture 50% of the market from the
22 time it captures 1% of the market. Judging by this thumb rule, there are not many
23 technologies to look forward to in the very near future. Though many technologies look
24 promising, they have yet to enter in global energy balances. Even if there are many successful
25 demonstrations of carbon free technologies, the ultimate test is to enter the global energy
26 balances, which at present still consist of coal, oil, gas, hydro and nuclear energy. In fact, it is
27 possible that the nuclear energy which is a part of the global and national energy balances
28 today, might make an exit without reaching its full potential. Thus, lead times required for
29 transition in energy system are very large. The lead times required for abatement technologies

- 1 to be effective and extent of abatement possible by each, thus, become important factors in
2 decision making.

3 **2.1.2.1 Relating scientific uncertainties with impact uncertainties:**

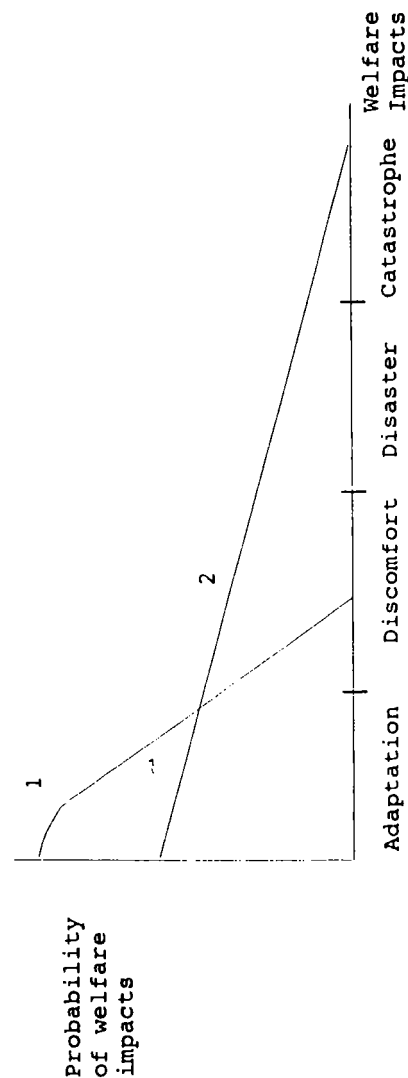
4 How are these uncertainties related? Scientific uncertainties concerning the changes in
5 climate variables, can be linked with impact uncertainties as follows. As figure 1a shows, for low
6 levels of climate change one is in the zone of adaptation. Further degrees of damages could lead
7 to what is termed as "discomfort" zone which extends to disaster for some. We refer to disaster
8 as "an extreme adverse effect on a part of the world or a group of the world's population due to
9 global climate change which occurs with moderate probability". For example, a small percentage
10 in sea level rise might cause catastrophic damage only to Bangladesh and Maldives but, might
11 not have as much effect on the rest of the globe. On the other hand, we define catastrophe as "an
12 extreme event affecting climate and biosphere as we know them and hence the mankind as a
13 whole." This can occur with a small probability for say a temperature rise of 4°C but with a
14 higher probability with a temperature change of 6°C. This has to be avoided even if the costs
15 seem very high, because apparent and hidden costs of irreversible damages and extensive
16 adaptation are high.

17 **2.1.2.2 Relating impact uncertainties with economic uncertainties:**

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

- 21 I. Impacts themselves may be higher in geophysical terms. For example, for a given rise in
22 global mean temperature, temperature rise in Indian subcontinent could be higher than in,
23 say, North America.
- 24 II. Even the same change say, 10°C temperature rise, could have more impact at 25°C average
25 temperature than at location with 15°C average temperature.
- 26 III. Even the same amount of adaptation costs say, \$1 billion, could have different economic
27 impacts due to differences in economic resources and technological capability.

DIFFERENT WELFARE IMPACTS FOR THE SAME CLIMATIC DAMAGE



1 : Rich country can accept more risks, they can be within adaptation zone

2 : The same risk can bring economic disaster to a poor country

Figure 2.2

Decision Making Framework

2.2.1 Concentrations not emissions:

The real climate change problem is one of high 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 Intergovernmental Negotiating Committee (INC), the concentration levels as shown in Fig.2.3b, are yet to be discussed. One should also note that those who emit early on and reduce much later pose bigger atmospheric burden (in terms of concentrations and their climate change effect) than those who emit much less now and who could potentially increase their cumulative emission later (Fig.2.3c). Hence, climate change decision problem should be addressed in terms of concentrations where earlier reductions should be rewarded to account for their less harmful consequences and to encourage early actions. While we decide to wait for more information, the stock of concentrations gets larger, passing a larger burden to future generations.

INSERT FIGURE 2.3 ABOUT HERE

2.2.2 Absorption capacity:

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

Greenhouse gas emissions are absorbed by forests, oceans, agriculture and so on. Thus, not all emissions end up as concentrations in the atmosphere. It is likely that this absorption capacity, also known as sinks, is eroding fast due to denuded forests and polluted oceans. Assuming that about 4 billion tons of carbon dioxide is absorbed, one implication could be that if humanity lived a lifestyle corresponding to about 0.66 tonne of emissions per person, per year, there would be no rise in atmospheric concentration of greenhouse gases for stabilisation at current level of concentrations and for current population. According to this principle, those who emit less than this amount are not responsible for climate change effects. In other words,

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.

INSERT FIGURE 2.1 AND 2.2 ABOUT HERE

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 the collective decision making criteria. 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, global policy instruments and sequential decision making. Various decision tools such as the notions of uncertainty, risk, bounded rationality, insurance and portfolio approaches to climate change are discussed in section 2.5. Finally, in section 2.6, we provide interlinkages between various components of climate change decision problem.

2.2 THE NATURE AND GENESIS OF THE CLIMATE CHANGE DECISION PROBLEM

In addition to uncertainties there are other features of the climate change problem as described below.

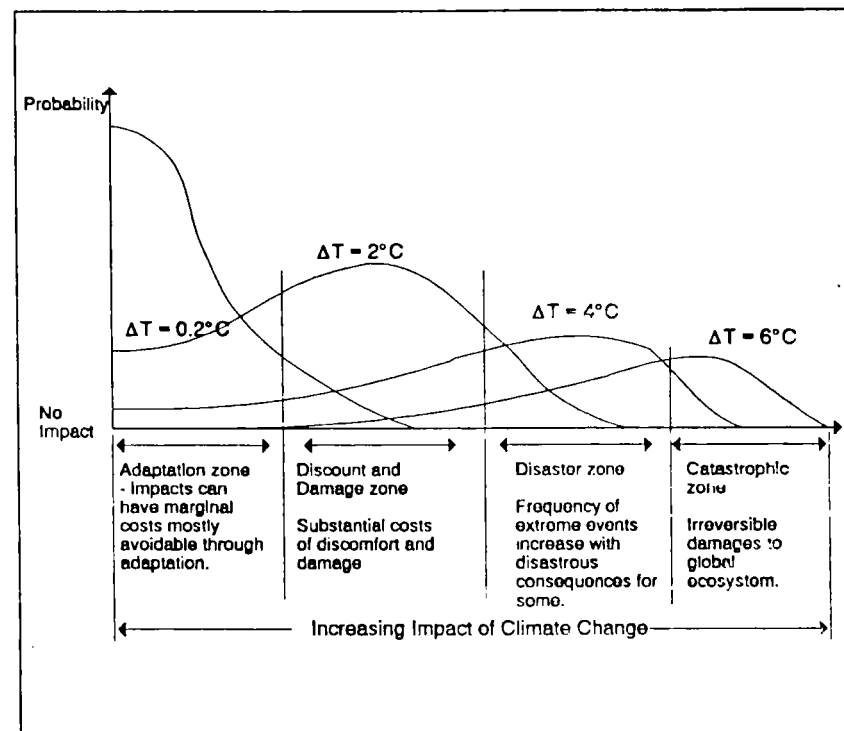
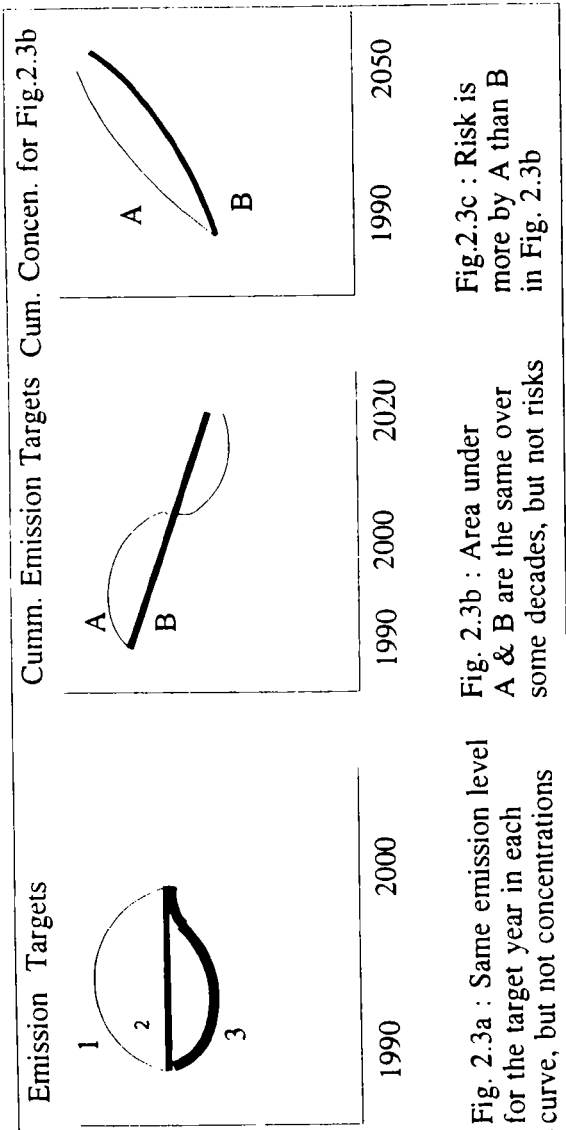


Figure 1: Schematic linkage between scientific uncertainties and impacts uncertainties.

Area under each probability distribution curve is 1. At $\Delta T = 0.2^\circ\text{C}$, the probability that there is no impact is much larger than at $\Delta T = 6^\circ\text{C}$. Reverse is the case for catastrophic zone. Similar relationships may be there for different levels of sea level rise.

EMISSIONS, CONCENTRATIONS AND CLIMATE CHANGE RISK



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 cumulative emissions. Fig.2.3b shows that the cumulative 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. Therefore, earlier reduction should be rewarded and delay should be penalised.

Figure 2.3

Decision Making Framework

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 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 , there will be similar and greater risk at time $t+1$. The benefits of abatement are additive. This has two implications: once it gets in motion, it would be difficult to halt it. Corollary of that is, it 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. That is, small but regular reductions may be desirable than hoping to reduce suddenly and a lot later, which can be traumatic, if not impossible. Since learning curve is usually slow in the beginning, it is better to begin early. 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 weapons before the war strikes, 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? One should also note that the insurance companies have indicated a rise in the frequencies of extreme events in recent times and as a result the compensation paid by them is also rising. Even one or two additional extreme events compared to the expected average are likely to bankrupt insurance companies. Increase in the risk premia would be too large in such a circumstances where the risk itself follows an increasing trend rather than a random

phenomenon. 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 should exogenously decide on a risk minimization strategy in terms of concentrations of GHG, which the North should be asked to lead.

2.2.4 Inequalities in responsibilities:

Climate change problem is beset with most difficult problem of inequalities in responsibilities. North continues to emit 70% of CO₂ 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 countries of the South have inadequate living standards with insufficient nutrition, provision for safe drinking water and access to sanitation. 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 privileged (viz., North) reducing and the underprivileged (viz., South) increasing their emissions, till some equality is reached. 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 point is analyzed in detail in the section on North-South transfers.

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. This forum should decide what is good for the global welfare. 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.

First stage involves decisions at global level, such as choosing concentration level stabilization and emission growth paths and their interregional allocations. Collective decision making has to be based on non-utility based criteria as we do not have a global welfare function that integrates utilities of different stakeholders. One can use risk based criteria. 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, they could have unequal rights, so as to have more say in this matter. It is seldom that polluters decide what level of pollution should be tolerated. Yet, their difficulties in responding quickly has to be kept in view. We collect such non-utility based criteria in the following box. The reader is referred to Morgan and Henrion (1990) for further details.

BOX 2.1: Examples of some collective decision criteria

(Risk based criteria)

Zero risk:	Irrespective of the costs and benefits, remove all risks involved in the decision problem
Bounded risk:	Irrespective of the costs and benefits, bound the risks to a particular prespecified level
Compensation:	Allow risks to be imposed only on people who are willing to be exposed to these risks with compensation.
Liability:	Risks might be imposed upon other people without their knowledge or consent in which case they should be eligible for liability damages from the parties whose actions resulted in such damages.

Conventions: If all the relevant parties involved in the decision making process are constrained by a set of rules, then any decision should adhere to this set of rules.

These non-utility based criteria play an important role in the global climate change decision problem. For example, when one is unaware of the probabilities relating to the impacts and when these negative impacts are irreversible, one might prefer the bounded risk criterion. If one takes a strong environmentalist view, one would prefer to have zero climate related risk: this would mean avoiding climate change at any cost. Under the liability rule, the parties whose actions inflict negative externalities upon others are liable for any damages they impose; the liable parties whose actions might cause possible damages could go in for liability insurance. If the parties involved are governed by a convention such as FCCC, then all the decisions should be made within the constraints set by the convention, which in turn are accepted by all the parties involved in the decision making process.

The need for an equitable distribution of tasks, both at national and international levels is the cornerstone of 1992 FCCC. 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" implied that the industrialized nations must assume the prime share of the effort - first by adapting specific national measures to stabilize GHG emissions, second by promoting the transfer of financial resources, knowhow and/or technologies to developing countries, in particular, the least developed countries (FCCC, 1992, BUWAL, 1994). All countries should participate collectively in efforts aimed at solving global environmental problems, based on an equitable sharing of responsibilities. In this regard, increased solidarity between the planet's rich and poor regions is essential. To achieve that end, the following considerations need to go into collective decision making.

2.3.2 Considerations of 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 anthropogenic 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 assessed the implications of climate change for world food supply taking account of : a) The uncertainty about the level of expected climate change. The estimates of committed warming for 'effective CO₂ doubling' used in the study are in the upper end of IPCC prescribed range. Therefore, the yield estimates of their study, using these high temperature estimates, would be pessimistic. On the other hand, the study also uses a high CO₂ concentration level of 555 ppm in the year 2060. Therefore, the yield estimates (helped by 'CO₂ fertilization effect') would be optimistic. Thus there is 'some sort' of balancing in the study. b) Different adaptive responses at the farm level. c) Alternative pathways of development including partial and full trade liberalization, low and moderate economic growth etc.

The study concludes that the world cereal production is estimated to decrease between 1 and 7%, depending on the Global Climate Model (GCM) climate scenario. 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 developed countries

1 there would be an increase in cereal production to the tune of 2 to 14% after taking into account
 2 the direct physiological effects of CO₂ and the farm level adaptations, there would be a decrease
 3 in developing countries to the tune of 6 to 12% even after taking the fertilization effects of
 4 carbon dioxide and the farm level adaptations. This loss of production in developing countries,
 5 together with rising agriculture prices, according to the study, is likely to increase the number of
 6 people at risk of hunger, in the order of 5-50%, depending on the GCM scenario.

7 Thus, CO₂ concentration levels of double the value of preindustrial values in 2060 may
 8 not be acceptable to the South. If 550 ppm is reached in 2060 AD, it is likely that given the long
 9 lead times required, stabilization reached by say, 2100 AD, would be much higher and the misery
 10 will continue. Such a course will be unacceptable to a large portion of humanity.

11 **2.3.2.2 Anthropocentric Vs Ecocentric approaches:**

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

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

25 An ecocentric view, on the other hand, views homo sapiens as one of the species on the
 26 planet earth expected not just to live in harmony and balance with other species but also to share
 27 the biosphere (which includes oceans, rivers, atmosphere, etc.) which provide sustenance to other
 28 species too. To put it sharply, humankind's abrogation of decision making powers regarding

1 nature is questioned. The ecocentric view proposes to curtail such decision making power. This
 2 view extends the ethical stand to include other animals and plants; Equality is not only among
 3 human beings but also between humans and other living species.

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

8 **2.3.2.3 Poverty and Climate Change:**

9 Another important issue while making climate change decisions is that of poverty and the
 10 linkages between poverty and climate change impacts. For example, increased occurrence of
 11 floods and other extreme events are indicated due to climate change. In such a situation, it is the
 12 poor who are always vulnerable compared to the well off. Take the case of the recent earthquake
 13 in India; in this natural disaster, more than 10,000 people died compared to only a few in the
 14 earthquake of similar intensity in California. In essence, the threshold level to withstand these
 15 impacts would be less for developing countries when compared to the developed ones. In such a
 16 case, given that the present accumulation of GHG in atmosphere is due to advanced countries,
 17 will they be forthcoming to insure the poor against such calamities?

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

26 While the rich can argue about whether to enjoy more now or pay later in the future and if
 27 so what discount rate to use, this is unlikely to be a major issue for the poor, who are on the
 28 margin of subsistence. If forced to reduce their GHG emissions or to be pushed to adopt to

climate change, they would have no option but to reduce their current consumption. Rising concentrations of GHG in atmosphere will bring more constraints on their future development. To conclude, 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 should address this primary concern. Such a concern automatically raises the issue of equitable distribution which we discuss later.

2.3.2.4 Intergenerational equity and discounting:

Efficient allocation warrants cost effective use of resources. A major tool used to choose a cost effective alternative among many alternatives is that of cost benefit analysis. 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 growth rates. In the former case, if the future benefits outweigh the present abatement costs, one would expect that the future 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-made 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.

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. Hence, 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).

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 one should not pass on liabilities. Abatement should not be looked at as an investment option giving returns in the future but as a liability reduction exercise. Hence, one should first decide exogenously the level of abatement of concentrations 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 should formulate their strategies to follow respective emission paths. While deciding who should do what, one has to take into account various factors such as 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 emissions mount, if no directions are given. A portion of every tonne of GHG emitted occupies some environmental space for about 500 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 and 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 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. That may be a small share of U.S. GDP, but such measures, even scaling for their coast lines, for say, Bangladesh, could require very large share of their GDP. Who shall pay Bangladesh 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 2.50C 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 hemisphere 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.

Unfortunately, most models developed in the North assume away capacity to adapt without offering to pay for adaptation to South. This would impose huge burden on South as well as future generations everywhere. 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.

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 transfers¹.

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 privileges 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. Cheaper opportunities have to be foregone.

¹ K. Smith (1991) has used a concept of natural debt to address these issues.

Hence, North-South transfers of large amounts are needed to compensate South for the development opportunities foregone. (Lost opportunities). As against all these, Global Environment Facility (GEF) gets replenishment of US \$ 2 billion for three years to address our different global environmental concerns such as climate change, biodiversity, international water, CFC reducing to serve Montreal protocol. 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.

INSERT FIGURE 2.4 ABOUT HERE

The first step in 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 CO₂, 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

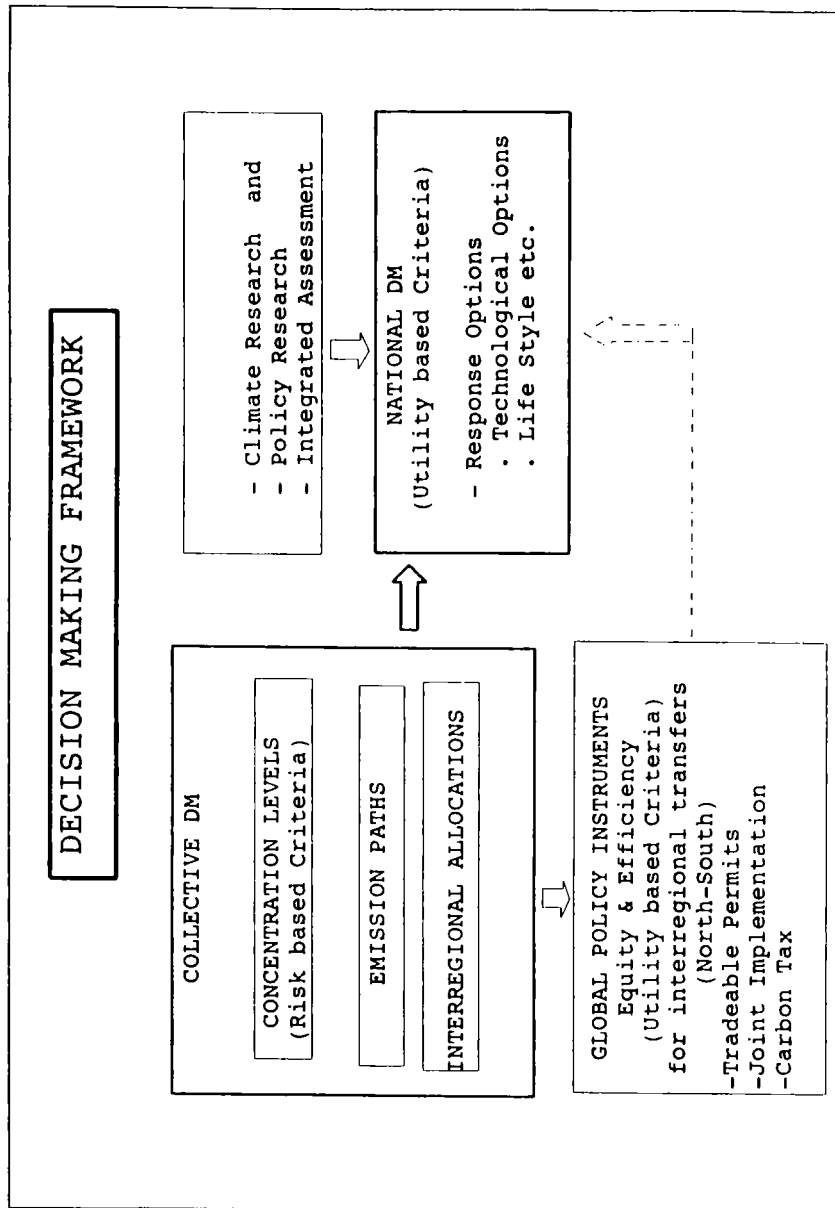


Figure 2.4

1 would be danger of irreversible damages and high adaptative costs. Remember that, if 550 ppm is
 2 chosen, it is difficult to go back to 440 ppm, but vice versa is possible.

3 INSERT FIGURE 2.5 ABOUT HERE

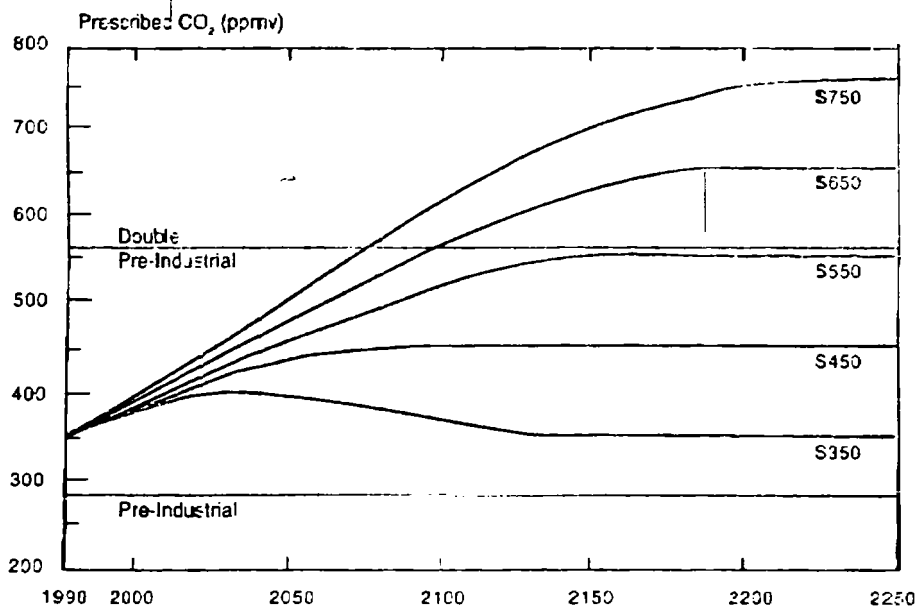
4 The second step is to determine global emission scenarios corresponding to the
 5 concentration levels decided in the first step. These alternatives are shown in figure 2.6.
 6 However, there will be some flexibility and there could be more ways to reach a particular target
 7 than the figure illustrates. It shows that time to act is now and 'wait and watch' attitude could
 8 land up in difficulty. For example, if the concentration level is decided to be fixed at, say, 450
 9 ppmv by 2050, then the corresponding global emission scenario could be somewhat close to a
 10 scenario like IS92c. In this scenario the annual growth rate of carbon emissions in the period
 11 1990-2020 are estimated to be about 0.56%, with the corresponding CO₂ emissions (per year) in
 12 the years 2025 and 2100 expected to be around 8.8 and 4.6 PgC respectively, it should be noted
 13 that one could think of other alternative scenarios that meet the same ppm level of 450. The task
 14 in step 2 is to select from amongst such alternative scenarios. In case of 350 ppm, Annex I
 15 countries may need to curtail severely their emissions, and non-Annex I countries can grow only
 16 to the extent that Annex I countries reduce. Parikh and Painuly (1994) suggested that to reduce
 17 adaptation burden, North should reduce their emissions to allow the South to grow and develop.
 18 That is, reduce to the extent so as to compensate for the rise in emissions by the South to keep
 19 1990 emission levels constant till such time as equal per capita levels are reached. This calls for
 20 more than 30% reduction by the North by 2025. This way, the North will have a stake in the
 21 development of the South so as to see that the South has access to the best of technologies so the
 22 emissions of South rise as little as possible, without compromising their development. In case of
 23 450 ppm, some development for non-Annex I countries is possible over and above the span given
 24 by reduction of North. In case of 550 ppm, large adaptations costs are foreseen.

25 INSERT FIGURE 2.6 ABOUT HERE

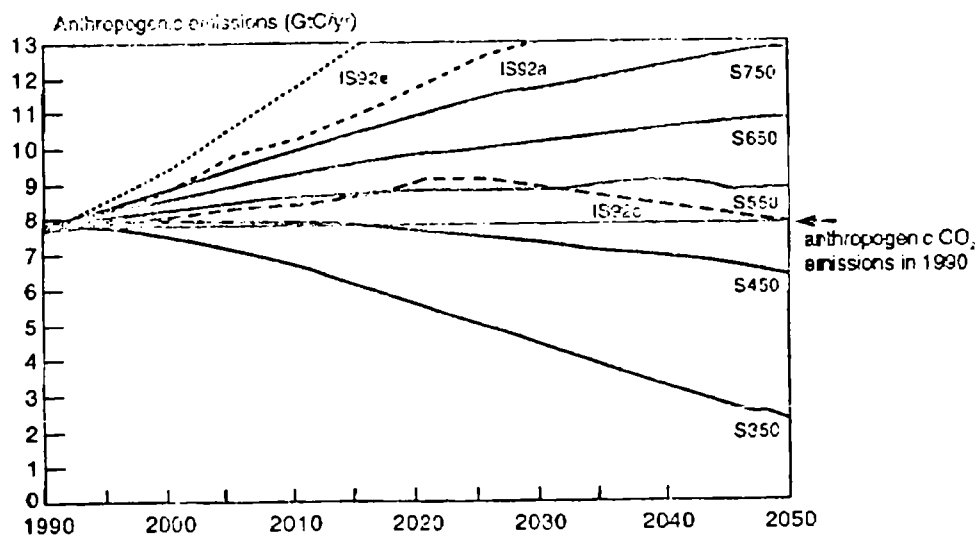
26 2.4.2 Criteria for Interregional allocations:

27 Having determined concentration levels for stabilization and emission paths, the next step
 28 is to broadly allocate goals. Requirement for minimum standard of living should be also used as

Profile of Atmospheric CO₂ Concentration Leading to Stabilisation at 350, 450, 550, 650 and 750 ppmv



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



criteria. It is also suggested in section 2.3 that some deterrent should be there to encourage action and stop free riding while these goals are being negotiated, such as liability for concentrations after a specific year. Those who use higher atmospheric capacity should have higher responsibility.

The distribution of per capita carbon emissions between regions is highly skewed. "North" has a per capita emission which is approximately four times that of "South". Within north, North America's per capita share is twice as much as that of western Europe. The same is true of south too; Brazil has a higher per capita emission than the rest of the south. If one compares emissions per unit of GDP, then, south and eastern Europe would have higher emissions per unit of GDP 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 infrastructures such as, schools, hospitals, power plants, in greater number due to unsatisfied development needs such as health, nutrition and so on. This is comparable to the fact that, growing children need more food than adults past fifty. Higher need for new infrastructure building explains high emission per GDP and also calls for higher growth in future. In addition, there is an adjustment 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 ² C/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 historical emissions from developing countries have been low and hence their share of the overall concentration is also low. A general argument put forward against such historical responsibilities runs as follows. The current generations of the developed countries cannot be held responsible for the acts of their

ancestors, whose emissions caused the present concentration problem. It might be true that the current generation has no moral responsibility for the actions of the past generations. But, 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 as environmental resources are common property.

2.4.3 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 making 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 above or other means. These are referred as global policy instruments. They can be selected based on utility (global) based criteria. Institutional failures such as lack of well defined property rights and market failures such as distortionary subsidies always lead to a gap 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 economic 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.

To elaborate, the 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) fiscal instruments (emission taxes, subsidies), (4) financial instruments (such as GEF, green fund, location incentives), and (5) liability instruments (liability standards, damage liability, liability insurance).

Property rights define ownership rights to the hitherto common property environmental resources. Once the rights are defined, market takes care of the optimal use of the environmental resources by internalizing the externalities. They are particularly applicable to land, water resources and minerals. But, in the case of global public goods such as biodiversity and environment, national sovereignty might come in the way of defining global community property rights. However, it should be recognized that behind any policy there is an implicit allocation of the global community property rights.

Tradeable emission quotas 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 such as equality of per capita emissions. Since the global quota will be fixed at or below the current emission levels, there will be scarcity and emission permits acquire market price. Countries with a deficit of permits either have to reduce emission from existing plants to accommodate new plants or they have to buy permits from the countries which have a surplus of such emission permits. Hence, the desired level of environmental quality is maintained at the minimum cost to the society and strong incentives are provided to improve efficiency of the existing plants and to develop new emission efficient technologies. It is necessary to recognise that the burden (benefit) imposed (accrued) depends critically on initial allocation of these permits. Justice and equity require that such allocations treat all human beings equally. Unless tradeable quotas are given immediately, South does not gain much from it. If given later on, it will only mean caps for their emissions. It will be difficult to get Annex I countries to agree later.

Alternatively, one could also use fiscal instruments such as carbon tax to correct the environmental externality. One should set the tax equal to the marginal environmental damage corresponding to the socially optimal level of pollution. Here, the marginal benefit from the

reduction of emissions equal the marginal cost of such reduction. The environmental taxes could be levied on the pollutant itself (say, emissions per se) or on final products associated with the environmental externalities. Taxes on pollutants, known as pollution charges, are directly applied to the offending substances, say a carbon tax. Once it is accepted that developing countries have a right to develop (i.e., increase their emissions of GHG, as is recognised by FCCC), global carbon tax should not apply to developing countries.

As opposed to the fiscal instruments which are correctives, legal instruments serve as deterrents. They induce socially responsible behavior by establishing legal liability for (1) environmental damage, (2) resultant damage to human life, (3) non-compliance to international environmental laws and regulations and (4) non-payment of environmental taxes and charges. Here, the threat of possible punishment and sanctions against offending countries forces compliance to the legal standard. Liability insurance has emerged as a major policy instrument for pooling and sharing liability risks among liable parties. But, a precondition for a successful use of legal standards is the existence of well defined legal systems.

Joint implementation has emerged as another policy instruments to reduce emissions. This is a cost effective tool by which the developed countries reduce emissions in developing countries and earn credits either in their own countries in the form of carbon tax rebate or at international level, if there is agreement on caps. This mechanism enables resource and technology inflow into developing countries from the developed country parties. But, one should keep in mind many controversies which surround this concept, especially in the area of sink enhancement. For a detailed account of joint implementation and problems associated with it, the readers are referred to Parikh (1994).

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.

2.4.4 Sequential decision making:

2.4.4.1 Hedging strategies:

The approach based on the exploration of the future by using scenarios is one of the few relatively useful instruments. Scenario analysis is, however, only one way to look at the here-and-now significance of alternative futures. Uncertainty is only indirectly treated. The analysis proceeds as if we definitely had the opportunity to learn the state of the world before taking action - in other words, as if all uncertainties are resolved prior to the date at which decisions are taken.

To deal with uncertainty proper, a hedging policy is needed to supplement current scenario analysis. A hedging strategy means acting without knowing which of the possible states of the world will occur - and then learning and acting again if the case arises. This leads to elect strategies that hedge against surprises associated to strong uncertainty in a sequence of decisions allowing new information to be incorporated into a complex decision process.

2.4.4.2 Scenario analysis and hedging strategy:

A scenario approach is oriented towards a "learn-then act" characterisation of the decision problem: all uncertainties are more or less resolved prior to the date at which action is taken. By contrast, a hedging strategy deals with an "act-then learn" characterisation of the decision problem: decisions are taken for the years to come without knowing which of the possible states of the world will occur (parenthetically, scenarios can be used to grasp those possible states).

Intuitively, a scenario analysis would lead to let us know the state of the world that might occur and then to make a decision in a certainty-like context. By contrast, an optimal hedging strategy is characterised by decisions that are taken at discrete points of time before the resolution of uncertainty; intuitively, this coincides with a low-regret policy.

Box:2.2 Scenario Analysis Vs. Hedging Policy

Strategy	Characterisation of the decision problem	Uncertainty	Decision
Scenario analysis	learn-then-act	As if there were the opportunity to learn the state of the world before taking action.	Tendency for taking action only once uncertainty is resolved.
Hedging Policy	act-then-learn	Strong uncertainty	Action is taken prior to the date at which uncertainty is resolved.

From 2020 onward, it is supposed that decisions will be made after the resolution of uncertainty. According to Manne and Richels (1992), it turns out that under "act-then learn", we make the decisions for 2000 and 2010 without knowing which of the states of the world (low, moderate, and high damage potential) will occur and must select an optimal hedging policy for the emissions levels. By contrast with the scenario analysis, the hedging strategy consists to adopting an emissions level that lies between the extreme case shown by different emissions

scenarios, and the size of the edging strategy will depend on the probabilities assigned to alternative outcomes.

2.4.4.3 Hedging policy and the carbon tax

According to Manne and Richels, although with the learn-then act approach, it is possible to adapt smoothly to whichever of the (three) states of the world that eventually occur, with act-then-learn, one does not know the state of the world during the initial years. The carbon tax rate must thus be identical until the uncertainties are nearly resolved. As a consequence, there is going to be some abrupt transition at the point when it becomes possible to learn which of the carbon limitations is going to be adopted. If a high carbon limitation is required, there are going to be heavy costs of a rapid transition for the economy.

Another example

Another example of a sequential decision making strategy is reported by Hammitt et al. (1992). According to well publicised works (see also for instance 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.

First, energy conservation represents a set of low-cost, quickly implemented policies. To illustrate, if adopted, 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 remitting 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 make 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 a the transition half-life, or the time until half the capital stock then operating is non-emitting" (Hammitt et al., 1992).

Hammit et al. (1992) consider two near-term policies, aggressive and moderate reduction. 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).

2.4.4.4 The value of improved information:

With learn-then act, the rules of the information depends on changes in the probabilities assigned to each scenario before and after the study. "If the probabilities of scenarios remain equal, then the study's value is zero; if, on the other hand, only one scenario can be selected, a study can be worth as much as 100 billion dollars" (Shlyakhter et al., 1994).

With act-then learn, there is an agreement that uncertainty cannot be resolved before a decision is taken. Certainty would be at a too high a cost. Therefore, initial decision relate to how much we are willing to pay to reduce uncertainties about the damage potential. The assumption, according to Manne and Richels (1992), is that a research program that is launched to improve our information will yield results soon enough to revise supply and conservation decisions for the year 2000. Regardless of the magnitude of research expenditures, it is unlikely that uncertainty can be fully resolved by 2000.

A decision tree reflecting this new sequential decision making is shown in figure 2.7. It shows that for the energy sector's near-term supply and conservation decision that must be made with respect to the uncertainty regarding the ultimate economic 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, moderate, or high (conditional probabilities; of Manne and Richels, 1992). This representation allows the use of standard probabilistic techniques to incorporate the outcome of the research program in the decision model (Global 2100, in this case). It should be noted that they only consider economic damage for present generation but do not compare it with damage in future for not abating. What are the benefits of the abatement costs? What is the value reduction of

extreme events? What is the value of reduced sea level rise and so on. These are not considered in their model. Nor do they consider paying for the emissions. Their conclusions are based on the assumptions of the possibility of free-riding.

INSERT FIGURE 2.7 ABOUT HERE

Maximum accuracy, or perfect information, would eliminate the need to hedge against surprise. Accuracy of the forecast, however, will not be maximum. We therefore will have to accommodate with hedging under imperfect information.

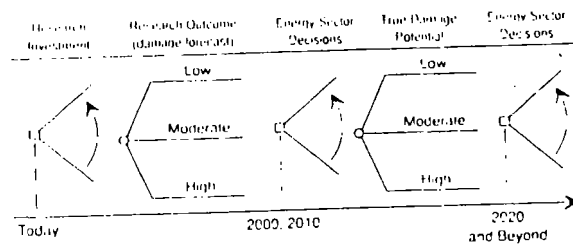
Critics of Manne and Richels' (1992) strategies stress that they are sensible only if something is done in the time between the discrete assessments (Shlyakhter et al., 1994), and that a 10-yr. delay may have little effect on the ensuing climate profile (Schesinger and Jiang, 1991) -- thus "the rate at which emissions can be reduced may be more important than when reductions begin" (Hammit et al., 1992).

The related "forms of insurance" would be put together as follows in a hedging strategy:

1. continued intensive science research to reduce climate and impact uncertainties;
2. development of new supply and conservation technologies to reduce abatement costs;
3. immediate reductions in emissions in order to slow climate changes.
4. reduce vulnerability.

As a consequence, policy makers should decide how to divide greenhouse insurance dollars among these four competing needs. What portion goes to resolving climate uncertainties? What portion goes to technology development? And what portion goes to immediate abatement of emissions? This concern raises the issue of insurance analysis which will be discussed in section 2.5.4.

Figure 2.7



2.5 CLIMATE RISK, INSURANCE, AND PORTFOLIO ANALYSIS IN NATIONAL AND COLLECTIVE DECISION MAKING

2.5.1 Uncertainty, Risk and Unpredictability: Some analytical insights:

Cognitive and computational limitations which characterise economic-oriented decision making are very relevant to climate change concerns. Accordingly, devices exist that can help to some extent at solving predictions where new information is needed to reduce uncertainties. "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).

We have to accommodate the supplementary uncertainty caused by possible changes in climate (Caselton and Luo, 1994) to make decisions. According to Chichilnisky and Heal (1993), today's concerns about global climate change break new ground in two ways with respect to uncertainty analysis. One is the global scope of the potential changes considered, such as changes in atmosphere of the planet. The second is that these changes appear to be driven by human activity, which has now reached levels at which it can affect the global climate. Climate has always been unpredictable, but the inclusion of these two new elements has extended this uncertainty both qualitatively and quantitatively. Classical formulation of uncertainty in economics might no longer suffice. There is uncertainty about basic scientific relationships, such as the link between gaseous emissions and global mean temperature. There is also uncertainty about the connections between global mean temperature and climate. If, from a scientific viewpoint, uncertainty about global mean temperature matters, from a socio-economic perspective, it is future climate, with associated wind patterns, humidity and rain patterns, regional and particular ecosystems impacts, conceivable trajectories and pace of change - together with future emissions of greenhouse gases, that matter. In turn, in so far as greenhouse gases emissions are man made emissions, and hence can be driven by economic activity and policy measures, the uncertainties and associated risks faced become endogenous. The fact is that they can be altered by agents.

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 statistical 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 statistical prediction - and consequently to the standard economic, namely "Bayesian", framework - and that is in short supply at present time.

What is the issue? Within the economic rationality framework, decisions are based on the valuation of outcomes and/or of alternatives. The valuation procedure describes uncertainties by means of the concept of "state of nature" (a description of the "state of the world"). Standard decision making is served by the Bayesian statistical approach which represents any information or knowledge concerning this state of nature by assigning probabilities. In this respect, the representation of information in the form of conventional, necessarily precise, probability distributions has been developed in the statistical literature for well over 100 years.

2.5.1.1 Rationality:

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). Assumptions also compose the 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. More radically, economic situations (and theory) are based on rationality, as a matter of principle.

Economic criteria of choice 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 ... 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).

Rationality and attached economic criteria or 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.

With respect to the climate change perspective, choices will be of collective and or longer-term view nature - they will no longer be individual and fixed choices (for instance, one cannot make the hypothesis that, in as far as global environmental concerns call for international agreements and actions, individual nations might act as individual economic agents do - also, 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). Choices will not be made with respect to a fixed set of alternatives, either. In addition, they will not be confined to market related decision situations, but will also be concerned with non-market related decision situations (including issues of ethics, equity, poverty, and fragility of natural ecosystems and species).

2.5.1.2 Utility based decision criteria:

Economists do not assert that human agents are "rational" by definition. Rationality is a lawlike refutable statement which "simply means behaviour in accordance with some ordering of alternatives in terms of relative desirability" (Arrow, 1951, Blaug, 1992). In this respect, it designates a "maximisation of something" (Arrow, 1987) which basically is the maximisation of the expected value of a given utility function (Savage, 1954). Subjective arguments are compatible components of the assumption of a consistent utility-maximising behaviour and profit-maximising conduct.

1 Main economic choice criteria are utility-based ones (cf. Box 2.3). Utility-based criteria
 2 mean maximising the expected utility. They entail decisions that are based on the valuation of
 3 outcomes - wealth levels, time streams of consumption, etc. - (Morgan and Henrion, 1990).

Box 2.3 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 ... maximize chance of best possible outcome, etc.	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. From among these losses find on with the maximum loss and try to minimise it. This a conservative criterion.

Maximin Gain.

Find the gains associated with each action and try to maximise the minimum of these gains.

1
 2 For example, utility-based criteria can involve a balancing of benefits and costs in a
 3 benefit-cost analysis framework. A more general formulation has been set up in terms of
 4 maximising a multi-attribute utility function (Box 2.3) for situations where options involve
 5 "collections of attributes that are incommensurate" (Keeney and Raiffa, 1976, Morgan and
 6 Henrion, 1990). The resulting decision models can thus avoid the dilemma of converting each
 7 attribute to an equivalent monetary value.

8 Variations to utility-based decision criteria are available. A cost effectiveness criterion
 9 can be used where the value of benefits cannot be estimated - but a choice must be made between
 10 alternatives (Morgan and Henrion, 1990). A maximum budget can be set to devote to risk
 11 management activity (bounded cost criterion). Finally, measures of "regret" can be chosen and
 12 the maximum regrets minimised (Box 2.3).

2.5.1.3 Bounded rationality:

14 As already mentioned, rational behaviour is a "first approximation" to actual behaviour.
 15 For instance, as soon as one faces either imperfect forms of competition or non-market resources
 16 allocation decisions, the knowledge requirements radically shift and exceed those usually
 17 required for the price system. It is, therefore, accepted that (economic) rationality hypotheses be
 18 supplemented by assumptions of a different character (e.g., information-gathering ability and
 19 limitation of both knowledge and computational capacity). It is accepted that rationality,
 20 obviously, is bounded (Simon, 1957, Arrow, 1987). Basically, these cognitive difficulties are

connected to decisions that lie far away from individual-related, standard economic situations; they are relative for example 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). This tells decision makers that rationality can be more concerned with the ways in which the actual decision-making process influences the decisions that are reached than with reaching decisions assuming the maximisation of utility, as we are used to consider from a standard economic viewpoint. This concept designates a different type of rationality, namely procedural rationality. Incidentally - though it is worth to be noted by decision-makers in the context of the Conference of the Parties (COP)₁ - a decision which optimises the expected value of utility will possibly be in opposition with a decision which optimises cooperation because the former places the focus on the decision to reach while the latter puts the emphasis on the decision process in itself.

2.5.1.4 Procedural kind of 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 (Faucheux and Froger, 1994).

Which kind of theory can best be applied to the decisions at hand? Shall we place interest in the decisions to be reached only, or shall we focus attention on the (international) decision-making process 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 can be at work for setting norms or institutional arrangements as a framework for further economic choices. What is the issue? Since the Framework Convention on Climate Change (FCCC) is currently into force, choices to be made vis-a-vis climate change can now be economically sounded choices - with due reference to other, economic as well as non-economic factors that affect decision making. In short, if one can consider ways and aims as equivalently important though separate objects in making decision, one can now consider that, to date, the way is fixed through FCCC, and that, consequently, one can put emphasis on the (economic) aims.

2.5.2 Formulation of a Decision Problem:

Decision problems under uncertainty and risk can be simplified. The classical ingredients of a decision problem under uncertainty are a set of feasible acts (B), 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 p assigned to each state s in S) (Schmediler and Wakker, 1987).¹ In choosing between acts, the decision-

¹ A specific way allowing to ... the case for uncertainty - originally about the availability of resources and about consumption and production possibilities - is the idea of contingent commodity ... by Arrow (1953) and developed by Debrue (1953). This device is added to

makers will elect that one with the highest "expected utility" - 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. Typically, however, reducing risk entails a reduction of benefits (Starr, 1989).

In view of the climate change concerns, and lack of knowledge and data, we undoubtedly have to address decision situations under "strong uncertainty" and even "near ignorance" in addition to those concerned with conventional levels of uncertainty or risk (see below). 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), and how to allow probability assignments to which subsets is going to be of paramount importance. This means that decision making to address climate change appears as a category of decision making which must envisage shifts to the traditional Bayesian scheme (Pate-Cornell, 1992, Caselton and Luo, 1994) when confronting to strong or even extreme uncertainties created by climate change¹. The

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.

¹ In decision making under "weak" 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 $p(B/A) = p(AB)/p(A)$, $p(B/A)$ is known as the posterior probability and depends upon $p(A)$ which is known as the 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

unpredictable characteristic of climate change gives rise to a kind of uncertainty which might not be straightforwardly reduced to Bayesian risk. While climatic and biological catastrophes normally imply a downward trend of expected revenue, technological or economic variability, which includes the prospect of being pleasantly surprised (Price, 1993), does not have this effect. In this respect, Price (1993) argues, risk is definitionally distinguished from uncertainty on the basis that the probability distribution of outcomes can be estimated, from historical data, modelling exercises, or even informed guesswork. Price (1993) continues, the most visible quantitative evidence of risk is, however, the higher rate of return generally demanded by investors in risky ventures.

2.5.2.1 Strong Uncertainty:

Certainty, to begin with, refers to situations in which chance is excluded because knowledge is sufficient. No probability distribution is needed (Fisher, 1930, Arrow, 1951).¹ Strong uncertainty refers to situations in which chance is included by knowledge is insufficient. It has always been thought of having an important effect on the workings of the economy. Unpredictability of climate changes can be partially understood under the concept of strong

global warming or climate change of unacceptable level is going to occur or not, then according to the "principle of sufficient 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 to get the posteriors. In summary, the Bayesian theory yields instructions on how to use new information to update beliefs "rationally" in certain circumstances.

¹ To formalise the conditions of certainty (and later on, of uncertainty), it is convenient to refer to Arrow's concept of state of the world, a description on the world so ... the consequences of every action would be known. The meaning of certainty is that the agent knows the state of the world.

uncertainty. In other words, the likelihood of an event occurring is not known at all (MIT, 1989) and the events upon which decision outcomes depend are not fully controlled by the decision agent - consequently, they are only known after the decision is made (Fishburn, 1987). Therefore, no probability distribution can be attached to the outcomes (Johansson, 1993) - e.g., conceivable outcomes will be known, but their probability of occurrence will not. According to the concept of state of nature, the meaning of uncertainty is that the agent does not know the state of the world (Arrow, 1971, 1984).

Yet, in the conjunction of utility theory and decision theory, probabilities of the events are made assessable with reference to personal judgement (subjective probability). Therefore, the criteria for choice can be based on numerical representations of the decision agent's preferences and values. The condition for making uncertainty computable is that agents at least believe that they know, even approximately, the revenue frequencies of the states of nature. In this case, however, a risk-like uncertainty is defined.

2.5.2.2 Addressing strong uncertainty:

Under climate changes situations, decision-makers need to pay attention to situations of strong uncertainty, which in this matter is not exactly an exceptional situation but rather 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 leads to mitigation and adaptation strategies, phasing out existing policies, climate and technology research, to hedge against surprises associated to strong uncertainty in a sequence of decisions allowing new information to be incorporated into the decision process.

Second, in so far as climate change risks can be delineated, the risk assessment of potential climate change will deliver probability distributions of the different estimates to policy makers (see integrated climate change risk assessment, Chapter 7). 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 would be natural to allow agents to trade securities insurance contracts.

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., 1994)?

These options can be reconciled by drawing distinctions between scenarios that are probable (risk situations) and those that are possible (uncertainty situations). According to Shlyakhter et al. (1994), 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. 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".

2.5.2.3 Risk:

Basically, risk refers to situations in which chance is included in the form of known probabilities. Risk refers to situations where probabilities are knowable (Johansson, 1993), or where the size of the event has a probability distribution (MIT, 1989). Individual insurance decisions and for instance technical situations usually fall within the risk category.

In economic situations, risk is exogenous and individual. It is for instance expressed by a set of exogenous states of nature whose values are random. At the beginning of our understanding of economics, risk was thought as unimportant because of our capability at hedging and diversifying and since risks could be perfectly insured (Knight, 1921, Bray, 1987). Knight's criterion was that "risk" was insurable while "uncertainty" was not inasmuch as the scientific method - namely the Bayesian scheme - could not be applied. This distinction has been since denied by many leading economists. The issue is that from a Bayesian standpoint, a subjective probability can always be formulated "as a bet on a certain event" and a decision-maker's beliefs can always be represented by a unique probability measure (Vercelli, 1991). Therefore, to the extent that agent have fully reliable information about a unique probability distribution, the scientific method can still be applied and uncertainty is reduced to "risk".

The climate change context makes associated risks endogenous and collective (Chichilnisky and Heal, 1993). Risk cannot anymore apply to any kind of uncertainty with

respect to the global environment. Indeed, climate-related risks cannot be expressed in a classical statistical sense (numerical probabilities) because of a lack of experiments, poor data and/or diverse data sources. For the insurance industry itself, circumstances have changed "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). Climate change implies a certain degree of irreducible unpredictability beyond the economic category of risk. This unpredictability arises in two ways. On the one hand, it appears with regard to the future structure and outcomes of any nature-economy joint system. On the other hand, it exists with regard to the characteristics of the evolution (rate, abruptness, etc.) of the processes involved. The unpredictability stresses strong uncertainty situations.

Box 2.4 Risks Associated to Climate Change

(After Chichilnisky (1994))

Climate change associated risks are:

- endogenous - they are affected by our actions
- correlative - they are not statistically independent risks.

They are defined as affecting large numbers of people in the same way. Think for instance about a 10 percent chance that 90 percent of the population will be harmed by global warming, a 25 percent chance that 50 percent of the population will be harmed, etc.

In addition, climate change associated risks can be characterised by (a) the scope, which is global on the nature side, and (b) the change in circumstances, which is man-induced.

2.5.2.4 Time:

We have presented decision making as if it was a one-shot process. In reality, one needs to make a series of decisions. For instance, the *Conference of the Parties (COP)* might be willing to wait for more information before deciding which levels of global carbon emissions are desirable. Before the information succeeds, one might have to take decisions regarding other issues (Parikh et al., 1994).

In particular, risks associated with such cases are known as temporal risks. In such *temporal situations*, as Machina (1984) points out, risk aversion is higher compared to the case of a temporal choices, and events with low probability (unlikeliness) and a possibly very large death toll such as catastrophes, become more important compared to "normal" physical risks.

Risky elements also lead to the role of interest for discounting. Basically, climate change is long-term oriented and is very large on the scale of the economy. It cannot be dealt with by private actions on this scale. Therefore, governmental actions are required, which are risky ones, and which consequently call for considerations about discounting (see Chapter 4), and other issues such as irreversibilities, insurance, and so on.

2.5.2.5 Information and value of information:

Will information, will more knowledge resolve uncertainty? Conventionally, improving information and knowledge should resolve uncertainties. As a paractical consequence, learning strategies are included in decision making in the form of sequential decision processes (Hammit et al., 1992).

For instance, learn-then-act strategies can be balanced against act-then learn options (Manne and Richles, 1992, Peck and Teisberg, 1993; see also section 2.5.1. below). Indeed, there is a fairly agreement on improving our understanding of the climate change problem (Peck and Teisberg, 1993). This led to the analysis of the *value of information* about global warming. According to Peck and Teisberg (1993), a resolution of uncertainty has high value relative to current research budgets¹. Moreover, Peck and Teisberg (1993) points out two interesting results. On the one hand, they found that there was not a high premium on immediate resolution of uncertainty in as far as this would occur within, say, twenty years. On the other hand, they found that "if the real world political process would result in a suboptimal control policy being chosen under uncertainty, and this choice could be prevented by early resolution of uncertainty, the *benefit of early resolution* may be as much as three orders of magnitude greater". This

¹ And "resolving uncertainty about the cost of warming is nearly as important as resolving uncertainty about the extent of warming"

constitutes a fair criterion if one wants to look into alternatives to current policy responses that could override both suboptimal policies and the difficulty at solving now "strong" uncertainties

The decisions we make as well as the results of the simplest models we run to stimulate the outcomes of decision-makings are contingent upon the level of information we possess e.g., about climate change prospects and impacts or that is assumed to be produced with time. As a matter of fact, progress in knowledge will have much influence on the decision to reach as well as on the decision process itself. This will for instance update the distribution of probabilities for the subsequent years (Peck, 1994). As another example, the possibility of future learning will influence current period decisions: facing a project which is reversible, learning leads to a lower value of the current period decision. Learning more about the net benefits of the investment at a future date will still allow subsequent investment decisions to be made (Ulph and Ulph, 1994).

A widespread assumption is that scientific knowledge will linearly increase with time, and give a perfect information after n years. This analysis proceeds as if we had -- in principle and at any step -- the opportunity to learn the state of the world before taking action (Manne and Richels, 1993). No information is forthcoming once the decision is taken; e.g., by the next period. This analysis is typically shared by deterministic models, which assume that all uncertainties are resolved *prior* to decision making.

The most plausible assumption, however, is that uncertainties will not be completely resolved with time. Therefore, information needs to be integrated in decision making under uncertainty and risk by *incorporating the opportunity for learning into the decision making framework*; that is, by making the decision process an ongoing, for instance an "act-then learn" process (Manne and Richels, 1992, 1993; also see section 2.5.1. below). In other words, incorporating information means making uncertainties endogenous and, therefore, entering a sequential-decision process. This also means that learning will be endogenously used to revise the distribution of probabilities for the years to come. Such a strategy comes into play for we know any action set up now will need to be revised later (Hammit et al., 1992). On the one hand, as scientific understanding of climate change improves and, on the other hand, as economic actions evolve and uncertainties are nearly resolved.

Incorporating information into decision making and thus entering a sequential decision making process means that forthcoming information carries a value. In other words waiting for information bears a value which can be computed as the option value for preserving an environmental asset. This "option value" can be defined as the gain from retaining the option to preserve or develop an area in the future (Krutilla, 1985), in other words, the gain from being able to learn about future benefits of not developing that area initially. A quasi-option value is defined as the increase in expected net benefits of not developing the area initially when the decision maker can make the decision after uncertainty is resolved (Johansson, 1993).

Basically, this value is born from the existence of uncertainties around the future benefits associated to the action taken now and the uncertainty about future generations and preferences. This refers to the cases for leaving more resource to the next generation, for conserving an ecological asset, when consumption is an irreversible depletion of a stock, and when emissions affect the global climate (for preserving the atmospheric environment). Indeed the benefits from the preservation of the (natural) asset that will accrue in the future -- and similarly for future preferences -- are yet unknown. As a rule, waiting for information will save the option of reconsidering the decision about to preserve the resource when improved information becomes available. In other words, economists allow for a future reduction of uncertainty by incorporating option value.

Preventing climate change what acting strongly now would depict -- should thus be credited with an option value, the value of waiting for scientific knowledge about the greenhouse effect. In a development versus conservation context, if the decision maker does not anticipate better information (does not allow for a future reduction of uncertainty), a possibility of over-reaction is created (Krutilla and Fisher, 1975, 1985). There is some controversy about expanding this result to the class of global warming problems (Ulph and Ulph, 1994).

Yet, option value is not identical to the value of information in a development decision problem. On the one hand, option value is conditional on a particular choice of first-period development whereas the value of information, which basically is the expected value of perfect information, is unconditional. Option value is thus connected to contingent decisions. On the other hand, the former can be equal to or greater than the latter.

Last, a good number of authors have established that option value was identical to a risk premium, and that it could be negative because preservation, and not only development, can bring risks. In sum, incorporating information into decision making processes makes subsequent decisions contingent upon future resolution of uncertainties and upon attitudes toward risk. Also, one must recognise that not every progress in knowledge is synonymous with reducing uncertainties. Especially for the climate system, progress in knowledge could also stress uncertainties because of the circular causality and non-linear cause-effect relationships (Gassmann, 1994).

What in fact happens is that, on the one hand, by additional knowledge, we realise that our view of climate dynamics was too simple being too much influenced by classical linear systems. So, the new results widen the spectrum of possible reactions of the global climate system to the anthropogenic CO₂-input and clearly, this widening results in an increased uncertainty.

On the other hand, however, by anticipating more possible reaction, the surprise potential is reduced and so is the probability of unfavourable response strategies. This new view about the relationships between knowledge and uncertainty is based on the evolving theory of non-linear systems. "Waiting for information" has also been explored on a more substantial basis in the context of the Arrow-Fisher-Henry irreversibility effect (1974) to which we turn in the next section.

2.5.2.6 Irreversibilities:

Irreversibilities has come to be known as an important choice variable in decision that have uncertain, though not reversible consequences. This decision factor evolved from economic-like situations with special environmental features as for instance unique natural environments and wildlife resources. This situation led to identify a new approach for making allocation decisions because of the existence of resources with no, no adequate, or only a few substitutes (uniqueness does not need to be absolute for the argument to hold) (Krutilla, 1967).

This conclusion gave rise to a conservation versus development debate. One noticeable consequence has been that efficient control policies might mean some restriction of the activity.

According to Arrow and Fisher (1974) irreversibility can be alternatively defined as follows: "A technically irreversible development could be characterised as one that would be infinitely costly to reverse".

With respect to climate change/technology linkages, the state of the world beyond ten or twenty years from now is dependent on today's decisions. The consequence of this dependence is the formation of irreversibilities (basically, the fact that there is no cheap process for removing CO₂ emissions from the atmosphere once emitted, makes the emissions of CO₂ irreversible). In other words, this dependence is responsible for the existence of irreversible or quasi-irreversible trends in technology because of lock-in effects for example in consumption and land-use patterns (Hourcade and Chapuis, 1994).

Schmalensee (1993) concludes that because today's CO₂ emissions will likely affect climate for at least a century, and because investments in energy-related technologies and capital goods also have very long-lived effects, both action and inaction can have effects that are for all practical purposes irreversible. The cost and benefits of actions taken today may be dominated by the values of options they foreclose or create decades hence.

Chichilnisky and Heal (1993) argue that in valuing environmental resources the irreversibility of decisions and events can be central. A key aspect of these resources is that once altered they cannot easily be restored to their current conditions, at least on a relevant timescale. Analysts have sought to capture this in a framework for benefit-cost analysis. This meets the concept of "option value"; that is, preserving a unique asset in its present state allows us the possibility of changing our minds later. Altering it irreversibly does not. Preserving it has thus to be credited with an "option value", because it keeps open the option of reconsidering the decision.

Chichilnisky and Heal (1993) review two distinct formulations of this issue, one in which the returns to a preservation project are uncertain at present but will be revealed in the future, and one in which the preference of future generations for environmental facilities are uncertain. In the first framework one needs three conditions for an option value to exist. These are irreversibility, the acquisition of information with the passage of time, and an asymmetry of the

underlying probability distribution. Similar results apply to the case of uncertainty about the preferences of future generations.

Cline (1992) provides the most thorough study of the cost and benefits of reducing climate change. However, although this study refers many times to the scientific uncertainties associated with predicting climate change, it at no point attributes an option value to preventing climate change. This means that Cline's study may systematically underestimate the benefit-cost ratio of preservation of the atmosphere in its status quo.

On the decision making side, irreversibility predominantly leads to risk averse type decisions (e.g., portfolio diversification, no-regret policy, minimum surprise). Note that there is some controversy about expanding *development versus conservation* results to global warming problems. Conventionally, the belief is that if the decision involves irreversibility, then current period decisions should involve less irreversible commitment (one should undertake less irreversible investment) if there is the possibility of future learning than if there is no such possibility. Although irreversibility and learning seem to have opposite effects on the current decision period, "whether there is learning or no learning, there will be less investment when investment is effectively irreversible, than when investment is reversible" (Ulph and Ulph, 1994).

2.5.3 Unpredictability due to climate change:

The anthropogenic nature of CO₂ - increase found wide acceptance in the scientific world and caused public concern. However, this acceptance does not yet mean an acceptance of anthropogenic climate change.

Many scientists, politicians and the public have a deep natural belief in the stability and robustness of the climate system by trusting yet unknown negative feedback-loops guaranteeing homeostasis. Indeed, our Holocene climate showed a seemingly convincing stability and steadiness over the last 10000 years with fluctuations of only plus minus half a degree (global average temperature) as derived from the most recent Greenland ice core (Dansgaard, 1993). Slow variations of unknown origin as the "Little Ice Age" or the medievaloptimum, modulated with irregular variations with periods of the order of 30-100 years, do not substantially disturb this trustful view because of their small amplitude. The well-known interannual variability due to

the evolution of high and low-pressure cells and also by other dynamical processes with inherent irregularity as "El Nino" (Graham and White, 1988) are not taken into account in the framework of the climate discussion by defining climate as the average state of the atmosphere over an integration period of 30 years. Other causes of such short term fluctuations are the regular 11-year sunspot cycle or irregular volcanic eruptions. However, these short term variations can hide continuous anthropogenic climate changes over several decades. If the prognosticated anthropogenic trend of +0.3 K per decade (Houghton et al., 1990) would be reality, the global temperature signal will be clearly out of the noise level by the years 2010-2020. It is a cheap and therefore, widespread excuse against taking measures to reduce greenhouse gas emissions, delegating any decision to the next generation that will better see what happens.

On the theoretical side, the important processes influencing the global climate are identified and can be understood at least in principle. Very detailed knowledge is available concerning long - and short-wave radiation transport through the atmosphere. Especially, 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 (the above mentioned +0.3 K per decade).

However, 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", 115.000 years ago) as being 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 at least 20 very 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 out of the scope of most of today's models. Consequently, they are not able to simulate ice ages as a whole nor the numerous and important climatic fluctuations within the last ice age or the Eem. From a general theoretical point of view, however, the observed step-like behaviour of the climate system is to be expected.

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. Thus, in the optimal case of complete knowledge about the system, the spectrum of possible metastable states could be described, but no time evolution could be predicted.

The main characteristics of the global climate system is its structure consisting of many interlinked feedback-loops, some of which being highly non-linear. Especially the hydrological cycle shows strong non-linearities: exponential saturation pressure curve for water vapour versus temperature, phase change from water to snow or ice at 0°C leading to abrupt surface albedo increase, critical sea surface temperature of 27.5°C for dramatic increase of deep convection and thunderstorms etc. An important property of the climate system is the strong coupling between different regions of the globe by atmospheric or sea currents. Furthermore, different important

delays complicate the dynamic response of the climate system. Examples are: heat capacity of the sea-surface layer (ca. 70 m deep), time for melting snow, ice, etc.

A system with intensive non linear feedback loops is a good candidate for self-organisation and whence abrupt changes at critical values of control-parameters or even for chaotic behaviour above a certain threshold. As the past 200,000 years including the last two glacial times as well as the Eem interglacial show everywhere abrupt changes and climate instabilities, it is indeed a so far unsolved problem why the past 5% of this time, the Holocene, showed a practically stable climate. As long as this question cannot be answered, this comfortable climate stability must be considered as exceptional and probably fragile. The most natural behaviour to be expected is not a gradual warming but rather an abrupt phase change, a transition to another climate regime (i.e., the Eem optimum regime with roughly 2K higher temperatures).

It turns out that one must pay attention to these emerging scientific insights. 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 (1-10 years), which seems to be a natural candidate based on theoretical reasons as well as new paleoclimatological 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. The issue for the policy-makers is to put together with the help of decision criteria and rules

- strong uncertainty (unpredictability, absence of probability distributions),
- uncertainty which is higher with respect to sub-systems (regions),
- risk (which are of collective nature and statistically independent risks),
- and non-linearity which is a possible cause for abrupt global or regional changes.

2.5.4 Climate change risks: An Insurance market framework:

According to Chichilnisky and Heal (1993), there are two standard ways in which societies can respond to the risks associated with uncertainty. One way is mitigation. The other is insurance. Insurance does nothing to reduce the chance of damage due to climate change. It only arranges for those who are adversely affected receive compensation after the event. Insurance is a major economic activity, involving both the insurance industry and large parts of the securities industry.

Chichilnisky and Heal (1993) argue that the Arrow-Debreu approach to risk allocation via state-contingent markets is in principle universally applicable. However, it is cumbersome and perhaps unrealistic in the case of risk with individual components. Insurance markets are more manageable, but leave uncovered collective or correlated risks such as the risk induced by ignorance of the true frequency distribution of harmful events. So it would be natural to allow agents to trade securities contingent on such collective risks, and cover this individual components of risks by mutual insurance contracts. This is precisely the approach developed by Chichilnisky and Heal (1993). Although new to the economics literature, it is by no means new in practice; some of the oldest risk-bearing institutions recorded, agricultural cooperatives, have exactly this structure.

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.

2.5.4.1 Use of financial markets:

Chichilnisky and Heal (1993) argue that although the risks associated with global climate change are very difficult to evaluate, there is nevertheless a market framework within insurance that can be provided. It involves first identifying the set of possible descriptions of collective risks. Next this framework involves introducing securities whose payoffs depend on which description of the risk is correct. This amounts to allowing agents to bet on which model of risk is correct. Finally, the approach involves establishing compensation agreements between harmed and unharmed regions that depend on which description of the risk turns out to be correct. Mutual insurance contracts or mutual compensation agreements are already part of our institutional framework.

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.

2.5.4.2 The value of Insurance:

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 buildup of carbon dioxide (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 change 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

Decision Making Framework

1 analysis to assess probabilities), and collective (by which the uncertainty about the relative
2 frequency of harmed agents is meant). In principle, however, once frequencies are at least
3 approximately known, actuarial calculations can be set up, and the problem can be conceived as
4 insurable.

5 Correspondingly, one must bear in mind that before 1989, natural disasters caused by
6 storm events with insured losses greater than one billion dollars were unknown (Weilenmann,
7 1994). For insurers, the most costly storm event to date has been 1992 hurricane "Andrew" with
8 insured losses of US \$ 15.5 billion (see Box 2.5). This kind of losses has become more frequent
9 and a potential rise is predicted. However, the causes for that trend are not clear. They also
10 depend upon the increasing concentrations of people and insured economic values in areas of
11 high risk.

12 Next, what a society believes it to be worth paying to reduce the risk of climate change
13 depends inter alia on two key characteristics of that society: its degree of risk aversion and its
14 discount rate.

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Box 2.5 Natural events and attached insured losses

Event	Date	Insured Losses (in billion US \$)
Hurricane Gilbert	September 1988	0.05
Hurricane Hugo	September 1989	5.80
Winter storms Europe	January/February 1990	10.00
Colorado storms	July 1990	1.00
Hurricane Bob	August 1991	0.62
Hurricane Andrew	August 1992	15.50
Hurricane Iniki	September 1992	1.60
East coast storms US	March 1993	1.60
Midwest floods US	Summer 1993	0.75

1 Source: Weilenmann (1994)

2 The degree of risk aversion is a measure of how much an individual or group is willing to pay to
3 avoid a risk¹. The discount rate is an equivalent measure of the value of the future relative to
4 the present (see Chapter 4).

5 It consequently turns out that different country's positions with respect to measures to
6 restrict greenhouse gas emissions depend on their discount rates and degrees of risk aversion

¹ 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. Many 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 chance 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 risky situation, is a measure of the person's risk aversion. *The more risk averse you are, the more you will insure* (Chichilnisky, 1994)).

(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 additions 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.

2.5.4.3 Collective risks and Insurance market framework:

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 correct¹ (Pillet, 1994). The existence of financial markets² is only a half way explanation. The question to pose is: How to interpret the trading of climate risk positions from a global ecological-economic viewpoint?

¹ "This amounts to allowing agents to bet on which model of the 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).

² For example, Chicago Board CAY Futures (for Catastrophe Futures) are securities which pay contingent on the frequency of the occurrence of a major weather risk such as earthquakes in the West Coast of the US, tornadoes in the East Coast of the US, and floods in the Midwest of the US. "They can be used to hedge the scientific uncertainty about the incidence of environmental risks as they are traded by insurance companies to hedge against their exposure to major climate risks" (Chichilnisky, 1994). The financial instrument was first proposed by Chichilnisky and Heal (1993). It has been since introduced and traded at the Chicago Board of Trade. To illustrate, an insurance company which offers insurance against floods may buy a contract which pays US\$ 5 billion if the frequency of floods in the US Midwest exceeds a given agreed number over the calendar year 1994 (see also Box 2.4).

The most interesting interpretation is based on the disparity between ecological and economic systems. On the one hand, ecosystems are driven by forcing functions, the ultimate one being the sun. On the other hand, conversely, economic models work according to some objective function from which prices are computed out. 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.

Under this perspective, one definitely cannot develop global environmental systems into economically sound systems. One better has to place the focus on the various matching and diverging points that dynamically occur, that is, on what will possibly emerge, on what will possibly pop up from such interconnections (Pillet, 1994). 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.

Global environmental systems (assets) cannot 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 usually are highly differentiated one (Pillet, 1994). In addition, this ultimately would oblige countries to reveal their true positions on ecological prospects their economies face and want to address (they will basically not be allowed to elude their publicly-professed positions on the global environmental risk, and thus for the risks from climate change would thus make a country's beliefs consistent with its public positions. This country would not be able without generating some cash cost to sell securities that pay off in the event of climate change not being serious, and buy those paying off if it is serious where this is not its true beliefs (Chichilnisky, 1994, Pillet, 1994). This is an example on how markets for the risks of climate change can make the link with countries' efforts to reduce greenhouse gas emissions.

A market framework with new financial institutions and the trading of risks has been introduced by Cass, Chichilnisky and Wu (1991), Chichilnisky and Heal (1992, 1993) and

Chichilnisky (1993b, 1994). It is aimed at addressing two levels of uncertainty in facing the risk of climate change. The first level is world-wide: "What will be the overall impact of climate change on the earth, in terms of how much of the population of the earth is made worse off, and by how much? What is the distribution of agents who are harmed in the economy? Will 60% be harmed, or only 30%? This is a question about the aggregate incidence of damage over the population as a whole". The second level of uncertainty is regional: it is about whether a given community or region is harmed or not by climate change. "It devolves about questions such as: given that 60% of the population will be harmed, will a particular region be harmed or not?".

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.¹ 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 include industrialised countries who would contribute funds (after IUCC, 1993). Grubb (...) however, questions why only those who suffer from sea level rise should be compensated and not

¹Examples are agricultural cooperatives 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.

others who suffer from temperature related damages such as loss in crop yields, deaths due to heat stress, livelihood derived from biological species that will be lost and so on.

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 negative 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.¹

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 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 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.

¹Others 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 Conventions* but was not included in the final treaty.

Yet, would insurance companies be able to address 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 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.

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 EU (also see Pillet, 1994)¹ 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).

2.5.5 Portfolio analysis analogy for climate change decision making:

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. The decision then is to choose the portfolio of policy measures best suited to the country's circumstances and to adjust the portfolio over time in response to new developments.

¹ 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).)

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.

2.5.5.1 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 cooperation to limit climate change;
- phasing out existing policies, such as subsidies to fossil fuels, that reduce welfare and directly or indirectly increase GHG emissions;
- measures to reduce emissions, or increase sequestration, of GHGs;
- measures to adapt to the consequences of climate change; and
- insurance orchestration to hedge against risks revealed by strong/unexpected uncertainties
- Insurance for additional costs incurred due to adaptation.

Government decisions concerning the portfolio of climate change policies must consider the different types of uncertainties associated with climate change and with the policy measures. The timing, magnitude and characteristics of climate change, particularly as they affect a specific

country, are uncertain. The costs and effectiveness of policies aimed at limiting climate change are also uncertain. What will be the nature, magnitude and timing of damage due to climate change? What will we learn about climate change given a particular research budget? Will technology research lead to more cost-effective mitigation measures? Will other countries abide by their commitments to limit climate change? Such uncertainties can never be eliminated, but they must be considered in the selection of climate change policies and policy options.

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 maximizing expected value behaviour. The investor can also impose constraints on the portfolio to reflect his 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.

2.5.5.2 Non-availability of an operational model:

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 among 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 insurance 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. If one believes that there are great risks from global warming and that the insurance premium is negligible, there is little reason to delay. If, on the contrary, the insurance premium is expensive, it may be

worthwhile to pursue alternatives to immediate cutbacks on emissions (Manne and Richels, 1993).

- Several researchers compare the costs of unilateral action and international cooperation to address climate change. The analysis consistently show large returns to international cooperation. International cooperation 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 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 the form of, say, building dikes to protect low lying coastal areas from sea level rise. Such measures can be implemented where they cost less than the damage that would otherwise occur.

2.5.5.3 Three main portfolio options:

It turns out that three main 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

1 reductions in order to slow down climate changes. The issue for the "option-taker" is not one of
 2 either-or but one of finding the right blend of options. Policy makers must decide how to divide
 3 greenhouse spending among competing needs. What portion goes to resolving climatic
 4 uncertainties? What portion goes to technology development? And what portion goes to
 5 immediate abatement of emissions? (Richals, 1994). Using the portfolio analysis analogy, a
 6 country must use the available information to decide upon the size of its investment in climate
 7 change limitation and on the allocation of that investment across policy measures.

8 At a global level, well formulated benefit-cost analysis can help establish an appropriate
 9 level of climate change investment. Climate change policy does not involve a one-time choice -
 10 or some go/not go type of decision - between distinct, long-term options (do nothing or
 11 implement policy "X" for the next century), the types of decisions to which benefit-cost analysis
 12 has historically been applied. Since climate change policy can be modified frequently and
 13 incrementally, the "option values" of decisions must also be considered (the option value of
 14 deferring action on climate change can be interpreted as an insurance premium to cover the cost
 15 of damages that may result).

16 The level of their investment in climate change policy will be influenced by factors
 17 beyond the strictly economic considerations mentioned above. Expected damage to ecosystems,
 18 expected sea level rise, potential socio-economic impacts, international equity concerns,
 19 intergenerational equity, and economic development strategies based on development of
 20 mitigation and adaptation technologies are examples of other considerations that may influence a
 21 country's climate change limitation spending.

22 Incorporating option values into the benefit-cost analysis of the policy measures indicated
 23 that some action on climate change is economically justified by every country. No country can be
 24 confident that it will not incur damage as a result of climate change. Thus, delaying action to
 25 limit climate change is an option that has a cost, at least an insurance premium. Every country
 26 has available policy measures that have negative or very low costs after accounting for any
 27 associated benefits. Thus every country has some climate change mitigation measures that are
 28 economically justified.

1 Normally, the mix of assets in the portfolio is adjusted so that the risk-return ratio is equal
 2 at the margin. As discussed above, only sketchy information is available on the expected costs
 3 and benefits of the main policy measures. The variability of the costs and benefits for these broad
 4 policy options is not known. Governments can make subjective assessments of the variability of
 5 costs and benefits of different policy measures. The risks associated with phasing out existing
 6 inefficient programs or implementing energy-efficiency measures are lower than those associated
 7 with reforestation to sequester carbon or construction of sea walls. The latter offer only climate
 8 change benefits, while the former yields other benefits also. Governments can change their
 9 portfolio of climate change policies in response to new information and developments.

10 2.6 LINKAGES OF CLIMATE SYSTEM WITH 11 DECISION MAKING FRAMEWORK

12 In this section, we briefly outline the linkages of decision making framework with climate
 13 system illustrated in figure 2.8. Each square is fully discussed by various chapters in this report,
 14 so we restrain from elaboration. There are two other working groups on scientific and impact
 15 assessments, summary of which have to be represented also.

16 INSERT FIGURE 2.8 HERE

17 The above figure shows that the chain of events start from cumulative emissions of
 18 greenhouse gases (square 1 in the figure 2.8). These cumulated emissions trigger off various
 19 climate related changes such as change in the temperature, sea level rise, moisture loss,
 20 precipitation change and extreme events (square 2). These climate changes would in turn have
 21 impacts such as damage to agriculture and fishing, migration of population from the coastal
 22 areas, species loss, and scarcity of water and so on, which in turn, will constrain irrigation and
 23 hydro power generation (square 3). However, the decision making today has to consider climate
 24 changes and impacts that may occur 25, 50, 100 years and beyond and respond to it now by
 25 formulating, say, 10 or 20 year strategies that have to be periodically revised. Since we do not
 26 know what may be in store, we have to rely on climate change research to say how the situation
 27 would look at different time periods. Economic costs of adaptation and irreversible damages for
 28 these impacts have to be compared with the abatement costs using various decision tools. Thus

LINKAGES BETWEEN CLIMATE SYSTEM AND DECISION MAKING

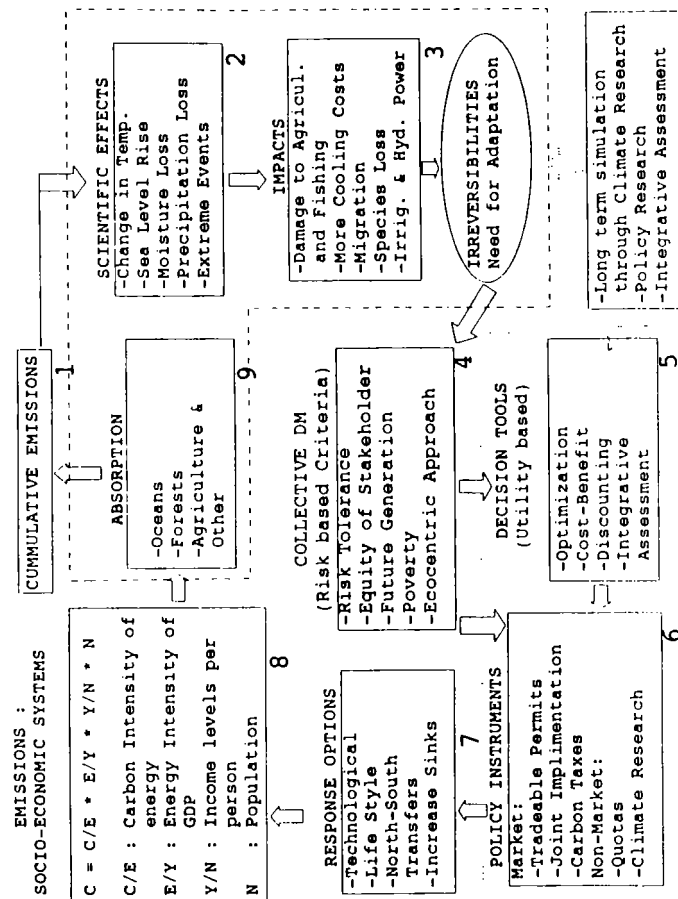


Figure 2.8

Decision Making Framework

1 research results are fed into collective decision making process, which takes into account issues
 2 such as inter-regional and intergenerational equity, ecological and poverty considerations apart
 3 from the various country specific factors such as risk tolerance and vulnerabilities (square 4). To
 4 assess the impacts and to facilitate the decision makers in designing the specific abatement
 5 policies, one can use various decision tools such as decision theory, optimization, simulation,
 6 forecasting and more importantly integrative assessment models (square 5).

7 Thus, collective decision making is required to arrive at revised strategies to take into
 8 account the new information from climate research, and policy research. This helps to choose the
 9 desired concentration levels and emission paths. Allocation of these emission levels among
 10 parties requires consideration of current and past emissions, need for development for meeting
 11 basic needs and resource endowments and global cost effective criteria. For global cost
 12 minimisation, collective decisions are needed to choose among various global policy instruments,
 13 such as marked based policy instruments, viz., tradeable quotas, carbon taxes, joint
 14 implementation, as well as other non-market policies such as setting standards, reduction targets,
 15 etc. One can choose a set of instruments or a combination of these instruments to achieve the
 16 targets of emission reductions (square 6). This also forms a part of policy research. The choice of
 17 a specific policy instrument at national level could be based on a variety of utility based criteria
 18 such as cost effectiveness, or cost benefit analysis, which may depend on the discount rate used.
 19 The national policy instruments would generate in certain response strategies; these may use
 20 utility based criteria (square 7). The response strategies could be chosen from among portfolio
 21 of options such as alternative technologies, changes in consumption patterns and life style,
 22 increase in the sinks, etc. These response strategies would again have an effect on the socio-
 23 economic emissions (square 8). The emissions of GHG would depend on socio-economic factors
 24 such as carbon intensity of energy, intensities of the GDP, per capita GDP and population. Land
 25 and forest use patterns also matter, but there may be a decreasing trend of the emissions
 26 associated with these. Some of these emissions are absorbed by oceans, forests, agriculture and
 27 other related activities (square 9). The fraction of the total emissions which could not be
 28 absorbed by the sinks accumulate in the environment over a period of time and leads to

1 cumulation (square 1) completing the cycle. Sequential decision making is required periodically
 2 to verify strategies.

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Chapter 3

Intertemporal Equity and Discounting

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3.1 Introduction

This chapter concerns the methodology for comparing effects at different points in time, and especially establishing trade-offs across different generations. How we think of these trade-offs involves issues of intertemporal equity. This issue is a matter of philosophy (and for some, religion and morals) because it involves reaching judgements about what is fair or just. The issue is also a matter of economics, because comparisons across time are appropriately judged in the light of changing standards of living over time as well as opportunities for productive investment.

3.1.1 Importance of the Discount Rate

The discount rate is the analytical tool economists use to compare economic effects that occur at different points in time. Identifying the proper discount rate is probably the single most important analytical step in economic analysis of global warming. It is also the most profound ethical question, since it inherently confronts present pain of abatement cost against damages suffered by future generations if no action is taken.

The issue of choosing an appropriate discount rate has been discussed in the context of general cost-benefit analysis (chapter 5) for many years (Dasgupta et al. 1972, Harberger 1976, Little and Mirrlees, 1974, Sen 1967, Stiglitz 1982). 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).

The emission of carbon dioxide causes effects likely to persist on a time scale of centuries. IPCC (1990a) estimates that the first half-life of CO₂, is 50 years and the second half-life another 250 years (with the decline to 1/e taking 120 years). In the absence of policy intervention carbon dioxide concentrations could continue to rise for the next 300 years, given current fossil fuel resources (Sundquist, 1990). Global warming thus poses unusual problems for economic analysis, which more typically considers issues with time scales of only a few decades at most.

The usual formulation for discounting over time involves exponential growth of the discount (or value-shrinkage) factor. Thus, one unit of consumption that arrives t years from today is equivalent to the fraction $1/(1+i)^t$ of one unit of consumption

3 - 2

available today, discounting at rate i .

Social scientists have debated the precise rate to use for global climate analysis (Broome, 1992; Cline, 1992; Nordhaus, 1993). There is general agreement that the choice of the discount rate has extremely powerful effects on the economic evaluation of policy of global warming because of the unusually long time horizons involved (e.g. Schmalensee, 1993). With benefits of greenhouse abatement accruing decades or even centuries into the future, if a high discount rate is used, the benefits get heavily discounted relative to the costs, the expenditures incurred today in trying to mitigate climate change.

For example, rates of 8% - 10% per annum are often used in project analysis. Such rates cause the future to vanish rapidly. Thus discounting at 8%, damage of \$1 billion 50 years from now is valued at only $[\$1 \times 10^9] / [1.08^{50}] = \$21,300$; and the same damage 200 years from now, at only \$200. This collapse of future values suggests the need to think especially carefully about proper discounting for global warming analysis.

3.1.2 Toward an Emerging Consensus

The framework of an emerging consensus on discounting for global warming analysis would include the following.

First, although economists have disagreed about (a) whether future generations at levels of welfare or utility equal to those of today should nonetheless be discounted relative to the present, and (b) how precisely to relate changes in "the discount factor" to changes in income, there is widespread (but not universal) agreement about the following propositions:

(i) Rejection of environmentally specific equalitarianism: future generations can be compensated for some environmental natural resource effects by offsetting accumulations of capital.

(ii) Acceptance of more generalized (but not, usually, absolute) equalitarianism: differences in the overall standard of living should be reflected in the discount rate. There is, in fact, remarkable consensus in the quantitative magnitudes by which future discounting should be affected by rising per capita income. Given the best available forecasts, expected increases in the standard of living should cause discounting on the order of 1/2 to 3 percent annually.

Second, trade-offs across generations are directly related to observed market rates of interest only under highly specialized conditions. The inadequacy of simply adopting market rates is already recognized in the literature on social cost-benefit analysis when the time scales are typically infragenerational, and is sharply reinforced when intergenerational horizons are involved.

Third, trade-offs across generations in environmental goods (

public goods) need not correspond to trade-offs across generations in private consumption goods. Economists have developed a standard operational procedure for dealing with this problem: converting other goods into their "equivalent" in private consumption goods, and applying the discount rate to the equivalents. As discussed below, this procedure will typically imply lower effective discount rates for environmental goods than for private consumption goods (and possibly negative effective rates), because of the likely rising relative price of environmental goods.

Fourth, issues of discounting involve the relative values of goods at different dates, and thus intertemporal pricing. Issues of pricing of risk need to be carefully separated out from those involving intertemporal pricing. The standard procedure for conventional models, involving impacts over a single individual's life, involves converting probabilistic consumption patterns into their certainty equivalents, and then discounting at the social rate of time preference -- not the incorporation of an incremental component into the discount rate itself. This procedure does not, however, deal adequately with uncertainties about future rates of growth of per capita income. Such uncertainties are much greater over centuries-scale horizons. Under plausible conditions, uncertainties about future rates of growth of per capita incomes should be reflected in a lower discount rate.

Fifth, issues of equity can be treated in a way analogous to those of risk, though the likely effect on the appropriate rate of discount have yet to be thoroughly studied.

3.2 Intergenerational Equity

Climate policy raises particular questions of equity between generations, because future generations are not able to influence directly the policies being chosen today that will affect their well-being (Mishan, 1975; Broome, 1992). Because climate change policy involves trading off near term costs (e.g. of emission controls) for long-term benefits of a reduced rate of warming, issues of intergenerational equity cannot be ignored.

The concern for fairness to future generations has long undergirded the environmental movement. This concern spans a broad range of political, social, and ethical considerations and viewpoints, and poses special challenges to economic science for proper formal treatment. Perhaps best known among recent formulations, the report of the Commission on Environment and Development (United Nations, 1987), led by former Norwegian prime minister Gro Harlem Brundtland, called for "sustainable development," defined as economic activity that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). (For a discussion of sustainable development, see section 3.6 below). Similarly, Brown-Weiss (1989, 25) has argued from the standpoint of international law that "each

generation is entitled to inherit a planet and cultural resource base at least as good as that of previous generations."

Within the economics literature, there is a longstanding debate on the intergenerational equity of discounting distant future benefits (Ramsey, 1928; Mishan, 1975; Rawls, 1971; Sen, 1982). The standard approach to issues of equity since Bergson (1977) has been to summarize views about interpersonal equity in the form of a "social welfare function," an algebraic formulation relating welfare to levels of consumption of the society's members at a given point in time and across time. Arguments about the choice among alternative social welfare functions then turn on the ability to derive a particular function from sound theoretical principles, and about the resulting reasonableness of its derived implications.

Two polar views are represented by the utilitarian approach, in which social welfare is the sum of utilities; and the Rawlsian approach, in which social welfare reflects the welfare of the worst-off individuals. While the utilitarian approach can be derived from what many view as a persuasive axiomatic (theoretical) structure (Harsanyi, 19), the Rawlsian approach is derived from a "max-min" strategy (maximize the minimum outcome for any given party) popular in game theory, but which itself does not rest on widely accepted axiomatic principles. While all social welfare functions have been criticized for assuming interpersonal comparability of utility, there seems to be no way of addressing the ethical issues involved in making decisions affecting different generations without making some assumptions implicitly or explicitly about interpersonal comparability.

The Rawlsian max-min principle is the strongest in assuring future generations' rights to consumption at least as great as that of the current generation. It is consistent with the Brown-Weiss (1989) approach noted above. The max-min criterion permits inequality in consumption between individuals (or in this case, between generations) only if it improves the position of the poorest. For intertemporal planning, in the absence of technical change this would imply that consumption per head should be the same for all generations. By contrast, the utilitarian criterion allows, in principle, for decreases in future consumption, provided the current generation is made sufficiently better off as a result. Correspondingly, it also allows for decreases in present consumption, provided the future generation is made sufficiently better off as a result.

The Rawls and utilitarian social welfare functions can be viewed as limiting cases of more general social welfare functions embracing social values of equality (Atkinson, 1971; Rothschild and Stiglitz, 1973). In practice, so long as there is sufficient scope for technological change, both criteria yield increases in consumption per capita over time. Moreover, both approaches yield the result that earlier generations are entitled to draw down the

pool of exhaustible resources so long as they add to the stock of reproducible capital.

The individualistic social welfare function, accepted by most economists as the basis of ethical judgments, accepts individuals' own relative valuations of different goods. It does not place separate valuations on inequality of particular goods, other than through their effects on the affected individuals. Although this represents the consensus view, there are some economists who insist that for particular goods, individuals' valuations need not be the basis of societal valuations. For instance, Tobin (1977), in what he called *specific equalitarianism*, argued that society might argue for greater equality in distribution of health care than would be reflected in individuals' own evaluations.

Sen (1982) similarly suggests a basis for not discounting when environmental effects are in question. He argues that a fundamental right of the future generation may be violated when the environment is degraded by the present generation, and that the resulting "oppression" of the future generation is inappropriate even if that generation is richer than the present and has a lower marginal utility of consumption. In this framework, intertemporal equity for environmental questions requires "a rejection of 'welfarism,' which judges social states exclusively by their personal welfare characteristics" (p. 349).

3.3 Discounting and the Social Rate of Time Preference

3.3.1 Basic Issues

Productive investments in both physical capital (e.g. machines) and human capital (e.g. education) yield a positive real return. That is, money productively invested today can be transformed into more money later, even after adjusting for inflation. Discounting converts each future dollar amount associated with the project into the equivalent present dollar amount that must be invested today in the general economy in order to yield the same future amount.

Greenhouse gas emission control may also be viewed as an investment: money is spent today on emissions controls today so that money may be received later in the form of reduced economic costs of global warming. If the real rate of return on investment in emission reduction exceeds the rate on investment in machines and education, then future generations would be better off if less were invested today in machines and education and more in controlling greenhouse gas emissions; the converse also holds.

The question of the appropriate discount rate involves issues in normative as well as positive economics. How ethically should we value impacts on future generations? And to what extent, for instance, will investments made to reduce greenhouse gas emissions displace investments elsewhere?

The debate is often confused both because the ethical and positive aspects are intermingled, and because there are, in fact, three separate issues that have to be addressed: How do we discount the welfare or utility of future generations? How do we discount future dollars? And how do we discount future "pollution"? The following discussion summarizes some of the salient issues in the debate, reaching the following conclusions:

1. In assessing total impacts on consumption across generations, the "social rate of time preference," a reflection of societal views concerning trade-offs of consumption across generations, should be employed. This tends to support a low rate of discounting.

2. In assessing the direct costs and benefits of a project, if the project displaces private investment, and if the returns of the two projects accrue to the same generations, then it is appropriate to use the opportunity cost of capital - the private return - discounting.

3. The effective rate of discount need not be the same for evaluating environmental goods as for evaluating pure private goods. Under plausible assumptions, the incorporation of environmental considerations may have consequences equivalent to those of adopting a much lower discount rate.

3.3.2 Formulation

The first issue in the analysis of the discount rate is the question of how we value consumption accruing to different generations. Within the predominant utilitarian (as opposed to Rawlsian) framework, there is relatively wide agreement on the form of the fundamental equation for the discount rate of consumption or the "social rate of time preference" (SRTTP):

$$3.1) \quad SRTTP = \rho + \theta g$$

where ρ is the rate of "pure" time preference, θ is the so-called "elasticity of marginal utility," and g is the growth rate of percapita consumption.

The first of the two terms, ρ , is the rate at which utility is discounted because it occurs later rather than sooner. Sometimes this term, the rate of pure time preference, is referred to as discounting for impatience or myopia.

The second of the two terms, θg , is the rate at which changes in consumption levels are discounted to be translated into the resulting changes in utility or welfare levels. The idea is that if percapita consumption is growing at a rate g , then an extra unit of consumption in the future should be discounted by the term θg to take account of the lesser increment to utility when consumption

levels are higher.

3.3.3 The Pure Rate of Time Preference Across Generations

Consider pure time preference first. In a society in which income levels are not expected to rise, impatience may still cause a household (or the present generation) to discount the future (generation), that is, to equate a smaller amount of consumption today with a larger amount in the future. In his classic paper on optimal saving, Ramsey (1928, p. 543) judged that any allowance for pure time preference ($\rho > 0$) "is ethically indefensible and arises merely from the weakness of the imagination." Correspondingly, he argued that future generations should have equal standing with the current generation; there was no moral or ethical basis for weighing the welfare of future generations less than that of the current generation.

For an individual, some non-zero value of pure time preference can make sense, because he or she has a finite life and thus uncertainty about being alive to enjoy future consumption. Nonetheless, for a life span of some 70 years, pure time preference at even 1 percent per annum implies willingness to accept consumption levels only half as high at the end of the life cycle as at the beginning.

Considerations for society as a whole are different, because society's life span is measured in at least millenia rather than decades. Nonetheless, arguments have been put forward contrary to the notion of zero pure time preference across generations, and instead supporting the conclusion that future generations should have less standing than current generations.

3.3.3.1 Discounting Utility for Human Extinction

One argument focuses on the fact that there is no absolute certainty that future generations will exist - any number of catastrophic events could occur. This argument, which might be called the "asteroid effect," might argue that it would make no sense to give up consumption today for the generation 200 years from now because it may not come into existence. Some economists believe it is appropriate for this reason to discount future consumption to reflect the inherent uncertainty in future conditions. However, the probability of human extinction would seem sufficiently small (especially within a time frame of two to three centuries) that the quantitative magnitude of discounting for this purpose is likely to be extremely small.

Thus, according to some estimates the probability that an individual will die because an asteroid hits the earth during his or her lifespan is about one in ten thousand, in the same order of magnitude as the probability that he or she will die in an airplane crash. The chances of earth's collision with an asteroid large

enough to cause species extinction (such as the 10-km-diameter object believed by some to have caused the Cretaceous/Tertiary dinosaur extinction) is far smaller (Wetherill and Shoemaker, 1982). However, to be generous to the extinction argument and for purposes of illustration, consider the individual risk at one in 10,000. The three-century horizon appropriate for global warming analysis is about four lifespans, so set the probability of asteroid impact over this period at 1/2,500, for purposes of illustration. Then at the end of this period, a given economic effect should be discounted enough to shrink its value by one-2,500th. The discount rate required for this shrinkage is vanishingly small ($= 0.133 \times 10^{-4}$ percent per annum).

Perhaps one reason the optimal growth literature includes discounting for extinction is that most of the literature emerged during the cold war, when nuclear annihilation was more plausible than today. For public policy purposes, even under those conditions it is arguably inappropriate to incorporate analytical assumptions that take as a premise the failure of policy (breakdown into nuclear war). In any event this motive for extinction-based discounting would seem even less appropriate for the future.

3.3.3.2 Discounting Utility for Acceptable Optimization Results

Another argument for non-zero pure time preference is that setting the rate at zero could imply that the present generation should accept near-starvation consumption levels, and correspondingly low utility, because with even very small returns on investment, an endless stream of future generations could enjoy increased consumption and (to a lesser degree) utility as a result. Koopmans (1965) thus emphasized the importance of considering the acceptability of optimization outcomes as an additional step going beyond the Ramsey first-principles approach.

To some extent, however, this concern is already addressed in the overall discount rate equation (3.1). As noted, the first term in that equation discounts utility (pure time preference), but the second term additionally discounts consumption to take account of falling marginal utility. The present generation can be protected against an optimizing program setting its consumption near zero by ensuring that the term for elasticity of marginal utility (θ) is large enough and marginal utility drops off fast enough to rule out impoverishment of the present generation for gains to future generations.

More fundamentally, a basic problem with this genre of concern about zero pure time preference has to do with the mathematics of maximization over an infinite time horizon. If the utility function has no upper limit, any savings-investment optimization problem is not well defined, because the sum of utilities over time is infinite. There is some literature (Weizsacker,) proposing criteria (the "overtaking criterion") to address this problem, but

the implications of these criteria for climate policy have not been examined.

Even when the optimization problem is made well-defined, for the purposes here, by setting an upper bound to utility (as in the function in annex equation 3A.3), there is a tendency toward knife-edge results, with one extreme outcome for zero pure time preference and the opposite extreme for non-zero rates. Thus, whereas the concern of Koopmans (1965), Mirlees (1974), and Chakravarty (1969) is that zero pure time preference can suppress current consumption to unacceptably low levels, just the opposite result can be reached in optimization models that take exhaustible resources into account. In some specifications of such models (Dasgupta and Heal, 1974; Solow, 1974a), any pure time preference rate in excess of zero generates the unacceptable result that optimal consumption falls to zero over the very-long term (although Stiglitz, 1974, shows that this awkward conclusion is not robust with respect to alternative assumptions about technological change, production functions, and utility functions).

Knife-edge results can of course result from other properties of utility maximization models as well (depending, for example, on whether the production function has non-unitary elasticity of substitution between factors, or whether capital-augmenting technical change is zero or positive). Because of the mathematical and knife-edge complications of optimization approaches, they do not go far toward specifying the proper magnitude for the rate of pure time preference, even though they might be seen as providing a set of arguments that the rate is greater than zero. Thus, considering the infinite horizon in such models, an infinitesimally small but non-zero rate of pure time preference could suffice to avoid prejudicing the optimal consumption path against future generations, depending on other assumptions of the model.

A somewhat stronger attack on very low discount rates is provided by those models which suggest that with low discount rates, savings rates for poorer economies should be unacceptably high. Only by raising the discount rate to higher, "more reasonable" numbers can savings rates of the kind actually observed be obtained (e.g. Mirlees, 1967; Chakravarty, 1969). This argument, however, assumes that the model captures accurately the structure of the economy; typically, these models imply much higher rates of return on capital than are in fact observed in LDCs. For example, Chakravarty (1969) assumes constant return on capital at 33 percent. Instead, the small differences between advanced and developing countries in observed rates of return in spite of large differences in capital labor ratios suggests either that the economies are not on the same production function, or that the constant returns to scale production function models employed are inappropriate. (See Stiglitz, 1988, Lucas, 1988).

3.3.3.3 Discounting Utility for Empathic Distance

Rothenberg (1993) and Schelling (1993) have suggested that although non-zero pure time preference might make sense for an initial two or three decades, beyond a certain future point it makes no sense to apply further discounting of consumption for pure time preference. Thus: "as the future recedes ... single generations come to be perceived more and more as homogeneous entities" (Rothenberg). Similarly: "time may serve as a kind of measure of distance ... Beyond certain distances there may be no further depreciation for time, culture, geography, race, or kinship" (Schelling). A graph of the fraction of face value accorded to each successive generation (for constant real consumption) would thus be a series of declining, successively shallower steps that eventually reach a horizontal plateau. A deep plateau signifies major discounting for empathic distance; a horizontal line beginning and remaining at unity is the zero pure time preference rate across generations recommended by Ramsey. Policy based on empathic distance (a shelf lower than unity) may be not defensible when the action is refraining from conferring a windfall gain (as in penurious aid budgets) than when it involves the imposition of windfall damage (as in global warming's effects on future generations).

3.3.4 Discounting for Rising Levels of Consumption and Utility

Even if future generations are given weight equal to that for current generations, so that pure time preference (ρ) is zero, there could still be an important basis for discounting future consumption: people are expected to be better off, so that an extra unit of consumption would not be worth as much in the future as today. Thus, if technological change continues to proceed at the rate at which it has over the last century, with productivity and living standards doubling every thirty years or so, then marginal changes in consumption of those future generations should be weighed much less. This consideration is captured by the second right-hand term in equation 3.1.

There are two questions, corresponding to the two elements in the final term of the equation. First, what are reasonable expectations concerning increases in per capita income (growth rate g in the equation)? Second, how should intertemporal differences in expected consumption per capita be translated into social weights, that is, marginal valuations of dollars of future income? This second question refers to the parameter θ , called the elasticity of marginal utility. This parameter essentially tells how rapidly the additional utility from an extra unit of consumption drops off as the level of consumption rises.

No consensus on the first question has emerged. The extremely low levels of productivity increase over the past two decades have raised the question: were the high rates of technological change experienced in the decades following World War II an aberration? (Are the low rates experienced from 1973 until 1993 an aberration?)

While it is also the case that no consensus has emerged on the answer to the second question, there is a generally accepted methodology for approaching the issue. The evaluation of any individual's consumption can be summarized by a utility function of the form $U = U(c)$ where the parentheses indicate that U , utility, is a function of c , per capita consumption. Marginal utility is positive ($U'(c) > 0$), but it declines as consumption rises ($U''(c) < 0$). That is why if consumption of some future generation is higher, the marginal valuation of its consumption will be lower. The question is, how much lower? Formally, the answer is given by the elasticity of marginal utility, θ , or: $[dU'/U']/[dc/c]$.

Individuals in their day-to-day decision making reveal information about their perceptions concerning their own utility functions, in at least two different contexts: behaviour towards risk and intertemporal allocation of consumption. In both contexts, there seems to be a consensus on elasticities of marginal utilities in the range of 1 to 2 (even though the empirical studies require strong assumptions about the specific form of the utility function (symmetric and time-separable)).

Thus, one of the most commonly used utility functions, logarithmic utility, has a unitary value for θ , meaning that if income rises by 1% the marginal utility of consumption falls by 1%. Attempts to estimate this elasticity by Fellner (1967) and Scott (1989) both place it somewhat higher, at 1.5; whereas recent estimates reviewed by Pearce and Ulph (1994) place it in the vicinity of 0.8.

Just as the choice of the rate of pure time preference (ρ) has important implications for intergenerational equity, as discussed above, so does the choice of the elasticity of marginal utility. The more weight the society gives to intergenerational equity, the higher the value of θ . Thus, a value of, say, 3, would mean that it would require a 30 percent rise in the next generation's percapita consumption to warrant a 10 percent reduction in that of the present generation; or, under a bleaker outlook, that if the future generation is expected to be poorer than the present, the present would be prepared to accept a 30 percent reduction in consumption to secure a 10 percent increase in that of the future generation (so long as the two relative consumption levels did not reverse). Even a unitary value is equity oriented, however. When $\theta = 1$, a 10 percent reduction in the richer generation's income will be an acceptable trade-off for a 10 percent increase in that of the poorer generation, even though the absolute reduction of the one exceeds the absolute increase of the other (because the absolute consumption base of the one is larger than that of the other).

3.3.5 Relationship between the Social Rate of Time Preference and Market Rates of Interest

Economists have long recognized that competitive market equilibrium

yield (Pareto) efficient outcomes, under appropriate conditions (perfect competition, no externalities, etc.). The distributions of income which they yield, however, have no special merit; that is, they do not, in general, maximize any particular social welfare function. It is a well recognized function of government to intervene in the distribution of income, e.g. by establishing programs for the very poor. By the same token, the intertemporal distribution of welfare that emerges from the market will not, in general, maximize any particular social welfare function discussed in the preceding section. While it is a legitimate function of government to intervene to change the intergenerational distribution of welfare, there is no presumption that the government has in fact intervened so that the observed resource allocations are those that maximize intertemporal social welfare.

In general, the market rate of interest--the relative price of consumption of one generation in one year of its life to consumption in another year--has nothing to do with the SRTP. In standard life cycle models, even with no technological progress and an economy in steady state, there would be no discounting for society's purposes. Nonetheless, the market rate of interest will be positive in any efficient equilibrium under certain reasonable assumptions about utility functions (such as individual impatience and zero bequest motive; Diamond, 1965). In such models the market rate of interest would thus always overestimate the SRTP.

Under some special conditions, with governments intervening with non-distortionary taxation to optimally redistribute income across generations, then observed market rates of interest will accord with the SRTP. But these are highly specialized conditions. (See Stiglitz, 1985, Pesteau, 1972))

Some economists have argued that a zero or very low pure time preference is "lower than would be consistent with observed real interest rates" (Nordhaus, 1992b); and that such a low rate of time preference would imply that society is seriously underinvesting (Nordhaus 1993). This analysis is based on the premise that there should be a close relationship between observed market rates of interest and SRTP, a conclusion which is valid, as we have seen, only under highly restrictive conditions. Moreover, real returns on treasury bills in the United States--the closest approximation to a risk-free rate of return available to consumers--has averaged only .3% over the past 60 years. As for the underinvestment argument, it would seem inappropriate to counsel against action in the area of global warming policy just because there are other areas in which additional social investment also might be worthwhile undertaking (Cline, 1992)

3.4 Producer or Consumer Interest Rates?

There is a large literature which has debated whether, for small changes in consumption levels, observed rates of interest provide

the appropriate basis of trading off government expenditures and changes in consumption of individuals of different generations at different dates. In a world in which there was no taxation, no market distortions, and a single individual living forever (or else "dynastic utility functions" in which individuals fully take account of their descendants' welfare), society's intertemporal discount rate should presumably correspond to that of the representative individual, and his trade-offs across time would be given by the market rate of interest.

But these assumptions are not generally satisfied, as evidenced by the marked discrepancy between the lower interest rates on savings typically facing consumers and the higher rates earned on investments by producers.

Part of the source of the frequent confusion about appropriate discount rates is a confusion about what is being discounted. In the social discount rate approach, what is being discounted is changes in consumption at different dates. Typically, in the producer interest rate approach, what is being discounted are the direct cash flows from the project. The two need not be inconsistent; under certain conditions, using producer interest rates in evaluating direct cash flows and using the social discount rate in evaluating changes in consumption will give the same results -- but only under the specialized conditions specified earlier.

Four schools of thought have emerged on the proper discount rate for public policy. One suggests that it should be the producer interest rate, representing the private rate of transformation between investment today and output in the future; one, the consumer interest rate; one, that it should be some combination of the two; and one, that it should have nothing to do with either. In the absence of any non-distortionary intertemporal social welfare maximization by the government, we have already noted the general result that the rate of discount should be neither.

There are special cases, however, when one of the other three schools of thought may be correct. For instance, if the government were comparing two projects, both of which cost the same, and both of which yielded their output in the same year, then a comparison of the rates of return would provide an appropriate basis of choosing among projects. If a public project displaced a private project of equal cost, the same reasoning would imply that the government should only undertake the public project if the rate of return exceeded the rate of return in the private sector (Stiglitz, 1982).

More generally, when the government undertakes a project, there are complex general equilibrium effects. The full consumption effects of these changes (or their consumption equivalents) need to be calculated, and then discounted using the SRTTP (Arrow and Kurz,

1970; Feldstein, 1970; Bradford, 1975; Stiglitz, 1982). Implementation of this approach can apply a shadow price of capital to convert all investment effects into their (magnified) consumption equivalents, and then applies the social rate of time preference for consumption to discount the resulting stream of consumption equivalents (Lind, 1982; Gramlich, 1990). A shadow price of capital greater than unity reflects the fact that the rate of return on capital exceeds the SRTTP; care must be exercised in evaluating the shadow price and its path over time (Cline, 1992).

Sometimes, as just discussed, one can look at the direct expenditures and apply an adjusted discount factor to those. There is a large literature emphasizing different aspects of this adjustment methodology. One body of literature emphasizes the effects on consumption versus investment, deriving a weighted average of the consumption and investment rates of return, with weights depending on the respective importance of the sources of finance (Sandmo and Dreze, 1971). Within the literature on optimal taxation and production (where the discrepancy between producer and consumer rates of interest arises from optimally determined taxes), if the government is relatively unrestricted in the set of commodity taxes that it can impose, the producer rate of interest should be used to discount (Diamond and Mirrlees, 1977; Pestieau 1977). However, in the more relevant regime in which government faces constraints on the sets of taxes that are imposed, there is no simple relationship between the appropriate public sector discount rate and the producer interest rate (Stiglitz and Dasgupta, 1971, Stiglitz, 1985, 1988).

3.5 Discounting for Risk

The standard treatment of risk in models involving impacts over a single individual's life is not to raise the discount rate for riskier projects, but instead to convert probabilistic consumption patterns into their certainty equivalents and then discount the results at the standard rate. The same should be true for the pure time preference component of the SRTTP when discounting across generations. This component should remain unchanged with respect to risk, and the influence of risk should be incorporated in the stream of expected consumption effects instead.

There would seem to be an argument for varying the growth-based component of the SRTTP with respect to risk, however. If there is uncertainty about the rate of per capita income growth, g , then consider the effect on the component θg in the SRTTP. Suppose there are two scenarios each with 50 percent probability: per capita income growth of 1 percent and per capita growth of 2 percent. There will be two resulting possible streams of marginal utility over time. The stream of expected value of marginal utility will be the average of these two streams. But because of diminishing marginal utility, this average will be greater than the stream of marginal utility generated by considering the simple average growth

rate over time, 1.5 percent. That is, with diminishing marginal utility, at any point in time marginal utility along the path for 1.5 percent growth will be closer to that of the 2 percent growth path than to that of the 1 percent growth path. Correspondingly, the expected marginal utility path lying halfway between the two scenarios will coincide with the marginal utility stream for a growth rate closer to 1 percent than to 2 percent. Essentially, the expected value of marginal utility is greater than the marginal utility of expected income. On this basis, there would be grounds for reducing the growth-based component of the S RTP under circumstances of risk.

Because the risk in predicting percapita growth on centuries-scale horizons is high, this consideration is particularly relevant for the problem of global warming. However, contrary to what is sometimes suggested, it means that incorporation of risk should reduce rather than increase the relevant discount rate.

3.6 Estimate Ranges

The approach described in the previous sections, under plausible assumptions, leads to low discount rates for changes in consumption of future generations. With high rates of productivity increase (and high g), of the order of 1.5%, and high values of the elasticity of marginal utility (θ), the social discount rate is of the order of 3%; with low rates of productivity increase, of the order of .5%, and low values of the elasticity of marginal utility, the social discount rate is of the order of .5%.

In general, there is no reason why the discount rate should be constant over time even if ρ and θ are constant, since g need not be constant. In fact, if we assume a gloomy scenario where future output and consumption decline, then g and thus the S RTP may be negative (Munasinghe, 1993).

Developing countries, with higher rates of productivity increase, can justify higher rates of discount, at least until the gap between their standards of living and those of the more developed countries have been closed. With labor productivity increases and percapita income growth of the order experienced by the Asian miracle countries of 5 to 8% per year, and elasticities of marginal utility of 2, discount rates of the order of 10% to 16% could be justified. Similarly, low-income countries close to subsistence levels could have high elasticities of marginal utility (rapid dropoff of marginal utility from initially extremely high levels associated with privation), so that their S RTPs could be high even if they were experiencing slow growth over long periods. These distinctions have important implications for global warming policy, because they would tend to mean that the calculus of trading off present abatement costs against future benefits from avoidance of global warming damage could be less attractive for developing countries than for industrial countries. However, there are other

elements in the calculus that could go the other way, such as the likelihood of higher relative future damage from global warming for the developing countries (see chapter 6).

Specific applications in the still new economic literature on global warming have adopted important differences in estimation of the discount rate. In a benefit-cost analysis of greenhouse abatement, Cline (1992) adopts a zero rate of pure time preference (ρ), and sets the S RTP at 1.5% per annum, the result of an assumed consumption growth rate of 1% per capita multiplied by an elasticity of marginal utility of 1.5. After taking account of the share of resources coming out of capita (20% economy-wide, versus 80% out of consumption) and shadow-pricing capital effects (at a price of about 1.6 consumption for each unit of investment, based on 8 percent return on investment and 15-year life for typical capital stock), Cline's effective discount rate is closer to 2% per annum. This is in keeping with recent work by Pearce and Ulph (1994).

In contrast, most global warming optimization models (e.g. Nordhaus, 1993a, b; Peck and Teisberg, 1992; Manne et al., 1993) apply a pure rate of time preference of 3%. They typically also use a logarithmic utility function, which, for a per capita growth rate of 1-2%, implicitly adds another 1-2% for utility-based discounting (θg), to give an S RTP of 4-5%. The divergent discounting methods explain much of the difference in the policy findings of different studies.

Table 3.1 presents a summary of the parameters that enter into calculation of the discount rate appropriate for policy toward global warming, and provides illustrative ranges for their values. Except for the rate of pure time preference, set here at 0.1 percent, the remaining central estimates are drawn from Cline (1992).

As indicated in the table, a central value for the social rate of time preference for the centuries-scale problem of global warming would appear to be about 1-1/2 percent. However, the table also shows that there could be a large range for the S RTP, resulting from the combination of endpoints in the ranges for the individual elements in the calculation. The range would be even larger if the upper bound of pure time preference were set at the 3 percent rate used in some studies (as noted above), but that level would seem excessive for the reasons reviewed above. In the adverse case of secular decline ($g < 0$), the overall discount rate is actually negative.

3.7 Discounting Environmental Impacts

The essence of social discounting is to convert all effects into their consumption equivalents at the proper relative prices, and then to discount the resulting stream of consumption equivalents at

the social rate of time preference. Incorporating environmental effects thus does not change the SRTTP itself, but requires special attention to the proper relative pricing of environmental goods over time.

While there is a generally accepted approach to valuing goods, there is less consensus concerning valuation of environmental impacts, other than those which are valued solely for their impacts on the production of goods. The question is addressed within the public finance literature in terms of the valuation of public goods. Assume consumers have utility functions of the form $U = U(c, G)$ where G is some public good (the quality of the environment). Then marginal rates of substitution between c at different dates may bear no correspondence to the marginal rates of substitution between G at different dates. This implies that there is no justification for discounting environmental degradation at market rates of interest. The appropriate procedure entails converting the environmental change into contemporaneous consumption benefits, and discounting those.

If there is environmental degradation occurring as society grows; and/or if the environment is an income elastic good on which people are willing to spend relatively more as their income rises, then presumably the marginal rate of substitution between environmental quality and private goods will systematically change over time, toward a higher relative marginal value of the environment. This tendency will lead not only to small effective discount rates for the environment, but possibly even negative ones (see annex 3A). However, it is important to reiterate that this process involves properly valuing the future scarcity of environmental benefits in arriving at the future flow of consumption, and does not change the appropriate discount rate itself at which the consumption stream should be discounted.

Much of the environmental literature that is critical of cost-benefit analysis, in contrast, argues for a zero discount rate without seeming to recognize the distinction between a zero rate of pure time preference (ρ) and a zero social rate of time preference, SRTTP (e.g. Daly and Cobb, 1991; Norgaard and Howarth, 1991). But from equation 3.1), so long as consumption growth is positive there will be a nonzero SRTTP. Similarly, some modern philosophers make the same mistake (e.g. Parfit, 1984; Cowen and Parfit, 1992).

Finally, there has been considerable discussion about the proper discounting method for environmental projects of official entities such as the Global Environmental Facility of the World Bank (see e.g. Munhasinghe, 1993). The method that follows from the social cost-benefit approach is to obtain consumption equivalents of the environmental effects over time and then discount at the SRTTP. The consumption equivalents of carbon emissions, for example, can be evaluated by applying the carbon shadow price from models of global warming damage and optimal abatement, so long as those models

themselves are implemented with discounting based on appropriate values for the rate of pure time preference and the elasticity of marginal utility (Cline, 1993). Within a fixed institutional investment budget, it may be that the collection of potential projects that successfully passes a cost-benefit test on this basis more than exhausts available funds. If so, efficient trade-offs within the menu of projects will appropriately involve cutoffs: higher internal project rates of return -- but always with benefit evaluation based on the consumption equivalence principle just outlined.

3.8 Implications for Sustainable Development

The concept of sustainable development can be viewed as a particular manifestation of the issue of intertemporal equity (discussed in section 3.2). Within developed economies, the classic statement of the meaning of sustainable development has been provided by Solow (1977): sustainable development requires that future generations be at least as well off as current generations. Under this definition, the central implication of sustainable development is that any environmental degradation must be offset by increases in capital stock sufficient to ensure future generations at least the same standard of living. Correspondingly, sustainable development does not preclude the use of exhaustible natural resources, but requires that any use be appropriately offset.

Within the economics profession, the concept of sustainable development has not received universal assent. It can only be justified by means of a Rawlsian social welfare function, and as noted above that social welfare function is not widely accepted. At a practical level, however, sustainability as defined by Solow provides few constraints on development paths for the more developed countries, so long as there are steady increases in productivity. Technical change alone, without further capital accumulation, should suffice to sustain future standards of living and offset effects of environmental degradation.

Some argue that the future damages from global warming are on the order of 1 to 2 percent of GDP or less whereas aggressive abatement costs are larger (Nordhaus, 1993). If so, taking strong actions to mitigate global climate change would have to be viewed as justifiable only on one of two bases:

1. We have a common, shared planet; changes are largely irreversible, and may occur rapidly; prudence calls for us not to engage in a massive experiment with our planet. This places a call for mitigation beyond the realms of normal economic calculus, on the plane of a fundamental value. Even if this view is taken, economics has much to contribute to the discussion: for nations must still address the question of the most cost effective way of reducing emissions and preserving the planet's atmosphere.

2. There is the potential of large, sudden, irreversible non-linearities with massive effects on the economy--particularly the economy of particular countries or regions.

Others argue that if a longer time horizon is considered than that of the conventional benchmark of $2\times\text{CO}_2$, and if upper bound warming and damages are taken into account, and considering the range of estimates for abatement costs, then even a standard economic analysis using the social discounting approach outlined here can conclude that the benefits of strong action outweigh the costs on economic grounds (Cline, 1992). This result obtains even though technical progress permits future percapita incomes to be eventually much higher than present, because with a reasonable range for the elasticity of marginal utility (θ) -- as opposed to the Rawlsian value of infinity -- the intergenerational bargain of exchanging modest costs today for large avoided damages in the future remains an attractive one. In this case, the two considerations just noted simply reinforce this conclusion.

For less developed countries, the above definition of sustainable development focusing on avoidance of future deterioration is generally not viewed to be sufficient, since it seems to place no weight at all on their aspirations for growth and development. Whereas publics in advanced countries may implicitly emphasize "sustainable" in their desire to assure their descendants continuation of a comfortable living standard, those in poor countries are more likely to emphasize "development" to assure their descendants that they do not live in such severe poverty as the present generation.

In North-South issues, formal models analyzing optimal development paths using a min-max (Rawlsian) criterion would, of course, focus exclusively on the welfare of the less developed countries in the first place. But the prescription would be simple: it would call for massive redistribution from the North to the South immediately, even without introducing the complication of long-term environmental problems. Even if there were limits on the transfers, it would suggest that all of the costs of mitigation--including those occurring within the South-- be borne by the North.

Of course, even the utilitarian approach ($\theta < \infty$) would tend to lead to higher general income transfers to poor countries than presently observed. It is thus a fair question to ask why the utilitarian construct is appropriate to apply for consideration of intergenerational equity (as in the identification of the SRTTP suggested in equation 3.1) if it is not applied in practice across (or, for that matter, within) countries at the present. In one sense, this question is another application of the principle suggested above that in the absence of optimal redistribution intervention by the government, observed "market" rates (in this case of North-South transfers) will not necessarily or likely equal social rates.

1 Some might seek to explain the paucity of present-day North-South
2 transfers on grounds of incentive effects. Thus, the massive
3 marginal tax rates on the North that would be required to equalize
4 income levels with the South could seriously reduce the amount of
5 output available for redistribution. Perhaps more relevant (in
6 view of the modest but unfulfilled international targets for grant
7 aid), the problems of still unaddressed poverty within the North
8 and sharp inequality within many developing countries complicate
9 attempts to improve overall welfare through North-South transfers.
10 The fundamental explanation, however, is that each country tends to
11 consider primarily the welfare of its own citizens, and only
12 secondarily that of others.

13
14 Despite the political constraints on present-day North-South
15 transfers that would otherwise be recommended by the utilitarian
16 approach, the time-discounting concepts of that approach, and the
17 SRTTP in particular, remain valid subject to these constraints.
18 Thus, consider a matrix with two rows -- North and South -- and two
19 columns -- present and future. The SRTTP can appropriately be
20 applied between the two columns along each row, even if there is a
21 barrier to its application between the two rows. Leaders and
22 publics in developing countries have cause for concern about their
23 descendants just as do their counterparts in developed countries.
24 As noted above, however, the value of the SRTTP is likely to be
25 higher for the South row than for the North row.

26
27 At the same time, both the Rawlsian and utilitarian approaches
28 imply that the South actively engage in mitigation financed by
29 transfers from the North, so that efficient mitigation can be
30 obtained. Any Pareto efficient development path (including any
31 reasonable definition of sustainable development) must have this
32 property of efficient mitigation. Thus, the level of mitigation
33 should be set based on eventual target of greenhouse gas
34 stabilization and implied levels of world emissions (without regard
35 to where those emissions originate). The magnitudes of actions
36 required to attain those levels of world emissions will, of course,
37 depend on the rates of growth of the less developed countries as
38 well as the increased energy efficiency among both the developed
39 and developing countries.

40
41
42

Annex 3A

Methodological Notes on Discounting

3A.1 Intertemporal Maximisation of Well-Being

In a remarkable set of contributions, Koopmans (1960, 1965, 1967, 1972a,b) conducted a series of thought-experiments on intertemporal choice so as to see the implications of alternative sets of ethical assumptions in plausible worlds. He suggested that we can have no direct intuition about the validity of discounting future well-beings, unless we know something concrete about feasible development paths. Applying this approach, Mirrlees (1967) and Chakravarty (1969) showed that in plausible economic models for developing countries, not to discount future well-being could imply that the present generation be asked to save and invest around 50 per cent of gross national product -- a stiff requirement when GNP is low. Nonetheless, these models tended to assume high rates of return on capital (a constant 33 percent rate in Chakravarty, 1969) and to consider time periods of decades rather than centuries. It is unclear that their findings hold for the centuries-scale problem of global warming, in part because of the much lower likely average return to capital over this horizon.

Koopmans (1960) considered the set of feasible consumption paths (from the present to the indefinite future) and the corresponding set of welfare or "well-being" paths. These paths could then be ordered to select the optimum path of well-being, according to the criterion:

$$3A.1) z = \int_{t=0}^{\infty} W(c_t) e^{-\rho t} dt$$

where $\rho > 0$.

Correspondingly, the discount rate for the time path of consumption is:

$$3A.2) i_t = i(c_t) = \rho + \theta(c_t) [dc_t/dt]/c_t$$

where $\theta(c_t)$ is the elasticity of marginal well-being, or marginal utility, at time t (Arrow and Kurz, 1970). (Note that whereas the main text treats this term as a constant, it is explicitly considered to vary with the level of consumption in the treatment here.) Along a full optimum path, the consumption rate of discount equals the productivity of capital (i.e. the social rate of return on investment). This is the famous Ramsey Rule.

A convenient form of W is that giving a constant marginal utility, such as:

As discussed in the text, the larger is the rate of pure time

$$3A.3) W(c) = -c^{-\theta}$$

preference, ρ , the lower is the weight accorded to future generations' well-being relative to that of the present generation. Mirrlees's (1967) computations essentially introduced this sort of bias ($\rho > 0$) as a way of countering the advantages to be enjoyed by future generations, should the productivity of capital and technological progress prove to be powerful engines of growth.

As noted in the text, a higher value of θ means greater emphasis on intergenerational equity. As $\theta \rightarrow \infty$, the well-being functional in 3A.1) resembles more and more the Rawlsian max-min principle; in the limit, optimal growth is zero.

In 3A.3), $W(c)$ has no minimum value. If $\rho = 0$, this ensures that very low consumption rates are penalized by the optimality criterion reflected in (3A.1). On the other hand, if ρ were positive, low consumption rates by generations sufficiently far in the future would not be penalized by (3A.1). This means that unless the economy is sufficiently productive, optimal consumption will tend to zero in the very long run. Dasgupta and Heal (1974) and Solow (1974a) showed in a model economy with exhaustible resources that optimal consumption declines to zero in the very long run if $\rho > 0$, but that it increases to infinity if $\rho = 0$.

It is in such examples that notions of sustainable development can offer some analytical guidance. If by sustainable development we mean that the chosen consumption path should never fall short of some stipulated, positive level, then it follows that the value of ρ would need to be adjusted downward in a suitable manner to ensure that the optimal consumption path meet the requirement. This was the substance of Solow's remark (see Solow, 1974b) that, in the economies of exhaustible resources the choice of ρ can be a matter of considerable moment.

So far an assumption underlying this discussion has been that well-being or utility has not been bounded. If we restrict well-being to be bounded, other results obtain, because of the mathematical properties of the space of bounded sequences. For such sequences present value calculations are not rich enough to capture all the subtleties of evaluation of a utility stream. Instead, one has to add to the present value another term. In an ingenious interpretation, professor Graciella Chichilnisky (1994) has suggested that the first term - the present value term - represent the requirement that the future should not be a dictator over the present; and that the second, new, term represents the requirement that the present should not be a dictator over the future. This second term will in general have the form of a long term average. It could be approximated by minimum requirements for the long run stocks of environmental resources.

3A.2 Resource Sourcing and the Consumption versus Investment Discount Rate

Sandmo and Dr  ze (1971) address choice of the correct rate of discount to use in the public sector when there are distortions in the economy, e.g. in the form of taxes, which prevent the equalization of marginal rates of substitution and transformation in the private sector. Under certain assumptions, the corporate tax drives a wedge between the marginal rate of time preference of consumers and the marginal rate of transformation in private firms.

They find that for a closed economy:

$$3A.4) 1+r < 1+i < 1+\frac{r}{1-t}$$

where r is the consumer interest rate, t is the tax rate, and i is the public sector's discount rate. This rate should thus be a weighted average of the rate facing consumers and the tax-distorted rate used by firms. Since $1+r$ measures the marginal opportunity cost of transferring a unit of resources from private consumption, and since $1 + r/(1-t)$ is the measure for transfers from private investment, a unit of resources transferred from the private to the public sector should be valued according to how much of it comes out of consumption and how much out of investment. For an open economy, the elasticity-adjusted rate on foreign loans also enters the calculus. However, for analysis of a global issue, this extension is probably inappropriate, as globally the economy is closed.

The discrepancy between public evaluation of a marginal dollar to future generations, and individuals' own intertemporal evaluations can arise even in the case of very simple social welfare functions. Thus, assume that there is a utilitarian social welfare function, which simply adds up the utility of successive generations, and for simplicity, assume each generation lives for only two periods. The t generation's utility is represented by a utility function of the form:

$$3A.5) U^t = u(c^t, c^{t+1})$$

where the first argument refers to consumption the first period of the individual's life, the second to consumption the second period. Then observed market rates of interest refer to how individuals are willing to trade off consumption over their own life. These may or may not bear a close correspondence to how society is willing to trade off consumption across generations. The former corresponds to u^t_2/u^t_1 , while the latter corresponds to u^{t+1}_1/u^t_1 .

If the government has engaged in optimal intertemporal redistribution and does not face constraints in imposing lump sum

(i.e. nondistorting) taxes on each generation, then the two will be the same, and equal to the marginal rate of transformation (in production, i.e. the return to investment). But whenever either of these conditions is not satisfied, then market rates of interest facing consumers (measuring their own marginal rates of substitution) need bear no close relationship to society's marginal rate of substitution across generations.

Diamond and Mirrlees (1970, 1971) show that if the only reason for the discrepancy between producer and consumer interest rates is optimally determined commodity taxes, and there is a 100% pure profits tax (or there are no pure profits or rents), then the government should use the producer rate of interest. Stiglitz and Dasgupta (1971) have shown that this result does not hold if either of these assumptions is dropped.

Under certain circumstances (in particular the existence of optimal intergenerational lump sum transfers), asymptotically the producer rate of interest will equal the pure rate of time preference of society. More generally, when the government must resort to distortionary taxes, not only is this not true, but the rates of discount employed may reflect distributional considerations. See Stiglitz (1985).

3A.3 Effective Discount Rate for Environmental Impacts

As noted in the main text, the effective discount rate for environmental effects can be low or even negative. Assume there is a Cobb Douglas utility function between private goods, c , and the environment, e :

$$3A.6) u = a \ln c + b \ln e$$

Assume c increases at the rate g_c , and e decreases at the rate $-g_e$. Then the derivative of the marginal rate of substitution between the two goods is:

$$3A.7) d \ln MRS / dt = a g_c + b g_e$$

With no pure rate of time preference, consumption is discounted at the rate g_c , so environmental goods are discounted at the rate: $(a-1)g_c - b g_e$, which will be negative.

Table 3.1

Discount Rate for Global Warming Analysis

Parameter	Concept	Central value (%)	Plausible range (%)
ρ	rate of pure time preference	0.1	0 to 1.0
θ	elasticity of marginal utility (absolute value)	1.5	0.8 to 2.5
g	growth rate of percapita income (2-3 centuries)	1.0	-0.2 to 2.0
SRTP	social rate of time preference, $= \rho + \theta g$	1.6	-0.4 to 6.0

1 References
2
3 [to follow]

4 JES
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S/K

**APPLICABILITY OF COST-BENEFIT ANALYSIS
TO CLIMATE CHANGE**

Prepared for

**WORKING GROUP III
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE**

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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 therefrom¹. If there are several alternatives, then one ought to pick that option whose benefits most exceed the costs².

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 problem³.

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 CO₂ 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 in *moderately*. 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 global warming 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 money⁵.

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 benefits may not occur at the same point in time. Thus, while costly actions to avoid future global warming must be taken in the very near future, the benefits of such actions may arise very 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 is indeed only one of several that may be employed.

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.

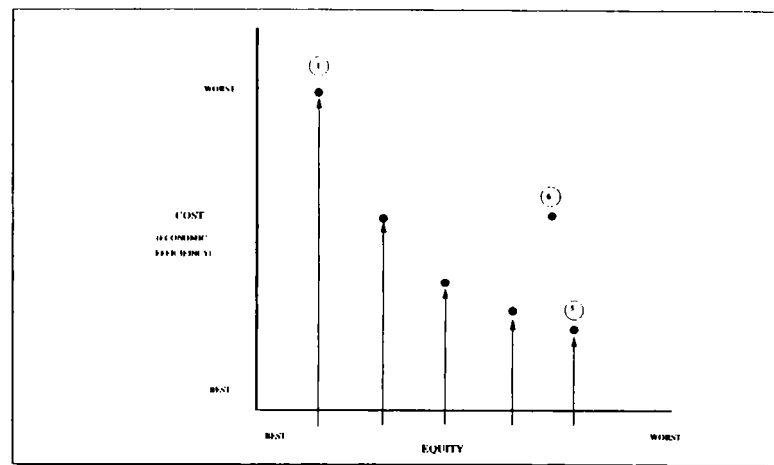


Figure 2.1: Multi-criteria analysis

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.

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 cost⁶. 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 cultures⁷.

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-comparable 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.

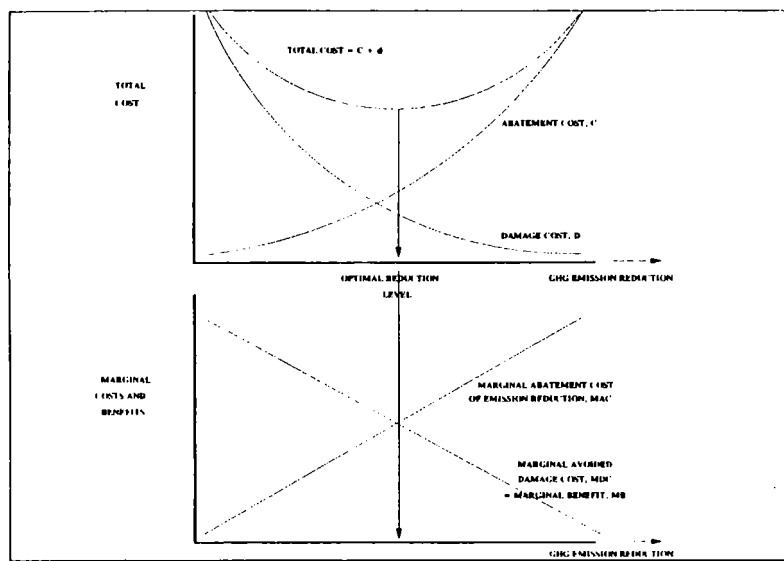


Figure 2.2: Total and marginal costs and emissions reductions.

Basic concepts

An economically efficient policy for emissions reduction is one that maximizes the net benefits, i.e. maximizes the benefits of reduced global warming less the associated costs of emissions reductions⁸. 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 next 5-6% requires chemical treatment, with high operating costs of chemical agents. 100% removal,

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).

The foregoing analysis ignores many complications. For example, the emission of a unit of CO₂ 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.

3. Unique features of global warming

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 global warming. 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.

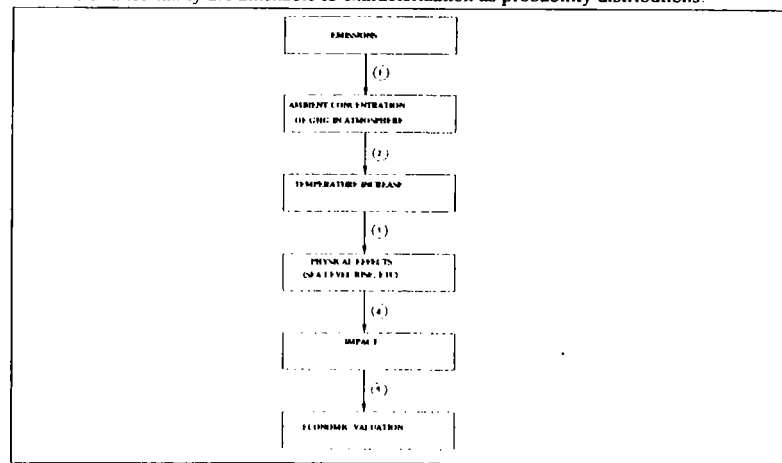


Figure 3.1: The chain of causality

theoretically possible, would require complete distillation, which is extremely expensive.

Figure 3.1 shows the chain of causality. It begins with emissions of greenhouse gases. While the most important of these is CO₂, it should be noted that there are many other gases that contribute to the global warming phenomenon, including methane, and CFCs. While estimates of CO₂ emissions from fossil fuel combustion are fairly straight forward, emissions from other sources are subject to much higher uncertainty.

The first link (1) is between emissions and the resultant ambient concentration of CO₂ in the atmosphere. Unlike other pollutants that are subject to complex chemical transformations in the atmosphere,¹⁰ the calculation of the ambient concentration increase that follows from a given increment of emissions of CO₂ 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.¹¹

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 linkage (#3) involves many different components. Some are relatively straight forward: for example, calculating the rise in sea level may be quite simple given assumptions about increases in mean sea temperature. Much 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.

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.

¹⁰ The acidity of precipitation is influenced by complex interactions between sulfur oxides, related oxidation products, and NO_x.

¹¹ For example, the presence of CFCs could affect global warming not only directly through its greenhouse warming potential, but also indirectly by its impact on biota like nanoplankton -- which in turn influence oceanic CO₂ uptake. Similarly, the degree of reliance on fossil fuels would affect CO₂ directly, and CO₂ absorption indirectly -- via the effects of acid rain on forests and biomass.

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.¹²

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 e.g. 11 years for methane to more than 100 years for CO₂, N₂O 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.

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, CO₂, is the marginal environmental cost of current emissions of this gas relative to the corresponding marginal cost of CO₂. It follows from the discussion above that the relative importance of GHGs depends on a number of economic assumptions which must be made.¹³

¹² 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.

¹³ See e.g. Hoel and Isaksen (1993, 1994) for a further discussion and numerical calculations.

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 global warming become apparent, it will then be too late to do anything about it.

Global characteristics

Most environmental pollution problems are local in scale.¹⁴ 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. 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.

Unlike some other trans-national pollution problems, poorer nations are likely to be more vulnerable to the impacts of global warming, since they lack the resources to protect themselves against sea level rise, extreme weather events, or desertification. In fact, the impacts of acid rain tend to be concentrated in richer countries, from emissions in poorer countries or regions (Japan from China¹⁵, Germany from E. Europe, the wealthy northeastern states of the US and Canada from Appalachia). These richer areas therefore have powerful incentives to promote emissions reductions programs in the source areas, including the provision of financial assistance.¹⁶ 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 global warming on the U.S. itself are relatively small), may have less obvious economic motivation to reduce emissions.¹⁷ Considerations of humanitarian solidarity and equity alone will unlikely be sufficient.

¹⁴ There are exceptions here as well, most notably the phenomenon of acid rain, which is largely a long-range phenomenon typically involving emissions in one country, and acid rain damage in another (e.g. emissions in the U.K. affect Scandinavia, emissions in the U.S. affect Canada, emissions in China affect Japan). 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.

¹⁵ 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.

¹⁶ 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. Annan *et al.*, *Economic Restructuring in Eastern Europe and Acid Rain Abatement Strategies*, *Energy Policy*, p.1187-1198, Dec. 1992.

¹⁷ 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.

Absence of actual impact data:

Unlike almost all other environmental externalities, there are no directly relevant data. All predictions of physical impacts are based entirely upon the predictions, judgments, and models of scientists.¹⁸ Only once (or if) global warming does in fact occur, will the impacts be known. However, the evidence of cause-and-effect will be difficult to substantiate, because of the likelihood that, at least initially, changes will be incremental.

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.

4. Cost-Benefit Analysis in the context of global warming

In light of these unique characteristics of the global warming 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?

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.¹⁹ 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 CO₂ saved (the height of each block), with the width of each block representing the tons of CO₂ 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.²⁰ 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.

What is interesting in these (and other studies²¹) is the significance of "below the line" options (i.e. MAC is negative but still upward sloping). These are measures that appear to

¹⁸ In some cases laboratory experiments -- such as growing plants in CO₂-enriched atmospheres -- do of course provide some actual data for predictions.

¹⁹ 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).

²⁰ See e.g. the review of eleven studies by London Economics (1992).

²¹ 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

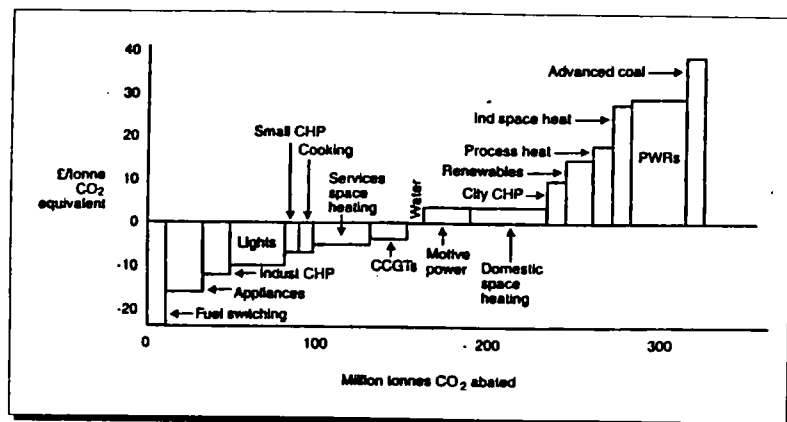


Figure 4.1: The marginal cost curve for the U.K.

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.²² 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, or other factors, such as high transaction cost (which might exceed the potential benefits)²³

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.²⁴ If the GEF

and T. Siyambalapittra, *Energy Sector Policy and the Environment*, World Bank Environment Department, 1993, for Sri Lanka.

²² 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.

²³ 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.

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.²⁵ But under such a definition, should demand side management programs which have negative incremental costs-- such as energy efficient lighting -- be funded by GEF?²⁶

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 $MB > MC$.

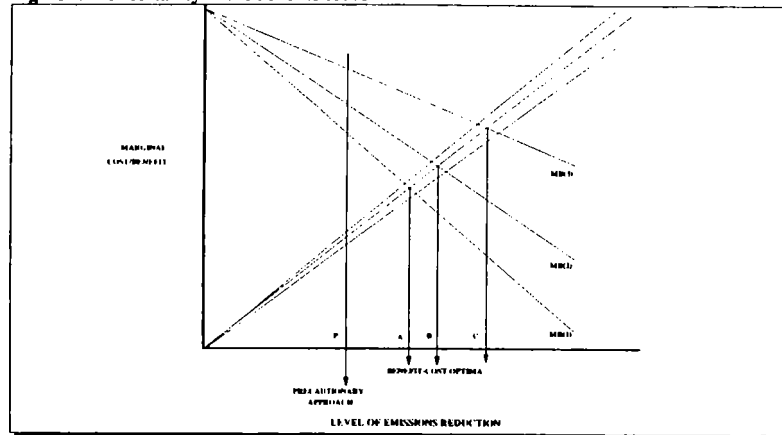
In fact, there exist few if any estimates of the benefits curve, and most of the estimates that do exist are not much more than single point estimates for some presumed level of GHGs in the atmosphere. Well known for the US is the work of Nordhaus, who begins by classifying the components of economic activity (national income) into three groups: (1) those potentially seriously impacted; (2) those with moderate potential impact; and (3) those having negligible effect.

²⁴ 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.

²⁵ 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.

²⁶ 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)".

Figure 4.2: Uncertainty in the benefits curve



For the sensitive sectors, Nordhaus then goes on to estimate the impacts associated with a doubling of CO_2 in the atmosphere (Table 4.1). He concludes that in fact damage from sea level rise is the most certain major impact, since estimates on the most sensitive sector, agriculture, range from a significant net cost to a significant net benefit. Overall, the central point estimate of impact is 0.26% of national income.

The implication is that countries in which manufacturing and services are the dominant activities are not likely to be greatly affected in overall macro-economic terms (e.g. in the U.S., only some 3% of GDP is in the farm and forestry sector).

Whether this type of approach in fact captures all the relevant costs is of course subject to debate, since a whole range of costs like damage due to extreme weather events and potential non-market impacts, such as loss of biodiversity, is ignored. Moreover, it is entirely unclear whether some of the areas that have been included in Nordhaus' analysis have been given adequate attention.²⁷ For example, municipal water supply, which presently accounts for a very small part of national GDP, may be potentially extremely sensitive to small changes in climate in the western US -- where even under present conditions costs are growing very fast.²⁸ However, as shown on Table 4.2, other estimates of the impact of global warming, including those which attribute much larger impacts to wetlands, species loss etc, do not result in significantly larger losses of output.

Despite the suggestion that the economic impact of global warming on the industrialized countries is quite small, 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

²⁷ For a critique of Nordhaus' estimates, see e.g. Williams (1993).

²⁸ A study of the impacts of global warming in California points to the severe problems that might be encountered in that state. Because of changes in the distribution of rainfall, resulting in winter runoff and lower spring runoff, water supply from reservoirs in the Central Valley Basin would significantly decrease. See EPA, *The Potential Effects of Global Climate Change on the United States, Report to Congress*, Office of Policy, Planning and Evaluation, Washington, DC, 1989.

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.²⁹ 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.³⁰

Table 4.1: Estimates of the impact of global warming on the US GDP

	% of GDP	% of total	cost billion 1981 \$
Total national income			
Potentially severely impacted		3.1	
farms	2.8		10.6 to -9.7
forestry, fisheries, other	0.3		small
Moderate potential impact		10.1	
construction	4.5		negative
water transportation	0.3		?
energy (electric, gas, oil)	1.9		
electricity demand			1.65
non-electric space heat			-1.16
water and sanitary	0.2		positive?
real estate (land rent)	2.1		
loss of land			1.5
protection of sheltered areas			0.9
protection of open coasts			2.8
hotels, lodging, recreation	1.1		?
Negligible effect		86.8	
mining	1.9		
manufacturing	24.1		
other transport & communications	5.5		
finance, insurance	11.4		
trade	14.5		
other services	13.5		
government services	14		
rest of world	2.1		
Total impact			6.2

Source: W. Nordhaus, *Economic approaches to greenhouse warming*, in Dornbusch and Poterba (Eds) *Global Warming: Economic Policy Responses*, MIT Press, Cambridge, MA, 1991.

²⁹ This is likely to be true even though higher CO_2 concentration itself may promote plant growth.

³⁰ 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).

Table 4.2: Estimates of the impact of global warming

	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

Unfortunately, to date, most of the discussions of impacts of global warming on the developing countries have been qualitative in nature,³¹ and there is an urgent need for more quantitative estimates for developing countries. According to a recent GEF survey of country studies³², 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.³³

Measuring costs and benefits

Nordhaus' 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.³⁴ It is well established (Weitzman, 1976, Brekke, 1994) that GDP is not

³¹ see e.g. the discussions of P. Gleick, *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).

³² J. Fuglestad 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.

³³ 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 Environment and Forests, January 1991). Similarly, neither Volume on Global warming published by the Asian Energy Institute (Pachauri and Behl, (Eds), 1991), nor the country studies conducted by UNEP (Reported in UNEP, 1992) contain any country 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.

³⁴ 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?

a welfare measure per se, but rather a convenient way to aggregate goods and services which clearly contribute to welfare.

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 analysis³⁵. 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 4.3).

Table 4.3: Impact of welfare losses of GHG abatement options in Sri Lanka (in \$/ton of avoided carbon)

	no coal	wind	CFI
supply cost impact	16	67	-472
consumer impact	10	66	-66
total	26	131	-538

source: Meier, Munasinghe, and Siyambalapitaya, *op. cit.*, 1993.

notes: negative numbers indicate a benefit

CFI= 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.

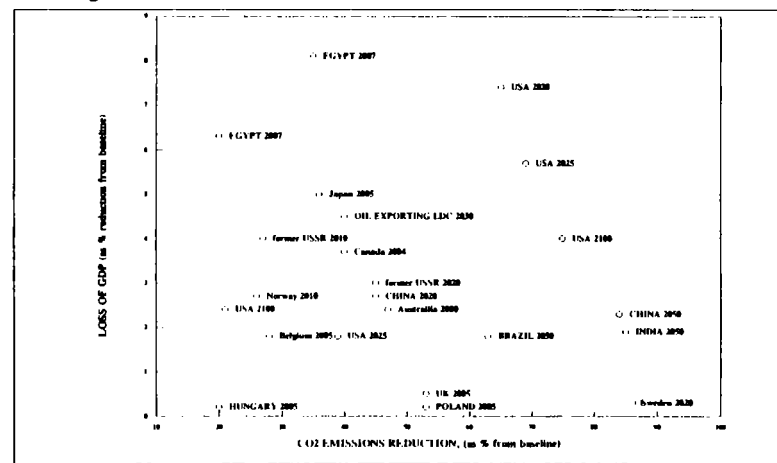


Figure 4.3: Impact of GHG emissions reductions on GDP

³⁵ 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,

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.³⁶

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 GDP.³⁷ 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.³⁸ 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.³⁹ 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.

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 CO₂ emissions -- a *global* benefit -- but also SO₂ 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 CO₂ emissions, may also impose new and different local environmental costs (such as loss of biodiversity associated with reservoir inundation).

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

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.

³⁶ The question of "green accounting" is one of valuing and aggregating marketable and non-marketable goods. The many 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.

³⁷ 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).

³⁸ S. Glomsrød, H. Vennemo, and T. Johnson, *Stabilization of Emissions of CO₂: a Computable General Equilibrium Assessment*, Central Bureau of Statistics, Discussion Paper 48, Oslo, Norway, 1990.

³⁹ 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).

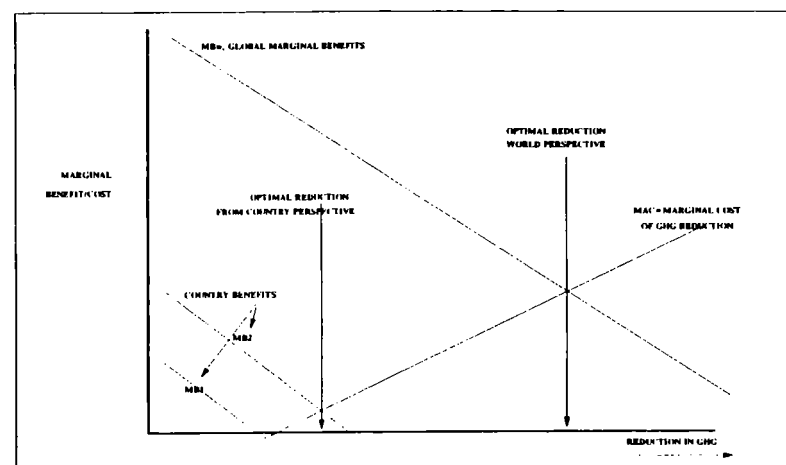


Figure 4.4: The marginal cost and benefits curve for an industrial country

reduction.⁴⁰ A recent Norwegian study (Alfsen, Brendemoen and Glomsrød, 1992) indicated 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.⁴¹

Adding the benefits of reductions in conjoint pollutants to the MB measure is one possibility. The other is to subtract these benefits from the MC measure. Since most of such benefits go to the country that bears the costs of abating the CO₂ emissions, while the benefits of less CO₂ 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 MB₁ were true, then the optimal policy would be only to implement the win-win

⁴⁰ For example, if we use the externality values suggested by the California Energy Commission (\$26/ton for CO₂, 14,483 \$/ton for NO_x, \$7,425\$/ton for SO₂, and \$57,620\$/ton for TSP), then estimated benefit of reducing electricity demand by 1 mwh is 23\$ for CO₂, and 74\$ for the reduction of NO_x, SO₂ and TSP, i.e. a ration of 3 to 1. (Assuming emissions rates for a coal-fired power plant meeting New Source Performance Standards.

⁴¹ 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 1.0-3.8 billion). (Alfsen, Brendemoen and Glomsrød, 1992, p.28).

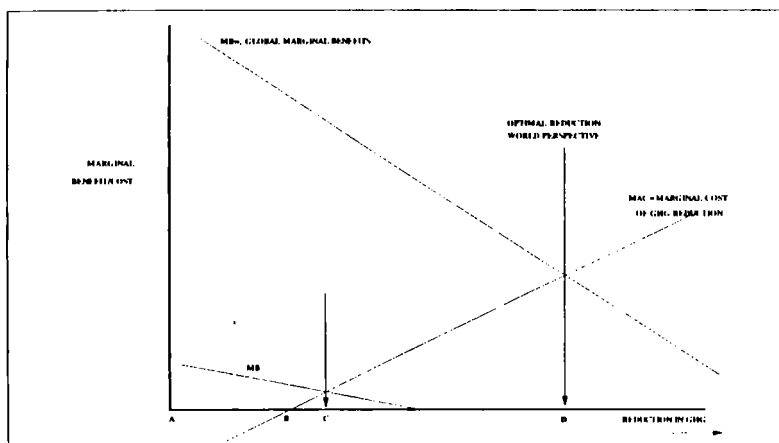


Figure 4.5: The marginal cost and benefits curve for a developing country

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 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.⁴²

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.⁴³

⁴² 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).

⁴³ 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 mtpy. 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 mtpy) and Poland (105.2 mtpy) dominate the results, indeed, the combined

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.⁴⁴

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 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.⁴⁵

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 4.4). 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. 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 India⁴⁶, the supply curves have the

estimated impact in India (54 mtpy), and China (45.4 mtpy) together is less than that for Poland

⁴⁴ 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.

⁴⁵ See, e.g., M. Munasinghe, Sustainable Energy Options for Developing Countries, *World Energy Council Journal*, 1, Dec. 1991, p.69-87.

⁴⁶ J. Hossain and C. Sinha, *Limiting CO₂ emissions in the power sector of India* *Energy Policy*, Oct. 1993, p.1028

expected classical upward sloping shape as illustrated on Figure 4.8 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.

Table 4.4: Comparisons of cost estimates for CO₂ abatement.

	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 CO₂ 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.

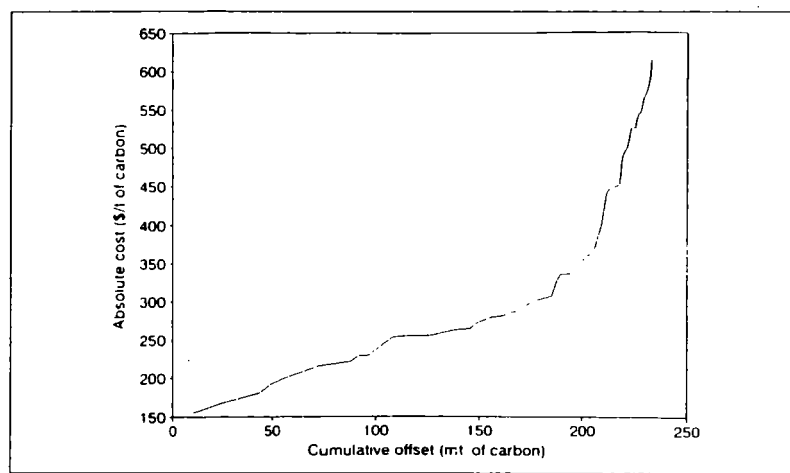


Figure 4.8: supply cost curve for windfarms in India

source: J. Hossain and C. Sinha, *Limiting CO₂ emissions in the power sector of India* *Energy Policy*, Oct. 1993, p.1028

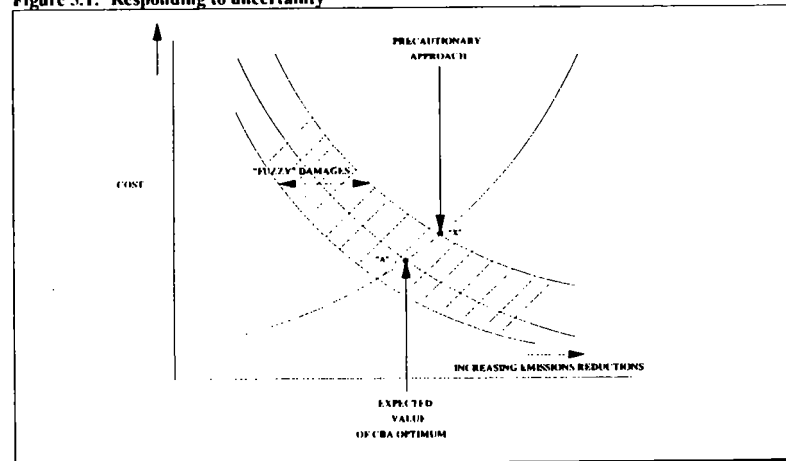
5. Issues

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 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 ("fuzzy damages"), 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 defined by the intersection of the cost curve and the upper envelope of the damage function.

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 turn out to be worse than expected, the world is stuck with a permanent, perhaps unwanted, climate change, which clearly is worse than if the climate could be reestablished after such a change.

Provided that the CBA is worked out correctly, however, the cost of irreversible effects would be included. This requires a vast amount of information, 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 measures causing irreversible effects have an extra cost, called quasi option value. This value can be interpreted as the value of keeping future options open, and suggest 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 turn 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 six major sources of uncertainty that need to be considered:

1. Uncertainty over the actual rates of emission. All 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 projections of CO₂ emissions from fossil fuel use may be reasonably well known, but the level of uncertainty increases as one moves to levels of possible fossil fuel use in the more distant future, the impact of deforestation, or to other GHGs such as methane.⁴⁷
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 SO₂ 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.⁴⁸ 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.

⁴⁷ For a full discussion of uncertainty in emissions, see e.g. Ebert and Karmali (1992).

⁴⁸ see note 42, *supra*

However, these joint benefits and costs are also subject to significant uncertainties (and also measurement problems).

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 global warming, 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 probabilities⁴⁹, 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)⁵⁰

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

⁴⁹ 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).

⁵⁰ 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 global warming 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: 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).

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.

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 J. Lave (*Are economists relevant? The efficiency of a carbon tax*, in Dornbusch and Poterba (Eds) *Global Warming: 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).

tradable permits) in a situation where there are both uncertain control costs and an uncertain environmental response (see Lave and Gruenspecht, 1991).

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. For non-marketable 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. "Synthetic" prices will 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 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) global warming actually does occur, and (2) that global warming 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. 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 global warming -- 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.⁵¹ 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).
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, together with an indication of the degree of valuation difficulties likely to be encountered.

Conceptually, the total economic value (*TEV*) of a resource consists of its use value (*UV*) and non-use value (*NUV*).⁵² 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). 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

$$TEV = UV + NUV$$

or

$$TEV = [DUV + IUV + OV] + [NUV]$$

⁵¹ "Preliminary results suggest that although US crop production could decline, supplies would be adequate to meet domestic needs" (EPA, *op cit.*, 1989, p.93).

⁵² For further details, see Munasinghe (1993), Pearce and Warford (1993)

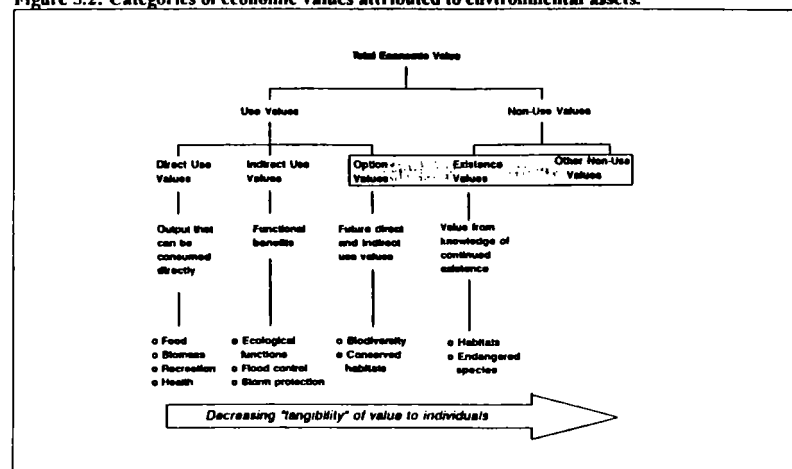
Table 5.1: Potential impacts to be valued (for the U.S.)¹

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 allergies
energy	changes in fertility due to stress 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 3). 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.¹¹

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.¹⁴ 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.

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.)

¹¹ For a recent overview of techniques suitable for valuing environmental costs and benefits, especially in developing countries, see Munasinghe (1993).

¹⁴ 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
Based on actual Behaviour	effect on production	travel cost	artificial market
	effect on health	wage differences	
	defensive or preventative costs	property values	
Based on intended behaviour		proxy marketed goods	
	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.

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.⁵⁵

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).

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 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.

Two concepts mainly help to shape the discount (or interest) rate in a market economy. First, there is the personal rate of time preference of individuals which determines how they compare present-day with future consumption. Second, there is the rate of return on (or opportunity cost of) capital, which determines how an investment (made by foregoing today's consumption) would yield a stream of future consumption (net of capital depreciation or replacement). In an ideally functioning market, the interest rate which equilibrates savings and investment, also equals both the marginal rates of time preference and return on capital. In practice, government policy distortions and market failures lead to divergences between the rates of time preference and return on capital. Furthermore, the social rate of time preference may be less than the individual time preference rate, because long-lasting societies are likely to have a bigger stake in the more distant future than relatively short-lived individuals.

One needs to take note 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.

The rate of capital productivity is very high in many developing countries, because of capital scarcity, and the rate of time preference also is elevated because of the urgency of satisfying immediate food needs rather than ensuring long term food security (Pearce and Turner 1990). Projects with social costs occurring in the long term and net social benefits occurring in the near term will be favored by higher discount rates. Conversely, projects with benefits accruing in the long run will be less likely to be undertaken under high discount rates. Thus, some environmentalists have argued that discount rates should be lowered to facilitate environmentally sound projects meeting the CBA criteria. However, this would lead to more investment projects of all types, thereby possibly threatening fragile environmental resource bases. Norgaard (1991) argues that lowering discount rates can in fact worsen environmental degradation -- by lowering the cost of capital and thereby lowering the cost of production, more is consumed in the near-term relative to the case where discount rates were higher. Further, using a very low discount rate to protect future generations is inequitable, since it would penalize the present generation and increase inequalities across time periods -- especially when the present contained widespread poverty (Pearce 1991).

In order to facilitate such intergenerational transfers, one option is to impose a sustainability constraint, whereby current well-being is maximized without reducing the welfare of future generations below that of the current generation. In practice, this would entail monitoring and measurement of capital stocks (man-made, human and natural), and a broad investment policy which sought to ensure that compensating investments offset depreciation of existing assets (Pearce 1991). Theoretically, the aim would be to ensure that the overall stock of assets is preserved or enhanced for future generations, but practical application of this principle would be difficult.

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 to attain a socially optimal development. 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.⁵⁶

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

⁵⁶ For a discussion, see Munasinghe (1993).

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 global warming 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 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 global warming is the average increase in global temperature, global warming 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).⁵⁷ 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 global warming 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.⁵⁸ Indeed, some developing

⁵⁷ 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.

⁵⁸ 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

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.

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. Economic efficiency is one of fifteen so listed

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

considerations are outlined in Rose (1990).

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.

The application of MCA methods involves the following steps:

1. Selection and definition of attributes, say A_i , $i=1, \dots, N$, 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 be 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 to 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, where 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).⁵⁹ This is sometimes combined with a 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.

⁵⁹ 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).

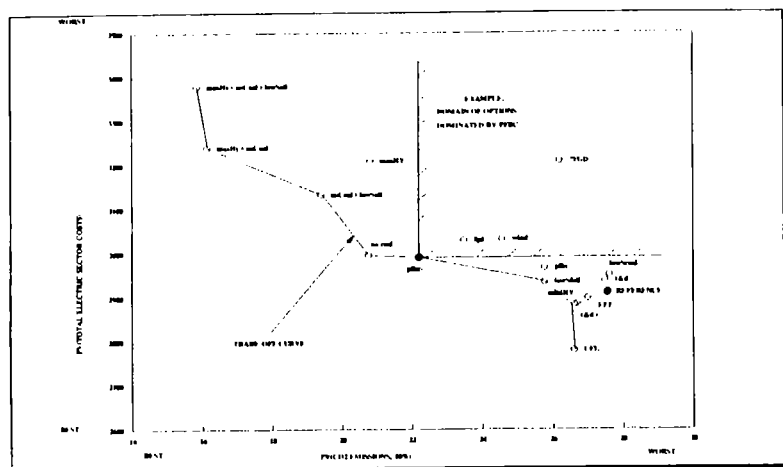


Figure 5.3: Trade-off curve

source: Meier, Munasinghe and Siyamhalapitiya (1993)

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.⁶⁰

Several useful concepts arise here. First is the concept of *dominance*⁶¹ 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.⁶²

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 "B" ("max hydro+no coal") to point "A" ("NoCoal+lowSoil") makes an implicit valuation of the

⁶⁰ We note also that the trade-off analysis and surfaces will be much more complex as the number of attributes increases.

⁶¹ 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.

⁶² 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.

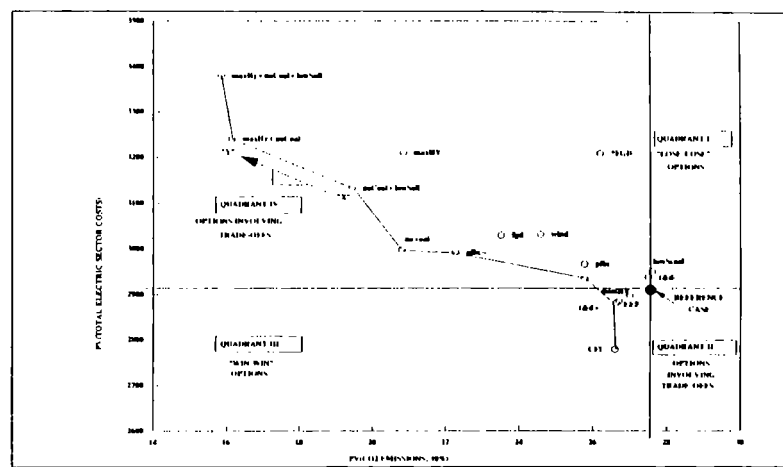


Figure 5.4: "Win-win" options

source: Meier, Munasinghe and Siyamhalapitiya (1993)

concomitant reduction of GHG emissions in terms of the increased costs (i.e. equal to the slope of the trade-off curve between A and B, about 200\$/ton of CO₂)⁶³

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. 12% goal delayed to 2003	TD+
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
clean fuels	with pessimistic capital cost assumptions use imported low-sulfur residual oil for diesels (0.5% S by weight rather than 2.5% S)	PFBC-- low S oil
FGD systems	use low sulfur (0.5%) coal (rather than 1% S coal) model free to choose optimal generation mix; coal plants must have FGD systems.	low S coal FGD
	FGD systems forced onto basecase solution	**FGD
no coal	model free to choose least-cost combination of diesels +hydro	noCoal

⁶³ 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.

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 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 readily answered by CBA: 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 remains the best guide to policy-making for dealing with the essential questions that must be faced in dealing climate change. CBA 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. And where non-monetary objectives must also be considered, 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, rather than intuition and rhetorical argument.

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DRAFT 5.1

Intergovernmental Panel on Climate Change Working Group III

Chapter 3

Equity and Social Considerations

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Notes

DRAFT 4.1

Intergovernmental Panel on Climate Change Working Group III

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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 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.

1.1 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 social 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 these institutions and processes. The institutional parallels at the international level are weak or non-existent. Yet in responding to climate change, humanity faces unavoidable decisions about the distribution of effort and burdens, and what constitutes acceptable behaviour, in circumstances where the internal activities of one country 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. Because of this, the relative weakness of international institutions may need to be compensated by great explicit emphasis in international actions on considerations of equity. Climate change may also have direct impacts on, and other implications concerning, equity within countries which should be considered.

1.2 Concepts of Equity

Since Confucius, Plato, Aristotle, and the Vedantic texts, theorists who have dealt 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 that similar cases and similarly situated claimants should be treated in a similar fashion. For exceptions to this principle to be regarded as equitable, they must be made on a principled basis. In this sense, the principle of equity suggests that law should govern decisions, and it provides guidance in how law should be applied. Laws are formulated abstractly, but are applied in specific circumstances. All of the circumstances in which a law would be applied can never be foreseen at the time of the formulation of the law. Starting with Aristotle, theorists have argued that equity demands that law be applied in terms of the intentions of those who established the law, the application should aim at achieving what the legislators would have intended in the specific circumstances or at achieving what would be required by "absolute justice." (Shapiro, 1990, p. 220) Absolute justice refers to a broadly accepted higher notion of what is just. It is in this way that in the Anglo-American common law tradition equity is often introduced into judicial decisions.

There are also other views of procedural equity. They center around notions of basic rights. 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 all. Robert Nozick (1974) 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. While applying theories that were originally developed for dealing with individuals to relations among groups or states may be problematic (Van Dyke, 1975), the notion that procedural equity demands that basic rights, 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.

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 be treated equally; 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 maximising 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 all. 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 emphasise principles that may advantage them. Nevertheless, the principles are useful guides to what might constitute equitable decisions. Illustrating the likely consequences of their application can clarify the choices that have to be made in seeking equity in concrete situations such 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.

1.3 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 1987).

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 Brundtland Commission--published its report *Our Common Future* (1987). That report identified a number of ingredients in sustainable development (not necessarily consistent with each other), with the central idea being that the present generation should not make changes that reduce the possibilities for future generations to achieve a comparable well-being. This is, obviously, an ethical norm which, if accepted by most decision-makers, may have far reaching consequences for how we view intertemporal justice. The implications of this in terms of the "discount rate" used to value future impacts is discussed 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 maximise 'something' with the resources available. Maximising GNP - or perhaps 'Gross World Product' - could involve highly inequitable outcomes. Seeking to maximise 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 maximise. 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. Through treaties and other international agreements, custom, general principles of law, and court judgments, international law has established basic rights of states. These rights are relevant to procedural equity.

A basic tenet of international law is the sovereign equality of all states. All states have equal rights and obligations notwithstanding differences of an economic, political, social or other nature. Each state has jurisdiction over its territory. Within its territory, a state has the right freely to choose and develop its political, social, economic and cultural systems. 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.

The rights and obligations of states include the right to develop their own policies and laws regulating the exploitation of their natural resources. Principle 2 of the Rio Declaration on Environment and Development proclaimed:

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 own 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. (UN, 1993, p.9)

This right then is coupled with an obligation not to cause damage beyond their borders.

International law is also relevant to consequentialist equity. The International Court of Justice (ICJ) has taken the position that in arriving at judgments it is bound to apply the concept of equity. In its judgment on the 1982 Continental Shelf Case (Tunisia/Libya), the ICJ 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. (ICJ, 1982, para. 71).

In developing this argument, the Court said that "the legal concept of equity is a general principle directly applicable as law." (ICJ, 1982, note 13 at p. 60, para. 71) The Court interpreted this as meaning not that it could fashion new law but that when it could choose among several possible 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 the requirements of justice." The Court has stressed that the concept of equity could not be used to invent new law or as a justification for taking into account equitable factors or considerations which lie outside the law. It has also maintained that the concept of equity must be applied in the particular legal and factual circumstances of each case.

Treaty law and judgments of the International Court of Justice have developed how the concept of equity relates to environmental issues, particularly entitlement to access and use of natural resources and the apportionment of such rights among states. This has involved limiting the application of the concept of equity to matters clearly before the Court. In a dispute between Malta and Libya about the continental shelf the Court declared that the application of equitable principles cannot be used for "refashioning geography or compensating for the inequalities of nature. . . ." (ICJ, 1985, para. 49) The Court went on to say that the concept of equity included

. . . the principle of respect due to all such relevant circumstances; the principle that although all States are equal before the law and are entitled to equal treatment, equity does not necessarily imply equality. . . nor does it seek to make equal what nature has made unequal; and the principle that there can be no question of distributive justice. (ICJ, 1985, para. 46)

In other words, on matters directly relating to natural resource issues, the Court has insisted that the relevant treaties frame how the concept of equity can be applied, the Court cannot go beyond this. Unless treaties have explicitly required it, the Court has refused to consider socio-economic issues.

In light of the Court's position, states have sought to include in treaties broad principles of equity, particularly relating to socio-economic issues, that the Court could use in interpreting the treaties. The United Nations Convention on the Law of the Sea states in Article 135 that the deep seabed and its resources are the "common heritage of mankind." This principle embodies a broad notion of distributive justice. Several principles that are concomitants of this broad principle are also included in the convention. Article 136 states that "no State may claim or exercise sovereignty or sovereign rights over any part of the Area or its resources" or appropriate parts of it. According to articles 138 through 155, resources in the Area can only be exploited in accordance with UNCLOS principles, procedures and managerial responsibility of the Authority and potential developers. The common heritage of mankind principle embodies a number of elements relevant to the equitable sharing of costs and benefits of deep seabed exploitation.

The concept of equity has also been developed in international law relating to the use of international rivers. The basic principle that has been developed is that states are entitled to a reasonable share in the beneficial uses of a transboundary resource.

The treaties that established the regime for the protection of the stratospheric ozone layer went to some length to give the concept of equity meaning in this context. Two treaties, the Vienna Convention for the Protection of the Ozone Layer (1985) and the Montreal Protocol on Substances that Deplete the Ozone Layer (1987) and the London Agreement (1990) define the ozone regime. The concept of equity as defined in the ozone regime specifies several techniques that are to be followed to achieve equity:

1. differentiated standards for developed and developing country Parties including: the 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;
2. financial assistance to developing countries, over and above overseas development assistance (ODA), to cover "all agreed incremental costs" and enable compliance;
3. transfer of technology, especially of best available, environmentally safer substitutes under fair and most favorable conditions, facilitated by the Montreal Protocol's financial resources if necessary;
4. export and import trade restrictions to minimize free rider problems;
5. limited operation of a tradable permit or joint implementation scheme to achieve "industrial rationalization";
6. an acknowledgment that developing countries' abilities to comply are conditional upon the "effective implementation" of developed countries' financial cooperation and technology transfer obligations;
7. an innovative, "non-compliance procedure" to avoid confrontational enforcement and dispute settlement machinery available to all Parties; and finally,
8. procedural techniques to facilitate continual assessment, review and adoption of further control measures through for example, information gathering mechanisms, flexible, in some cases non-unanimous but binding decision-making procedures, and mandatory reviews every four years regarding the adoption of further control measures.

The ozone regime requires the participation of all countries, developed and developing. The history of the negotiations makes it clear that the regime would not have been established and would not be effective if these techniques of achieving the concept of equity had not been included and followed. (Benedick, 1991).

The Framework Convention on Climate Change took into account the tradition of international law and was explicitly patterned on the ozone regime. It provides detailed guidance as to the relative weight that the signatories would assign to several formulae relevant to how the concept of equity should be applied in the context of the effort to deal with climate change. Several other articles, paragraphs, sentences, and phrases of the treaty have implications for the concept of equity as it is used in the treaty's first principle, and they provide a context for the choices that must be made in efforts to achieve the objectives of the treaty. This context should be seen in its entirety before addressing particular issues of equity that will arise. Logic and international law require that particular sections of treaties be interpreted in light of the whole

treaty and more broadly in light of general principles of international law not in isolation. (Brierly, 1963) As highlighted above, the first principle outlined in Article 3 paragraph 1, insists that actions taken under the treaty be based on equity and it specifically mentions the concept of intergenerational equity. It does not, however, state that climate change is a "common concern of mankind," as the UN General Assembly Resolution 43/53 that initiated the international response to climate change did. Thus there is no connotation in the substantive parts of the Climate Convention of proprietary rights (communal or otherwise) so far as access or use of the climate system or the atmosphere are concerned.

Many sections of the treaty deal with equity among regions and countries. Beyond the prominent statement in Article 3, paragraph 1, equity is also explicitly mentioned in two other paragraphs of the Framework Convention on Climate Change. Under Article 4, paragraph 2 (a) the developed country Parties² to the treaty 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."

This paragraph indicates the Parties' intention that equity should be applied not only between developed and developing countries, but among developed countries as well.

The concept of equity also appears in Article 11, paragraph 2. This article relates to the financial mechanism established under the Convention. The paragraph says that:

"The financial mechanism shall have an equitable and balanced representation of all Parties within a transparent system of governance."

The article seeks to insure equitable procedures and outcomes by mandating rules for the composition of the financial mechanism.

It also enters into the way in which developed countries may implement their obligation to adopt national policies mitigating climate change. A sentence is included in Article 4, paragraph 2 (a) that states that: "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. . . ." Joint Implementation (JI) can be seen as a vehicle for transfer of resources.

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 adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”

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

Paragraph 4 of Article 3 proclaims that all Parties “have a right to, and should promote sustainable development.” It goes on to say that measures to protect the climate system should be appropriate to each Party’s specific conditions. Paragraph 5 of the same article states that the Parties should “cooperate to promote a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties. . .” 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 Framework Convention differentiates between developed and developing country Parties. The preamble notes that developed countries have been and are responsible for the largest share of greenhouse gas emissions, and that the share of greenhouse gas emissions from developing countries will grow. As mentioned above, developed country Parties are required to take immediate action to limit greenhouse gas emissions

The Framework Convention also singles out categories of Parties for special consideration, thus broadly defining how the concept of equity should be applied. Even though they have the obligations of developed Parties, countries undergoing the transition to market economies are allowed some flexibility. (Article 4, Paragraph 6)

Paragraph 2 of Article 3 states:

“The specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change, and of those Parties, especially developing country Parties, that would have to bear a disproportionate or abnormal burden under the Convention, should be given full consideration.”

A 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.

The point can be made more specific by recalling that The Framework Convention creates obligations and mechanisms for the transfer of financial resources and technology from developed

country Parties to developing country Parties to help them deal with the adverse effects of climate change and in the implementation of measures to mitigate climate change. All of the categories listed in the preceding paragraph and others that are especially vulnerable are singled out as meriting special consideration in the transfer of resources.

As is readily apparent, the Framework Convention on Climate Change provides a substantial context for the interpretation of equity in designing measures to attain the Convention’s objectives.

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 in ways 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
- Social considerations and institutional capabilities
- Impacts - the distribution of and vulnerability to climate change
- 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 "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 rich tend to be dominated by activities such as driving private cars, home central heating, and energy embodied in a wide variety of manufactured goods and the use of such goods. The welfare impacts of cutbacks of greenhouse gas emissions may thus differ greatly according to the level of personal wealth (WCED, 1987; DCCSD, 1993).

Obviously there are great variations within countries, but in aggregate the same broad issues apply concerning wealth disparities between countries. The aggregate relationship between wealth, consumption of a variety of natural resources, and emissions of various pollutants have been explored methodically by a number of authors. Using cross-sectional data, Parikh (1992) shows that consumption of a wide variety of resources - many of which involve emissions of greenhouse gases in their extraction, processing and application - is closely related to the level of wealth. Williams *et al* (1987), Drucker (1990) and others have argued that in many developed economies, a decoupling of wealth from the volume of material consumption has occurred since the 1970s and that this will accelerate, though others have disputed this (Herman *et al*, 1989); but the aggregate relationship at middle and lower income levels seems undisputed. The *World Development Report 1992* (World Bank, 1992) notes that direct emissions of many pollutants declines beyond a certain stage of economic development, but considers that this point has not been reached for most greenhouse gases, particularly CO₂ and (to a lesser extent) CH₄ from sources other than land use.

Wealth is not only one of the most important determinants of greenhouse gas emissions (at present), it also has a very important bearing upon vulnerability to climate change. Richer countries, because they are richer, will tend to find it easier to deal with the costs of coping with climate change and measures to abate climate change. Poorer countries, because agricultural

production--which is particularly vulnerable to climate change--comprises a larger share of their economies than that of richer countries, will be more vulnerable to climate change. Climate change could lead to substantial migration within and among poorer countries, creating environmental refugees.

Poverty also has an important bearing upon national priorities and the timescales considered in policy. Economists have long noted that personal discount rates decline with rising income. Richer people can afford to look further ahead, have greater security, and can afford to invest more for the future (though in fact the pattern of investment as a fraction of wealth is very variable). Poor people tend to be focused more upon short-term concerns, including those of striving to ensure that they can meet basic needs. This has important implications for the potential equity impact of policies to address climate change within countries, as noted earlier in this chapter, and the same applies at the level of national 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 ...'

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. There are several different ways of accounting for and presenting these contributions: this section summarises the main approaches that have been taken and the results obtained. Contributions to climate change span many different gases and sources.³ The range of sources and sinks considered is not in itself an equity issue; but the conclusions that may be drawn from different ways of aggregating and presenting the data can be, as was vividly illustrated in an important debate about data presented initially by the World Resources Institute (see box).

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.

In the following discussion, the main focus is upon CO₂, and where feasible and appropriate, methane. CO₂ 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 (though the radiative impact of various proposed replacements is a matter of close scrutiny) and the distributional implications of focusing upon CFCs could be complex. 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 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.

Table 1
Historic CO₂ and Methane Contributions by Region

	Past contribution, 1800-1988 in percentages		
	Industrial CO ₂	Total CO ₂	CO ₂ + CH ₄
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
Oceania	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.

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%; the industrialised countries together account for 84% of the total. When estimates of biotic (mostly deforestation) emissions are included, the North American figure is reduced to about 30%, and the contribution from a number of developing countries becomes significant; in total the North accounts for about two thirds of the total. 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 CO₂ 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"⁴ 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.⁵

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 CO₂ 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 CO₂ 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 exceed 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% of global fossil carbon emissions, with about half of this being from the US; the former USSR and Eastern European countries account for 17% (with half of this being from Russia); and the developing countries contributed just under a third of gross fossil carbon emissions (with over 40% 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, 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 higher 'carbon productivity' 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 CO₂, 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 CO₂. Most notably, almost all emissions from deforestation - thought to be in the range 15-25% of total CO₂ 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 CO₂ 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 CO₂ emissions alone from these countries those of the OECD by 2020. And in many scenarios, before the year 2050, fossil CO₂ 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.⁶ As 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. This in itself is not an equity issue, but the distribution of effort and payment is, and is discussed below.

III.4 Social considerations and institutional capabilities

The importance of social considerations and institutional capabilities is considered later in this chapter. The important point here is simply to note the extent to which 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 themselves be vulnerable to the stresses that climate change may bring.

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.

III.5 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 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). 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.

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
- 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 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 (1) is the subject of the next chapter. Concerning impacts within countries (3), 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. None of the literature attempts to present reasons why the same principle should not apply concerning transboundary impacts potentially arising from climate change.

Indeed, this is a point which was formally accepted at the intergovernmental level in Principle 21 of the Stockholm Declaration, and re-emphasised in Principle 13 of the Rio Declaration:

- .. 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.

The 'fault-based' rationale aligns closely (though not perfectly) with that arising from the likely distribution of impacts: poorer nations tend to be more vulnerable, and richer nations tend to be greater past and current emitters of greenhouse gases. It is also an issue for which historical emissions are of direct relevance, since climate impacts are a function of atmospheric concentrations which depend strongly upon the cumulative emissions.

IV.3 *Sharing risks*

The question of who should pay is not solely about equity; it 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, and bears some relationship to 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).

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 $pM_A + (1-p)M_B$ which we will denote by M . Is the decision-maker indifferent between the uncertain prospect ($pM_A, (1-p)M_B$) 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:

$$pu(M_A) + (1-p)u(M_B) = u(M) = u(pM_A + (1-p)M_B),$$

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:

$$pu(M_A) + (1-p)u(M_B) < u(pM_A + (1-p)M_B).$$

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 cost of risk-bearing. Let C be this cost. Then it is defined from:

$$pu(M_A) + pu(M_B) = u(pM_A + (1-p)M_B) - C$$

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,⁷ even 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.⁸

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. International agreements on climate policy need to address this issue of risk bearing.

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.

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 cooperatives. 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.

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.⁹

- 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.

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 Climate Convention proposed, by analogy with the nuclear precedent, funding through a combination of GNP and CO₂ 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 was proposed as proved loss attributable to sea level rise, including storm surges. However, discussion of the proposal does not attempt to explain why the principles involved should be restricted to the case of sea level rise; it would appear more equitable to extend the scope of such a fund to insurance against all kinds of climate impacts. 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.

The 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].'

This much has been formally agreed in the Framework Convention on Climate Change: 'developed countries shall take the lead in combating climate change and the adverse effects thereof.'

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 places the emphasis upon ensuring a "reasonable level" of emissions for each country - a level that would support a consistent, modest standard of living, given the national climatic or other conditions. Allocations would be granted for emissions at this level, but not for those "luxury" emissions exceeding this. The actual level - presumably somewhere between survival emissions and reasonable comfort - and the extent to which it might vary between countries if at all, is of course somewhat ambiguous.

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.¹⁰

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).

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 idealised application of this Kantian Rule for abatement is analysed 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.

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. But they do not give specific rules that could determine a unique allocation of emission entitlements or abatement costs.¹¹ 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 industrialised and developing countries. The general characteristics of this allocation are argued to be ethically appealing - it requires substantial cutbacks from the industrialised 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.¹² 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)¹³ 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 riches, 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 criticised 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 industrialised 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.¹⁴ 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 industrialised 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 industrialised 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", though Ghosh (1993) comments that 'pollution rights have no common law sanction. It is indeed doubtful if the adverse possession principle is sustainable under any modern juridical system in respect of common property'.

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 industrialised 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 Climate Convention. Concerning paying for abatement, this effectively divides the world into three groups. Annex 1 countries (all the industrialised countries) are expected to bear their own abatement costs. Those also listed in Annex II (which is almost synonymous with the OECD) agree in addition to fund the efforts of the third group, developing countries, which states that Annex II countries:

"shall provide new and additional financial resources to meet the 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 agreed 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. It does not imply anything about the degree of abatement in developing countries: this still has to be "agreed." Some of the process issues have been resolved for the present with the confirmation of the Global Environmental Facility as the interim funding agency and its restructuring, to give greater accountability and weight to developing countries.

With the reference to measures implemented "singly or jointly" the Convention also may permit a second avenue of funding, through the mechanisms of "joint implementation" via offset investments in third countries - a subject of strenuous debate at present which is considered further below - or through tradable permits (or "entitlements").

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 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 equity implications of allowing countries to sell forever the "right" to emit. 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. One conception is that of a pollution tax, but in the international context this raises several questions, including that of how the revenues should be disbursed. 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 recognise 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 CO₂ 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) criticises 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), Kasperon and Kasperon (1993), and Grubb *et al* (1992) note three counter-arguments about the equitability of what the last of these characterise 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 and migration shift over time and are intricately interwoven. Boundary changes could also create 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.¹⁵

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,¹⁶ 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);¹⁷ 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, favouring 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 global utility. 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 equalised 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 standardised 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).¹⁸ 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 industrialised 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 CO₂ 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 CO₂ as coal - is very likely to be favoured in CO₂ 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.

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 programmes, especially the structural adjustment programmes in Southern countries, but also programmes 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. More specifically, without the explicit incorporation of intra-country equity into the analysis, it would be impossible (given the large variations in national institutional capacities), to reassure Southern countries of the justice of joint implementation.

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 inequitous 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 being 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 (1977), 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 1997, Banuri 1992, Comia et al 1983). Earlier critics argued that the orthodox adjustment programmes were both ineffective and unnecessarily painful. They proposed heterodox, or supply-side approaches, which aimed to increase production directly through investment promotion, labour 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, labour, 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 programmes.

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 programmes 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, 1977, Krueger 1977), and has been accompanied by calls for privatization and de-regulation. Other critics have used similar arguments to recommend institutional development programmes. 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 programme.

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 programmes.

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 Chencry 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 1977, Krueger 1977) 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 1977, Alam 1977, 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, 1977), people centered development (Korten 1977), 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 programmes of community development, rural development, and capacity building. At national levels, it might ask for a broad based programme, 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 process. For example, Nozick (1977), 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 realise 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 (eg. *Millennium* 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 specialised 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 industrialised 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 effectively 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 programme (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 centres 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 organisations have an important role to play in the process: in harnessing and analysing 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 it 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 tax 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.

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

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

The Framework Convention on Climate Change offers some guidance on all of these issues, particularly at the aggregate 'North-South' level. It indicates that developed countries bear responsibility for helping developing countries cope with the impacts of climate change and the costs of abatement measures. It also mandates that the relative share of the greenhouse gas emissions of developing countries should increase, and that associate bodies such as the Financial Mechanism should have a 'fair and balanced' representation.

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, points 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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1. Four main types are identified. A 'hierarchical' 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.. The article refers to "developed country Parties and other Parties included in annex I. 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).

3.. 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 CO₂ - especially from fossil fuels, for which national emissions are generally known to within $\pm 5\%$ (uncertainty range of 10%) or better. CFC emissions - measured as defined in the Montreal Protocol - are known to similar accuracy. Other sources are more uncertain. National estimates of CO₂ and other emissions from deforestation and other land use changes can vary by at least $\pm 30\%$, both for individual countries and even in aggregate; most methane emissions are similarly uncertain. Contributions from other gases (N₂O, 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% 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.

4.. This would apply, for example, if one considered the impact of a single country's emissions in the absence of any other 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.

4. 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.

6.. 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?].

7.. 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' (Rückversicherungs-Gesellschaft, 1990, p. 11).

8. 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.

7. 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.

10.. A detailed discussion of Rawlsian criteria applied to CO2 abatement is given in Benestad (1993).

11.. Footnote on the difficulties of defining comparable burdens etc?

12.. '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).

13.. David A. Wirth and Daniel A. Lashof, *Ambio*, Vol.19 October 1990 pp305-310: to be checked.

14.. 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 intergenerational equity issues discussed in the previous section but the literature has not explored this in any depth.

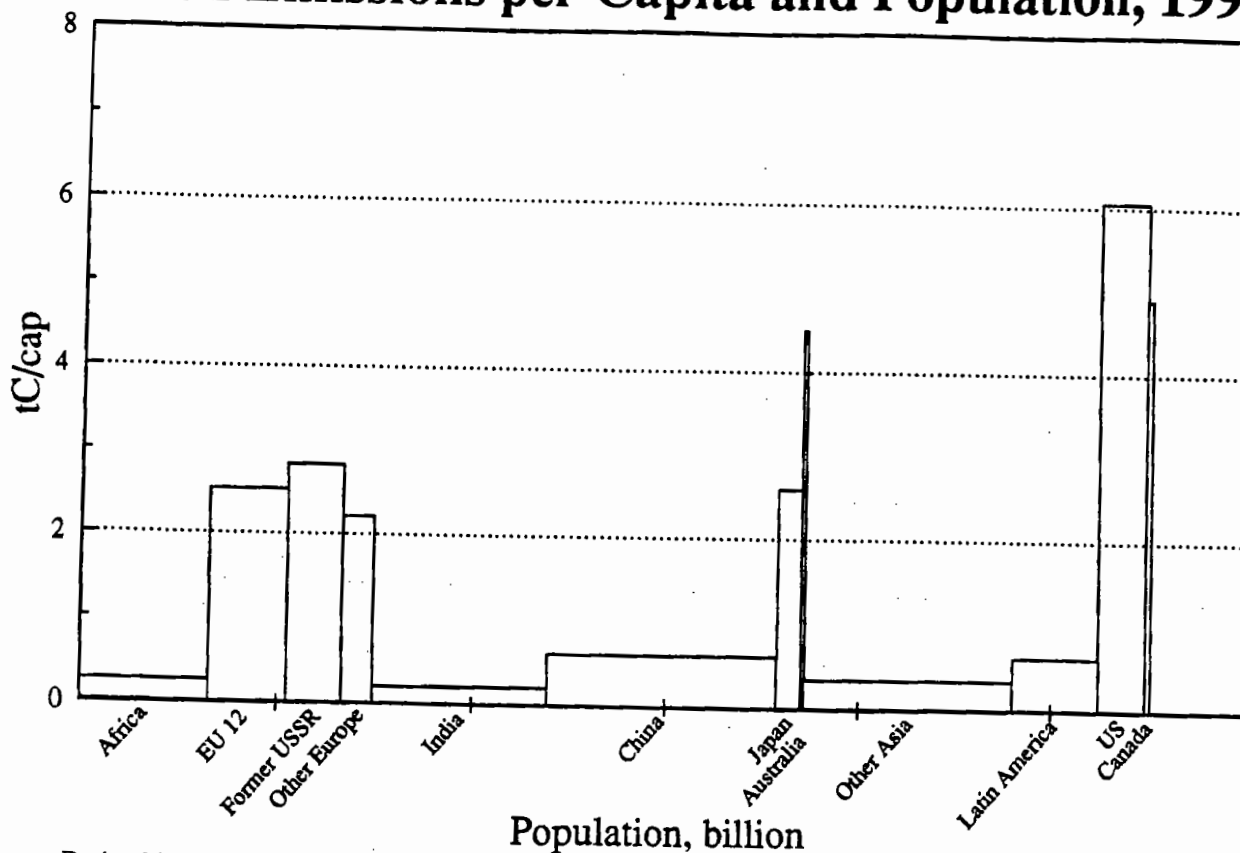
15.. As one relevant indication, the peak energy intensities achieved by countries in the process of industrialisation has steadily declined over the century, as those developing later can draw upon better technologies developed elsewhere (Haefele, 11981).

16.. 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.'

17.. Clarify p.79

18.. 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.

Carbon Emissions per Capita and Population, 1993



Source: Derived by the author from BP Statistical Review of World Energy 1994 and World Population Prospects, UN