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IPCC [Intergovernmental Panel on Climate Change] - Volume III [2]

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From: Sally M. Kane (KANE_S)
To: Stiglitz_J
Date: Monday, March 20, 1995 6:39 pm
Subject: IPCC WGIII mtg in Paris - DOE will pay

DOE has agreed to pay for my trip to the IPCC lead author's meeting in Paris (99% certain).

*** They are concerned with the changes made to the technical review of the IPCC chapters as a result of the State Department led review.

*** Abe Haspel wants a clear message from the USG about the content deficiencies of the chapters and the extensiveness of changes needed in the summary for policy makers.

*** I leave on Tuesday late afternoon.

CC: Branch_L

probability of a loss, or the costs of future adaptation.

The magnitude of those expenditures depends on (a) society's degree of risk aversion; and (b) the magnitude of the risk. The *risk premium*—the extra amount that society is willing to pay to reduce a risk—is small if the stakes (say, the maximum loss) are small, and large if the stakes are large. An investment of a 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. If a possible outcome is a loss of 10%, even though the expected loss is only 3%, then the *certainty equivalent* loss will exceed 3%. A dollar investment that reduces this certainty equivalent loss by more than a dollar should be undertaken; such an investment could either reduce the average loss, 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 actual expenditures and the *no-regrets* benefits (the benefits other than those associated with greenhouse gas emissions). Thus, investments in fuel efficient cars may have a direct benefit in reducing the cost of running a car. The mitigation investment is only the additional investment for climate purposes.

The economic principles of risk aversion and portfolio theory provide the rationale for going beyond no-regrets policies. Naturally, actions that reduce greenhouse gas emissions at zero or negative costs should be undertaken. But a prudent response to the risk of greenhouse gas warming goes beyond no-regrets policies to some policies incurring net costs.

Traditional insurance involves pooling a large number of diversifiable risks. Insurance exist when people differ in their ability to bear a given risk, or would be affected differently by the risk. Insurance markets *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 risk¹⁷. By transferring risk, traditional insurance can address one aspect of the risk from climate change: the large differences in expected regional impacts. This holds irrespective of who pays the cost, because wealthier individuals and countries are better able to bear risk¹⁸, 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 South¹⁹.

Traditional insurance will not, however, address all risks from climate change. Shipowners can buy insurance against storm loss because shipping risks are diversified: one storm is unlikely to sink all the ships covered by the insurer. But because climate change

is global by nature, and therefore undiversifiable, traditional (intragenerational) insurance cannot fully insure against climate change risks. Rather, some form of intergenerational insurance is likely to arise as a way to redistribute more of the risk.

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.²⁰

1.3.1.3 Precautionary investments

A business makes precautionary investments to reduce the total risk of its portfolio. Numerous policy measures are available to reduce risks to future generations from climate change. Four have dominated discussions in recent years: 1) immediate reductions in emissions to slow climate change²¹; 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.

Precautionary investments may also enhance the ability of future generations to react. An important reason that people establish savings accounts is to reduce the impact of unfavorable events in the future. Similarly, a society may elect to accumulate capital against the possibility of a large loss from climate change. This is one thread of the debate over discount rates in Chapter 3. Those who argue for a discount rate close to the opportunity cost of capital point out that society may choose between immediate greenhouse gas mitigation, at a cost, and delayed mitigation, with some of the money saved put aside as a savings account for our grandchildren in the event of large climate-induced damages.

1.3.2 Sequential Decision Making

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

A more useful formulation is: "Given current knowledge and concerns, what actions should we take over the next one or two decades to position ourselves to act on new information that will become available?" (Lind 1993) For example, decisionmakers would like to know if the possibility of irreversible damages²² justifies immediately undertaking an aggressive abatement program²³.

Climate change demands a decision process that is sequential and can incorporate new information. Timing will be a key element, and the date of resolution of uncertainty an important element of the analysis. Figure 1 shows schematically the progression from a simple decision to a sequence of linked decisions. The simple decision is sometimes referred to as the "learn, then act" model, the second as "act, then learn"; or, in the case of the decision depicted, "act, then learn, then act."

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

For example, the choices might be 1) immediate investment in new plant and equipment 2) aggressive R&D on greenhouse abatement technology or 3) deferring large investment for 10 years, until the nature and size of the threat is better understood, and when costs will presumably have dropped and the job can be done more efficiently.

Because of the high cost of being wrong in either direction, the value of information about climate change is likely to be great. In particular, the value of information about the sensitivity of temperature to CO₂ increases, the temperature damage function, the gdp growth rate, and the rate of energy efficiency improvement is likely to be high (Chao 1991, Peck and Teisberg 1991, Manne and Richels 1992, Nordhaus 1994)²⁴.

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

1.3.3 Dynamics

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

Dynamic analyses have 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 are likely to be less costly. This suggests large potential gains from flexibility in timing of emission reductions²⁵.

1.3.3.1 Kaya Identity

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

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

or, expressed in rates of change:

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

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 population²⁶.

This identity clarifies different approaches to reducing emissions. For a developed country with a stable or slowly growing 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 second term on the right-hand side, for example from cars to public transportation, from less to more fuel-efficient cars and homes²⁷. Fuel switching (for example, from coal-based electricity to oil, gas, hydroelectric, wind, and geothermal), represented by the first term, also offers the potential to limit CO₂ emissions in many countries.

For many developing countries, emissions will increase unless energy efficiency and greenhouse gas emissions per unit of energy change to offset growth in per capita output and population. For many developing countries with rapidly growing populations, pressures for economic development will make it difficult to direct capital from investments with higher greenhouse gas emissions to those with lower greenhouse gas emissions²⁸.

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., how much does aggressive emission reduction depress economic growth? Order-of-magnitude calculations suggest the presence of only limited trade offs, at least for the near term; (b) do developing countries have the institutional capacity to achieve the desired increases in emissions efficiency?

1.3.3.2 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 itself²⁹.

The central problem with natural resources, whether renewable or not, is timing. Many renewable resources 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 flows later³⁰.

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 postponed³¹. Conversely, research on "learning effects" shows that if actions taken today will lower costs faced tomorrow, then these dynamic benefits should be included in the calculus (Arrow 1962, Atkinson and Stiglitz 1969). In the context of climate change, if emissions constraints stimulate technical or other developments that help to lower the costs of continuing or additional emission abatement, then reductions should be accelerated (Grubb 1993, 1995). If discount rates are high, the costs borne by future generations will carry less weight than if discount rates are low. In the presence of risk, non-linearities, or irreversibilities, the principle of risk aversion suggests a strategy of early mitigation.

The theory of non-renewable resources has a second set of lessons for climate change policy. Among the four energy categories -- coal, gas and oil, biomass and non-carbon

sources -- gas and oil are exhaustible; this limits total emissions from gas and oil. With exhaustible natural resources, the question is not how much will be consumed, only when³².

Figure 2 depicts fuel use in 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 oil and gas 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 sources³³. 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 coal-rich countries 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.

1.3.4 International Public Goods

The atmosphere is an *international public good* in that atmospheric concentrations are the result of combined actions by all countries. A pure public good (Samuelson, 1954) has two properties: 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*).³⁴ The atmosphere has both characteristics. One country's greenhouse gas reductions affect all other countries as well. If this thwarts

climate change, all countries benefit³⁵.

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 emissions³⁶.

1.3.4.1 Property rights

An important strand of economic thought associates externalities with a failure to assign property rights (Coase 1990). Assigning property rights to the atmosphere is particularly difficult, since this would require the agreement of many sovereign states. 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.

1.3.4.2 Paying For An International Public Good

Who should pay for a global public good? every country faces this question internally in determining who should pay for the public goods it provides. Who should, for instance, pay for pollution control within a country?

Economists generally agree on 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.

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.

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

Economists agree less about the framework for deciding the burden of financing mitigation and adaptation. At least four approaches have been proposed to determine how the burdens of taxation should be shared. One approach looks at *benefits*: just as those who benefit from private goods must pay for them, those who benefit from a public good should be made to pay for 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.

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

A third approach is based on contribution to the problem. Because the North has contributed more than two-thirds of the stock of greenhouse gases in the atmosphere today, this approach seems to suggest a large responsibility for the North. On the other hand, by the time greenhouse gas concentrations double from preindustrial levels, the developing countries are projected to be contributing more than half of annual emissions, and roughly half of the total stock in the atmosphere (IPCC, 1990; Cline 1992). Thus under this criterion, the developing countries might eventually pay far more of the mitigation costs than under the other principles described earlier.

Economists have turned to a fourth approach -- the social welfare function -- to answer the question of how much extra different parties should pay, as well as the question of how to distribute the surplus. The discussion of equity below differentiates between the Rawlsian and utilitarian approaches. In this case, both approaches yield similar results: In the absence of incentive problems, both imply that all of the surplus should be allocated to the poorer countries, or that the burden of effort be borne by the richer countries³⁷.

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 obtained³⁸; and (b) that the outcome is independent of how property rights are assigned³⁹. Coase also emphasizes the importance of transactions costs, which will often influence the choice of policies.

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To: Sally
R. A. Bradley

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**U.S. Comments on the Policy Makers Summary
to the Working Group III 1995 Assessment**

The U.S. review of the *Policy Makers Summary* contains both general and specific textual proposals for changes. We believe that the *Policy Makers Summary* as written could be greatly improved by a complete redrafting. Our proposed changes reflect the following principles:

- The purpose of a policy makers summary is to identify those conclusions from the literature for which there is broad consensus among the professional community of economists. As such it is an assessment of the state of knowledge, not a recipe for policy implementation.
- Conclusions in the *Policy Makers Summary* should follow from conclusions found in the underlying chapters.
- Where there are established differences of opinion in the literature, the summary should represent all differences of professional opinion. If one of those views is in the distinct minority, then the summary should characterize that fact as well.

In addition to general comments on the major difficulties with the Summary, we have provided specific textual changes at the end of these comments. It is our view however, that editorial changes at the margin of this document is not the best way to reach the best document possible. Starting from the ground up is required. Accordingly, we have included a list of "Major points that should be made in *Policy Maker's Summary*." We have attempted to word these proposed additional and substitute bullets with care so as reflect our understanding of the literature.

General Comments on Summary for Policymakers

- **Policy statements should be deleted.**

The Summary for Policymakers at times violates the directions that Bert Bolin gave in Maastricht, Fortaleza and Nairobi: IPCC reports should focus on the science and should not contain "policy judgments". For example, the second page states the policy judgment that "The precautionary principle (Article 3.3) and the estimated damages due to current emissions of greenhouse gases (Chapter 6) argue for action beyond 'no regrets' measures." Page two also contains the policy judgment that:

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"The Convention thus incorporates, and the literature assessed in the report (Chapters 1, 2, 8 and 9) supports a strategy of 'act - then learn - then act'...." Similarly, much of the language in the section on "The Benefits of Limiting Greenhouse Gas Emissions and Enhancing Sinks" is judgmental. Potential damages and impacts are discussed as if they are absolutely real instead of being computer projections. Simply adding "potential" or changing "would" to "could" would correct many of these misleading statements in this section. 1)

The beginning of the Summary should make clear that the purpose of the report is to assess the application of socio-economic analysis to the climate change issue. The types of policies to be undertaken and their timing clearly falls under the purview of national governments, and soon the Conference of the Parties, not the IPCC.

- **The organization of the Summary could be improved**
We recommend that the section entitled "A Portfolio of Possible Policy Actions" be moved to the end of the Summary. We suggest that the Summary follow the outline of the report. It should begin with a brief introduction to the economic tools that will be assessed for applicability to the analysis of climate change, and then go on to describe those tools, following the outline of the report. The decision making framework, with its emphasis on sequential decision-making, should come first. Then should come equity considerations and the discount rate, and the tools of analysis considered in the cost-benefit chapter. Then the report should move on to the empirical study of damages, mitigation, adaptation, and integrated assessment. The analysis of policy instruments and the portfolio of possible policy actions should conclude the summary, in a non-judgmental fashion.
- **Linkages to other economic issues should be identified**
The report as a whole is a comprehensive review of the economics literature on global climate change. However, the Summary does not give a broad vision or sense of perspective as to how global climate change fits into the likely economic future, or how important the issue might be relative to a host of other problems and challenges we will face over the coming centuries. We must recognize that we face the risk of climate change against a background of concern over the scope of tasks that governments have taken on, such as education, health care, pensions, clean water, and crime, plus a myriad of other competing issues.

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The Summary also fails to represent adequately the fundamental uncertainties and limitations in economic analysis of this issue. Economics must play a fundamental role in the analysis of climate change policies. At the same time, however, it must be made clear to policymakers that the core demands of climate change analysis exist where economic analysis has its greatest difficulties. These demands include very long term forecasts of human behavior and economic activity, intergenerational investment and consumption issues, equity issues within and among nations, evaluation of non-economic impacts, human response to policies that are outside our experience, decision making under uncertainty, and modeling low-probability but potentially catastrophic events. In part because of these difficulties, some parts of the report have fallen back to theoretical formulations which may be attractive in the abstract but which are unworkable at the analytical or at the policy level. The Working Group III report should make clear those issues where economics cannot provide definitive answers.

It is cavalier to assume that economic policies can effect large changes in the production and consumption structure of the world economy at little cost, and it goes against bitter experience of the limits of what economic policy has achieved in the past. There really is no precedent for an effort to change to a significant degree the technology of our economy or the behavior and lifestyles of the world's consumers. The potential that proposed policies could do harm as well as good is hardly apparent in the report. To undertake such policies is not without serious risks. Investment funds are a scarce asset and choices among competing issues as well as alternative technologies must be made carefully to avoid waste.

- **Uncertainties should be discussed more fully**

The text sometimes seems to imply that the harmful effects of climate change are a reality, instead of a possibility. Given all the caveats which are still being given regarding the reliability of impact projections, WG III should not make more definitive scientific statements than WG I. In a number of instances, the language chosen by the IPCC is very misleading to policymakers even if it is literally accurate. Just one example occurs in the discussion of stabilizing atmospheric concentrations of carbon dioxide in the 350 to 750 ppmv range. On page 5 (lines 14-16) the report states that: "These emissions profiles indicate that at some stage major reductions of CO₂ emissions (on the order of 50% of current emissions)

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will be required to eventually stabilize concentrations." While "eventually" is literally true if you believe Figure 1, in three of the five scenarios shown eventually is more than 100 years away, and in two of the five scenarios eventually appears to be about 200 years away. Language that reflects the letter as well as the spirit of the findings is required if this document is to make a contribution to the debate.

It is unlikely that the uncertainties about the cost of climate change response options exceed the uncertainties about the possible damages. But the Summary provides at least five specific estimates of the damages of potential climate change, one estimate of emission reductions associated with removal of energy subsidies (which largely reflect action by non-Annex I countries which have no real obligations under the Framework Convention), one estimate of the possible extent of negative to slightly positive cost energy efficiency measures (which is debated in Chapter 9 but the debate is not acknowledged in the Summary) and one estimate of the cost of enhancing carbon sinks. There are, however, but no other estimates of the costs of limiting greenhouse gas emissions, to which Chapters 8 and 9 are entirely devoted. Based on the Summary for Policymakers, policymakers will undoubtedly be given the mistaken or at least highly debatable impression that large scale emission reductions can be accomplished nearly costlessly.

In some areas, the Summary selective and inconsistently reports "findings". For example, on page 7 (lines 21-25) it is stated that "Because of the large uncertainties surrounding estimates of damages due to climate change (Chapter 6) and the costs of mitigation (Chapter 9) make it difficult in practice to rely solely on cost-benefit analysis...." However, on page 8 (lines 12-14) it states that "Most estimates of the additional damage done by CO2 emitted now range from \$5 to \$25 (1990 \$ U.S.) per tonne of carbon...." If the uncertainties are so large as to limit use of benefit cost analysis, then providing the estimate of damages without qualification about their uncertainty is inconsistent and misleading.

Another broad area of difficulty is the description of the science of climate change in the draft report. Not only does uncertainty in the underlying science limit the applicability of economic analysis in many ways, but the science is rapidly changing. In part, this means that many of the economic analyses discussed in the draft report may reflect assumptions that are no longer widely held. This leaves two very difficult burdens on

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the report writers: 1) the description of the science of climate change contained in the Working Group III report must be consistent with that in other recent IPCC reports such as the 1994 IPCC Special Report or the reports nearing completion by Working Groups I and II; and 2) the writers must carefully distinguish between an assumption made in a cited economic analysis and current knowledge of climate science.

- **Some important topics have been omitted**

The Summary for Policymakers should be expanded to include a discussions of 1) the possibility of enhancing sinks, 2) issues of monitoring and enforcement, particularly given the Rio Convention's emphasis on national sovereignty, and 3) nuclear power as an energy resource.

Major points that should be made in Policy Maker's Summary

These bullets reflect conclusions that the U.S. government believes should be included in the *Policy Maker's Summary*. Some of these points are not made in the current chapters of this document. However, U.S. comments on each chapter reflect our view that these points should be developed in the appropriate chapters.

We believe that the present Summary reflects in general the literature of the economics professions and is not an in depth assessment of a broader social science literature that is relevant to an understanding of the climate change impacts and response strategies. This should be made clear to the reader. Accordingly, we propose that the following caveat be included at the beginning of the Summary in addition to being included in Chapter 1.

- This document addresses various socio-economic issues relevant to global climate change. It has been undertaken...[text from first paragraph in SUMMARY]... In examining these issues, the document relies primarily on scientific insights and perspectives from the economics literature. The document should not be considered, therefore, a comprehensive assessment of other social and behavioral sciences that may be of interest in climate policy debates.

Points which should be included from Chapter 1 are as follows:

- Climate change represents a unique and formidable policy problem involving large uncertainties, the potential for irreversible damages or costs, a very long planning horizon, long time lags between emissions and

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effects, an irreducibly global problem, wide regional variation, multiple greenhouse gases, and the possibility of a catastrophic loss. [Pages 4-7]

- There is tremendous variety in potential policy responses to climate change, under the broad categories of mitigation and adaptation. Representative examples include carbon or energy taxes, carbon quotas or tradable permits, removing energy subsidies and other market barriers to technology penetration, voluntary measures and research on greenhouse gas abatement technologies and on climate change effects. [Pages 26, 33-36]
- The potential for catastrophic loss, plus the principles of risk aversion and portfolio balancing provide the rationale for going beyond "no-regrets" policies to those that incur net costs. [Page 9, and also in Chapter 2]
- Climate change demands a decision process that is sequential, can respond to new information with mid-course corrections, and can include insurance, hedging and the value of alternative courses of action. The challenge is to identify short-term strategies for the next few years, rather than a fixed course for the next 100 years, knowing that a prudent hedging strategy will allow time to learn and change course. [Page 11, and also in Chapter 2]
- In an interrelated global economic system, an attempt to reduce greenhouse gas emissions in one region or one sector of the economy may be offset by increases in other regions or sectors. [Page 20]
- Efficiency requires that emission reductions occur where their cost is lowest, irrespective of who bears the financial responsibility. [Page 12]

Points which should be included from Chapter 2 are as follows:

- A well-chosen portfolio of policies will yield greater benefits for a given cost than any one option undertaken by itself.
- Climate change will require collective decision making; the scientific literature has much less to say about collective decision making than individual decisions making.

Points which should be included from Chapter 3 are as follows:

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- Equity has both consequential -- in other words it flows from outcomes of decisions -- and procedural dimensions -- in other words it partly depends on perceptions about the process used to reach decisions.
- Equity issues associated with climate change involve addressing the following considerations:
 - costs of adaptation
 - unequal costs of climate impacts
 - future emission rights
 - costs of abatement, and
 - institutional and procedural fairness.
- There are substantial variations within the "north" and the "south" in terms of absolute and per capita emissions; the likely impacts of climate change, institutional strengths and preferences, cultural perspectives, and endowment of natural resources that may be affected by mitigation.
- Both efficiency and equity concerns will influence the choice of mitigation and adaptation measures. [While a robust literature suggests that equity and efficiency can not be meaningfully separated, it is nevertheless worth while to conduct analysis of the efficiency implications of particular ethical principles and vice versa.]

Points which should be included from Chapter 4 are as follows:

- Climate change raises particular questions of equity among generations, because future generations are not able to influence the policies chosen today directly. [Intergenerational equity concerns have been argued on the basis of ensuring future compensation for damages caused by current decisions, trustee obligations, and society's consideration of current versus future consumption in a world of improving economic conditions.]
- [Literature in environmental ethics employs the trustee rationale to support setting policy goals that do not allow discounting the value of particular environmental assets.] More generally, however, economic models recognize the possibilities for substituting resources and examine changes in environmental goods and services and their implications for consumption over time.
- The choice of discount rate matters significantly: the higher the rate, the less future benefits and the more current costs matter in the analysis.

main view

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[Which approach is best for choosing a discount rate remains an unresolved question in the economics literature. Analysts typically resolve the issue by conducting sensitivity studies that vary the rates according to the different perspectives. In the case of developed countries, this often results in using rates as low as 1-2% and as high as 10% to evaluate a particular government investment.

*Not
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Chapter*

Points which should be included from Chapter 5 are as follows:

- Cost Benefit analysis (CBA) offers a very useful guide for policy making for dealing with the essential questions that must be faced in analyzing climate change issues.
- A central motivation for CBA is to explicate the consequences of alternative actions, including that of no action, on a quantitative basis.
- Traditional CBA developed originally for project-level decision making with 20-30 year planning horizons is being used in a more broadly defined context to deal with climate change. Special features of the climate change problem include very long time-horizons, high levels of scientific and economic uncertainty, and a global scale of analysis.
- CBA, as an organizing principle for information, can employ a variety of techniques to address issues important to climate, such as:
 - risk, uncertainty, and irreversibility
 - valuation of non-market benefits and costs
 - discounting, particularly over long time horizons
- In addition to CBA, other techniques have been developed to respond to limitations in analyzing certain resource problems. These complementary techniques include:
 - cost effectiveness analysis
 - multi-criteria analyze
 - decision analysis

Points which should be included from Chapter 6 are as follows:

- A small number of studies estimate global damages for a scenario of 2.5 degree C warming and obtain a range of damages from 1.5% to 2.5% of gross world product. Two of these studies disaggregate damages by region and find that some developing countries may experience damages that are

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two to five times more severe than damages in developed countries. The estimates of climate change damages, however, are dependent upon a host of assumptions regarding highly uncertain inputs to the analysis. Researchers have widely varying views on the probabilities that should be associated with different sets of assumptions. Because of this lack of consensus, estimates such as those cited above and in the chapter are best interpreted as illustrations of the rough magnitude of damages that are consistent with particular sets of assumptions, assumptions whose validity are controversial and difficult to evaluate. [They should not be interpreted as best estimates, nor as providing upper or lower bounds on likely damages.]

- Climate change damages are the consequences of climate change evaluated from the perspective of human welfare, where human welfare is defined broadly to include anthropocentric concern for the natural world. Damages are estimated so far as feasible in monetary terms. This provides a common metric by which the severity of different types of damages can be compared and aggregated. The monetary estimates are based upon economic concepts of individual and social welfare. Methods exist to estimate damages in monetary terms for both market and non-market effects, but much less confidence is placed in estimates for non-market damages than for market damages. Examples of market effects might include changes in the production and consumption of foodstuffs, forest products, energy and other commodities. Examples of non-market effects might include changes in human health, flood protection, outdoor recreation, and preservation values for species and natural places.
- Damages will depend upon:
 - the magnitude and rates of changes in mean global and regional temperatures and other climate variables;
 - changes in the variability of climate such as the frequency of drought, storm and flood events;
 - the effects of climatic changes on physical and biological systems such as sea level, water balances and flows, and ecosystems;
 - the adaptations that individuals and societies will make in response to changes;
 - the consequences of the changes and adaptations for the production and consumption of market and non-market goods and services and
 - the value of the affected market and non-market goods and services to individuals and societies.

Handwritten notes in the top right margin:

North America
South America
Europe
Africa
Asia
Oceania
Antarctica
World to include

Handwritten notes in the right margin:

Because of
high uncertainty
in each
aspect
of the
total
damages
estimated
by the
IPCC
More
recent
studies
do not
seem to be
convinced
in a
precise
value
for
climate

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- Because of uncertainties in each of these linkages, there is substantial uncertainty regarding severity of climate change damages. Scenario analysis is applied to the evaluation of climate change damages as a method for dealing with uncertainty. Damages are estimated for a scenario conditional upon a set of assumptions that characterize the scenario. Estimates of climate change damages are highly sensitive to scenario assumptions and estimates are needed for multiple scenarios to fill in a picture of the potential consequences of climate change.
- Comparisons of damage estimates from different studies suggest that damage categories of particular concern include agriculture, coastal zones, water resources and human health. However, there is little agreement across studies about the magnitude of damages for these and other categories of damages and little agreement in the relative ranking of damage categories.
- Agricultural damage is a concern because of the importance of food supply to human welfare and the importance of climate as a factor in agricultural production. Research results, however, are inconclusive about the severity of agricultural damages and many studies indicate the potential for agriculture to benefit. Important factors contributing to differences in damage estimates include differences in the climate scenarios, differences in the modeling of adaptation, and differences in modeling beneficial effects of higher concentrations of carbon dioxide for plant photosynthesis and water use efficiency. Analyses which incorporate warming of 2 to 3 degrees C, wide latitude for adaptation, and substantial beneficial effects from carbon dioxide suggest modest agricultural damages or benefits for much of the world. Analyses which incorporate more warming, narrow the latitude adaptation and lesser beneficial effects from carbon dioxide suggest modest to severe agricultural damages that could put more people at risk from hunger.
- Also of concern are damages that may arise from the disruption of natural ecosystems by climate change. These potential damages are of concern because there is a high degree of uncertainty about how these systems will respond to climate change and low confidence in available valuation methods to adequately account for the importance of these systems to human welfare. A few researchers have made monetary estimates of

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damages to natural ecosystems from climate change, but the estimates are speculative and not comprehensive.

Points which should be included from Chapter 7 are as follows:

- The conceptual basis for establishing the cost of response options is well-established but there are wide differences in estimates among empirical studies. These include:
 - differences in the technical description of the inputs and outputs of the technology or response options
 - differences in the prices used to cost inputs (e.g. labor, capital, materials)
 - whether or not estimates consider how market prices may change as the scale of the industry changes; learning and demonstration effects may reduce costs as scale increases but competition for resources (e.g. competition for land from agriculture) may cause costs to increase with scale
 - dependence of costs on varying quality grades of the resource (e.g. solar insulation, regularity of wind, the rate at which forests/biomass will grow or where the resources is limited in quantity may lead to increases in the cost of the response option as scale increases.
 - whether and how market prices of traditional inputs and outputs have been adjusted to reflect the full social cost (and benefits) of the option; such adjustments may reflect other labor, capital, and other market distortions.
 - whether the cost includes other socially beneficial or detrimental effects such as effects on the environment or the distribution of income/employment.
 - finally, the full cost of the option must be compared with the full cost of the current practice that will be replaced by the option; the full environmental costs of current practices are not uniformly incorporated in current market prices or these alternatives may be subsidized. The current practice being replaced can vary (e.g. oil or gas-fired power plants substituting for coal would provide CO₂ benefits but if they replace hydroelectric power they would increase CO₂ emissions).
- The generic set of responses to climate change that have been identified in the literature are:
 - mitigation including
 - ♦ reducing or changing the activities that lead to trace gas emissions

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- ♦ scrubbing (removal of trace gases from combustion by-products)
 - ♦ sequestration (enhancing the uptake of greenhouse gases)
 - adaptation (acting to limit the impacts of changing climate)
 - geoengineering (large scale interventions in the earth system in an attempt to counter-balance the atmospheric changes and radiative forcing caused by greenhouse gases)
- Estimates of the potential of "no regrets" energy efficiency improvements and low cost alternatives to fossil fuels vary widely. While there may be considerable unexploited technical potential, there is little consensus on the full cost of various options compared with current practices (for more detail on the technical options see WG-II).
 - **[Is this what we want to say?]** The failure of "no regrets" options to succeed under current economic, political, and social conditions has many possible explanations; specifically identifying why these options fail is a necessary precondition to devising remedies that would encourage their broader application. The reasons vary widely across technological options and across countries ranging from tax systems that provide favorable treatment to fossil-fuel using activities, direct fossil fuel subsidies, and lack of reliable and concise information that allow purchasers of energy-using durables to accurately estimate their operating costs to the lack of incentives for households and firms to take into account the full social costs (and benefits) of current fuels and their alternatives.
 - While a full assessment is not possible at this time, existing evidence makes clear that both the technical potential and the cost (or cost-savings) of various non-carbon fuel alternatives and of energy efficiency improvements vary substantially by geographic region and across different social, political, and economic systems. Among the reasons for these differences are:
 - There are wide differences in energy-using characteristics among countries with similar economic and social conditions; while recognizing this significant within group variation, 1990 energy use per capita in the developed and eastern Europe and countries of the former Soviet Union was over seven times higher than in countries of Africa, Latin America, the Middle East, and Asia. At the same time, the developed west used less than one-half the energy per unit GNP than eastern Europe and the countries of the former Soviet Union and one-third the energy per unit of GNP of developing countries. While

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suggestive of opportunities for efficiency gains and low or no-cost opportunities for energy-savings [this aggregate evidence is insufficient to conclude that the economic, political, and social costs (or benefits) of options are greater or lesser for different groups of countries.]

- Relatively fewer studies have assessed the costs of adaptation to changes in climate. The potentially affected activities span a broad range from agriculture and energy use, to health, coastal communities, and recreation and ecosystem preservation. Among each of these broad sets of activities there are many possible adaptive responses. (For identification and discussion of such options see WG-II).
- Still less evidence on the costs and technical feasibility of geoengineering and scrubbing exist. These options have not been technically proven at an operational scale; moreover, these options pose substantial potential environmental risks of their own.

Points which should be included from Chapter 8 are as follows:

- A complete evaluation of the costs of GHG mitigation would require an accurate technical description and pricing of all of the inputs and outputs in all markets affected by the policy, and would describe how output and prices in all markets are affected by the policy over time. This is a very difficult task because the economy will respond in many ways to changes in policy that, for example:
 - Raise fossil fuel prices or promote new technologies.
 - Economies of scale and learning associated with broader use may reduce the costs of new technologies as their scale of production grows.
 - On the other hand, dependence on limited resources of varying levels of quality may increase costs as scale grows.
 - Markets for existing technologies may also respond introducing more efficient energy technology or non-fossil energy supplies may drive down the prices of fossil fuels.
- An evaluation of full social costs and benefits of a policy will be particularly difficult:
 - where market institutions do not exist;
 - where market prices fail to reflect external costs such as pollution; or
 - where information costs play a significant role, as is the case with new technologies.
- In each of these cases, it is very difficult to quantify the costs because they are not fully captured in prices that reflect buyers' and sellers' evaluation

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of goods and services and hence are not readily observable and measurable.

- Existing studies use a variety of methodological approaches and definitions of cost to assess the costs of mitigating GHG emissions. No existing study yields a complete evaluation of full social costs and benefits. Instead, studies present a range of cost estimates: some provide estimates of direct financial costs of specific technological options; others provide estimates of the effects of broad policies on aggregate economic activity; still others attempt to estimate welfare costs. It is important to be clear about which type of cost is being estimated in any specific study.
- The range of methodologies can be grouped into two generic classes:
 - "Bottom-up" studies begin with detailed assessments of engineering costs of a wide range of available or forecasted technologies. The studies calculate the financial costs of these options, generally at current market prices, and compare the options to each other and to current technologies in the market. They do not quantify the aggregate impact of technology adoption on related markets and on the overall economy. "Bottom-up" studies generally show that the best existing technologies yield very high energy cost savings relative to the cost of continuing to use installed equipment and not adopting the best technology, so that it appears financially profitable to replace a large quantity of existing equipment. As a consequence, these studies generally conclude that a significant quantity of emissions reductions - well beyond stabilization at 1990 levels for the next two decades or so - can be achieved at net savings, where costs are calculated as the sum of the equipment and energy costs to individual equipment users.
 - "Top-down" studies use a wide range of methodologies to try to calculate the response of the entire national, regional or global economy to a policy option, typically to an emission tax such as a carbon tax. These studies typically evaluate costs as the difference between gross domestic product (GDP) in a no-policy "business-as-usual" base scenario and GDP in a policy scenario; some models attempt to quantify the change in overall economic welfare as defined by economists. Because the models represent markets in a fairly aggregate way, they do provide for detailed assessments of particular technologies. Instead, they attempt to quantify in a more general way the response of the aggregate economy and the slow adjustment of all markets, thus trying to account for components of full social cost not

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quantified in the "bottom-up" studies. The processes are modeled on the basis of statistical analysis of historical behavior. "Top-down" studies yield a range of cost estimates, and the results depend critically on the choice of modeling framework. On one end of the spectrum, general equilibrium studies, which provide for rapid adjustment of markets, yield relatively low cost estimates (e.g. \$5/ton to \$20/ton for stabilization of emissions at 1990 levels over the next decade or two); on the other end, macroeconomic studies, which try to represent the more gradual adjustment that is typically found in real economies, yield medium to high cost estimates (e.g. \$40/ton to over \$100/ton for stabilization of emissions at 1990 levels over the next decade or two).

- The different cost assessment methodologies are gradually being integrated. The most detailed current models provide for highly detailed representation of the energy sector and also for representation of the rest of the economy; however, peer-reviewed results from these models are not yet generally available. This convergence means that differences in results from integrated models increasingly will be driven mainly by differences in input assumptions - particularly assumptions about the rate of penetration of new technologies - rather than differences in model structure.
- Despite convergence of methodologies, different types of models will remain best suited to answer different kinds of questions. Models with more detailed representation of technology are more suited to identifying technical potentials and financial costs and savings; models with more detailed representation of broader economic activity - consumption, investment, international trade, and so on are more suited to identifying costs in terms of higher or lower economic growth. However, none of the existing approaches is very effective at quantifying long-term costs because there are likely to be a range of very different long-term socio-economic and technological development paths that would give rise to quite different emissions scenarios and costs of mitigation. Future analysis should focus on improving our ability to explore long-term development paths that are significantly different those typical of the past few decades.

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- There is substantial disagreement over the reasons for the wide difference between the low mitigation costs found in "bottom-up" studies and the higher mitigation costs found in most "top-down" studies.
 - Proponents of the low-cost view tend to view the high costs found in the "top-down" studies as evidence of a range of market failures, such as lack of information, capital constraints and inadequate investment in research, development and commercialization of new technologies. They point to the low adoption rate of profitable technologies as a priori evidence that there must be a range of market failures; they tend to conclude that the economy is operating inefficiently, and that its performance can be substantially improved at relatively low cost.
 - Proponents of the high-cost view tend to believe that these costs generally reflect a range adjustment costs, information costs, and other intangible costs that are not measured in detail but are nevertheless captured in the aggregate by the "top-down" models. They regard the low market penetration of what appear to be profitable technologies as a priori evidence that there must be a range of costs not captured in "bottom-up" studies. As a consequence, they tend to conclude that the economy is operating near its maximum potential.
- As a consequence on the controversy described above, there is substantial disagreement over the extent of "no regrets" potential for GHG emissions reduction. The extent of "no regrets" potential depends on how efficiently the economy is operating. The conclusion of some researchers that significant "no regrets" potential exists is based on their view that (i) significant market inefficiencies or market failures exist which give rise to increased GHG emissions (i.e. society is below its production possibility frontier), and (ii) that policies can be designed and implemented at low cost that eliminate these market inefficiencies or correct these market failures.
- Although researchers attempt to incorporate their best understanding of development processes into the studies, neither the baseline nor the intervention scenarios should be interpreted as representing likely future conditions, especially more than two decades into the future. Policymakers should place more confidence in the insights generated by modeling analyses than in the specific numerical results of any one analysis. Here are some of the important insights that have been generated.

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- The magnitude of mitigation costs depends critically upon the assumptions built into the baseline of the model. Models with high assumed economic growth rates tend to show high rates of energy use and therefore greater costs of mitigation. Likewise, the greater the assumed efficiency in the economy, the greater the costs of mitigation; and the more emissions reduction built into the baseline, the greater the costs of further reduction.
- Economic instruments such as taxes and tradable permits are likely to be more efficient than regulatory approaches.
- Decisions about provision of infrastructure are critical because they have long-lasting effects that can allow or restrict future options, and different decisions can lead to very different cost outcomes. The issues include transportation infrastructure, electricity generation, and land use regulation. This issue is of particular importance to developing countries, where major infrastructure decisions will be made over the next 25 years.
- Mitigation policies may have beneficial or harmful side effects. Two potential benefits may be very important in determining the net cost of mitigation.
- Emission taxes, such as carbon taxes, will raise substantial revenues, and how the revenues are redistributed can dramatically affect the cost of mitigation. If the revenues are used to remove distortions in the existing tax system and thus reduce the excess burden of taxation, there may be an additional economic benefit. On the other hand, if the revenues are used to fund wasteful activity, the tax could be even more burdensome.
- GHG emission taxes would reduce emissions of other pollutants, with additional benefits. It is important to distinguish between gross costs of mitigation measures and net costs (net beneficial or harmful side-effects of or double dividends from mitigation). From a policy point of view, decision-makers will be served best by being provided with information on both gross costs and net costs.
- The areas of greatest short-term potential for cost-effective emission reduction include energy and non-energy conservation and forestry.
- Encouraging energy supply or conservation lowers overall energy prices, resulting in some increased energy demand and emissions. This is called the "bounce-back effect."

Points which should be included from Chapter 9 are as follows:

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- There is extensive research on the costs of mitigating greenhouse gas levels through changes in ~~forecasted~~ energy use, the emissions source of greatest concern. Less research covers programs that increase carbon sequestration and reduce greenhouse gas emissions from activities that do not involve energy use.
- Many countries have studied how to reduce greenhouse gas emissions by future energy use. There are also regional analyses and world-wide studies. Studies have time frames from about 25 years to more than 100 years. Although there is an extensive peer-reviewed literature on the results, many of the energy models have not had extensive peer review. Despite the valuable research that has been completed, much more needs to be done to improve the ability of energy models to provide insights to decision makers on the effectiveness of different types of government policies seeking to produce behavioral changes and value of different energy use and supply technologies over time throughout the world.
- **[Possible overlap with points in Chapter 8]** There are two major areas of research on the costs of changing energy use patterns throughout the world that offer insights on the costs implications of actions that could be taken over the next 25 years, where current forecasts of energy use have the greatest validity. They have been labeled the "bottoms up" and "top down" literature.
- **[Possible overlap with points in Chapter 8]** "Bottoms-up" research has considered where energy-efficient technologies are underutilized due to the reported existence of market imperfections. These studies conclude that many countries should be able to reduce carbon emissions substantially with significant savings from energy use and fuel switching. Government actions include establishing energy efficiency standards, supplying information on better energy technologies, improving electric power generation and transportation planning, and using market incentive programs. The bottom-up studies report that there could be adjustments over time in energy use and supplies that lead to annual carbon reductions of 10 to 60 percent below what they would have been in a business as usual (baseline) scenario. Most the literature provides annual carbon reduction estimates under 40 percent for various countries.

*Costs of
reduction
need results*

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- **[Possible overlap with points in Chapter 8]** The "bottoms up" studies identify areas where government programs could be focused to address market imperfections, such as the lack needed information. Questions have been raised over whether these studies have sufficiently evaluated how well government actions can improve the functioning of energy markets, the significance of transactions and information costs involved in making these corrections, and the overall adjustments to economic growth that would occur when money is invested in energy efficient technologies over other activities in the economy.
- **[Possible overlap with points in Chapter 8]** The "top-down" research has considered how the use of emissions taxes can be used to change energy use practices throughout an economy. Research has shown that results appear to depend critically on the choice of a macroeconomic modeling framework and how the tax revenues will be used)) *which*
- Country-specific, regional, and world-wide top-down modeling of the use of emission taxes has most often shown reductions in economic growth of .5 to 2 percent that results in efforts to "stabilize" carbon levels (return them to annual rates that existed around 1990), or reduce annual greenhouse gas emissions by 20 percent of what initial baseline forecasts had placed them at in 2020.
 - Several studies have considered how the revenues collected could be used. If the revenues are used to remove distortions in existing tax systems, it appears that the net costs of the emissions taxes will be at the bottom end of the above range, or that the use of these taxes may actually stimulate economic growth. How countries redistribute an emissions tax matters.
 - Work done on more aggressive reduction targets and over longer periods of time where there is far greater uncertainty over the adjustments that can be made has shown the potential for higher costs.
- Limitations in top down studies exist due to their reliance on an emissions tax as a way of implementing broad government policies to produce changes in energy use. Questions also have arisen over their ability to consider future energy efficiency improvements and adoption of cleaner fuel technologies and reliance on past behavior during limited periods to predict future actions.

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- The collective work that has been done examining the costs of programs to reduce carbon levels from energy use throughout the world suggests several other valuable insights important to decision makers:
 - Infrastructure decisions on energy supply and energy use systems are critical. They can enhance or restrict the types of future options countries will have to address the greenhouse gas problem through energy efficiency improvements and fuel switching. For example, a country relying heavily on nuclear power for electricity, will not need to focus on conserving electricity to reduce carbon levels.
 - There are large differences in the costs of reducing greenhouse gas emissions among countries due to their state of economic development, infrastructure choices, and natural resource base. This suggests that international cooperation can significantly reduce the global price-tag for emissions reduction. Some research has shown the potential for substantial savings that are possible in a global emissions trading program.
 - Given the nature of the current global economy, some research suggests that the lack of international cooperation may lead to significant levels of "leakage" of carbon as manufacturing activities shift between nations, if some countries act to address the issue and others do not.
 - Timing of programs for emissions reductions is a critical policy variable in determining the overall price tag due to the need for change over in the capital stock in a manner that is not disruptive to economic activities in various countries and the ability to take advantage of technological innovations that are becoming available.
 - Removal of some types of energy subsidies could stimulate energy efficiency gains than produce carbon reduction benefits.
- Research on carbon sequestration has focused on increased forest management using forest plantations, forest management to slow deforestation and increase regeneration on degraded lands, expand agroforestry practices combining forestry in agriculture, and production and substitution of bioenergy fuels for fossil uses. Studies of carbon sequestration estimate costs ranging from less than \$1 to about \$50 per metric ton on carbon, although a few studies provide estimates as high as several hundred dollars per metric ton.
- A substantial amount of enhanced carbon sequestration can occur at the bottom end of the cost range. One major study indicates the potential to

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store about 50 billion tons of carbon for about \$5 per metric ton, or less, and another 20 billion tons at less than \$20 per metric ton.

- Recent studies have considered the costs of actions to reduce methane releases from natural gas systems, coal mining, waste disposal, livestock, and other anthropogenic activities. Some research has considered how to reduce greenhouse gas emissions from fertilizer production and use, aluminum production, and CFC replacement manufacturing. U.S. research has found that actions to reduce releases from methane sources, aluminum production, and the manufacturing of CFC replacements can save money.

Points which should be included from Chapter 10 are as follows:

- Integrated assessment models contribute a convenient framework for integrating results from a wide range of disciplines and most models provide estimates of benefits and costs that would be incurred by adopting certain policy options. The models are useful because they can provide insights about the climate change problem not available from an examination of individual disciplinary studies. The models are sensitive to input assumptions, such as damage functions, that are often calculated by other researchers. These models also place the research program into a perspective that allows the setting of research priorities. Early model results are instructive to the policy debate. However, the state of integrated assessment modeling is still immature both because modelers have not yet fully assimilated disciplinary research results and because individual disciplinary research areas are themselves constrained in their ability to provide explicit results. There is much borrowing among models. Results need to be accepted with some care. Furthermore, certain low-probability/high-consequence outcomes might negate some of the results.
- A measure commonly used to indicate the degree of action to reduce greenhouse gas emission is the optimal carbon tax or, equivalently, the marginal damage. Most integrated assessment models find that optimal carbon taxes in the near future (twenty years or less) are generally low (\$5 to \$13/tonne -- an average U.S. automobile emits about 1 tonne of carbon in a year [check]). These strategies with moderate near-term policies reflect cost advantages to waiting before initiating more intense emission reductions. Waiting saves because a) discounting makes future actions less costly in today's dollars, b) capital is not replaced before it is ready to

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be retired, c) research and development on technologies is likely to offer less expensive abatement alternatives, and d) research in the natural and social sciences will reduce some of the uncertainty. The models indicate that policy instruments of choice in the near term emphasize points c) and d), while more stringent policies are required later to meet specific atmospheric concentration objectives.

- Replacement of carbon-based fuels with carbon-free fuels has a possible negative consequence. Reducing carbon-based fuel use can result in lower sulfur emissions, which, while reducing environmental insult from acid deposition, reduces the potentially beneficial climate cooling effect of aerosols.

Points which should be included from Chapter 11 are as follows:

- A clear distinction needs to be drawn between policies for global climate change mitigation and adaptation. Mitigation reduces emissions and thereby reduces potential changes in climate, while adaptation reduces the damages caused by whatever climate change does occur (such as by developing drought-resistant plants). [Page 17]
- Policy instruments designed to mitigate global climate change must be used by a large coalition of countries to be effective; unilateral or small-group mitigation policies are ineffective, because leakages from non-cooperating countries offset much or all of the direct reductions. Adaptation policies, however, can be effective unilaterally. [Pages 7, 36-37]
- There is tremendous variety in potential policy responses to climate change. Representative examples include carbon or energy taxes, carbon quota or tradable permits, removing energy subsidies, performance or technology standards, product bans, demand side management, and research on greenhouse gas abatement technologies and on climate change effects. [Pages 5-8, 18-22]
- There exist "no-regrets" policies for mitigation. Primary among those is removing existing energy market distortions from government policies that encourage too much energy consumption or that bias the fuel consumption mix. Examples include electric power sold by the federal government below marginal cost, vehicle transportation modes that do not

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pay their full social costs including pollution and highway congestion, and agricultural water subsidization. [Pages 12-16]

- Market-based policies are generally considered most cost-effective. A choice of tradable quotas at the international level would provide maximum flexibility for instrument choice at the level of individual countries, which may have different sets of criteria for assessing policy instruments. Under an internationally harmonized carbon tax, incentives exist for individual countries to alter related policies to reduce welfare effects, such as production subsidies, which would make harmonized tax policy less effective. Policies should be reviewed on a case-by-case basis, however, since some market-based policies may have may higher administrative, monitoring, and enforcement costs than some non-market-based policies such as technology standards. In addition, technology for accurately monitoring many sources and sinks of greenhouse gases has not yet been developed. [Pages 9, 31-34, 41-45]
- The more steeply the expected costs of emission reduction rise as allowed emission levels are tightened, and the more uncertain are those costs, the more advantageous is a tax system over a quota system. The more steeply the expected damages from emissions rise as emissions levels rise, and the more uncertain the damages, the more advantageous is a quota system. A tax system allows fixing of per unit CO₂ reduction costs, while a quota system allows a fixing of emissions levels. [Pages 44-45; needs more support in text]
- A system of joint implementation of carbon emission reductions if properly designed could be a cost-effective method of targeting for reduction those emissions involving the lowest mitigation costs, regardless of where the emissions occur geographically. Such a scheme could operate similarly to an international tradable quota system. [Pages 29-30]

Points which should be included from Chapter 12 are as follows:

- Almost all published emission profiles for non-intervention scenarios, including the IS92 scenarios of the IPCC, project an increase in annual greenhouse gas emissions over the next century. The six IS92 scenarios show a wide range of projected annual CO₂ emissions by 2100, spanning from 4.6 to 34.9 Gt C per year. Cumulative emissions from 1990 to 2025 range from 230 to 320 Gt C; cumulative emissions from 1990 to 2100 range from 700 to 2080 Gt C.

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- All of the IS92 emission scenarios would result in an increase in the atmospheric concentration of carbon dioxide above the current concentration and none would stabilize the concentration by the year 2100. Four of the six scenarios would produce a doubling from the pre-industrial concentration before the year 2070 with rapid rates of concentration growth. Neither of the other two scenarios result in doubled pre-industrial CO₂ concentrations by the year 2100, but nonetheless project growing concentrations through 2100. (Summary for Policymakers, Working Group I).
- The wide range of projected emissions of the IS92 scenarios is a product of differences in scenario input assumptions that reflect uncertainties about the factors and processes driving emissions growth. For energy-related CO₂ emissions, population and economic growth assumptions usually play a key role. Also influential are assumptions about the responsiveness of carbon-based fuel demand to income growth and technological change. For land use CO₂ emissions, the deforestation rate and the carbon content of vegetation are important input assumptions.
- The IS92 scenarios is representative of the range of emissions found in other, non-IPCC scenarios. Based upon a comparison of the IS92 scenarios to other published scenarios, the IPCC judges that the IS92 scenarios are suitable for use as inputs to climate analyses of the potential consequences of non-intervention scenarios. Because of the substantial uncertainty regarding greenhouse gas emissions, as illustrated by the IS92 scenarios, it is recommended that the full range of IS92 emission profiles be used in such analyses.
- The uncertainty regarding greenhouse gas emissions also argues in favor of evaluating policies against a wide range of reference emission scenarios. Given the wide divergence of possible future emissions, it is wise to assess the costs of mitigation policies and their effectiveness in achieving emissions objectives under a wide range of assumptions.

Specific Comments on Summary for Policymakers**Page 2, Lines 1-2**

Delete "of 'act - then learn - then act'". This language, which attempts to summarize the discussion in Chapter 1 in a short phrase, could incorrectly be

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taken to imply that actions should be taken even before anything is learned. The Summary should emphasize that considerable knowledge exists, but that it is by nature imperfect, and that actions should be taken concurrent with the search for more precise information.

Page 2, Lines 4-6:

Delete the last sentence of the paragraph. The current language is too vague. It is unclear just what sort of "guidance", if any, the ultimate objective provides concerning initial decisions on measures to address climate change.

Page 2, Line 9

Substitute "the Parties" for "their". The current language incorrectly implies that actions can have responsibilities.

Page 2, Lines 18-20

Revise: "The precautionary principle (Article 3.3) and the estimated damages due to current emissions of greenhouse gases (Chapter 6) have caused some to argue for action beyond "no regrets" measures."

In order to "argue for action", one needs to make a political judgment. In principle, the risk of loss can justify some investment to prevent the loss, but in this case the potential level of reduction in emissions from "no regrets" actions, which is large according to some, also needs to be considered. It is pointless to take shots at the "no regrets" position when more positive and less controversial statements can be made. It should not be implied that everyone agrees that action beyond "no regrets" is needed at this time.

Page 2, Line 21

The sentence beginning on this line may not be correct if decisions "taken in the near future" have fundamental, long-lasting effects well beyond the near future. Over the longer term, the possibility of non-linear climate responses to atmospheric concentrations of greenhouse gases may become of greater concern.

Page 2, Line 25ff

The text should make it clear that the actions listed are merely examples of measures that may have net benefits, and that the actions are not necessarily ones that all nations should undertake simultaneously and immediately.

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Most analysts would agree that the most cost-effective of these measures should be undertaken without further scrutiny (negative-cost measures to reduce emissions, phasing out of existing distortionary policies, etc.). Less cost-effective measures (e.g., fuel switching) should not necessarily be undertaken, however, as long as there are more efficient alternatives from which to choose. In other words, governments should plan and undertake actions along an optimal path: in the short-run, governments should reduce energy subsidies and eliminate other distortions in energy markets; accelerate research and development; and promote joint implementation. Beyond this, for target concentrations within the range of 450 to 750 ppmv, only mildly costly mitigation actions are indicated.

Page 2, Lines 28-32

Listing of "implementing low cost measures to reduce emissions..."

The portfolio of possible actions should be listed in a more economic order, beginning with phasing out of distortionary measures, moving on to climate change research measures upon which there is widespread agreement, and then proceeding to positive cost measures, including "low cost measures to reduce emissions...."

The statement that "There is broad agreement that in most countries there are some measures, such as energy efficiency, that can reduce emissions of greenhouse gases at negative to slightly positive costs" would be better left out. To get broad agreement, the statement will have to be so qualified that it becomes meaningless. At a very minimum, an issue that needs to be acknowledged is the element of cost-effectiveness of energy efficiency measures: too fast, and there is excess capital scrappage. Also, "most countries" should be followed in parentheses by "both Annex 1 and non-Annex I countries".

Edit the last sentence to read: "Achieving such reductions may or may not require policy intervention which takes into consideration the normal turnover of energy using equipment."

Page 2, Line 34

delete "to" insert "for".

Page 2, Line 37

add "," after pollutants.

DRAFT OF Sunday, March 12, 1995**Page 3, Lines 8-9**

The importance of forestry to the climate change issue deserves specific mention. Forestry issues receive considerable attention in Chapter 7. The portfolio of possible actions as described on pp. 1-2 is excessively weighted toward energy.

Page 3, Line 19

delete "conducting technological".

Page 3, Line 22

delete second "of".

Page 4, 1st paragraph

Delete. This discussion does not seem to follow logically from list of options in the previous paragraph, and adds little information. Singling out an "illustrative simulation" in the Summary incorrectly makes it appear to be a reliable analysis rather than an illustration. Moreover, the figure of "\$50 per tonne of carbon" seems misleading, and contradicts results reported in other chapters that \$5 to \$20 per ton is the right range.

Page 4, Line 14

Replace "international equity" with "the impacts on different nations". As Chapter 3 demonstrates, there are no objective criteria for determining international equity.

Page 4, Line 17

Add "availability of capital for investment and research" to the list of considerations.

Page 4, Line 19ff

Change sentence to read "A country's climate change actions will also reflect its objectives, economic conditions, and constraints."

The current list of considerations confuses conditions particular to a given country, and conditions that are more universal. More generally, the list of considerations does not add much to the Summary, and does not reflect any consensus about the most salient factors.

Page 4, Line 25

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Delete "limitation", insert "control measures".

Page 4, Line 30

All countries will make, "significant infrastructure investments," in the next decades, not just developing countries, and climate change policies involve much more than infrastructure investments.

Page 5, Line 3-4

The sentence beginning on line 3 reflects a highly political viewpoint, and suggests that the science is understood better than it is. The sentence should be revised as follows: "The potential negative effects from climate change increase as the concentration of greenhouse gases in the atmosphere rises".

Page 5, Lines 5-8

"The discussion below focuses on the effects associated with stabilization of atmospheric concentrations of CO₂ within the range of 350 to 750 ppmv..."

It is important to note that the degree of stabilization that will be required remains unknown. Add the following sentence. "However, science and economics cannot at this time suggest to policymakers what level of concentrations might be considered dangerous when taking into consideration ecosystem adaptation, food production, sustainable economic development, and the impacts of limiting emissions on these criteria as specified in Article 2 of the Framework Convention."

Page 5, Lines 7, 14-16

These sentences discuss the need for emissions eventually to decrease below 1990 levels at various stabilization targets. The statement is true, but is still misleading. The implication is that "eventually" means within the next few decades, or sooner. If one examines Figure 1, it clearly shows that at 650 ppm and 750 ppm, emissions would not need to return to 1990 levels for about 200 years. In Maastricht, the U.S. delegation argued against including this clarification in the text, because the graph showed a "richness" of results that cannot be done justice by words. The policy implications of having to reduce emissions "eventually" below 1990 levels and having to reduce them to 1990 levels within the next 200 years are very different. Language which clarifies the dates by which emissions need to return to 1990 levels is essential.

Page 5, Lines 11-14 and Figure 1

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The "illustrative profiles of anthropogenic emissions" here do not look like cost-effective paths. The work of Richels and Edmonds (Energy Policy, forthcoming 1995) as well as some unpublished work with the CETA model both suggest that as the concentration ceiling is lowered, cost-effective emissions paths tend to be very similar in the early decades, and increasingly different in the later decades. Since this is one of the more robust conclusions from economic analysis of the climate change problem, it would be highly desirable to show cost-effective emissions paths here, instead of these "illustrative paths."

Page 5, Line 14

Figure 1 is incorrect and should be redrawn. The paths indicated do not represent optimal paths, but simply conjectures reported in some scenario comparisons. An important recent result, referred to obliquely on p. 2, is that the optimal (least-cost) path is the same in the near term whether the ultimately desired concentration is 450 or 750 ppmv. The figure should be revised consistent with the results of EMF-12 and EMF-14.

Page 5, Line 18-21

Even though these lines are a direct quote from the Summary for Policymakers of the Radiative Forcing Report, they again mislead the reader by omitting important information that should be added to footnote 11. While IS92a does track above the S750 level, it does so only slightly for the next 100 years, at which time there is a sharp upward trend. This suggests that the IS92a scenario is a very reasonable scenario to follow for the next 100 years, by which time the curve would need to begin decreasing. Depending on the technology at that time, stabilization could still be attained at 750 ppm or less. This means that society should put energy technology development on a "fast track" for the next 100 years, but otherwise allow emissions to be dictated by market place demands.

Page 6, Lines 3-4

The sentence "Thus stabilization of atmospheric concentrations of greenhouse gases will require very low population and economic growth rates...." is highly judgmental and does not belong in an IPCC report. The "lesser" reductions being talked about are only 10% for methane. Rapid development of new technology could also achieve the desired stabilization. As stated on page 4, line 24: "Governments can and should adjust their portfolio of climate change actions in response to new information and development." This

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document is not the place to argue a final solution to the climate issue; it is a place to discuss the options.

Page 6, Lines 6-8

Before "The current commitments (of Annex I countries) are not sufficient to stabilize atmospheric concentrations of CO2..." insert: "In the absence of some commitment by other countries,". Without the insert, the reader is left to conclude that the answer is to tighten up on the commitments of Annex 1 countries. But as several chapters demonstrate, without a commitment by the developing countries, atmospheric concentrations cannot be stabilized.

Page 6, Lines 6, 8

The word "commitments" is used in reference to the FCCC and Annex I parties. Our understanding is that there are no "commitments" under the FCCC to reduce greenhouse gases, only "aims". The text should refer to hypothetical emissions policies of Annex I countries, not commitments.

Page 6, Line 14ff

Few economists would subscribe to, let alone know what the report is talking about, when referring to a "safe minimum standard." The "safe minimum" approach also uses two terms that few economists would find meaningful: "reduce the risks of climate change to an acceptable level at an acceptable cost." Using this sort of language would significantly interfere with the credibility of the IPCC report in the economics community and beyond, and would likely be sharply criticized by some governments.

There is no reason even to discuss the absolute standard. It is not required by the Rio Convention, and there is no precedent for it. The standard is also virtually unenforceable within the national sovereignty protections of the Rio Convention. If reference is made to the absolute standard and/or safe minimum standard, it must be clearly stated that most economists do not accept these approaches, and argue for the use of a cost-benefit approach, with appropriate attention paid to the treatment of risk.

All of the approaches mentioned can be embraced in cost benefit analysis, incorporating different degrees of risk aversion. The order of magnitude of anthropogenically induced climate changes is smaller than those which have occurred naturally in the past. It is now generally understood that absolute standards are points of reference to be adjusted using cost-benefit considerations. In the discussion of cost benefit, it should explicitly be stated

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that risk considerations can and should be brought into the cost benefit analysis.

Figures 3(a) and 3 (b)

These Figures are particularly troublesome, as they draw attention to statements in the text about acceptable and unacceptable risks, while nowhere providing a formal way of quantifying the effects or valuing those effects relative to the economic impacts.

Page 6

The discussion on this page contains a confused logic and a misstatement of the objective of cost-benefit analysis of climate change policies. A careful reading of the, "safe minimum standard," approach reveals it to be a kind of cost-benefit analysis, since it compares risks with costs. In order to make such a comparison, risks must be measured in the same units as costs, i.e. in dollar terms. Since avoidance of risks would be a benefit, comparing them with costs is a benefit-cost approach.

The statement of cost-benefit analysis on line 28 is inaccurate with respect to objectives and, considered narrowly, reflects an improper criterion for decision. Financial and economics textbooks point out the mistake in making a decision by setting discounted costs and benefits equal to each other.

Page 7, Line 11

The special meaning attached to the italicized word "could" is unclear. The correct word is "can", with no italics needed.

Page 7, Line 22-25

Delete "Because of" at the beginning of the sentence on line 22. Replace "selection of an appropriate stabilization objective" with "decision-making with respect to climate change policies".

Page 7, Line 28

Insert "now exist but" before "are quite new."

P 7 and P 10

The following discussion should be added to the discussion on P. 7 and replace P. 10 lines 30-44. The figures should replace those with the same numbers on pages 7 and 11. Insert the following on p. 10 instead of lines 30-44 and replace Figure 8.4. "Figure 8.4 illustrates different views about the

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relation between cost and emission reduction in the case of a carbon tax. Each curve in Figure 8.4 shows how marginal costs would increase for higher levels of emission reduction, given different views about the nature and effectiveness of offsetting policies. these re marginal costs, and therefore represent the cost of achieving an additional ton of emission reduction, once the emission reduction indicated on the horizontal axis has been achieved.

Curves A, B, C, and D assume that there are no reducible market imperfections in energy markets, so that there are no negative cost potentials.

Curve A assumes that all revenues from a carbon tax are recycled through lump sum transfers, rather than removing existing distortionary taxes. In this case, even a small carbon tax imposes positive marginal costs, as illustrated by Curve A starting at a point above 0 on the vertical axis, because it increases the excess burden of existing taxes. Curve B assumes that carbon tax revenues are optimally recycled by reducing general taxes like personal and corporate income taxes. In this case marginal costs are never negative, because leaving aside environmental benefits it is unlikely that the cost of a carbon tax will be smaller than the cost of the general taxes it replaces.

Curve C represents the most favorable case for recycling, where revenues are used to replace highly distorting taxes in specific sectors.

Curve D includes an environmental dividend represented by the other environmental benefits induced by GHG emission reduction, as well as the optimistic assumptions about recycling induced by GHG emission reduction, as well as the optimistic assumptions about recycling included in Curve C. Curve E included all offsetting policies in Curve D, plus the "negative cost potential" described in section 1.2.1 above. All these curves are theoretically possible. Sufficient empirical evidence is not available to determine which of the influences affecting the location of the marginal cost curve is most important. Therefore the marginal costs of small carbon taxes could be positive or negative, and there may or may not be a range of emission reductions that could be achieved at zero or negative costs."

Page 7, Line 36-39

Change "seem unavoidable" to "might occur but their magnitude, timing, and location are highly uncertain, and may be offset, at least in part, by some benefits of climate change."

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Climate science is uncertain, and so are impacts and damages. While some increases in concentrations seem inevitable, this does not mean that damages are certain or that no impacts of climate change can be beneficial.

Page 7, Line 37

The fact that some increase is unavoidable raises the question, "What's the Baseline?" If we are looking at policy choices, and if 2 x CO₂ (i.e., 560 PPM) is inevitable, then policy comparisons are between higher concentrations and, perhaps, different speeds of reaching that level.

Page 7, Lines 37-39

This statement is not necessarily true, and should be modified. It is possible that atmospheric concentrations could increase from the current levels yet still remain below the level necessary to trigger climate changes.

Page 7-8, Line 36 ff.

This section discusses climate change damages and impacts as if they were absolutely real, instead of being computer projections. WG III should not make scientific-sounding statements that are the domain of WG I and which go far beyond WG I documents. WG III can discuss the "potential climate change damages" (page 7, line 36; page 8, line 2) or "potential impacts (page 7, line 38) or "potential damage" (page 8, line 6). "Would" should be changed to "could" in the entire section.

Page 8, Lines 1-10

The discussion of aggregate damage estimates and GDP losses would benefit from some estimates of the magnitude of GDP losses. The reaction of most economists to recent estimates of the size of losses associated with a 2.5 degrees Celsius warming for developed countries has been that they are comparatively small, particularly for losses to the market economy. 1.5 to 2.5% of GDP is less than one year's average growth. Higher impacts for developing countries is also misleading, because most of these countries will be at much higher income levels by the time a warming problem arrives. Indeed, it is not clear that changes in their economies over the coming decades have been taken into account in the estimates of GDP losses in developing countries.

Page 8, Lines 12-14

Delete " although a few estimates range up to \$125 per tonne of carbon". The economic literature referenced in Chapter 10 supports marginal damage

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estimates of \$5 to \$25 per ton, but does not support an estimate as high as \$125 per ton.

Page 8, Lines 12-17

This paragraph is not appropriate for the summary, and should be deleted. As the Chapter 6 discussion itself notes, cost estimates are sometimes developed using hypothetical and very simple damage functions based on assumptions rather than estimated damage streams. Moreover, in some cases the estimates are actually carbon tax estimates rather than damage estimates. It is not possible within a short paragraph to provide adequate characterization of the limitations in the summary and all the relevant assumptions. Additionally, since the estimates of "additional damage" come after the benefit-cost discussion, and particularly after discussion of Figure 3, text needs to be added that acknowledges that the existence of damage by itself is not a basis for more stringent policies.

If the paragraph is not deleted, it should identify the temporal range associated with the cost estimates cited. It should also be expanded or footnoted to acknowledge, for example, that U.S. gasoline taxes were recently raised by \$0.043 per gallon, several times the \$0.0035 per liter figure cited in footnote 13, or that European gasoline taxes are times higher than this. For balance, it also should be noted that the \$.0035 per liter estimate excludes consideration of enhancing sinks or trade-offs between reducing CO₂ and reducing other greenhouse gases, both of which may be cheaper alternatives. Therefore the \$.0035 per liter estimate would have to be characterized as an upper bound.

If the paragraph is not deleted, the following language could be added: "Note that some of these estimates are based on estimates of carbon taxes rather than additional damage done by current carbon emissions. The models generating these carbon taxes arrive at their estimates using "optimizing" functions that may or may not represent revealed social welfare. Additionally, these models generally do not include enhancement of carbon sinks, relative costs of reducing other greenhouse gases, cost effective adaptive action, and recent increases in gasoline or other energy taxes in many countries that exceed the hypothesized \$.0035 per liter figure, and therefore represent an upper bound estimate."

Page 8, Lines 19-20

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Add the following text at the beginning of the sentence starting on line 20:
"To cite just one example,". It is true that "climate change benefits of emissions reduction measures can be very complex to estimate", but the sulfate aerosol problem is hardly the only, or even the main, reason.

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Add some indication of the uncertainties associated with the cited damage estimates. For example, the statement is made that, "Small islands and low lying coastal areas are particularly vulnerable." This implies that ocean level rise may be a greater danger than drought or violent storms, but no rationale for this is provided. A range for estimated loss of GDP is presented, but that range is quite uncertain and, again, based on highly simplified analyses.

Page 8, Line 32

The sentence beginning on this line argues that only costs of adaptation or mitigation options are important for policy, not benefits as well. That is a major mistake. [CHECK Chapter 8]

Page 9, Line off

Figure 4 is misleading and should be redrawn. The double dividend idea is in part an argument that more distortionary and burdensome taxes should be replaced by less distortionary and burdensome taxes. All public finance economists would like to see taxes reformed in this way. But tax reform is not the same thing as climate change mitigation, and the two should not be thrown together.

Curve C implies that revenue recycling will indeed yield the economic "double dividend" that some have suggested. But scholarly opinion differs on the magnitude and even the sign of the dividend. Some results have suggested that Curve C may even lie above curve B.

Curve D implies that concentrations of greenhouse gases and ordinary (criteria) air pollutants change in the same way. This is true for some gases, but not for others. For example, as the IPCC 1992 summary concludes, sulfate aerosols reduce radiative forcing in the short run; reducing sulfate aerosols would increase thus add to global warming. This means that curve D may well lie above Curve C (and therefore above Curve B).

If the figure is to be used, it should be accompanied by a statement that it is only schematic, and that the magnitudes of the effects displayed, and even relative locations of the curves, could differ from those shown.

Page 9, Lines 14-17

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Delete the sentence beginning "Some analysts ...", which suggests a policy that economists do not endorse. Economists set marginal benefit equal to marginal cost, not total benefits equal to total cost!

Page 9, Lines 14-17

Delete the sentence beginning on line 14. Alternatively, the text should explain what such a statement implies, by adding a sentence such as: "Such a strategy would involve adopting some policies that cost more than the incremental benefits that they produce."

Page 9, Lines 19-22

The statement (Page 9, line 20) that 10% to 30% of current consumption can be eliminated at negative to slightly positive costs is without foundation and does not summarize Chapters 8 and 9 correctly. The discussion in Chapter 8 and 9 is much more balanced than this, and cites substantial evidence that any reductions in emissions will be costly.

First, there is no top-down study that yields this results. Second, page 1 of Chapter 9 makes reference to "many studies showed savings..." without even a footnote to identify any of these bottom-up studies. Third, some of the bottom-up studies that are cited in the report indicate positive marginal costs -for example, see Chapter 9, page 21, lines 3-9 and Figure 9.1.2.2.3.4. Fourth, the conclusion appears to be inconsistent with the Other-OECD bottom-up results discussed on Chapter 9, page 19 (lines 4-6). Fifth, if this conclusion is limited to countries in transition, or developing countries, or specific circumstances where institutions or subsidies prevent market pricing of fuels, then this must be noted in the conclusion section. This statement is also repeated in section 9.4 on page 55, and also should be corrected there.

Moreover, Figure 4 is drawn incorrectly. Curve A should intersect the Y-axis at a positive cost, whenever there are prior tax distortions or there is a possibility that revenues will be spent on programs with returns less than their private costs. Lump-sum transfers cannot offset these costs.

Page 9, Line 29

This is an excellent point that is well supported by the literature and clearly belongs in the Summary for Policymakers.

Page 9, Lines 31-34

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This makes an excellent point concerning the value and importance of "no regrets" policies.

Page 9, Line 36

True -- there might be a reference to "top-down" vs. "bottom-up" models as well.

Page 9, Line 36

Estimates of costs do vary widely, and it is important that this be noted in the Summary for Policymakers.

Page 10, Line 7

Substitute "macroeconomic" for "long-run aggregate economic growth" models.

Page 10, Line 14-16

This is an important point that should definitely be provided to policymakers.

Page 10, Line 29

The phrase "where damages occur" should be "where damages may occur". WG I cannot say with surety that the model projections are correct.

Pages 10-12, Entire Section "Equity and Social Considerations"

Include a discussion of the cost to society of climate impacts which would occur if one assumed that all greenhouse gas emissions ceased today (this is the concept from the IPCC Technical Guidelines). It is clear that future societies will face a great "climate burden" and economic risk from climate impacts, regardless of the level of greenhouse gas emissions. The difference in liability between the costs of climate impacts with "business as usual emissions" and with "no further emissions" provides an estimate of the true benefit from emission reduction efforts. Since this concept is found in a recent IPCC document, it should be acknowledged and discussed in this one. Failure to discuss impacts in this way can lead to unrealistic assessments of future climate impacts (IPCC, Technical Guidelines for Assessing Climate Change Impacts and Adaptations, page 25, box).

In addition, the Summary for Policymakers should answer the question: have the climate impacts been assessed following the guidelines given by the IPCC, or has WG III verified that "many studies have assumed a fixed baseline, often failing to recognize that conditions in the future will be quite

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different from those at present, even in the absence of climate change." ?
(IPCC, Technical Guidelines, page 25, paragraph 1).

Page 10, Line 37

Population growth should be mentioned here as a factor. Suggested insert:
"Total emission increases arise both from increases in emissions per capita and from increases in population. Whether emission rights are to be distributed on a per capita basis, and whether countries will be rewarded for controlling population growth, must be addressed by future negotiations."

Page 10, Line 38

The judgment expressed, that "Issues of equity and efficiency can for the most part be separated," is a judgment not universally shared among economists. For example, in the area of taxes, it requires the limitation of taxes to lump-sum, non-distorting taxes, which is a limitation never achieved.

Page 11, Lines 1-10

Two additional bullets are needed:

- Enforcing the above distributions. Making international agreements truly operational and enforceable among sovereign nations is a difficult equity issue that needs to be acknowledged.
- Distributing the costs of impacts of climate change.

Page 11, Line 16

This is a good point. It needs to be acknowledged with respect to the discussion on page 6, line 16, indicating that these costs and benefits of climate change policies impact different countries and different groups within countries differently.

Page 11, Line 32

Left out on the list of reasons why the implications of climate change policies are different for developing countries is the fact that they are in the process of changing their production and consumption structures in ways that are of great importance for greenhouse gas emissions and the impact of climate change.

Page 11, Lines 23-25

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Differences in land use and population density matter as well, with respect both to the current "initial conditions" and future trends.

Page 11, Lines 30-31

Please retain this important point.

Page 11, Line 36

This paragraph should include a sentence such as: "However, past emissions will not have contributed much to ambient concentrations a century or more from now, when the impact of greenhouse gas concentrations are likely to be felt."

Page 12, Line 4

While there would clearly be losers if the climate changes, the report should acknowledge that there would be winners as well, even within most regions. Additionally, while the science of impacts is rudimentary, it is likely that many forms of adaptation and simple defensive mechanisms might well be inexpensive. As one of the Chapters points out, automatically compensating losers means that they will not undertake socially efficient levels of adaptation and avoidance. Also, the report should in a footnote acknowledge that: "Just as science cannot yet identify a global warming signal despite the fact that radiative forcing from anthropogenic greenhouse gas emissions is roughly that of a 50% increase in CO₂, it may be difficult to accurately identify future climate change 'winners and losers' because of other simultaneous changes and interactions between man and the environment."

Page 12, Lines 4-30

Delete the sentence that begins on line 12. It is political, procedural, and judgmental, and therefore inappropriate for an IPCC document. The role of IPCC is to inform policymakers about the science. The policymakers can then decide for themselves how to use the information.

Page 12, Line 10ff

Delete this paragraph, which calls for increased travel budgets for representatives of developing countries. It is out of place in a summary of the state of economic knowledge on climate change.

Page 12, Line 34 through page 14, line 15

This summary of Chapter 4 overstates the merits of the prescriptive approach relative to the merits of the descriptive approach, in two respects. First, both

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Chapter 4 and the summary overstate the difficulty of transferring capital to future generations via non-environmental investment, and ignore the difficulty of transferring capital to future generations via emissions reduction investments. Second, the summary does not even mention that the prescriptive approach is fundamentally based on value judgments that are strikingly at variance with the value judgments implicit in other observed policy choices.

Barring an event like the "Dark Ages," investments which expand the stock of technological knowledge cannot easily be squandered by future generations. Moreover, since the benefits of advancing technology are significantly a public good, it is not plausible that these benefits will somehow fail to help the particular individuals in future generations who may be most harmed by climate change. Likewise, investments in education, particularly of women, seem to produce self-sustaining social change which lowers population pressure, and this too has spillover benefits to all members of future generations. Thus some very important classes of non-environmental investments are likely to have enduring payoffs in future generations, and those payoffs are likely to be available to those who are ultimately most harmed by climate change.

Conversely, environmental investments we make now to reduce CO₂ emissions can be undone in the future, as long as oil, gas, and coal resources remain available to be used at some future date. Thus today's investment in CO₂ emissions reductions may be equally or more at risk of being squandered or "misappropriated" than investment in other kinds of non-environmental capital, particularly education and research.

As Chapter 4 acknowledges, the prescriptionist viewpoint is fundamentally an ethical position, shared (more or less) by many social scientists who are highly educated and wealthy, at least relative to the people likely to bear the cost of controlling CO₂. If the observed income redistribution policies of the world's governments are grossly inconsistent with the ethical norms of these individuals, the common sense explanation is that most of humanity does not share these ethical norms. While Chapter 4 at least acknowledges that this is possible, the Summary for Policymakers ignores this point entirely.

Significant changes in Chapter 4 would be required to address some of the above objections. Assuming this is not reasonable at this stage of the review cycle, the discussion of the prescriptive approach should include a critique

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(just as does the discussion of the descriptive approach). I suggest adding the following paragraph after line 35 on p. 13:

"The prescriptive approach incorporates value judgments made by its proponents concerning the weights that should be given to the welfare of the present generation relative to future generations. These value judgments appear to be inconsistent with value judgments implicit in present government policies regarding investment in research or education, income redistribution, and foreign aid policies. These inconsistencies suggest that the value judgments implicit in the prescriptive approach may not be widely shared."

In addition, since certain non-environmental investments are quite feasible, strike "be able to" on p. 14, line 1.

Page 12, Line 34

This statement incorrectly implies that the discount rate is the only tool used by economists to compare economic effects that occur at different points in time.

Comparisons of economic effects that occur at different points in time involve more than the use of the discount rate. There is a large literature on the subject ranging from classic articles by Paul Samuelson to the recent work of Avinash Dixit and Robert Pindyck which would contradict this sentence.

Page 12, Line 35-36

Revise this sentence to read, "The choice of discount rate is probably the single most important step..."

Our concern is with the phrase "proper discount rate", because there is no definitive answer to this question. Important considerations, both prescriptive and descriptive, are raised in the text, but economics cannot provide a definitive answer as to how the consumption of future generations should be valued. This is an issue of ethics and fundamental values (in the non-dollar sense of the word). The role of economics here is to clarify the issue more than to provide a numerical answer. To reflect uncertainty, consideration might have to be given to a recommendation of analysis with two different discount rates reflecting different views of the appropriate rate (theoretical versus opportunity cost approaches) rather than the suggested average of the two views.

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The differences in methods ascribed to the prescriptive and descriptive approach is not correct. Both require a social welfare function and both require intertemporal efficiency and consideration of opportunity costs.

The discussion of the social rate of time preference is confused, and to suggest that there is agreement on estimates of pure time preference and the social rate of time preference is quite wrong.

The decision rule proposed in lines 34 and 35 repeats an earlier mistake.

Page 13, Lines 11-27

Policymakers, many of whom are non-economists are likely find the very brief discussion of "social rate of time preference" difficult to grasp. The terms used in this section should be clearly and simply defined, and their relevance should be clearly stated.

Page 13, Line 29

Add "to" after important.

Page 13, Lines 29-35

The text seems to be saying that, where mitigation projects displace other investment, future consumption must be reduced by the consumption that the displaced investment projects would have generated, and that it is net consumption that is to be discounted with the social rate of time preference. This appears to be a compromise between using low social discount rates throughout the analysis and using the opportunity cost of capital throughout the analysis. However, what is done in practice is unclear. Any investment can be argued to displace some other investment that would generate (at least) the opportunity cost of capital. The discounting method suggested is likely to be both confusing and subject to manipulation. Thus, it should not be included unless a specific example is given to clarify the method proposed.

Page 14, Line 4

The notion of a global social rate of time preference implies incorrectly that there are perfect financial markets.

Page 14, Lines 1-3

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"... society is not likely to be able to set aside investments over the next three centuries and earmark the proceeds [for] the eventual compensation those adversely affected."

Society doesn't not necessarily need to set aside investments for eventual use as compensation. If we invest less in mitigating climate change now, and more in economic growth, more economic resources will be available to society in the future, and this is exactly what is necessary. Earmarking is a misleading issue. The compensation issue is not one of us setting aside a trust fund for future generations, but one of society in the future being prepared to redistribute its resources to compensate those most affected. In other words, the money does not need to be set aside in a fund now, it only has to be invested and not dissipated. The business of setting aside investments and earmarking proceeds is a false issue; the future redistribution mechanism cannot and does not need to be solved now.

Page 14, Line 4

The notion of a global social rate of time preference incorrectly implies that there are perfect financial markets.

Page 14, Line 7

A rationale is needed for this statement.

Page 14, Line 30

Rewrite. (e.g. Governments may consider the following criteria when selecting policies to address climate change: distributional...) Add enforceability as a criterion.

Figure 5

Because of varying initial conditions between countries, this chart should be presented in terms of improvement over time (perhaps using 2 or 3 year intervals), not as a 1993 snapshot.

Nevertheless, the Figure provides a valuable and clear way to illustrate in a single chart the total national [as l] as per capita emissions of carbon in CO2 in major countries. Still we have some concerns: 1) it would be clearer if the nations were ranked, probably in descending order by level of per capita emission (i.e., US, Canada, Australia...India, Africa), and 2) units are needed on the X axis (The caption says "Population, Billion," but there are no unit numbers.)

DRAFT OF Sunday, March 12, 1995

Figure 6

Because of varying initial conditions between countries, this chart should be presented in terms of improvement over time (perhaps using 2 or 3 year intervals), not as a 1993 snapshot. Also, the units for the X axis should be clearly stated. A ranking of some kind might work here as well as in Figure 5.

FACSIMILE COVER SHEET
OFFICE OF ECONOMIC POLICY

DATE: 24 FEB 95

NUMBER OF PAGES TO FOLLOW: 6

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COMMENTS/SPECIAL INSTRUCTIONS:

***** U N C L A S S I F I E D *****

SECTION I: BIOGRAPHICAL INFORMATION

Name: Joseph E. Stiglitz
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The following comments are on

Chapter 2: Decision Making Framework

SECTION II: SUMMARY OF COMMENTS

- Chapter is not yet in a form that can be reviewed by experts or governments.
- Chapter presents normative conclusions unsupported by scientific argument. This is not appropriate to a scientific assessment.
- Chapter fails to focus attention on its major conclusions; the conclusions it does highlight are often at variance with economists theory and empirical results.
- Logical foundation for many claims is shaky.
- Chapter does not make a balanced presentation of the issues.
- Writing is not up to the standard of a major IPCC publication.

SECTION III: DETAILED COMMENTS

Notes:

- 1) The rough state of the present draft makes it difficult to give helpful comments yet;
 - 2) These comments are only a small fraction of the many that could be offered. Addressing these comments alone without other major work would probably still not result in a chapter that would gain acceptance in the economics profession.
- p. <Summary, page unnumbered> 1. 23-24. Causal relationship not established.
 - p. 2, section 2.1.2. Uncertainties are summarized better in

Chapter 1; this list should be improved or deleted.

- p. 3, l. 2-5. "Some expect ..." This is what economists generally believe, and should be presented as the prevailing view.
- p. 3, point 3. Text leaves the impression that Cline's damage estimates, which have not received wide acceptance among economists, are the accepted values. Nordhaus, Tol, and Fankhauser have also published comprehensive damage estimates.
- p. 4, section 2.1.2.1. This paragraph assumes the conclusion.
- p. 5, l. 6-7. "... sea level rise in Indian subcontinent could be higher than in, say, North America." How would the Indian Ocean rise more than the Atlantic and Pacific Oceans?
- p. 5, l. 8. Insert words in bold: "... could have more or less impact ..."
- p. 5, figure 2.1. Delete temperature estimates. It is not the accepted view that for 2°C warming, damage would be "substantial." Also, graph appears to present probability density functions (but then what is the curve that starts highest on the probability axis?). If that is the case, the areas under the curves should be the same, the tails of the curves should extend to the left of the origin (implying some probability of benefits from warming), and other logical problems should be corrected.
- p. 5, figure 2.2. Probability of welfare impacts is irrelevant to the discussion. I suggest a graph of delta Temperature (x-axis) against delta Welfare (y-axis).
- p. 6, l. 32. Text missing.
- p. 7, l. 14-16. Assumes the conclusion, which may be wrong.
- p. 8, l. 10 ff. "... if humanity lived a lifestyle corresponding to about 0.66 tonne of carbon equivalent emissions per person, per year..." With no warning, sentence suddenly appears to endorse one side of a delicate political issue; out of place in a scientific assessment.
- p. 8, section 2.2.3. "... trend risk and not a sudden risk..." What does this mean? L. 28: "... higher abatement costs are justified in case of trend risk..." Why is this? Because CO₂ in atmosphere has an infinite lifetime?
- p. 9, l. 1. "Therefore, small but regular ... if not impossible." This may be correct, but it is not self-evident and does not fit here.

- p. 9, section 2.2.4. Why insert this political argument here? Political arguments belong in the INC.
- p. 11, l. 1. What is the "apex forum?"
- p. 11, l. 11. Change sentence: "To a few low-lying island states, climate change may threaten their existence. To oil exporters, climate change mitigation measures threaten their revenues."
- p. 11, l. 12. "Again, it concerns differently economists and environmentalists." What does this mean?
- p. 12, l. 7. Parry and Rosenzweig (cited) do not find large vulnerability in food supplies, contrary to impression left by text.
- p. 13, section 2.3.2.2. Economists will not take seriously this presentation of "Ecocentrism," e.g., "To put it sharply, humankind's abrogation [?] of decision making power's regarding nature is questioned. The ecocentric view proposes to curtail such decision making power... Equity is not only among human beings but also between human beings and other living species." In economics, value is generally defined with reference to willingness to pay. Resources have value because of someone's willingness to pay for their use (or even just for their existence). Section 2.3.2.2 appears rest its argument on the idea that a resource may have value to other species; do other species have a willingness to pay, apart from our willingness to pay to protect them or make them happy?
- p. 14, l. 20. "While the rich can argue ..." This political argument does not belong in a scientific assessment.
- p. 15, l. 6. "... the practice of discounting the future is severely questioned," etc. Sentence should be deleted, as Chapter 4 settles this issue. Also, Cline's estimate cited in first paragraph is not widely accepted by economists. This reference should carry a note to that effect, or should be deleted.
- "This substitutability assumption is highly questionable." This statement assumes the conclusion. The section should either make the case for its assertion, or be silent.
- p. 16, l. 4. "... then not doing anything is morally unacceptable." This is a moral judgement, not a statement of scientific agreement.
- p. 16, section 2.3.3.1. First paragraph should also note that cutting back on growth in the North -- for example as a result of climate change programs -- is likely to hurt residents of the South as well, through a drop in southern exports.

- p. 18, l. 5. "That is, due to delay in abatement, global risks are externalized." Alternatively, spending a lot now on the wrong programs could easily impoverish our descendants.
- p. 18, l. 25. "Thus risk tolerance of, say South should matter more than that of North." This conclusion is unsupported.
- "... homeless dying from heat stress ..." At least in the U.S. many more homeless die during winter than during summer.
- p. 18, l. 27. "Most models developed in the North do not effectively build in the perspectives of the South in adapting to climate change." Economic models, like physical models, should be value-free. Do we speak of Northern physics and Southern physics -- or just good physics and bad physics? An economic model may be flawed for several reasons: it may be poorly formulated, or based on flawed estimation results; it may be internally inconsistent, or may predict poorly. We may say that it fails to reflect available resources, or misstates likely behavioral responses, but not that it does or does not "build in perspectives of the South."
- p. 19, section 2.3.3.4. This section presents political conclusions as if they were scientific conclusions, e.g., "Currently there are many countries whose use of environmental space far exceeds their justifiable share of that space. J. Parikh has indicated that these privileges are worth US \$70 billion per year."
- The section also presents apparently scientific conclusions that are probably wrong, e.g., "The cost of delay in emission reduction (by the North) in terms of South's foregone opportunities to development is substantial." (see Richels and Edmonds 1993, Schlesinger and Zhang 1992, etc.)
- p. 20, section 2.4.1. This section -- and indeed the entire chapter -- inappropriately presses a certain political point of view. For example, l. 28: "Remember that if 550 ppm is chosen, it is difficult to go back to 440 ppm, but vice versa is possible."
- p. 22, above table. "This is referred as purchasing power parity." Wrong use of the term.
- p. 27, section 2.5. Why begin with the quote from Dowlatabadi and Morgan? Placed at the top of the section "Economic Formulation of Individual and Collective Decision Making", it suggests that the most important consideration is the prejudices of the decision makers. These may indeed be important, but the contribution of scientific analysis lies elsewhere.
- p. 28, l. 17-20. "... Bayesian approach, which represents information in the form of conventional, necessarily precise,

probability distributions ..." The writer appears to be unaware of the voluminous and widely disseminated work on decision analysis that has appeared since the late 1950s.

- p. 29, l. 26 ff. "From such a standpoint, a subjective probability can always be formulated as a 'bet on a certain event'." What does this mean?

- p. 29, l. 12. "In sum, climate change seems to imply a certain degree of irreducible unpredictability beyond the common categories of risk and uncertainty." Climate change is a difficult analytical problem, but not for this reason. Decision analysis has been applied to many questions involving great uncertainty.

- p. 31, l. 3. "The most catastrophical fluctuation yet analyzed ..." Why describe this event as catastrophic? I don't believe we have any evidence of any large die off of plants or animals, or of an unusual number of species extinctions.

- p. 31, l. 7. "The discrepancies between the paleoclimatic observations of abrupt change and the smooth gradual warming prognosticated by today's models could not be more pronounced." This is false and irrelevant. GCMs can in general show rapid changes.

- p. 32, l. 13. "...low probabilities attached to large potential damages." This is not a fatal problem, as the text claims.

- p. 35, l. 8. "... there might be as many rationalities as there are cultures." This may or may not be true, but it adds nothing to an assessment of the state of scientific knowledge.

- p. 38, l. 11 ff. The writer does not seem to be familiar with the terms that economists use in describing risk. E.g.: "A risk averter can be a diversifier and spread his portfolio over different assets--or a "plunger" and invest wholly in bonds and money." "Cautiousness: Defined as decreasing risk aversion ... (Schaifer, 1961; after Pratt, 1995)." It would be useful to consult a basic text such as Raiffa (1964).

- p. 38, l. 26 ff. This section strings together terms from decision theory like cranberries on a Christmas tree, with no explanation of their meaning, and no attempt to relate them. Throwing around jargon and padding it with scholarly references will not help most readers.

- p. 40, l. 10. "... trade securities insurance contracts." Of what relevance is this here?

- p. 40, l. 15. "According to Shlyakhter et al. (1995), those risks that fall below a particular threshold of probability--and thereby are ignored by a particular group or society--are called

"de minimis" risks."[emphasis in original]. This is not a research result but merely a definition.

- p. 40, l. 29. "... 5 percent chance of a climate-related catastrophe within their lifetime." It is difficult to imagine what climate-related catastrophe could occur by, say 2050.

- p. 44, l. 6. "... implies that the industrialized nations should take strong measures..."[emphasis in original]. This is a political conclusion. Why is it included here?

- p. 54, l. 14. "... would it not be cautious to insure ...?" This statement assumes the conclusion, and inappropriately makes a policy recommendation.

- p. 55, l. 5 ff. Paragraph is highly speculative and does not belong here.

- p. 55, footnote 19. "The more risk averse you are, the more you will insure (Chichilnisky, 1994)."[emphasis in original] This is not a research result.

- p. 56, l. 8. "Economics is about differences in preferences leading to trade (Chichilnisky, 1994)." This is not a research result.

- p. 56, l. 9. "Betting on climate states ..." What is this sentence saying?

- p. 56, l. 23. "To illustrate, the Alliance of Small Island States (AOSIS) has proposed that an "International Insurance Pool" be established...." Here, and in many other places, a tangential discussion deflects the reader's attention from the major arguments. This should go in a footnote or be deleted.

- p. 60, l. 4. "An operational model to analyze the optimal portfolio of climate change policies for a country is not feasible given the state of our knowledge." No economic model will produce an error-free, bullet-proof answer to anything; on the other hand, several models already exist to examine precisely the question stated. The writer may want to consult recent papers of the Energy Modeling Forum at Stanford (for projects EMF-12 and EMF-14) for more details.

- p. 64, figure 2.8. What is the message of this figure?

TO: JOE STIGLITZ, CEA
FROM: RAY SQUITERI, TREASURY

cc: SK

SECTION I: BIOGRAPHICAL INFORMATION (slight corrections 2/20)

Name: Joseph E. Stiglitz
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Fax: 202-395-6958
E-mail: none

The following comments are on The Executive Summary

SECTION II: SUMMARY OF COMMENTS

- Economists do not subscribe to the idea of an absolute standard or a safe minimum standard. If these ideas are to be introduced, it must be clearly stated that most economists reject these ideas.
- Summary needs to state an important conclusion of recent economic research: near-term decisions along an optimal path will be the same (i.e., modest-cost mitigation measures) for a wide range of ultimate target concentrations.
- While the Summary reflects the view that one should go beyond no-regrets policies, it leaves the impression (without explicitly so stating) that immediate costly actions are in order; this is inconsistent with the chapters to follow.
- Summary omits important points made in Summary to Chapter 1.

SECTION III: DETAILED COMMENTS

- p. 2 l. 4-6. "The ultimate objective ... provides guidance ..." Statement is tantalizingly incomplete. What guidance? My understanding of recent decision analysis research (e.g. Richels and Edmonds 1993) is that for concentrations between 450 and 750 ppmv, the least-cost path requires only modest reductions in emissions in the near term. See comment on the bulleted list (p. 4), below.
- p. 2 l. 21. "However, these decisions are not very sensitive to the level ..." Paragraph says the optimal solution is robust, but does not say what that optimal (least-cost) solution is. I believe the key research result is that modest emissions reductions in the short run are consistent with a wide range of desired equilibrium concentrations.
- p. 2 l. 25ff. Are these actions being recommended? Text leaves the impression that they are. Most analysts would agree that the most cost-effective of these measures should be undertaken

without further scrutiny (negative-cost measures to reduce emissions, phasing out of existing distortionary policies, etc.). Less cost-effective measures (e.g. fuel switching) should not be undertaken while we still have more efficient alternatives to choose from. I suggest a sentence indicating the actions that would be included along an optimal path: in the short-run, governments should reduce energy subsidies and eliminate other distortions in energy markets; accelerate R&D; and promote joint implementation. Beyond this, for target concentrations within the range of 450 to 750 ppmv, only mildly costly mitigation actions are indicated.

- p. 4 l. 1. " ... \$50 per tonne of carbon ..." This number seems to have been pulled out of a hat, and contradicts results reported in other chapters that \$5 to \$20 per ton is the right range. Delete \$50 or make it consistent with later chapters. In this and other places, the chapter leaves the (incorrect) impression that economists agree that high-cost near-term mitigation are justified.
- p. 4 l. 19ff. Change sentence to read "A country's climate change actions will also reflect its objectives, economic conditions, and constraints."

The list of considerations that follow confuses conditions particular to a given country, and conditions that are more universal, such as international equity. More generally, the list of possible factors does not add much to the Summary, and does not reflect any consensus about the most salient factors. I suggest deleting remainder of paragraph. (Otherwise, it could be used as an excuse for less developed countries not to take any action.)

- p. 5 l. 14. Figure 1 is incorrect and should be redrawn. The paths indicated do not represent optimal paths, but simply conjectures reported in some scenario comparisons. An important recent result, referred to obliquely on p. 2, is that the optimal (least-cost) path is the same in the near term whether the ultimately desired concentration is 450 or 750 ppmv. I suggest asking John Weyant to produce a revised graph consistent with the results of EMF-12 and EMF-14.
- p. 6 l. 1. I continue to believe that since at this point in the report, there is no accepted goal of eventual concentration levels, it would be better simply to describe the thresholds: (a) if the eventual goal is stabilization at the level of.... then emission reductions of this magnitude are likely to be required; (b) if the eventual goal is.... then.....; (c) On the other hand, if the eventual goal is stabilization at a level of or above, then it is likely that no further substantial interventions will be required, at least before.....

- p. 6 l. 6-8. Before "The current commitments [of Annex I countries] are not sufficient to stabilize atmospheric concentrations of CO² ..." insert: "In the absence of some commitment by other countries" Without the insert, the reader is left to conclude that the answer is to tighten up on the commitments of Annex 1 countries. As several chapters demonstrate, without a commitment by the LDCs, atmospheric concentrations cannot be stabilized.
- p. 6 l. 14ff. To restate an earlier criticism: Few economists would subscribe to, let alone know what the report is talking about, when referring to a "safe minimum standard."

All of these standards can be embraced in cost benefit analysis, incorporating different degrees of risk aversion. Using this kind of language would significantly interfere with the creditability of the IPCC report in the economics community and beyond, and is likely to be sharply criticized by some governments. This is particularly true, given that the term "dangerous anthropogenic interference..." is nowhere defined. The order of magnitude of anthropogenically induced climate changes is smaller than those which have occurred naturally in the past. While it is true that environmentalists often argue for the absolute standard, and it is sometimes used in establishing health standards, most economists are strongly opposed to these approaches.

The "safe minimum" approach uses two terms that few economists would find meaningful: "reduce the risks of climate change to an acceptable level at an acceptable cost."

In the discussion of cost benefit, you should explicitly say that risk considerations can and should be brought into the cost benefit analysis.

If reference is made to the absolute standard and/or safe minimum standard, it must be clearly stated that most economists do not accept these approaches and argue for the use of a cost benefit approach, with appropriate attention paid to the treatment of risk.

Figures 3(a) and 3(b) are particularly troublesome, as they draw attention to statements in the text about acceptable and unacceptable risks, while nowhere providing a formal way of quantifying the effects or valuing those effects relative to the economic impacts.

- p. 9 l. 4ff. Figure 4 is misleading and should be redrawn. The double dividend idea is in part an argument that more distortionary and burdensome taxes should be replaced by less distortionary and burdensome taxes. All public finance economists would like to see taxes reformed in this way. But tax reform is not the same thing as climate change

mitigation, and the two should not be thrown together.

Curve C implies that revenue recycling will indeed yield the economic "double dividend" that some have suggested. But scholarly opinion differs on the magnitude and even the sign of the dividend. Some results have suggested that Curve C may even lie above curve B.

Curve D implies that concentrations of greenhouse gases and ordinary (criteria) air pollutants change in the same way. This is true for some gases, but not for others. For example, as the IPCC 1992 summary concludes, sulfate aerosols reduce radiative forcing in the short run; reducing sulfate aerosols would increase thus add to global warming. This means that curve D may well lie above curve C (and therefore above curve B).

If the figure is to be used, it should be accompanied by a statement that it is only schematic, and that the magnitudes of the effects displayed, and even relative locations of the curves, could differ from those shown.

- p. 10 l. 27ff. Either this section or somewhere else needs a statement to the effect that:

Efficiency will require full participation of the developing countries, including some forms of commitments for emission reductions. Without some form of commitment, actions by the developed countries can be partially, largely, or more than completely offset by actions in the developing countries.

- p. 10 l. 37. Population growth needs at least a mention. Suggested insert:

Total emission increases arise both from increases in emissions per capita and from increases in population. Whether emission rights are to be distributed on a per capita basis, and whether countries will be rewarded for controlling population growth, must be addressed by future negotiations.

- p. 11 l. 36. This paragraph should include a sentence such as: "However, past emissions will not have contributed much to ambient concentrations a century or more from now, when the impact of greenhouse gas concentrations are likely to be felt.
- p. 12 l. 10ff. This paragraph, which calls for increased travel budgets for the LDC representatives, seems out of place in a summary of the state of economic knowledge on climate change.
- Points to be added to Executive Summary, taken from Conclusions of Chapter 1:

- The risks of climate change are highly asymmetrical, with a large probability of a small loss, and a small probability of a large loss.
- Even in the presence of significant uncertainty, this asymmetry, plus the principles of risk aversion and portfolio balancing provide the rationale for going beyond no-regrets policies to those that incur net costs.
- Climate change demands a decision process that is sequential, can respond to new information with mid-course corrections, and can include insurance, hedging, and the option value of alternative courses of action.
- The challenge today is to identify short-term strategies in the face of long-term uncertainty. The question is not, what is the best course over the next 100 years, but rather, what is the best course for the next few years, knowing that a prudent hedging strategy will allow time to learn and change course.
- In an interrelated global economic system, an attempt to reduce greenhouse gas emissions in one region or one sector of the economy may be offset by increases in other regions or sectors.
- Efficiency requires that emission reductions occur where their cost is lowest, irrespective of who bears the financial responsibility.

Lisa's
copy

February 17, 1995

To: J. Stiglitz
From: S. Kane
Subject: IPCC status: comments for government review and beyond

I have spoken with Ray, Randy Lyon, and Mike about preparing comments on WGIII draft chapters and executive summary. We are striving to get comments compiled and ready for your review by cob Tuesday February 21st or Wednesday 22nd.

Here is the current version of the executive summary and the comments that I submitted on our behalf. I have marked the comments that Jim Bruce accepted.

on the previous version.

Future Strategy for the executive summary:

Bob Watson knows about the problems with the executive summary based on comments from me, Richard Moss, and others. He suggested setting up meetings between you and Jim Bruce at the next lead authors meeting taking place next month in Paris. I believe this makes good sense.

To make the most of the interactions with the Canadians and other members of the Bureau, we should have as many wording changes and section replacements as possible.

Government Review:

Ed Haspel's office is coordinating the formal government review. Your comments will be compiled with those of all reviewers. During the week of March 6th, interagency meetings will take place to select the changes that we will be advanced in the government review.

Paris lead authors meeting:

To be prepared for the lead authors meeting, we will need to be fully conversant with the government's review package. Moreover*, we will need to have additional suggestions, text changes, and strategies to share with the WGIII Bureau. One idea might be to send materials or talk with the Korean co-chair, since he seems well versed in economics and would agree with our ideas.

**SUMMARY FOR POLICYMAKERS
SECOND ASSESSMENT REPORT, WORKING GROUP III**

The Context

This assessment of the socio-economic literature related to climate change has been undertaken in the context of sustainable development as reflected in the Framework Convention on Climate Change. This Convention is now a key element in the decision making framework on climate change (Chapter 2).

The ultimate objective of the Convention is "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 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."¹

The Convention specifies that to achieve this objective the "Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures should be cost-effective ..."²

Each of the Annex I Parties is committed to "adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs."³

¹ *United Nations Framework Convention on Climate Change*, Article 2. The Intergovernmental Negotiation Committee (INC) requested that the IPCC assess the scientific evidence that might help policy makers interpret Article 2 of the Convention. This topic will be addressed in the IPCC's Second Assessment Report to be published in 1995.

² *United Nations Framework Convention on Climate Change*, Article 3.3.

³ *United Nations Framework Convention on Climate Change*, Article 4.2(a).

The Convention thus incorporates, and the literature assessed in this report (Chapters 1, 2, 8 and 9) supports a strategy of "act - then learn - then act" where the actions to address climate change are periodically adjusted in light of new knowledge and developments. The ultimate objective of stabilizing atmospheric concentrations of greenhouse gases, although not yet operationally defined, provides guidance for policymakers when considering initial actions to address climate change.

The Convention establishes a collective decision making process where actions, reflecting their common but differentiated responsibilities, are agreed upon by the Parties. The report identifies a number of general principles and findings that are relevant regardless of the decisionmaking process, such as those concerning the design of cost-effective policies. It should be recognized that a collective decision making process may not reach the same conclusions as analyses that adopt a global optimization perspective.

A Portfolio of Possible Actions to Limit Climate Change

The precautionary principle (Article 3.3) and the estimated damages due to current emissions of greenhouse gases (Chapter 6) argue for action beyond "no regrets" measures.⁴ The decisions to be taken in the near future will necessarily have to be taken under great uncertainty. However, these decisions are not very sensitive to the level at which atmospheric concentrations are ultimately stabilized and can be adjusted based on experience, new knowledge and other developments.

Actions analysed in the literature which countries can take, individually or jointly, to limit climate change and its impacts include:

- implementing low cost measures to reduce emissions of greenhouse gases. There is broad agreement that in most countries there are some measures, such as energy efficiency, that can reduce emissions of greenhouse gases at negative to slightly positive costs (Chapter 9). Achieving such reductions may require policy intervention;
- phasing out existing distortionary policies, such as some subsidies to fossil fuels, that reduce welfare and, directly or indirectly, increase

⁴ No regrets measures are those whose benefits, such as reduced energy costs and reduced emissions of conventional pollutants equal or exceed their cost, *excluding* the benefits of climate change mitigation.

greenhouse gas emissions.⁵ Global emissions reductions of 5% to 20% have been estimated for removal of energy subsidies worldwide (Chapter 11);

- implementing fuel switching measures, such as coal-fired generation to natural gas, to reduce emissions of greenhouse gases (Chapters 9 and 11);
- implementing measures to enhance sinks or reservoirs of greenhouse gases;⁶
- instituting forms of international cooperation to limit greenhouse gas emissions such as joint implementation and technology transfer;
- undertaking research aimed at better understanding the causes and impacts of, and adaptation to, climate change. Economic studies suggest that such research can yield high returns by reducing the uncertainty as to the most cost-effective actions to address climate change (Chapter 2);
- conducting technological research aimed at enhancing energy efficiency, minimizing emissions of greenhouse gases from continued use of fossil fuels, and developing commercial non-fossil energy sources. The timing and availability of cost-effective of non-fossil energy technologies is one of the major determinants of addressing climate change in the long run (Chapters 9 and 10);
- planning, and implementing as necessary, measures to adapt to the consequences of climate change; and
- developing institutional mechanisms, such as insurance, to share the risks of damages due to climate change (Chapters 1 and 2).

⁵ Energy prices that do not reflect the externalities associated with energy use can be considered a distortionary policy. Under some circumstances, kerosene subsidies to reduce fuelwood use, can increase welfare or decrease emissions (Chapters 2 and 11).

⁶ Some actions to increase sinks may have indirect effects, such as a change in albedo. In such cases the net effect of the measure should be considered.

An illustrative simulation of global options with marginal costs of up to \$50 per tonne of carbon suggests about 50% of the total reduction/sequestration would be forestry measures, 25% would be through energy conservation and efficiency improvements, and the remainder would come from a mix of renewable energy use, fuel switching, CO₂ removal and disposal, and nuclear energy. The mix of options and the magnitude of the reduction/sequestration relative to current emissions varies significantly by region (Chapter 7).

Opportunities for Action Vary by Country and Over Time

Each country's approach to climate change can be represented as a portfolio of actions that reflects its objectives, economic conditions and constraints. The actions taken by a particular country may reflect considerations such as their cost, secondary benefits, the impacts on different socio-economic groups, international equity, intergenerational equity, the expected damage due to climate change or sea level rise within the country, and economic strategies based on development of new technologies. The size of the investment will reflect the country's obligations under international agreements, adjusted for resources transferred to or received from other countries, as well as domestic goals and priorities. A country's climate change actions will also reflect other priorities aimed at sustainable development, including eradication of poverty, increased levels of education, protection of environmental resources, and improved human health.

Governments can and should *adjust* their portfolio of climate change actions in response to new information and developments. Indeed, both the investment in climate change limitation and the mix of policies will probably change over time. That does not imply complete flexibility. Many of the measures involve capital and technology commitments with long life times. Reversing such commitments could be relatively costly, however that risk would be incorporated into the analysis of the options before the commitments are made. This is particularly important for developing countries and countries with economies in transition where significant infrastructure investments will be made over the next few decades.

Stabilization of Greenhouse Gas Concentrations

Climate change impacts are related to the stock of greenhouse gases (concentration) in the atmosphere, rather than the annual emissions, hence the ultimate objective of

the Convention is to stabilize atmospheric concentrations of greenhouse gases.⁷ Currently, the atmospheric concentration of CO₂ is about 360 ppmv; the pre-industrial concentration was about 280 ppmv.⁸ The danger of significant harmful effects from climate change increase as the concentration of greenhouse gases in the atmosphere rises. The discussion below focuses on the effects associated with stabilization of atmospheric concentrations of CO₂ within the range of 350 to 750 ppmv "could be attained only with global anthropogenic emissions that eventually drop to substantially below 1990 levels."⁹

The IPCC's six emissions scenarios assume virtually no new policies specifically designed to reduce greenhouse gas emissions (Chapter 12).¹⁰ Three scenarios that span the full range (IS92a, IS92c and IS92e) are compared with the illustrative profiles of anthropogenic emissions consistent with stabilization of atmospheric concentrations at levels between 350 and 750 ppmv in Figure 1. These emissions profiles indicate that at some stage major reductions of CO₂ emissions (of the order of 50% of current emissions) will be required to eventually stabilize concentrations. The pattern and timing of reductions of emissions can have a major effect on the overall costs of mitigation. "Emissions for all stabilization levels studied are lower than those for IS92a and e, even in the first few decades of the 21st century. Emissions for the IS92c Scenario lie between the emissions [profiles] which ... achieve stabilization at 450 and 550 ppmv."¹¹

⁷ It is not clear from the Convention whether the ultimate objective is to stabilize the atmospheric concentration of each gas at a particular level or to stabilize greenhouse gas concentrations, expressed in terms of CO₂ equivalents, at a particular level.

⁸ ppmv is parts per million by volume, a measure of concentration.

⁹ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 4. Analyses of emissions profiles consistent with stabilization of atmospheric concentrations of CO₂ at levels lower than 350 ppmv or higher than 750 ppmv are presently not available in the literature.

¹⁰ *The 1994 Special Report of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 7.

¹¹ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 15.

Stabilization of the atmospheric concentrations of other greenhouse gases at today's levels requires lesser reductions, but nevertheless reductions, of the emissions of those gases.¹² Thus, stabilization of atmospheric concentrations of greenhouse gases will require very low population and economic growth rates (as assumed for IS92c), a major "natural" change in energy technologies, or intervention to reduce emissions and enhance sinks. The effect of the initial commitments of Annex I Parties, assuming that they are achieved and continued to 2050, is shown in Figure 2. The current commitments are not sufficient to stabilize atmospheric concentrations of CO₂, except under scenario IS92c which has emissions below current commitments (Chapter 12).

Applicability of Cost-Benefit Analysis

A stabilization objective could be based upon an absolute standard, an affordable safe minimum standard, or a cost-benefit analysis, the approach favoured by most economists. These approaches are illustrated in Figure 3. The absolute standard approach would define a maximum atmospheric concentration of greenhouse gases that is considered to constitute "dangerous anthropogenic interference with the climate system" on the basis of predicted changes to the climate system or of the predicted impacts of climate change *regardless of the cost of achieving this concentration*. Environmental standards designed to safeguard human health are often established using this approach.

The safe minimum standard approach would specify a maximum atmospheric concentration of greenhouse gases based on an assessment of the risks associated with different atmospheric concentrations and the costs of achieving those concentrations. The standard would seek to reduce the risks of climate change to an acceptable level at an acceptable cost. Cost-benefit analysis attempts to value the impacts of climate change and seeks the atmospheric concentration where the marginal value of the net impact is equal to the marginal cost of abatement.

Working Group III was specifically requested to assess whether cost-benefit analysis is applicable to climate change. Cost-benefit analysis was broadly interpreted to include traditional project level cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis and decision analysis. The traditional cost-benefit approach is

¹² *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 18 and 20.

depicted in Figure 3(c). Cost effectiveness analysis seeks to find the lowest cost option to achieve a specified objective; the marginal cost of abatement curves in Figures 3(b) and 3(c) represent cost-effective options. Multi-criteria analysis is designed to deal with problems where benefits and/or costs can not be valued; it could be used for the approaches described in Figures 3(a) or 3(b), where non-economic effects are brought into the analysis, but without a formal way of valuing those effects relative to the economic impacts. Decision analysis focuses expressly on making decisions under uncertainty and conceptually could be used in any of the approaches described in Figure 3.

Cost-benefit analysis (broadly defined) could contribute to resolution of three questions facing decisionmakers. These are:

- By how much should emissions of greenhouse gases be reduced or sinks of greenhouse gases be enhanced?
- When should emissions be reduced or sinks be enhanced?
- What methods should be employed to reduce emissions and enhance sinks?

Because of the large uncertainties surrounding estimates of damages due to climate change (Chapter 6) and the costs of mitigation (Chapter 9) make it difficult in practice to rely solely on cost-benefit analysis for the selection of an appropriate stabilization objective at this time. Still, the information provided by cost-benefit analysis is critical in making judgements not only about that decision, but also about the timing of emission reductions and the design of cost-effective strategies. Integrated assessment models best suited to such analyses are quite new (Chapter 10).

However, cost-effectiveness analysis can and should be used to evaluate adaptation and mitigation options.

The Benefits of Limiting Greenhouse Gas Emissions and Enhancing Sinks

The benefits of limiting greenhouse gas emissions and enhancing sinks are the climate change damages avoided. Since some increase in atmospheric concentrations from the current level is virtually inevitable, some impacts and damages due to climate change seem unavoidable.

The literature contains a few aggregate (across all sectors and regions) estimates of the damages associated with a climate characterized by a globally-averaged 2.5°C warming. The estimates suggest that if such warming occurred now it would impose net damages equivalent to 1.5% to 2.5% of world GDP on the present world economy (Chapter 6). The regional variation in climate change damage would be substantial. Damage in developing countries is estimated to be at least 2% with a maximum central estimate of 9% of GDP for some regions. Small islands and low lying coastal areas are particularly vulnerable. Climate changes of this magnitude are not expected to be realized for some decades and damages in the interim would be smaller.

Most estimates of the additional damage done by CO₂ emitted *now* range from \$5 to \$25 (1990 \$ U.S.) per tonne of carbon, although a few estimates range up to \$125 per tonne of carbon.¹³ The models used to develop these estimates are simplistic and are poor representations of dynamic processes, but they reflect the current state of the art. The wide range of estimates reflects variations in models, scenarios, discount rates and other assumptions.

Climate change benefits of emissions reduction measures can be very complex to estimate. Some energy efficiency and fuel switching measures simultaneously reduce emissions of greenhouse gases and sulphate aerosols. The negative radiative forcing from sulphate aerosols is significant. "Tropospheric aerosols have a lifetime of only a few days ... So the atmospheric concentration of aerosols responds rapidly to changes in emissions. Control of sulphate emissions ... would immediately reduce the amount of aerosols in the atmosphere."¹⁴ A recent model analysis finds that replacement of fossil fuels with carbon-free energy sources leads to lower temperature increases in the long run, but higher temperatures in the interim due to the reduced sulphur emissions (Chapter 10).

Costs of Response Options

What matters from a policy perspective is the net cost (total cost adjusted for secondary benefits and costs) of a mitigation or adaptation option apart from its

¹³ A tonne is a metric ton or 1,000 kg. \$5 per tonne of carbon corresponds to approximately 0.35¢ per litre of motor gasoline.

¹⁴ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC, Summary for Policy Makers, IPCC, 1994, p. 24.*

climate change benefits (Chapter 8). A wide range of estimates of the costs of response options is found in the literature. The wide range is due in large measure to differences in assumptions. Alternative views of the costs of emissions reduction are shown schematically in Figure 4. Curve A assumes that there are no reducible market or government induced imperfections; thus there are no "no regrets" options. Curves B, C and D all assume market failures or government induced imperfections exist in one or more sectors that can be corrected by policies that reduce costs and also lower greenhouse gas emissions. Curve B includes only measures whose direct benefits yield net cost savings. Curves C and D incorporate secondary economic and environmental benefits into the calculation of the net cost of the option.

The potential for "no regrets" policies is represented by the line OD₂. The area OD₁D₂ is the potential net benefit to society of implementing all "no regrets" measures. Some analysts have argued that measures with a positive cost should be implemented to the point where the total net cost to society is zero, i.e. to a point D₂>D₁ such that the area under curve D between D₁ and D₂ is equal to that area OD₁D₂.

Despite significant differences in views, there is agreement that some energy efficiency improvements (perhaps to 10% to 30% of current consumption) can be realized at negative to slightly positive costs in many countries, depending on the baseline assumptions and the time frame (Chapter 9). Measures to reduce greenhouse gas emissions often yield additional economic benefits (such as reduced traffic congestion) and/or environmental benefits (such as reduced emissions of acid rain and urban smog precursors). The magnitude of these secondary benefits depends on local circumstances. Studies for Norway, the U.K. and some other countries indicate that secondary benefits could offset 30% to 100% of abatement costs (Chapter 6).

The long run costs of addressing climate change will ultimately be determined by the rate of capital replacement, the discount rate and the effect of research and development. Implementation of "no regrets" measures will increase the time available to learn about climate change and to bring new technologies to the market. Infrastructure decisions are crucial because they can enhance or restrict future options and different choices can lead to very different cost outcomes.

Estimates of the costs of stabilizing CO₂ emissions vary widely as a result of differences in the baseline scenario, the estimated long run costs of mitigation measures, and the date for achieving the stabilization objective. Differences among models are less significant than differences in the underlying assumptions. Indeed widely differing methods can produce quite similar results when calibrated to the

same set of input assumptions, such as the cost and availability of different energy sources.

Top-Down and Bottom-Up Models

In the jargon of modelers "top-down" models are aggregate models, often macroeconomic models, that analyse how changes in one sector of the economy affect other sectors and regions. Early top-down models tended to have little detail on energy consumption, especially at the technology-specific level, but explicit treatment of behaviour and economic interactions. In contrast, "bottom-up" models tended to describe energy consumption in detail, however consumer behaviour and interactions with other sectors of the economy tended to be down played.

This simple characterization of top-down and bottom-up models is increasingly misleading as more recent versions of each approach have tended to provide greater detail in the areas that were less developed in the past. This convergence means that differences in model results are increasingly driven by differences in input assumptions rather than model structure. Most results available in the literature do not reflect the effects of this convergence of model structure since the evolution in model structure is a relatively recent occurrence.

Nevertheless, differences in model structure remain important as different models are best suited to answer different types of questions.

Equity and Social Considerations

Equity considerations are an important aspect of climate change policy and feature prominently in the Convention. Inaction is likely to impose costs on future generations and on regions where damages occur, often regions with low greenhouse gas emissions. Action to address climate change is likely to impose some costs on the present generation. Since actions to address climate change are deliberate, explicit decisions can be made as to how to share these burdens.

The Convention recognizes the differentiated responsibilities of the Parties, but it does not include an explicit formula for sharing the costs of addressing climate change. It also lists factors to be considered in determining how the burden should be shared and provides for development of mechanisms for sharing the burdens. Issues of equity and efficiency can for the most part be separated. Cost-effective strategies can be developed embracing a variety of ways for sharing the burden.

Equity issues involved in addressing climate change may be divided into four categories:

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

The Convention offers some guidance on all of these issues, but doesn't resolve any of them.

A variety of ethical principles, including the importance of meeting people's basic needs, are relevant to sharing the burden of addressing climate change. No single rule will command universal agreement. Furthermore, any arrangement may need to change over time to continue to be perceived as equitable and to take new developments into account. Analysts can not prescribe how the burden of addressing climate change should be shared, they can only clarify the implications of different principles (Chapter 3).

Countries differ in terms of current greenhouse gas emissions (see Figures 5 and 6), vulnerability to climate change (Chapter 6), wealth, resource endowments, and institutional capacity to respond effectively. The Convention provides that these circumstances be reflected in differentiated responsibilities. Developed countries have undertaken commitments through the Convention for technology transfer and contributions to the financial mechanism.

A rigid "north-south" delineation of equity issues is inappropriate and may be highly damaging in the long run, although it permeates much of the debate at present. The implications of climate change for developing countries are different than those for developed countries because the former are generally poorer, have contributed much less to past emissions and still emit much less per capita, have shorter policy time-horizons, often weaker institutions, other urgent priorities, and are generally more vulnerable to climate change. However, 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, over the next century some developing countries will continue to make marginal

contributions to the problem, while emissions from others may well start to dominate it.

Countries (such as low lying coastal regions and islands 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.

All Parties have equal status under the Convention. Procedural equity also requires that all Parties be able to participate effectively in international negotiations related to climate change. Assistance to enable developing country Parties to participate effectively in negotiations would increase the prospects for achieving effective, lasting and equitable agreements on how best to address the threat of climate change.

Intergenerational Equity

Climate policy raises particular questions of equity among generations, because future generations are not able to influence directly the policies being chosen today that will affect their well-being and because it might conceivably not be possible to compensate future generations for reductions in well-being that might be caused by current policies.

Sustainable development and the concept of an environmental trust have been proposed to address intergenerational equity. Sustainable development would meet "the needs of the present without compromising the ability of future generations to meet their own needs." An environmental trust, as proposed by Brown-Weiss, would require each generation to ensure that the next inherits "a planet and cultural resource base at least as good as that of previous generations."

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. The choice of discount rate is important in climate change analyses because the time horizon is extremely long and the abatement costs tend to come earlier than the benefits of avoided damages. 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 literature on the appropriate discount rate for climate change analysis can be divided into two approaches. The prescriptive approach asks whether a particular action would make society better off, given a plausible social welfare function. The discounting rules specify how consumption at different dates should be valued to provide the correct answer to that question. The descriptive approach focuses on intertemporal efficiency and opportunity costs.

The *prescriptive* approach discounts consumption accruing to different generations using the "social rate of time preference" (SRTP). The SRTP is composed of two components, "pure time preference" and the incremental welfare derived from future consumption:

- Pure time preference is a reflection of impatience. Although there is debate in the literature, values tend to range from zero to 1%
- The incremental welfare of future consumption accounts for rising per capita income over time and the resulting decline in the incremental welfare (marginal utility) derived from the higher future consumption.

Depending upon the values assumed for the different parameters, values for the SRTP on a global basis tend to fall between 0.5% and 3.0% per year. Developing countries may have much higher (10% to 20%) rates of SRTP due to high rates of per capita income growth or high elasticities of marginal utility for small increases in per capita income from subsistence levels.

It is important remember that in making choices concerning alternative policies, that while differences in consumption at different dates will be valued using the SRTP, those differences in consumption will be affected by the opportunity cost of capital, which typically is in the range of 7% to 15% real. Thus, where mitigation projects displace other investments yielding higher returns, the mitigation projects typically will not be chosen unless they yield returns at least equal to those on the displaced capital.

The *descriptive* approach to the discount rate looks at returns to investments in the real world. Market rates of return usually exceed the values estimated for the SRTP. Conceptually, funds could then be invested in projects that provide a higher return with the proceeds being used to increase future consumption. In the context of

climate change, however, society is not likely to be able to set aside investments over the next three centuries and earmark the proceeds the eventual compensation of those adversely affected. Determining the discount rate on the basis of descriptive or market considerations yields a global rate in the range of 3% to 6% real, with rates declining within this range as income rises.

Increasing the discount rate because of risk is generally inappropriate.

Policy Instruments

A clear distinction needs to be drawn between actions to reduce the impacts of climate change and actions to reduce emissions. The former also involve consideration of adaptation policies.

Policy instruments designed to mitigate climate change need to be assessed at the international and domestic levels. Such instruments can help participating countries comply with multilateral commitments on climate change abatement, including international transfers of resources and technology. The international and domestic policy instruments need not be the same, but international agreements may constrain the choice of domestic policy instruments.

The policy instruments available internationally and for adoption by groups of countries include: non-tradeable quotas, tradeable quotas, joint implementation, harmonized domestic carbon taxes, international carbon taxes, various international standards and technology transfer. Domestic policy instruments include carbon taxes, tradeable permits, deposit-refund systems, technology standards, performance standards, product bans, voluntary agreements, energy taxes, energy efficiency subsidies, non-fossil fuel subsidies, and removing existing market distortions.

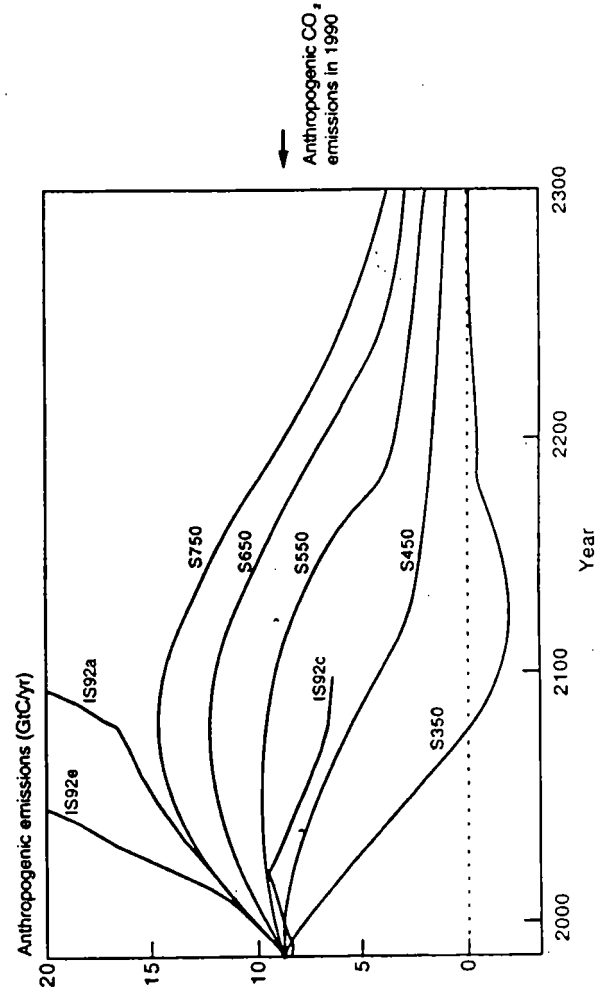
Among the criteria that governments can consider when selecting from among the available policy instruments are: distributional (including intergenerational) equity, flexibility in the face of technological change and new information, efficiency or cost-effectiveness, compatibility with the institutional structure and existing policies, and understandability to the general public. A mix of instruments may be needed to achieve the best results. Governments may apply different criteria with different weights to the selection of international and domestic policy instruments.

Cost-effectiveness should always be a criteria for selecting policy instruments, but it becomes more important at both the international and domestic levels as the abatement effort becomes more stringent. The economic literature suggests that the

more economically efficient instruments include carbon taxes and tradeable quotas. Although there are implementation problems associated with each, both can be made consistent with equitable international burden sharing. The consequences of climate change policy will be determined by the choice of policy instrument as well as the design and implementation of those policies. The effectiveness of policies will also depend on their acceptability to the public and to governments.

Figure 1

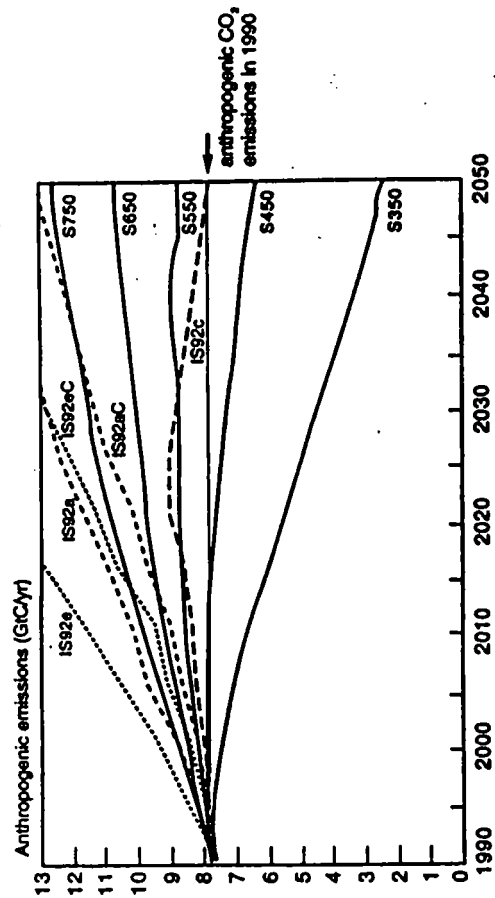
Illustrative Anthropogenic Emissions Profiles of CO₂ Leading to Stabilization at Concentrations of 350 to 750 ppmv Using a Mid-range Carbon Cycle Model and CO₂ Emissions for the IS92a, c and e Scenarios



Source: 1994 Special Report of the IPCC

Figure 2

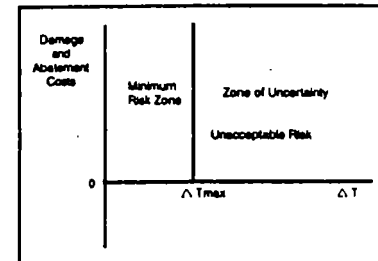
Comparison of IPCC Emissions Scenarios Adjusted for Current Commitments and Emissions Profiles Consistent with Stabilization of Atmospheric Concentrations of 350 to 750 ppmv



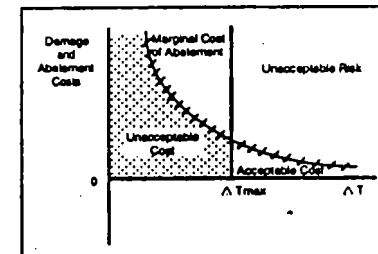
Legend: IS92aC (IS92aC) is scenario IS92a (IS92a) adjusted for current commitments by Annex I Parties extended to 2050
Source: Based on Chapter 12 (adjusted for current commitments by Annex I Parties extended to 2050)

9/30/02, 10:00 AM

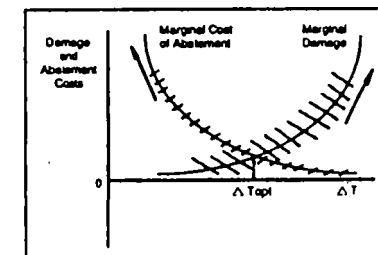
Figure 3
Global Warming, Cost-Benefit Analysis and Sustainable Development



(a) Absolute Standard Approach



(b) Safe Minimum Standard Approach



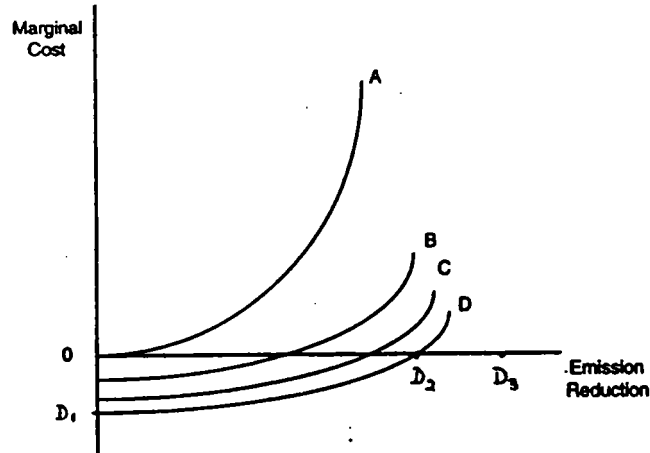
(c) Cost-Benefit Approach

Source: Chapter 6

9/30/02, 10:00 AM

Figure 4

Alternative Views on Costs of Emission Reduction



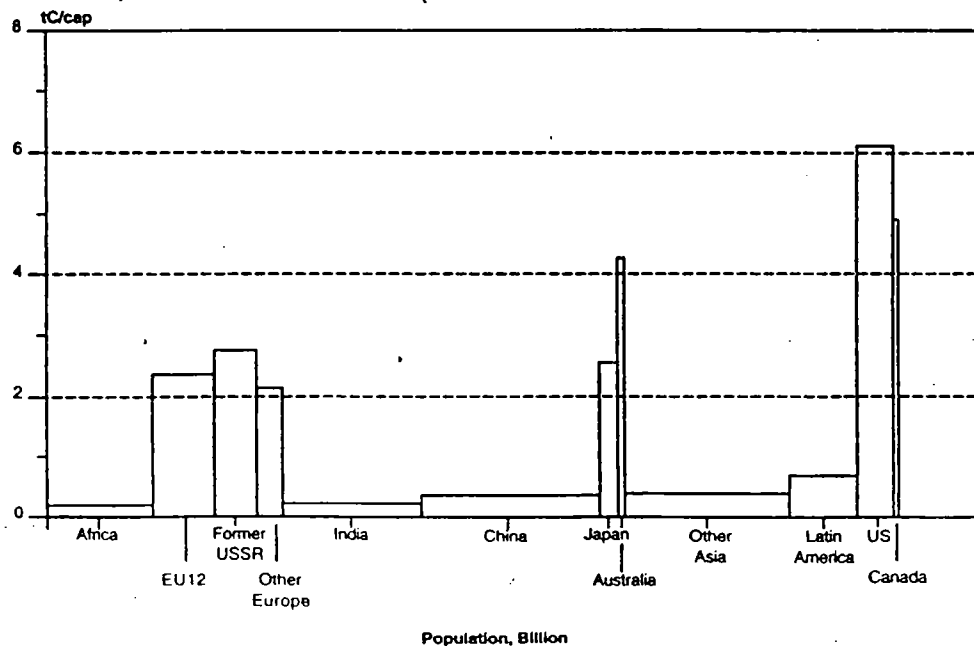
- A - No reducible market imperfections *and/or distortion*
- B - "Negative cost potential" achieved
- C - Curve B plus "economic double dividends"
- D - Curve C plus "environmental double dividends"

Source: Chapter 8

910025 Apr 1995

Figure 5

Carbon Emissions per Capita and Population, 1993

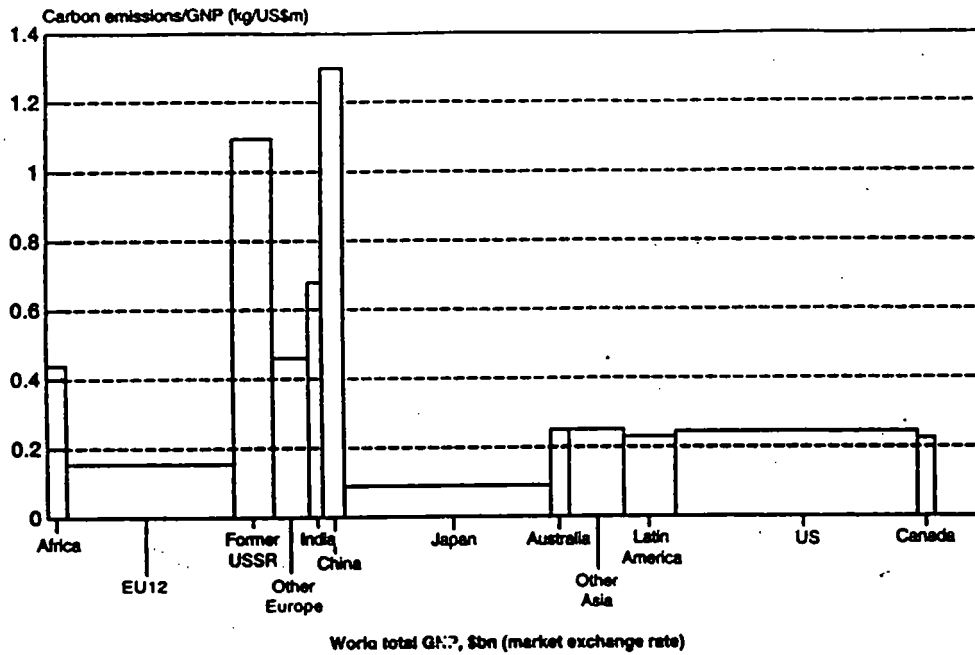


Source: Derived by M. Grubb from BP Statistical Review of World Energy 1994 and World Population Prospects, UN

910025 Apr 1995

Figure 6

Carbon Emissions/GNP and Total GNP, 1992



Source: Chapter 3

January 25, 1995

To: E. Haites

From: J. Stiglitz
S. Kane

Subject: Comments on the Summary for Policy-Makers

Thanks for letting us take a look at the policymaker summary. We have combined our comments to give you the broadest response, hopefully providing useful insights based on technical expertise and institutional knowledge of the IPCC as it applies to economics.

Our recollection is that the previous draft is, in some ways, both stronger and more complete. Enriching this version of the summary with greater discussion of the no-regrets strategy (from a technical standpoint) and its place in the decision process; important research areas to help policy makers understand more fully the uncertainties in the climate and economic systems; the underlying assumptions in the emissions scenarios; the challenges and benefits from conducting research using integrated frameworks like integrated assessment; summary of abatement cost estimates in the literature; and the importance of discounting would improve the summary considerably.

A continuing problem that we have observed is the overall "tone" of the summary, which too often is normative. The summary should be simply a presentation of scientific evidence for the use of policymakers, telling policymakers what they should do. To the extent that there are explicit policy statements that need to be made, they should be of the form, "If this is your objective.....then the least cost way of addressing this problem is....."

Moreover, there are some ideas that get considerable attention in the policymakers summary which are far from the consensus view--indeed, we would describe them as explicitly rejected by 99% of all economists. We should either drop these perspectives (saying somewhere in the introduction that there are other views, discussed in the papers, but the policymaker summary focuses on the "consensus perspectives.") or introduce them briefly, with the above described caveat. Unless we say that, the report will not be taken seriously, and the entire report will be dismissed out of hand as not reflecting the overall judgment of the disciplines.

We appreciate the difficulty in summarizing material for policy makers. Please let us know how we can be of further assistance.

COMMENTS ON SUMMARY FOR POLICY MAKERS

X p. 1. par. 1.

Context for the report is the economic principles and research findings on climate change, with particular focus on topics relevant to the Convention – not sustainable development from the perspective of the Convention.

Delete paragraph.

modified
p.2. par. 1.

Statement of intentions of the Convention should not be made.

Delete "The Convention thus implies and".

X Many considerations guide policy makers in undertaking policy actions.

Delete last sentence.

✓ p. 2 par. 2

Little of the literature assessed in the report comes from the framework of a single global decision maker. Replace beginning with second sentence:

The report identifies a number of general principles and findings that are relevant regardless of the decision making process, such as those concerning the design of cost effective policies.

X p. 2. par. 3.

Estimates of damages are rough. Concerns center on non-market effects.

Insert "non-market" before damages on line 17.

sec 1.9
No-regrets needs to be more fully explained. Many countries are starting with these measures and should be able to see the actions in the context of decision-making.

✓ p. 2 bullet 2

There is not consensus on the desirable of the use of regulatory instruments. The sentence is too normative.

Delete last sentence.

✓ p. 3. lines 1-2

Replace sentence beginning with "Emissions" with:

Global emissions reductions of 5% to 20% have been estimated for removal of energy subsidies worldwide (chapter 11).

p. 3. bullet 5

Last sentence is very important. Begin with

The timing and availability of cost-effective non-fossil energy technologies ...

p. 3 fn. 5

First sentence does not read well. Second sentence may not be correct, because of the "sink" capacity of forests.

p. 4 par. 1, line 7-8

Replace 1st sentence with:

"Each country's approach to climate change can be represented as a portfolio of actions that reflects its objectives, economic conditions, and constraints."

The list of considerations that follow mix up conditions that are particular to a given country, and those which are more "universal" such as "international equity."

More generally, the laundry list of possible factors does not seem to say much, and does not reflect any consensus about what are the most salient factors. I suggest deleting sentence beginning on line 12-15 (it is too normative and could be used directly as an "excuse" for less developed countries not to take any action.) The last sentence should delete "will" and add "and protection of other environmental resources and human health." to the end of line 17.

p. 4. line 24

Replace "should" with "would"

p. 5 after line 4

Replace sentence lines 1-4 with

"Clearly, the dangers of significant harmful effects from global warming increase the greater the concentration of greenhouse gases in the atmosphere. The discussion below focuses on the effects associated with concentration levels in the order of magnitude of...."

p. 5. par 2.

Insert the following before "in Figure 1"

"at levels between 350-750 ppm range"

Delete the last sentence (in quotes) and add the following sentence

Studies cited here establish that the pattern of timing of reductions of emissions can have a major effect on the overall costs of mitigation. More paced emission reductions reduce the costs associated with premature retirement of capital and allow taking further advantage of technological improvements that are likely to become available in the future.

p. 5. par. 3

X Delete paragraph and Figure 2. We consider it problematic to discuss "initial commitments of Annex I parties" in the summary; another approach could be to qualitatively discuss "aims" (rather than commitments) included in the Convention under the presumption that they are extended beyond 2000 and are actually achieved. Because of the amount of discussion that would have to be added to convey this idea correctly, we do not believe it should be included in the summary (especially not with figures).

The discussion referring to alternative scenarios will not be of much use to most policymakers, who will not be apprised of the assumptions that underlie them. If one refers to them at all, one should spell out their key assumptions. The working group on scenarios has made a clear distinction between the uses of the scenarios: direct policy analysis we do not believe was condoned. Since the analysis underlying both figures 1 and 2 will attract so much negative reaction, yet not provide any indication about which levels are preferable (and how to decide), we strongly believe they should not be included in the summary. We have seen the extreme sensitivity to the discussion of the scenarios and their use in the following meetings: discussions of the work plan for the yet to be formed working group in Nairobi 1992, 1st Working Group III meeting in Montreal spring 1993, and at the plenary for the working group approving the scenarios chapter fall 1994.

We should not be recommending that 650 ppm or lower (or any other level) be a stabilization target (see p. 6 lines 2-4).

Recommended approach: Since at this point in the assessment effort, there is no accepted goal of eventual concentration levels, it would be better simply to describe the thresholds:

(a) if the eventual goal is stabilization at the level of.... then emission reductions of this magnitude are likely to be required; (b) if the eventual goal is.... then.....; (c) On the other hand, if the eventual goal is stabilization at a level of or above, then it is likely that no further substantial interventions will be required, at least before.....

p. 6 first full par.

X J. Stiglitz has criticized this par. before. His words: Few economists would subscribe to, let alone know what the report is talking about, when referring to a "safe minimum standard." All of these standards can be embraced in cost benefit analysis, incorporating different degrees of risk aversion. Using this kind of language would significantly interfere with the creditability of the IPCC report in the economics community and beyond, and is likely to be sharply criticized by some governments. This is particularly true, given that the term "dangerous anthropogenic interference..." is nowhere defined. The order of magnitude of anthropogenically induced climate changes is smaller than those which have occurred naturally in the past. While it is true that environmentalists often argue for the absolute standard, and it is sometimes used in establishing health standards, most economists are strongly opposed to these approaches.

Safe minimum uses two terms that few economists would find meaningful: "reduce the risks

of climate change to an *acceptable* level at an *acceptable cost*."

In the discussion of cost benefit, you should explicitly say that risk considerations can and should be brought into the cost benefit analysis.

If reference is made to the absolute standard and/or safe minimum standard, it must be clearly stated that most economists do not accept these approaches and argue for the use of a cost benefit approach, with appropriate attention paid to the treatment of risk.

✓ p. 6. par. 3. line 33

... in Figures 3(a) or 3(b), where non-economic effects of climate change are brought into the analysis, but without the development of a formal way of quantifying the effects and/or valuing those effects relative to the economic impacts.

✓ p. 7 First sentence of first full par. I do not believe that there is a consensus on this conclusion. Better to say

"Because of the large uncertainties ... of non-market damages due to ... , it is difficult in practice to rely solely on cost benefit analysis for the selection of an appropriate stabilization objective at this time. Still, the information provided by cost benefit analysis is critical in making judgments not only about that decision, but also about the timing of emission reductions and the design of cost effective strategies."

Delete the last two sentences. The next to the last sentence is somewhat misleading. One can easily extrapolate the benefits and costs associated with different levels of atmospheric concentration (climate change) within a range, at least, based on currently available studies.

✗ p. 7 par. 4

Need to add sentence that states that the estimates of damages for many economies in the temperate and Northern climate zones are small, and in some cases possibly negative.

✓ line 25 add "a few aggregate (across all sectors)" after contains.

✗ line 27 replace "between ... (end of sentence)" with anywhere from less than 1% to 2.5% .

✗ line 29 replace "at least 2% with a maximum central estimate of 9% for GDP for some regions" with "higher than OECD countries". Little is known about the impacts in the developing countries and the chapter on social costs rightly points out the strong uncertainty yet qualitatively describes why the impacts are thought to be higher than that found in OECD countries.

✓ p. 8 par. 2

line 25 replace "market imperfections" with "no reducible market or government induced imperfections"

✓ line 26 insert "or government induced imperfections after "market failures" ...

p. 9. lines 6-7

Replace last sentence with "Findings from a few studies suggest that secondary benefits could offset 30% to 50% of abatement costs in Norway and up to 100% of abatement costs in the United Kingdom."

p. 9 first full par.

Discussion would be enhanced by a brief discussion of the most important differences in "input" assumptions.

p. 10 1st full par.

Discussion of costs of action versus inaction is too simplistic; there are costs of both to future generations.

Delete 1st and 2nd sentence.

p. 11, 1st full par.

We should not be giving recommendations about appropriateness of issues under discussion by the international negotiators.

Delete 1st sentence.

p. 11 3rd full par.

We should not be advocating assistance.

Delete paragraph.

Somewhere in this section one needs to add:

"Issues of equity and efficiency can, however, for the most part be separated. Cost effective strategies can be developed embracing a variety of ways for sharing the burden. Efficiency will require full participation of the developing countries, including some forms of commitments for emission reductions. Without some form of commitment, actions by the developed countries can be partially, largely, or more than completely offset by actions in the developing countries."

p. 11, around full par. 1. line 8

Insert

Total emission increases arise both from increases in emissions per capita and increases in population. The extent to which "rights to emission" should be distributed on a per capita basis, and the extent to which they should reflect country's obligations given other considerations and circumstances will be questions that will also have to be addressed by future negotiations.

p. 11 Add somewhere on this page

However, the extent to which pass emissions will have contributed to ambient concentrations 100 or more years from now, when the impacts of greenhouse gas concentrations are most likely to be felt, are limited.

p. 12

Add after second par. (replacing last sentence of par.)

"It is important to bear in mind that in making choices concerning alternative policies, while the differences in consumption at different dates will be valued using the SRTTP, those differences in consumption will themselves be affected by the opportunity cost of capital, which typically is in the range of 7% to 15% real. Thus, where mitigation projects displace other forms of investment yielding these higher returns, they typically will not be chosen unless the mitigation projects themselves yield returns at least equal to those on the displaced capital."

p. 12 Second par.

Replace lines 16-22 with the following text:

Two approaches have been used to derive a discount rate. As notes above, the discount rate for policy analysis may exceed zero even if the rate of pure time preference is assumed to be zero if the level of income is projected to rise, as is implicit in the emissions scenarios. The *prescriptive* (or normative) approach begins from ethical considerations, taking as zero the rate of pure time preference. The approach includes starting with the opportunity costs of capital (or market rates of interest) in calculating the cost of an investment, arrives at a new stream of changes in consumption (possibly including environmental goods) and applies a social rate of time preference to the consumption stream.

The *descriptive* (or market) approach, on the other hand, looks at returns to investments in the real world. Using a discount rate for consideration of climate policy that is lower than for other public or private investment decisions risks diverting investment away from higher-return investments in physical capital and education that would benefit future generations more than climate mitigation (which is only desirable at a lower discount rate). A wide variety of discount rates can be observed in the markets. Real return on equity in industrialized countries averages around 6 percent. For individual consumers in industrialized countries, real returns to investments in education and real costs of borrowing are significantly higher. In developing countries, required rates of return are higher than in industrialized countries because financial markets and financial intermediation are less well developed.

In summary, an approach that focuses on prescriptive or normative considerations alone, assuming that the pure rate of time preference for intergenerational decisions is set at zero, supports discount rates in the neighborhood of 1.5 percent. Allowing for a positive rate of pure time preference would add to this value, in some calculations approaching 3 percent. An approach that emphasizes descriptive or market considerations in the

Modified

determination of a discount rate favors the adoption of real rates between 3 and 6 percent, with rates declining within this range as income grows.

Increasing the discount rate because of risk is generally inappropriate.

p. 13, last par line 23
Insert after "quotas."

only
1st
system
taken

Though there are implementation problems associated with each, both can be made consistent with equitable international burden sharing. On the other hand, most economists believe that technology standards and other regulatory mechanisms are among least cost effective ways of attaining emission reductions.



MEMBER

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

February 15, 1995

Handwritten signature/initials

Dear Erik:

This is a quick response to your February 14 inquiry. The basic procedure that we advocate involves converting risks (benefits and costs) into certainty equivalents, and then discounting those certainty equivalents at the risk free rate. Thus, you are perfectly correct that costs and benefits may not be treated symmetrically--the risk premia may well differ--but they would still be discounted at the same rate.

I hope this answers your question.

With best wishes,

Handwritten signature of Joseph E. Stiglitz
Joseph E. Stiglitz

Erik Haites
IPCC
145 King Street, West
Suite 1002
Toronto, Ontario M5H 3X6
CANADA



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

145 King Street West, Suite 1002, Toronto, Ontario M5H 3X6 CANADA

Tel: (416) 369-0900 Fax: (416) 369-0922

Handwritten initials: AC, RS, SP

MEMORANDUM

TO: Chapter 4 Writing Team

FROM: Erik Haites *[Signature]*

RE: Multiple Discount Rates?

DATE: February 14, 1995

My limited understanding of finance theory is that each cost stream should be valued using a discounted rate that reflects its own risk. If this is correct, shouldn't mitigation costs and benefits of reduced climate change damage be discounted at different rates? That raises the question of the appropriate values of the discount rates for different cost and benefit streams, which is the principal subject of the existing text. My sense, however, is that the existing text focuses on the value of the appropriate discount rate for the benefits stream. A, presumably shorter, discussion of the appropriate value of the discount rate for the cost stream would be useful. If the discount rates for the cost and benefit streams differ, it would be interesting to note that all of the available benefit-cost studies use the same discount rate for both the cost and benefit streams.

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Post-It™ Fax Note	7671E	Date	Feb. 14	Pg. 1
To	Joseph Stiglitz	From	Erik Haites	
Co./Dept.		Co.		
Phone #		Phone #		
Fax #	(202) 395 6958	Fax #		

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DATE: 02/15/95

NUMBER OF PAGES: 02

FROM: Prof. José Goldemberg

TO: Erik Haltes

FAX: (001-415) 369-0922

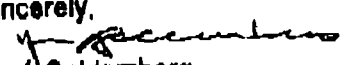
MESSAGE:

Dear Erik,

1. Thanks for Bert Bolin's comments which, I understand, result from the Second Askö Meeting.
2. Writing Team I was quite aware of most of the points made by Bolin and we tried to address them in Section 1.5.3.1 (Revising National Accounts) and 1.6 (Sustainable Development). Bolin's paper in page 4 - top paragraph and footnote 10 say that.
The idea of "delinking" economic growth and environmental degradation is well known and the empirical evidence shows that for "local" and "regional" pollution such delinking is taking place (except for municipal waste, which in principle could be solved by recycling). It's only for "global pollution", i.e. changes in the composition of the atmosphere that things do not go that way. May be one could highlight that.
3. However the only novelty I see in the paper is the idea of "ecosystem resilience" which could be incorporated in our Overview, particularly a reference to Vitousek et al (Bioscience 36, 368, 1986) which attempt to quantify the problem.

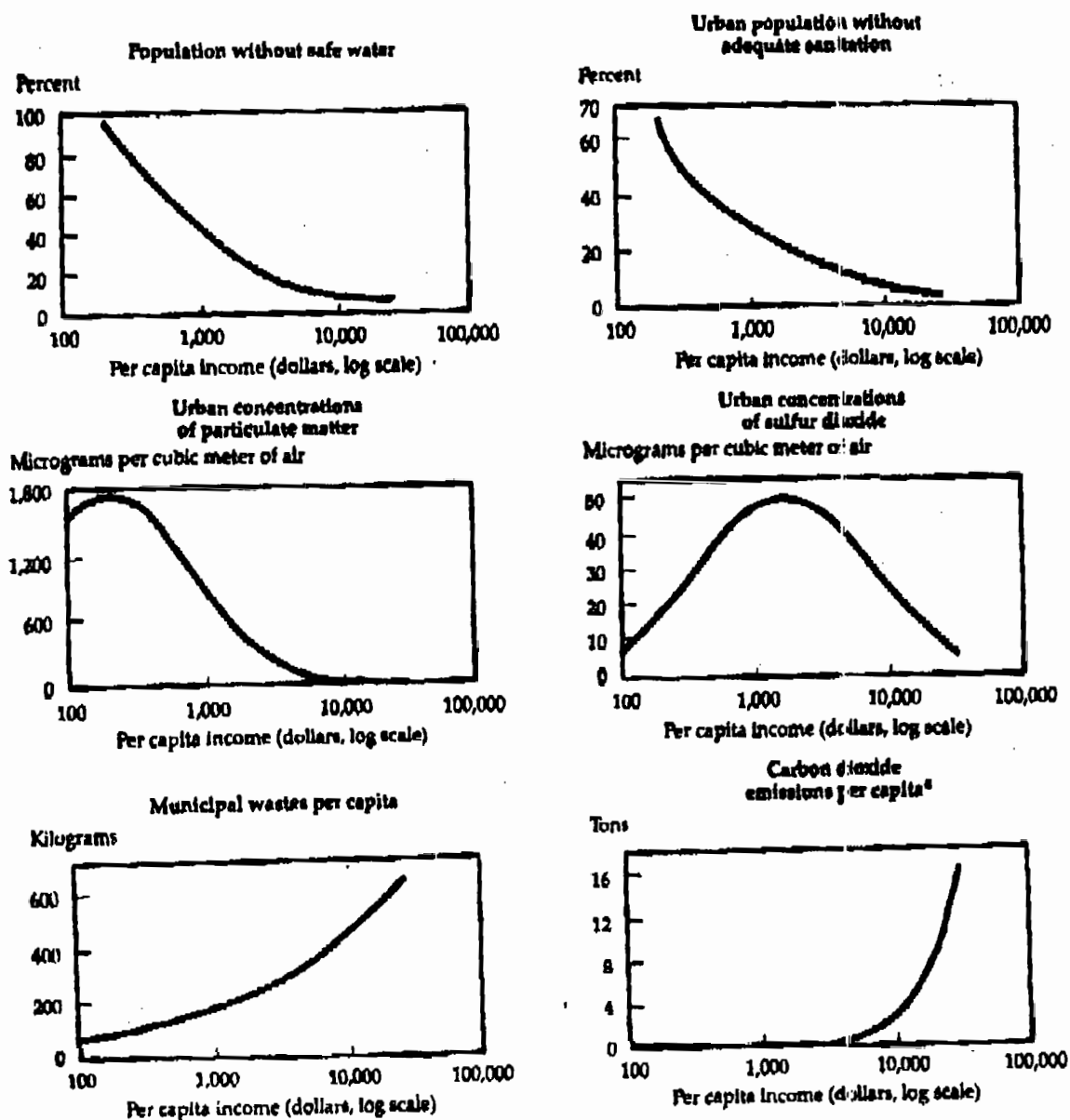
Please retransmit this FAX to Joe Stiglitz (and to Bolin if appropriate).

Sincerely,


José Goldemberg

Environmental problems may worsen or improve with income growth, some worsen, then improve

Figure 4 Environmental indicators at different country income levels



Notes: Estimates are based on open country regression analysis of data from the 1980s.

^a Emissions are from fossil fuels.

Source: Ghaffar and Pandeyopadhyay, background paper, World Bank data.



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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cc: KS
S/K

TO: Writing Team 1
FROM: Erik Haites *Erik*
RE: Comments from Bert Bolin
DATE: February 14, 1995

The attached are comments from Bert Bolin on issues that should be addressed in the Summary for Policymakers. However, to be included in the Summary, it has to be discussed in one of the chapters, would you consider covering these issues in your chapter?

Post-It™ Fax Note 7671E		Date Feb 15	# pages 12
To Joe Stiglitz	From Erik Haites		
Co./Dept.	Co.		
Phone #	Phone #		
Fax # (416) 395 6958	Fax #		

Economic Growth, Carrying Capacity, and the Environment

by

**Kenneth Arrow, Bert Bolin, Robert Costanza, Partha Dasgupta,
Carl Folke, Buzz Holling, Bengt-Owe Jansson, Simon Levin, Karl-
Göran Mäler, Charles Perrings, and David Pimentel¹**

¹ K. Arrow is in the Department of Economics, Stanford University, Stanford, CA 94305, U.S.A. B. Bolin is in the Department of Meteorology, University of Stockholm, 106 91 Stockholm, Sweden. R. Costanza is Director of the Maryland International Institute for Ecological Economics, University of Maryland, Box 38, Solomona, MD 20688 USA. P. Dasgupta is in the Faculty of Economics, Cambridge University, Cambridge CB3 9DD, UK. C. Folke is in the Beijer International Institute of Ecological Economics, Royal Swedish Academy of Sciences, Box 5005, S-104, 05 Stockholm, Sweden. C.S. Holling is in the Department of Zoology, University of Florida, Gainesville, FL 32611, USA. B-O. Jansson is in the Department of Systems Ecology, University of Stockholm, 106 91 Stockholm, Sweden. S. Levin is in the Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544, USA. K-G Mäler is Director of the Beijer International Institute of Ecological Economics, Royal Swedish Academy of Sciences, Box 5005, S-104, 05 Stockholm, Sweden. C. Perrings is Head of the Department of Environmental Economics and Environmental Management, University of York, York, YO1 5DD UK. D. Pimentel is in the Department of Entomology, Cornell University, Ithaca, NY 14853, USA.

National and international economic policy has usually ignored the environment. In areas where the environment is beginning to impinge on policy, as in the GATT and NAFTA, it remains a tangential concern, and the presumption is often made that economic growth and economic liberalization (including the liberalization of international trade) are, in some sense, good for the environment. This notion has meant that economy-wide policy reforms designed to promote growth and liberalization have been encouraged with little regard to their environmental consequences, on the presumption that these consequences would either take care of themselves or could be dealt with separately.

Here we discuss the relationship between economic growth and environmental quality, and the link between the carrying capacity of the environment and economic activity (2). We first focus on the driving forces behind environmental degradation and their connection with the process of economic growth. This is followed by a discussion of the link between economic growth, carrying capacity and ecological resilience. We conclude by reconsidering the scope for addressing environmental degradation through a strategy of economic growth.

Economic growth, externalities, and the environment

The general proposition that economic growth is good for the environment has been justified by evidence that there exists an empirical relation between per capita income and some measures of environmental quality, similar to the Kuznets relation between income and income inequality (3). More particularly, as income goes up it has been shown that there is increasing environmental degradation up to a point, after which environmental quality improves. That is to say, the relation has an "inverted U" shape (Figure 1 provides an example).

So far the relation has been demonstrated only for selected pollutants (4). However, as it is consistent with the notion that environmental quality is a luxury good (as their income rises people will spend proportionately more on it), economists have conjectured that it applies to environmental quality generally (5). It is, however, important to be clear about the conclusions that can be drawn from these empirical results. They do indicate that economic growth may be associated with improvements in some environmental indicators as income increases. But they do not imply either that economic growth is sufficient to induce environmental improvement in general or that the environmental effects of growth may be ignored.

First, the inverted U relation between income and environmental quality has been shown to be valid for pollutants involving substantial local short-term costs (sulphur, particulates, fecal coliforms, etc.) but the jury is still out on pollutants involving

longer-term and more disperse costs (such as carbon dioxide), and the accumulation of stocks of waste that have no immediate, apparent, environmental costs are unambiguously increasing functions of income (6). The relation is also less likely to hold wherever there are significant stock feedback effects (7). Resources with stock feedback effects are those for which the stock of the resource affects production, such as soil or forests. The kinds of air pollutants for which the inverted U relation has been shown do not have these strong stock feedback effects. More generally, the relation is less likely the more the relevant indicator is a consequence of transboundary or intertemporal externalities (7).

Second, the inverted U relation — like the notion of demographic transition — predicts that growth will, at some point, induce a reduction in some types of emissions. Recent studies using pooled time-series and cross sectional data (8) of total country emissions rather than of urban concentrations have shown that although the inverted U relation does hold for SO_x , NO_x , CO, and particulates, the turning points in the curves are at much higher income levels than previously estimated (closer to \$10,000 per capita rather than \$5,000 per capita). Most of the world's population therefore has a long way to go just to reach the turning points for emissions. In the absence of corrective measures, this implies that aggregate emissions of these pollutants are still expected to rise into the foreseeable future. We return to this point in the next section.

Third, the inverted U relation is a strictly partial one. It says nothing about the general equilibrium or whole-system consequences of emission reductions. For example, reductions in one pollutant may be made possible by increases in another pollutant, or by transfer of the pollution to other countries where their effects are not as fully internalized. Without information on the general equilibrium effects of changing levels of emissions, it is difficult to infer much about the general environmental consequences of a change in emissions of any one pollutant.

Unless demand for environmental quality does increase with income, economic growth will necessarily lead to increased environmental degradation. Environmental externalities will not be internalized. The inverted U-relation shows that demand for some indices of environmental quality does increase with income above a certain point. In most such cases, this has been associated with institutional reforms, environmental legislation and market-based incentives designed to internalize harmful external effects. But these have occurred where local communities have an incentive to internalize the environmental costs of their own activity: i.e. where the costs are borne by those able to change institutions, laws or economic policy. Where the environmental costs of economic activity are borne by the poor, by future generations, or by other countries, the incentive to address environmental questions

has been much weaker. The environmental consequences of changes in the structure of production in growing market economies may, accordingly, be very mixed (7,9).

Economic growth is not the solution to environmental externalities, and in the short run, it is certain to increase the rate of environmental degradation. The solution to environmental externalities is institutional reforms which compel private users of environmental resources to take account of the social costs of their actions (10). The inverted U relation is evidence that this has happened in some cases. It is not evidence either that it will happen in all cases, or that it will happen in time to avert the important and irreversible global consequences of growth.

Carrying Capacity and Ecosystem Resilience

Are there limits to the scale of the economy or the carrying capacity of the planet under a given structure of production and consumption? The answer to this is unambiguously, yes. If ecosystem deterioration cannot be delinked from economic activity, then at some point, economic growth will be stopped by the planet's limited capacity to absorb such deterioration. On the other hand, if pollution and ecosystem deterioration *can be* delinked from economic activity, then continual economic development is possible. This does, however, imply major change in the structure of production and consumption: in favour of resource-conserving qualitative improvements in productivity (development) and away from resource-consuming extensive growth. The proposition that economic development is consistent with improving environmental quality implies that, at least in some respects, this is currently happening. However, the core of the problem of environmental externalities in growing economies is the absence of effective signals of the environmental effects of economic growth. This is particularly serious if growth threatens the carrying or assimilative capacity of the environment.

The simple version of the notion of carrying capacity comes out of the logistic equation for the growth of a single animal population in a limited, highly simplified environment. Carrying capacity in this simple form is of limited use for the complex issues described above. Actual carrying capacity in nature is not a fixed, static or simple relation for either animal or human populations. It is contingent on technology, preferences, and the structure of production and consumption. It is also contingent on the everchanging state of the interactions between the physical and biotic environment. The capacity of the planet to support human life is limited for a given set of preferences and technology. This limit can be raised by lowering average quality of life or by changing technology and preferences so that production and consumption are less damaging to the environment (11). It is not, therefore, useful to state a single number for human carrying capacity. Such a number would

be meaningless because the consequences of both human innovation and of biological evolution are inherently unknowable. Nevertheless, a general index of the current scale or intensity of the human economy in relation to that of the biosphere is still useful. For example, Vitousek et al. (12) calculated that the total net terrestrial primary production of the biosphere currently being appropriated for human consumption is around 40%. This number says nothing about the carrying capacity, but it does put the scale of the human presence on the planet in perspective.

A more useful and operational concept for environmental sustainability is that of ecosystem resilience. Resilience is generally understood in two different ways. One, due to Pimm, focuses on ecosystem dynamics in the neighbourhood of an equilibrium. It is a measure of resistance to disturbance and speed of return to such an equilibrium (13). A second, due to Holling, focuses on ecosystem dynamics where there exist multiple (locally) stable equilibria. It is a measure of the disturbance that can be absorbed before a system centered on one locally stable equilibrium flips to another (14). Ecological economic systems are sustainable only if they are ecologically resilient. While ecological resilience may be difficult to measure and varies from system to system, and from one kind of disturbance to another, some useful indicators and early warning signals may be possible. For example, the diversity of organisms or the heterogeneity of ecological functions have been suggested as signals of ecosystem resilience. But ultimately, the resilience of systems may only be tested by intelligently perturbing them and observing the response using what has been called "adaptive management" (15). That approach essentially turns regional development policy and management into experiments where interventions at several scales are made to achieve understanding, to produce social or economic product, and to identify options.

The loss of ecosystem resilience is potentially important for different reasons. For one, the discontinuous change in ecosystem functions as the system flips from one equilibrium to another may be associated with sudden loss of biological productivity, and so to a reduced capacity to support human life under any technology. For another, it may imply an irreversible change in the set of options open both to present and future generations. If there are significant irreversible effects, or effects are very expensive to reverse, the hopes that future increases in current national income may be associated with a reduction in the level of emissions offers no protection against the consequences of environmental degradation. Effects that are in this category include soil erosion, depletion of ground water reservoirs, desertification and loss of biodiversity. More than this, though, the potential for discontinuous and irreversible change from familiar to unfamiliar states increases the uncertainty of the environmental effects of economic activities.

In order to assure the sustainability of economic development, it is important to assure the resilience of the ecological systems on which the economies depend. In a static regime of fixed preferences and fixed technologies, and in a non-evolutionary environment, this might well imply restricting the level of economic activity to that allowed by the carrying capacity perceived for those systems. In an evolving system where the notion of carrying capacity is less helpful, the limits on the nature and scale of economic activity are much less certain. But they are nevertheless real, and the problem for environmental policy is to ensure that they are taken into account.

Economic Growth and Environmental Policy

Economic growth will not automatically resolve the problem of environmental degradation. Nor will it automatically be sustainable. The source of difficulty is that appropriate signals of environmental damage, including the loss of ecological resilience, do not typically occur incrementally but abruptly. Moreover, the signals that do exist are often not observed or are wrongly interpreted. This is due to ignorance about the dynamic effects of change in ecosystem variables (especially thresholds, buffering capacity, and loss of resilience) and to the presence of institutional impediments, such as the nonexistence of property rights. The development of appropriate institutions, depends on our understanding on ecosystem dynamics and the maintenance of appropriate indicators of change.

Better science is a precondition for improved management through institutional reform. But the key feature is that this science must recognize that ecosystems and economic systems are of inherently limited predictability. We must determine what aspects of the system's performance are in principle predictable and design signals, adaptive management systems, and instruments that probe, test, and respond to the unpredictable and changing properties of human and biological nature. The most limited capacity we have is our capacity to understand and predict the future. In the face of this fundamental uncertainty and unknowability, and the dramatic consequences for the entire species of guessing wrong, we should act in a precautionary way to maintain the variability and diversity that sustains ecosystem resilience and buffering capacity.

Economic growth in itself is neither the problem nor the solution to dealing with the environment. It is neither a panacea for improving environmental quality nor does it have an inherently negative impact on the environment. What is important is the content of growth. It is better to concentrate on internalizing external environmental effects and protecting the resilience of ecological systems. The first will promote greater efficiency in the allocation of environmental resources at all income levels. The second will assure a sustainable scale of the economic system. Even low income

countries can and should improve efficiency and hence welfare by internalizing environmental externalities and even high income countries can and should restrict consumption and production so as to protect the resilience of the ecological systems on which they depend.

NOTES:

1. We would like to thank the editor and two anonymous referees for helpful comments.
2. This is a report of the Second Askö Meeting, held August 31 - September 2, 1994 in the archipelago outside of Stockholm, Sweden. The meeting was sponsored by the Beijer International Institute of Ecological Economics, Royal Swedish Academy of Sciences, Box 5005, S-104, 05 Stockholm, Sweden. The aim of the meeting was to establish a substantive dialogue among a small group of ecologists and economists, to get a sense as to whether there is an interdisciplinary consensus on the issues of economic growth, carrying capacity, and the environment, and to determine what could be said about the joint development of economic and environmental policy.
3. S. Kuznets, *Am. Econ. Rev.* 45, 1 (1955)
4. Phenomena for which the relation holds most clearly includes poor sanitation, impure water supplies, suspended particulates, SO_2 , NO_x , and CO . N. Shafik and S. Bandyopadhyay. Economic growth and environmental quality: time series and cross country evidence. Background Paper for the World Development Report, World Bank, Washington, DC (1992). G.M. Grossman and A.B. Krueger, pp. 165-177 in *The U.S. Mexico Free Trade Agreement*, P. Garber, ed. (MIT Press, Cambridge, 1993).
5. W. Beckerman, *World Development* 20, 481 (1992).
6. Shafik and Bandyopadhyay (see (4) above), find that CO_2 emissions are an increasing function of per capita income. W. Moomaw and M. Tullis, pp. 157-172 in *Industrial Ecology and Global Change*, R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. (Cambridge Univ. Press, Cambridge, 1994) show that while cross-sectionally CO_2 emissions per capita rise with income per capita, the experience in individual countries over time is highly variable, depending on the structure of individual economies. They conclude that there are many different development paths, some of which can delink economic growth from CO_2 emissions, but adequate institutions are required and it is by no means an automatic consequence of growth.

7. R. Lopez, *J. Environ. Econ. Manag.* 27, 163 (1994).
8. T.M. Sciden and D. Song, *J. Environ. Econ. Manag.* 27, 147 (1994)
9. K. Anderson and R. Blackhurst, eds. *The Greening of World Trade Issues* (Hemel Hempstead, Harvester Wheatsheaf, 1992)
10. A related issue is the measurement of economic growth at the macro level. The conventional measure — Gross National Product — is far from adequate as a measure of true economic performance. We need a more comprehensive index that includes the flow of environmental services as well as the value of net changes in the stocks of natural capital so that the true social costs of growth can be internalized.
11. Ehrlich, P.R. , pp. 38-56 in A.M. Jansson, M. Hammer, C. Folke, and R. Costanza, eds. *Investing in Natural Capital: The Ecological Economics Approach to Sustainability* (Island Press, Washington, DC, 1994)
12. P.M. Vitousek, P.R. Ehrlich, A. H. Ehrlich, and P.A. Matson. *BioSciences* 36, 368. 1986.
13. S.L. Pimm, *Nature*, 307, 321 (1984)
14. C.S. Holling, *Annu. Rev. Ecol. System.* 4, 123 (1973).
15. C.S. Holling, ed. *Adaptive Environmental Assessment and Management*. (Wiley, London, 1978). C.J. Walters, *Adaptive Management of Renewable Resources* (MacMillan, NY, 1986). K. Lee, *Compass and the Gyroscope*. (Island Press, Washington, DC 1993).

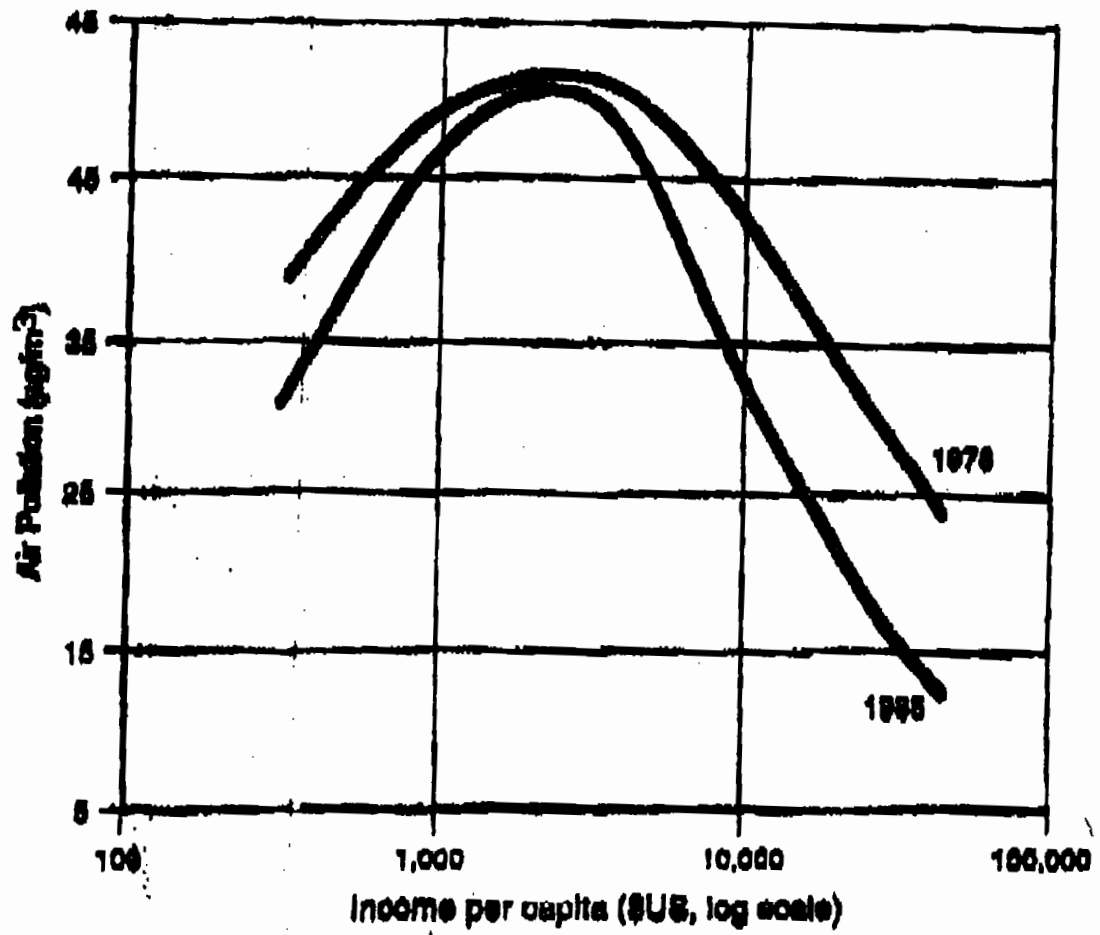


Figure 1. Income per capita versus. air pollution (4).



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

145 King Street West, Suite 1002, Toronto, Ontario M5H 3X6 CANADA
Tel: (416) 369-0900 Fax: (416) 369-0922

Handwritten initials: RS, SP

MEMORANDUM

TO: Chapter 4 Writing Team

FROM: Erik Haites *[Signature]*

RE: Multiple Discount Rates?

DATE: February 14, 1995

My limited understanding of finance theory is that each cost stream should be valued using a discounted rate that reflects its own risk. If this is correct, shouldn't mitigation costs and benefits of reduced climate change damage be discounted at different rates? That raises the question of the appropriate values of the discount rates for different cost and benefit streams, which is the principal subject of the existing text. My sense, however, is that the existing text focuses on the value of the appropriate discount rate for the benefits stream. A, presumably shorter, discussion of the appropriate value of the discount rate for the cost stream would be useful. If the discount rates for the cost and benefit streams differ, it would be interesting to note that all of the available benefit-cost studies use the same discount rate for both the cost and benefit streams.

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Post-It™ Fax Note 7671E		Date Feb. 14	# of pages 1
To Joseph Stiglitz		From Erik Haites	
Co./Dept.		Co.	
Phone #		Phone #	
Fax # (202) 395 6958		Fax #	

OFFICE OF THE U.S. GLOBAL CHANGE RESEARCH PROGRAM

300 D Street, S.W., Suite 840
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cc: Ray S
Sally K

February 9, 1995

Dr. Joseph Stiglitz
Council of Economic Advisers
315 Old Executive Office Building
Washington, D.C. 20500
Fax: (202) 395-6958

Dear Dr. Stiglitz:

We understand that, in the expert round, you were given an opportunity to review at least one chapter in the 1995 IPCC WG III report. The IPCC WG III office has asked us to provide you an opportunity to review the revised version chapter (or any other chapters) and the draft Summary for Policymakers as part of the final review round. Unfortunately, the IPCC was unable to tell us what chapter you reviewed (or might want to review). If you would like to participate in this process, please request chapters from Ms. Susan Henson, phone (202) 651-8240; fax (202) 554-6715; e-mail office@usgcrp.gov.

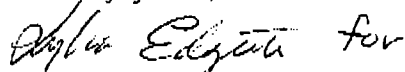
The U.S. Government review of this report (and within the next few months the WG I and WG II reports, which are not yet available for reference) is being carried out as a three-pronged effort. First, we are seeking input from the research community, especially to ensure that the quality and authority of the chapters meet national and international research standards. Second, we are seeking review by the public, including especially stakeholder groups, on the breadth and objectiveness of the perspectives. Third, we are seeking review by the research and policy sides of U. S. government agencies, especially of the quality and insightfulness of the presentation and of the implications for policy formulation. Overall, the review is thus both open and broad, and the documents may be freely distributed to others for comment.

Given our open process, please also feel free to pass on copies to your colleagues or others who may be able to contribute to the review process. We should note that the reviewers will be acknowledged by name and institution in the IPCC report, so reviewers should be separately named. Also, in that this is a public process, the reviews will be made available, with names attached, for public inspection.

We have enclosed a set of guidelines for returning comments. The most daunting requirement is that we need to RECEIVE COMMENTS BY 5:00 PM ON FEBRUARY 21, 1995. This deadline is necessary so that we can collate comments and meet the IPCC deadline of March 11 for a U.S.-approved, integrated set of comments. As an invited reviewer, you need submit to us only one copy of your review (we will make the additional copies); we would appreciate also receiving it electronically by e-mail or on disc.

We apologize for the very tight deadline and would be grateful for whatever assistance in this review that you can provide.

Sincerely yours,

A handwritten signature in cursive script, appearing to read "Michael C. MacCracken", followed by the word "for".

Michael C. MacCracken, Director
Office of the USGCRP
(mmaccracken@usgcrp.gov)

Enclosure

Second Assessment Report, IPCC Working Group III

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Information and Guidelines for Reviewers Participating in the US Government Review of the 1995 Second Assessment Report

Background of the IPCC

The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess the professional literature related to the climate change issue and to provide scientific advice related to the negotiation and implementation of the Framework Convention on Climate Change. The IPCC has three working groups. Working Group I, which is co-chaired by the United Kingdom and Brazil, is assessing the state of science with respect to the functioning of the climate system. Working Group II, co-chaired by the United States and Zimbabwe, is assessing potential impacts, as well as adaptation and mitigation measures. Working Group III, co-chaired by Canada and South Korea, is assessing the economic implications of climate change. IPCC scientific assessments are written in such a way as to address the needs of policymakers and non-specialists. They also serve the research community by identifying components of the climate change issue which deserve priority attention. To date, the IPCC has produced the 1990 Assessment Report and a 1992 Supplement. Currently, the process is underway to prepare the Second Assessment Report (SAR) scheduled for completion in late 1995.

As an intergovernmental body, each IPCC report undergoes both a peer review by experts and a technical/scientific review by all governments. The peer review of the technical chapters of the SAR has been completed and the revised draft chapters are being circulated for Government review.

Nature of the Accompanying Drafts

Enclosed for your review are the revised drafts of one or more technical chapters of the WGIII portion of the Second Assessment Report and the draft Summary for Policymakers. The technical chapters, which serve as the foundation for the Summary for Policymakers, critically examine and summarize available scientific and technical information related to climate change impacts, adaptations, and mitigation strategies. The Summary for Policymakers is intended to focus on those key issues presented in the technical report which are of particular relevance to the policy-making community. Information presented in the Summary for Policymakers must be consistent with the underlying technical chapters.

Your Role as a Reviewer

As a reviewer, you are asked to:

- judge whether key issues are addressed in adequate depth
- identify gaps and redundancies within and across chapters

- ensure that the documents accurately reflect uncertainties and, where relevant, the alternative theories surrounding them
- suggest, wherever possible, solutions to errors or discontinuities that you find rather than simply flagging them
- determine whether the assertions made in relevant sections of the Summary for Policymakers are consistent with the technical report

Review comments which express agreement with draft text, particularly where the issue is a complicated or sensitive one, are also 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.

Procedures for Submitting Review Comments

1. Please follow the enclosed sample format for submission of comments. This will greatly ease the handling of your comments by the Review Secretariat. For comments associated with a specific portion of the text, please include a clear reference to page and line number.
2. The comments themselves should a) suggest specific changes to the text (additions, deletions, revisions); b) offer an explanation for the recommended changes; and c) provide references to the literature which support the point, as necessary, particularly if the comment deals with an issue the reviewer judges to be controversial.
3. To submit comments, please choose one of the following three options:
 - a) E-mail on Internet to: "comments.wg3@usgcrp.gov". Please provide a hard copy backup by mail
 - b) Mail or deliver hard copy along with a 3.5" disc (file in either Microsoft Word or WordPerfect) to the USGCRP Office:
IPCC WG III Review Secretariat
Office of the U.S. Global Research Program
300 D Street, S.W.
Suite 840
Washington, D.C. 20024
 - c) Comments of less than two pages total may be faxed to the U.S. Global Change Program Office at (202) 554-6715 or mailed.

The U.S. Government is committed by the IPCC process to provide a single, integrated set of comments on each Working Group report; these comments will be drawn from the set of comments received and from input and evaluation of the U.S. Review Team. The U.S. will forward its integrated comments and a set of all the comments received to the IPCC Working Group III Technical Support Unit.

Deadline for Comments

For consideration in the U.S. Government Review process, all comments must be received at the USGCRP Office by 5:00 P.M. on February 21. For questions, please call (202) 651-8240.

IPCC WORKING GROUP III U.S. GOVERNMENT REVIEW

SAMPLE FORMAT FOR SUBMISSION OF COMMENTS

We suggest that you follow the format below in preparing your comments. This will greatly ease the handling of your comments by the Review Coordinator. Please remember to send your comments on a computer disk (with a label identifying the software used) or via electronic mail.

SECTION I: BIOGRAPHICAL INFORMATION

Name:

Organization:

Area of Expertise:

Phone:

Fax:

E-mail:

The following comments are on Chapter:

SECTION II: SUMMARY OF COMMENTS

Please itemize, or describe in one or two paragraphs, the substance of your comments on this chapter.

-
-
-

SECTION III: DETAILED COMMENTS

1. Page Number: X, Line Number: Y
 - suggest specific changes to the text with proper explanation
 - include detailed description
 - cite relevant literature if required
2. Page Number: , Line Number:

/DCC

Both normative and positive considerations may be seen as entering into determination of a discount rate for use in climate policy analysis.

Normative Considerations: As noted above, the discount rate for policy analysis may exceed zero even if the rate of pure time preference is assumed to be zero if the level of income is projected to rise, as is implicit in the IPCC emissions scenarios. The effect of rising income on discounting of consumption levels depends on the assumed relationship between income levels and the level of welfare, with most analyses assuming that additional income increases welfare, but at a decreasing rate.

The rate of pure time preference (PTP) is also important, since pure time preference would add to the discounting resulting from the projected increase in income and consumption levels alone. Within a single lifetime, individuals in both developing and developed economies appear to exhibit pure time preference -- that is, given a choice between an increment of real consumption now or later, without any expected growth in income levels, current consumption is preferred. This revealed preference, however, is not necessarily dispositive for problems involving intergenerational as well as merely intertemporal considerations.

Market considerations. Another approach involves looking to the market for a guide to discounting. This approach focuses on the reality that investments in climate

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mitigation compete with other investments that can raise the level of welfare of current and future generations. Use of a lower discount rate for consideration of climate policy than for other public or private investment decisions risks diverting investments away from higher-return investments in physical capital and education that would benefit future generations more than climate mitigation that is only desirable at a lower discount rate. Use of market rates is also consistent with the use of other market prices in analyses surrounding climate change. For example, the costs of mitigation options are typically evaluated at current and projected market prices of energy, not at "normative" prices that attempt to correct for the exercise of seller power or other market distortions.

There are a wide variety of discount rates observed in markets. The real interest rate on bonds issued by preferred (risk-free or nearly so) borrowers ranges between 0 and 2 percent. However, required real returns on equity in industrial countries are significantly higher, averaging near 6 percent. For individual consumers in industrialized countries, real returns to investments in education and real costs of borrowing are significantly higher. Required rates of return are generally higher in developing countries, where financial markets and financial intermediation is less well developed.

Bottom Line: An approach that focuses on normative considerations alone, and assumes that the pure rate of time preference for intergenerational decisions is appropriately set at zero, supports discount rates in the neighborhood of 1.5 percent. Allowing for a positive rate of PTP would add to this value. An approach that emphasizes market considerations in the determination of a discount rate for policy analysis generally favors adoption of real rates between 3 and 6 percent, with rates declining within this range as income grows.



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MEMORANDUM

TO: Working Group III Lead Authors

FROM: James Bruce Hoesung Lee

RE: Revised Draft of the Second Assessment Report

DATE: January 27, 1995

A copy of the revised draft of the Second Assessment Report which was circulated for government and organization review is enclosed.

The current draft is much improved. We would like to thank all Lead Authors for their excellent work and their conscientious adherence to our tight deadlines.

We encourage you to read the whole report so that we can discuss issues of consistency, completeness and tone at the Lead Authors meeting in Paris from March 22 through 24.

The Bureau tried faithfully to integrate the key results from the respective chapters into a readable Summary for Policymakers. We would particularly welcome your comments on how to improve this part of the report.

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**SUMMARY FOR POLICYMAKERS
SECOND ASSESSMENT REPORT, WORKING GROUP III**

The Context

This assessment of the socio-economic literature related to climate change has been undertaken in the context of sustainable development as reflected in the Framework Convention on Climate Change. This Convention is now a key element in the decision making framework on climate change (Chapter 2).

The ultimate objective of the Convention is "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 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."¹

The Convention specifies that to achieve this objective the "Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures should be cost-effective ..."²

Each of the Annex I Parties is committed to "adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs."³

¹ *United Nations Framework Convention on Climate Change*, Article 2. The Intergovernmental Negotiation Committee (INC) requested that the IPCC assess the scientific evidence that might help policy makers interpret Article 2 of the Convention. This topic will be addressed in the IPCC's Second Assessment Report to be published in 1995.

² *United Nations Framework Convention on Climate Change*, Article 3.3.

³ *United Nations Framework Convention on Climate Change*, Article 4.2(a).

The Convention thus incorporates, and the literature assessed in this report (Chapters 1, 2, 8 and 9) supports a strategy of "act - then learn - then act" where the actions to address climate change are periodically adjusted in light of new knowledge and developments. The ultimate objective of stabilizing atmospheric concentrations of greenhouse gases, although not yet operationally defined, provides guidance for policymakers when considering initial actions to address climate change.

The Convention establishes a collective decision making process where actions, reflecting their common but differentiated responsibilities, are agreed upon by the Parties. The report identifies a number of general principles and findings that are relevant regardless of the decisionmaking process, such as those concerning the design of cost-effective policies. It should be recognized that a collective decision making process may not reach the same conclusions as analyses that adopt a global optimization perspective.

A Portfolio of Possible Actions to Limit Climate Change

The precautionary principle (Article 3.3) and the estimated damages due to current emissions of greenhouse gases (Chapter 6) argue for action beyond "no regrets" measures.⁴ The decisions to be taken in the near future will necessarily have to be taken under great uncertainty. However, these decisions are not very sensitive to the level at which atmospheric concentrations are ultimately stabilized and can be adjusted based on experience, new knowledge and other developments.

Actions analysed in the literature which countries can take, individually or jointly, to limit climate change and its impacts include:

- implementing low cost measures to reduce emissions of greenhouse gases. There is broad agreement that in most countries there are some measures, such as energy efficiency, that can reduce emissions of greenhouse gases at negative to slightly positive costs (Chapter 9). Achieving such reductions may require policy intervention;
- phasing out existing distortionary policies, such as some subsidies to fossil fuels, that reduce welfare and, directly or indirectly, increase

⁴ No regrets measures are those whose benefits, such as reduced energy costs and reduced emissions of conventional pollutants equal or exceed their cost, *excluding* the benefits of climate change mitigation.

greenhouse gas emissions.³ Global emissions reductions of 5% to 20% have been estimated for removal of energy subsidies worldwide (Chapter 11);

- implementing fuel switching measures, such as coal-fired generation to natural gas, to reduce emissions of greenhouse gases (Chapters 9 and 11);
- implementing measures to enhance sinks or reservoirs of greenhouse gases;⁶
- instituting forms of international cooperation to limit greenhouse gas emissions such as joint implementation and technology transfer;
- undertaking research aimed at better understanding the causes and impacts of, and adaptation to, climate change. Economic studies suggest that such research can yield high returns by reducing the uncertainty as to the most cost-effective actions to address climate change (Chapter 2);
- conducting technological research aimed at enhancing energy efficiency, minimizing emissions of greenhouse gases from continued use of fossil fuels, and developing commercial non-fossil energy sources. The timing and availability of cost-effective of non-fossil energy technologies is one of the major determinants of addressing climate change in the long run (Chapters 9 and 10);
- planning, and implementing as necessary, measures to adapt to the consequences of climate change; and
- developing institutional mechanisms, such as insurance, to share the risks of damages due to climate change (Chapters 1 and 2).

³ Energy prices that do not reflect the externalities associated with energy use can be considered a distortionary policy. Under some circumstances, kerosene subsidies to reduce fuelwood use, can increase welfare or decrease emissions (Chapters 2 and 11).

⁶ Some actions to increase sinks may have indirect effects, such as a change in albedo. In such cases the net effect of the measure should be considered.

An illustrative simulation of global options with marginal costs of up to \$50 per tonne of carbon suggests about 50% of the total reduction/sequestration would be forestry measures, 25% would be through energy conservation and efficiency improvements, and the remainder would come from a mix of renewable energy use, fuel switching, CO₂ removal and disposal, and nuclear energy. The mix of options and the magnitude of the reduction/sequestration relative to current emissions varies significantly by region (Chapter 7).

Opportunities for Action Vary by Country and Over Time

Each country's approach to climate change can be represented as a portfolio of actions that reflects its objectives, economic conditions and constraints. The actions taken by a particular country may reflect considerations such as their cost, secondary benefits, the impacts on different socio-economic groups, international equity, intergenerational equity, the expected damage due to climate change or sea level rise within the country, and economic strategies based on development of new technologies. The size of the investment will reflect the country's obligations under international agreements, adjusted for resources transferred to or received from other countries, as well as domestic goals and priorities. A country's climate change actions will also reflect other priorities aimed at sustainable development, including eradication of poverty, increased levels of education, protection of environmental resources, and improved human health.

Governments can and should *adjust* their portfolio of climate change actions in response to new information and developments. Indeed, both the investment in climate change limitation and the mix of policies will probably change over time. That does not imply complete flexibility. Many of the measures involve capital and technology commitments with long life times. Reversing such commitments could be relatively costly, however that risk would be incorporated into the analysis of the options before the commitments are made. This is particularly important for developing countries and countries with economies in transition where significant infrastructure investments will be made over the next few decades.

Stabilization of Greenhouse Gas Concentrations

Climate change impacts are related to the stock of greenhouse gases (concentration) in the atmosphere, rather than the annual emissions, hence the ultimate objective of

the Convention is to stabilize atmospheric concentrations of greenhouse gases.⁷ Currently, the atmospheric concentration of CO₂ is about 360 ppmv; the pre-industrial concentration was about 280 ppmv.⁸ The danger of significant harmful effects from climate change increase as the concentration of greenhouse gases in the atmosphere rises. The discussion below focuses on the effects associated with stabilization of atmospheric concentrations of CO₂ within the range of 350 to 750 ppmv "could be attained only with global anthropogenic emissions that eventually drop to substantially below 1990 levels."⁹

The IPCC's six emissions scenarios assume virtually no new policies specifically designed to reduce greenhouse gas emissions (Chapter 12).¹⁰ Three scenarios that span the full range (IS92a, IS92c and IS92e) are compared with the illustrative profiles of anthropogenic emissions consistent with stabilization of atmospheric concentrations at levels between 350 and 750 ppmv in Figure 1. These emissions profiles indicate that at some stage major reductions of CO₂ emissions (of the order of 50% of current emissions) will be required to eventually stabilize concentrations. The pattern and timing of reductions of emissions can have a major effect on the overall costs of mitigation. "Emissions for all stabilization levels studied are lower than those for IS92a and e, even in the first few decades of the 21st century. Emissions for the IS92c Scenario lie between the emissions [profiles] which ... achieve stabilization at 450 and 550 ppmv."¹¹

⁷ It is not clear from the Convention whether the ultimate objective is to stabilize the atmospheric concentration of each gas at a particular level or to stabilize greenhouse gas concentrations, expressed in terms of CO₂ equivalents, at a particular level.

⁸ ppmv is parts per million by volume, a measure of concentration.

⁹ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 4. Analyses of emissions profiles consistent with stabilization of atmospheric concentrations of CO₂ at levels lower than 350 ppmv or higher than 750 ppmv are presently not available in the literature.

¹⁰ *The 1994 Special Report of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 2.

¹¹ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 15.

Stabilization of the atmospheric concentrations of other greenhouse gases at today's levels requires lesser reductions, but nevertheless reductions, of the emissions of those gases.¹² Thus, stabilization of atmospheric concentrations of greenhouse gases will require very low population and economic growth rates (as assumed for IS92c), a major "natural" change in energy technologies, or intervention to reduce emissions and enhance sinks. The effect of the initial commitments of Annex 1 Parties, assuming that they are achieved and continued to 2050, is shown in Figure 2. The current commitments are not sufficient to stabilize atmospheric concentrations of CO₂, except under scenario IS92c which has emissions below current commitments (Chapter 12).

Applicability of Cost-Benefit Analysis

A stabilization objective could be based upon an absolute standard, an affordable safe minimum standard, or a cost-benefit analysis, the approach favoured by most economists. These approaches are illustrated in Figure 3. The absolute standard approach would define a maximum atmospheric concentration of greenhouse gases that is considered to constitute "dangerous anthropogenic interference with the climate system" on the basis of predicted changes to the climate system or of the predicted impacts of climate change *regardless of the cost of achieving this concentration*. Environmental standards designed to safeguard human health are often established using this approach.

The safe minimum standard approach would specify a maximum atmospheric concentration of greenhouse gases based on an assessment of the risks associated with different atmospheric concentrations and the costs of achieving those concentrations. The standard would seek to reduce the risks of climate change to an acceptable level at an acceptable cost. Cost-benefit analysis attempts to value the impacts of climate change and seeks the atmospheric concentration where the marginal value of the net impact is equal to the marginal cost of abatement.

Working Group III was specifically requested to assess whether cost-benefit analysis is applicable to climate change. Cost-benefit analysis was broadly interpreted to include traditional project level cost-benefit analysis, cost-effectiveness analysis, multi-criteria analysis and decision analysis. The traditional cost-benefit approach is

¹² *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 18 and 20.

depicted in Figure 3(c). Cost effectiveness analysis seeks to find the lowest cost option to achieve a specified objective; the marginal cost of abatement curves in Figures 3(b) and 3(c) represent cost-effective options. Multi-criteria analysis is designed to deal with problems where benefits and/or costs can not be valued; it could be used for the approaches described in Figures 3(a) or 3(b), where non-economic effects are brought into the analysis, but without a formal way of valuing those effects relative to the economic impacts. Decision analysis focuses expressly on making decisions under uncertainty and conceptually could be used in any of the approaches described in Figure 3.

Cost-benefit analysis (broadly defined) *could* contribute to resolution of three questions facing decisionmakers. These are:

- By how much should emissions of greenhouse gases be reduced or sinks of greenhouse gases be enhanced?
- When should emissions be reduced or sinks be enhanced?
- What methods should be employed to reduce emissions and enhance sinks?

Because of the large uncertainties surrounding estimates of damages due to climate change (Chapter 6) and the costs of mitigation (Chapter 9) make it difficult in practice to rely solely on cost-benefit analysis for the selection of an appropriate stabilization objective at this time. Still, the information provided by cost-benefit analysis is critical in making judgements not only about that decision, but also about the timing of emission reductions and the design of cost-effective strategies. Integrated assessment models best suited to such analyses are quite new (Chapter 10).

However, cost-effectiveness analysis can and should be used to evaluate adaptation and mitigation options.

The Benefits of Limiting Greenhouse Gas Emissions and Enhancing Sinks

The benefits of limiting greenhouse gas emissions and enhancing sinks are the climate change damages avoided. Since some increase in atmospheric concentrations from the current level is virtually inevitable, some impacts and damages due to climate change seem unavoidable.

The literature contains a few aggregate (across all sectors and regions) estimates of the damages associated with a climate characterized by a globally-averaged 2.5°C warming. The estimates suggest that if such warming occurred now it would impose net damages equivalent to 1.5% to 2.5% of world GDP on the present world economy (Chapter 6). The regional variation in climate change damage would be substantial. Damage in developing countries is estimated to be at least 2% with a maximum central estimate of 9% of GDP for some regions. Small islands and low lying coastal areas are particularly vulnerable. Climate changes of this magnitude are not expected to be realized for some decades and damages in the interim would be smaller.

Most estimates of the additional damage done by CO₂ emitted *now* range from \$5 to \$25 (1990 \$ U.S.) per tonne of carbon, although a few estimates range up to \$125 per tonne of carbon.¹³ The models used to develop these estimates are simplistic and are poor representations of dynamic processes, but they reflect the current state of the art. The wide range of estimates reflects variations in models, scenarios, discount rates and other assumptions.

Climate change benefits of emissions reduction measures can be very complex to estimate. Some energy efficiency and fuel switching measures simultaneously reduce emissions of greenhouse gases and sulphate aerosols. The negative radiative forcing from sulphate aerosols is significant. "Tropospheric aerosols have a lifetime of only a few days ... So the atmospheric concentration of aerosols responds rapidly to changes in emissions. Control of sulphate emissions ... would immediately reduce the amount of aerosols in the atmosphere."¹⁴ A recent model analysis finds that replacement of fossil fuels with carbon-free energy sources leads to lower temperature increases in the long run, but higher temperatures in the interim due to the reduced sulphur emissions (Chapter 10).

Costs of Response Options

What matters from a policy perspective is the net cost (total cost adjusted for secondary benefits and costs) of a mitigation or adaptation option apart from its

¹³ A tonne is a metric ton or 1,000 kg. \$5 per tonne of carbon corresponds to approximately 0.35¢ per litre of motor gasoline.

¹⁴ *Radiative Forcing of Climate Change: The 1994 Special Report of the Scientific Assessment Working Group of IPCC*, Summary for Policy Makers, IPCC, 1994, p. 24.

climate change benefits (Chapter 8). A wide range of estimates of the costs of response options is found in the literature. The wide range is due in large measure to differences in assumptions. Alternative views of the costs of emissions reduction are shown schematically in Figure 4. Curve A assumes that there are no reducible market or government induced imperfections; thus there are no "no regrets" options. Curves B, C and D all assume market failures or government induced imperfections exist in one or more sectors that can be corrected by policies that reduce costs and also lower greenhouse gas emissions. Curve B includes only measures whose direct benefits yield net cost savings. Curves C and D incorporate secondary economic and environmental benefits into the calculation of the net cost of the option.

The potential for "no regrets" policies is represented by the line OD₂. The area OD₁D₂ is the potential net benefit to society of implementing all "no regrets" measures. Some analysts have argued that measures with a positive cost should be implemented to the point where the total net cost to society is zero, i.e. to a point D₁>D₂ such that the area under curve D between D₂ and D₁ is equal to that area OD₁D₂.

Despite significant differences in views, there is agreement that some energy efficiency improvements (perhaps to 10% to 30% of current consumption) can be realized at negative to slightly positive costs in many countries, depending on the baseline assumptions and the time frame (Chapter 9). Measures to reduce greenhouse gas emissions often yield additional economic benefits (such as reduced traffic congestion) and/or environmental benefits (such as reduced emissions of acid rain and urban smog precursors). The magnitude of these secondary benefits depends on local circumstances. Studies for Norway, the U.K. and some other countries indicate that secondary benefits could offset 30% to 100% of abatement costs (Chapter 6).

The long run costs of addressing climate change will ultimately be determined by the rate of capital replacement, the discount rate and the effect of research and development. Implementation of "no regrets" measures will increase the time available to learn about climate change and to bring new technologies to the market. Infrastructure decisions are crucial because they can enhance or restrict future options and different choices can lead to very different cost outcomes.

Estimates of the costs of stabilizing CO₂ emissions vary widely as a result of differences in the baseline scenario, the estimated long run costs of mitigation measures, and the date for achieving the stabilization objective. Differences among models are less significant than differences in the underlying assumptions. Indeed widely differing methods can produce quite similar results when calibrated to the

same set of input assumptions, such as the cost and availability of different energy sources.

Top-Down and Bottom-Up Models

In the jargon of modelers "top-down" models are aggregate models, often macroeconomic models, that analyse how changes in one sector of the economy affect other sectors and regions. Early top-down models tended to have little detail on energy consumption, especially at the technology-specific level, but explicit treatment of behaviour and economic interactions. In contrast, "bottom-up" models tended to describe energy consumption in detail, however consumer behaviour and interactions with other sectors of the economy tended to be down played.

This simple characterization of top-down and bottom-up models is increasingly misleading as more recent versions of each approach have tended to provide greater detail in the areas that were less developed in the past. This convergence means that differences in model results are increasingly driven by differences in input assumptions rather than model structure. Most results available in the literature do not reflect the effects of this convergence of model structure since the evolution in model structure is a relatively recent occurrence.

Nevertheless, differences in model structure remain important as different models are best suited to answer different types of questions.

Equity and Social Considerations

Equity considerations are an important aspect of climate change policy and feature prominently in the Convention. Inaction is likely to impose costs on future generations and on regions where damages occur, often regions with low greenhouse gas emissions. Action to address climate change is likely to impose some costs on the present generation. Since actions to address climate change are deliberate, explicit decisions can be made as to how to share these burdens.

The Convention recognizes the differentiated responsibilities of the Parties, but it does not include an explicit formula for sharing the costs of addressing climate change. It also lists factors to be considered in determining how the burden should be shared and provides for development of mechanisms for sharing the burdens. Issues of equity and efficiency can for the most part be separated. Cost-effective strategies can be developed embracing a variety of ways for sharing the burden.

Equity issues involved in addressing climate change may be divided into four categories:

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

The Convention offers some guidance on all of these issues, but doesn't resolve any of them.

A variety of ethical principles, including the importance of meeting people's basic needs, are relevant to sharing the burden of addressing climate change. No single rule will command universal agreement. Furthermore, any arrangement may need to change over time to continue to be perceived as equitable and to take new developments into account. Analysts can not prescribe how the burden of addressing climate change should be shared, they can only clarify the implications of different principles (Chapter 3).

Countries differ in terms of current greenhouse gas emissions (see Figures 5 and 6), vulnerability to climate change (Chapter 6), wealth, resource endowments, and institutional capacity to respond effectively. The Convention provides that these circumstances be reflected in differentiated responsibilities. Developed countries have undertaken commitments through the Convention for technology transfer and contributions to the financial mechanism.

A rigid "north-south" delineation of equity issues is inappropriate and may be highly damaging in the long run, although it permeates much of the debate at present. The implications of climate change for developing countries are different than those for developed countries because the former are generally poorer, have contributed much less to past emissions and still emit much less per capita, have shorter policy time-horizons, often weaker institutions, other urgent priorities, and are generally more vulnerable to climate change. However, 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, over the next century some developing countries will continue to make marginal

contributions to the problem, while emissions from others may well start to dominate it.

Countries (such as low lying coastal regions and islands 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.

All Parties have equal status under the Convention. Procedural equity also requires that all Parties be able to participate effectively in international negotiations related to climate change. Assistance to enable developing country Parties to participate effectively in negotiations would increase the prospects for achieving effective, lasting and equitable agreements on how best to address the threat of climate change.

Intergenerational Equity

Climate policy raises particular questions of equity among generations, because future generations are not able to influence directly the policies being chosen today that will affect their well-being and because it might conceivably not be possible to compensate future generations for reductions in well-being that might be caused by current policies.

Sustainable development and the concept of an environmental trust have been proposed to address intergenerational equity. Sustainable development would meet "the needs of the present without compromising the ability of future generations to meet their own needs." An environmental trust, as proposed by Brown-Weiss, would require each generation to ensure that the next inherits "a planet and cultural resource base at least as good as that of previous generations."

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. The choice of discount rate is important in climate change analyses because the time horizon is extremely long and the abatement costs tend to come earlier than the benefits of avoided damages. 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 literature on the appropriate discount rate for climate change analysis can be divided into two approaches. The *prescriptive* approach asks whether a particular action would make society better off, given a plausible social welfare function. The discounting rules specify how consumption at different dates should be valued to provide the correct answer to that question. The *descriptive* approach focuses on intertemporal efficiency and opportunity costs.

The *prescriptive* approach discounts consumption accruing to different generations using the "social rate of time preference" (SRTP). The SRTP is composed of two components, "pure time preference" and the incremental welfare derived from future consumption:

- Pure time preference is a reflection of impatience. Although there is debate in the literature, values tend to range from zero to 1%
- The incremental welfare of future consumption accounts for rising per capita income over time and the resulting decline in the incremental welfare (marginal utility) derived from the higher future consumption.

Depending upon the values assumed for the different parameters, values for the SRTP on a global basis tend to fall between 0.5% and 3.0% per year. Developing countries may have much higher (10% to 20%) rates of SRTP due to high rates of per capita income growth or high elasticities of marginal utility for small increases in per capita income from subsistence levels.

It is important remember that in making choices concerning alternative policies, that while differences in consumption at different dates will be valued using the SRTP, those differences in consumption will be affected by the opportunity cost of capital, which typically is in the range of 7% to 15% real. Thus, where mitigation projects displace other investments yielding higher returns, the mitigation projects typically will not be chosen unless they yield returns at least equal to those on the displaced capital.

The *descriptive* approach to the discount rate looks at returns to investments in the real world. Market rates of return usually exceed the values estimated for the SRTP. Conceptually, funds could then be invested in projects that provide a higher return with the proceeds being used to increase future consumption. In the context of

climate change, however, society is not likely to be able to set aside investments over the next three centuries and earmark the proceeds the eventual compensation of those adversely affected. Determining the discount rate on the basis of descriptive or market considerations yields a global rate in the range of 3% to 6% real, with rates declining within this range as income rises.

Increasing the discount rate because of risk is generally inappropriate.

Policy Instruments

A clear distinction needs to be drawn between actions to reduce the impacts of climate change and actions to reduce emissions. The former also involve consideration of adaptation policies.

Policy instruments designed to mitigate climate change need to be assessed at the international and domestic levels. Such instruments can help participating countries comply with multilateral commitments on climate change abatement, including international transfers of resources and technology. The international and domestic policy instruments need not be the same, but international agreements may constrain the choice of domestic policy instruments.

The policy instruments available internationally and for adoption by groups of countries include: non-tradeable quotas, tradeable quotas, joint implementation, harmonized domestic carbon taxes, international carbon taxes, various international standards and technology transfer. Domestic policy instruments include carbon taxes, tradeable permits, deposit-refund systems, technology standards, performance standards, product bans, voluntary agreements, energy taxes, energy efficiency subsidies, non-fossil fuel subsidies, and removing existing market distortions.

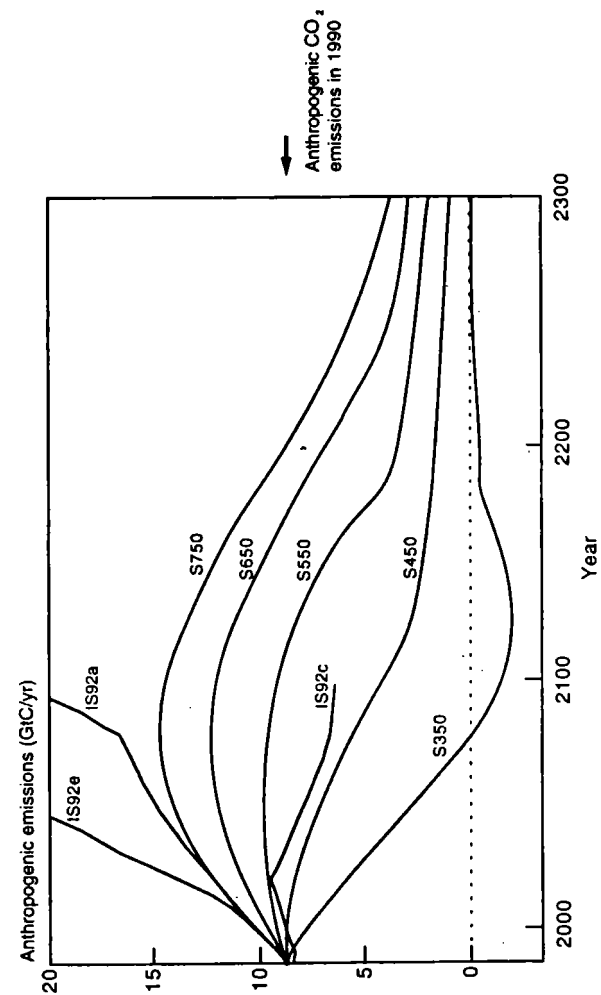
Among the criteria that governments can consider when selecting from among the available policy instruments are: distributional (including intergenerational) equity, flexibility in the face of technological change and new information, efficiency or cost-effectiveness, compatibility with the institutional structure and existing policies, and understandability to the general public. A mix of instruments may be needed to achieve the best results. Governments may apply different criteria with different weights to the selection of international and domestic policy instruments.

Cost-effectiveness should always be a criteria for selecting policy instruments, but it becomes more important at both the international and domestic levels as the abatement effort becomes more stringent. The economic literature suggests that the

more economically efficient instruments include carbon taxes and tradeable quotas. Although there are implementation problems associated with each, both can be made consistent with equitable international burden sharing. The consequences of climate change policy will be determined by the choice of policy instrument as well as the design and implementation of those policies. The effectiveness of policies will also depend on their acceptability to the public and to governments.

Figure 1

Illustrative Anthropogenic Emissions Profiles of CO₂ Leading to Stabilization at Concentrations of 350 to 750 ppmv Using a Mid-range Carbon Cycle Model and CO₂ Emissions for the IS92a, c and e Scenarios

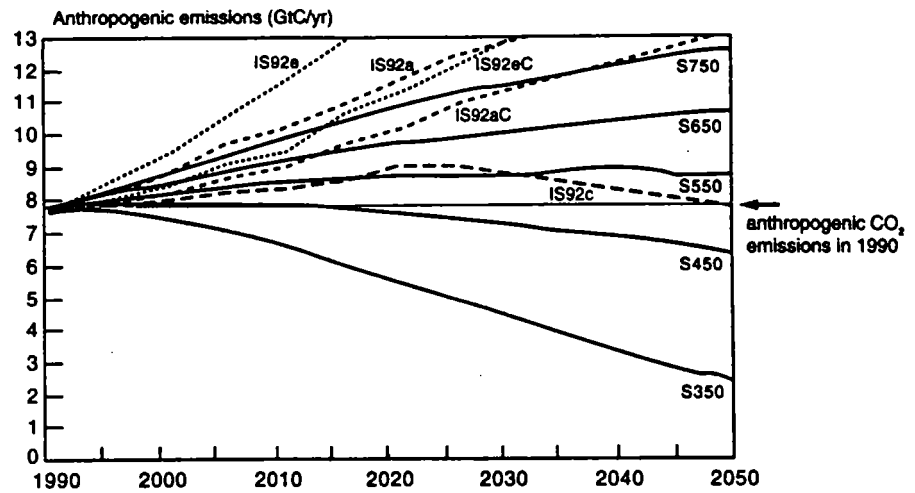


Source: 1994 Special Report of the IPCC

93M002 Rep. 1/93

Figure 2

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

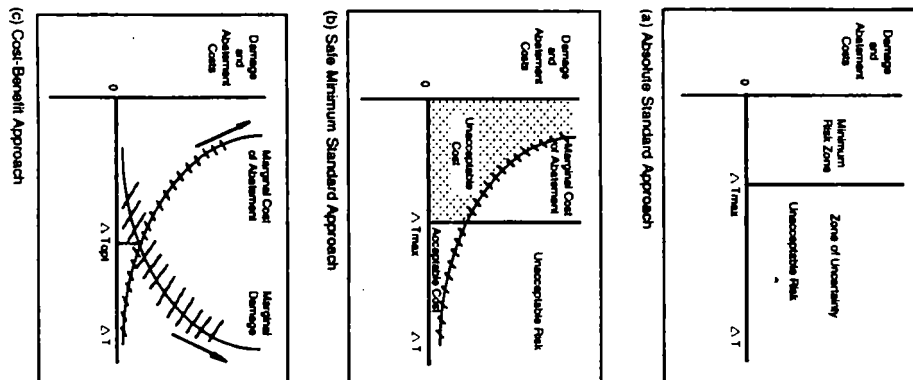


Legend: IS92aC (IS92eC) is scenario IS92a (IS92e) →

Source: Based on Chapter 12, adjusted for current commitments by Annex I Parties extended to 2050

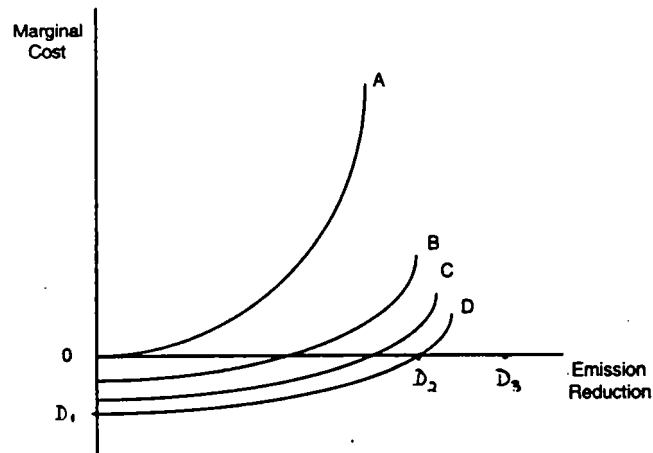
938025 fig 1/95.jp

Figure 3
Global Warming, Cost-Benefit Analysis and Sustainable Development



Source: Chapter 6

Figure 4
Alternative Views on Costs of
Emission Reduction

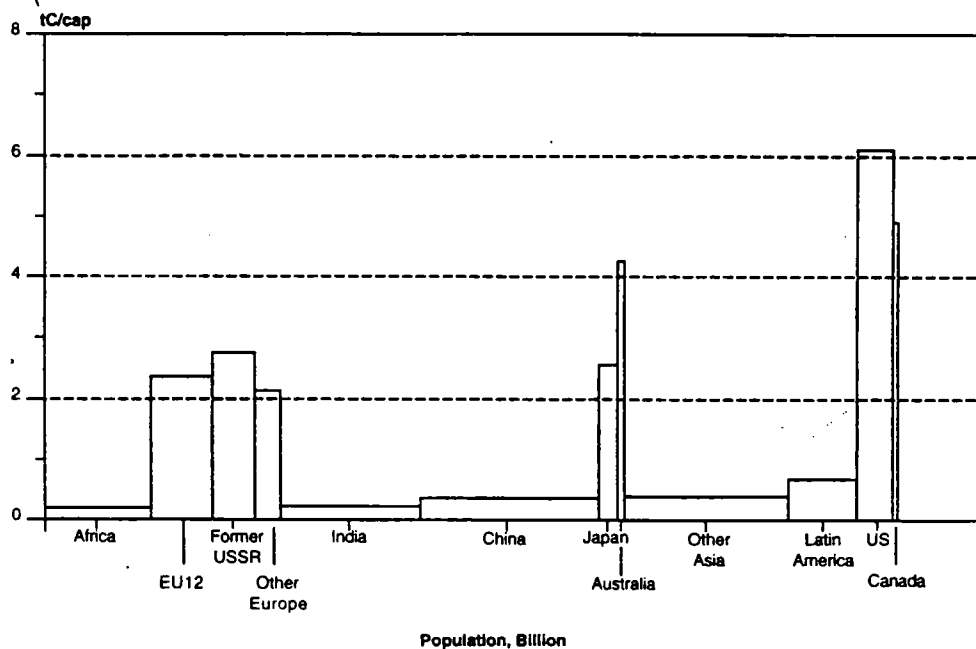


- A - No reducible market imperfections *and/or distortion*
 B - "Negative cost potential" achieved
 C - Curve B plus "economic double dividends"
 D - Curve C plus "environmental double dividends"

Source: Chapter 8

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Figure 5
Carbon Emissions per Capita and Population, 1993

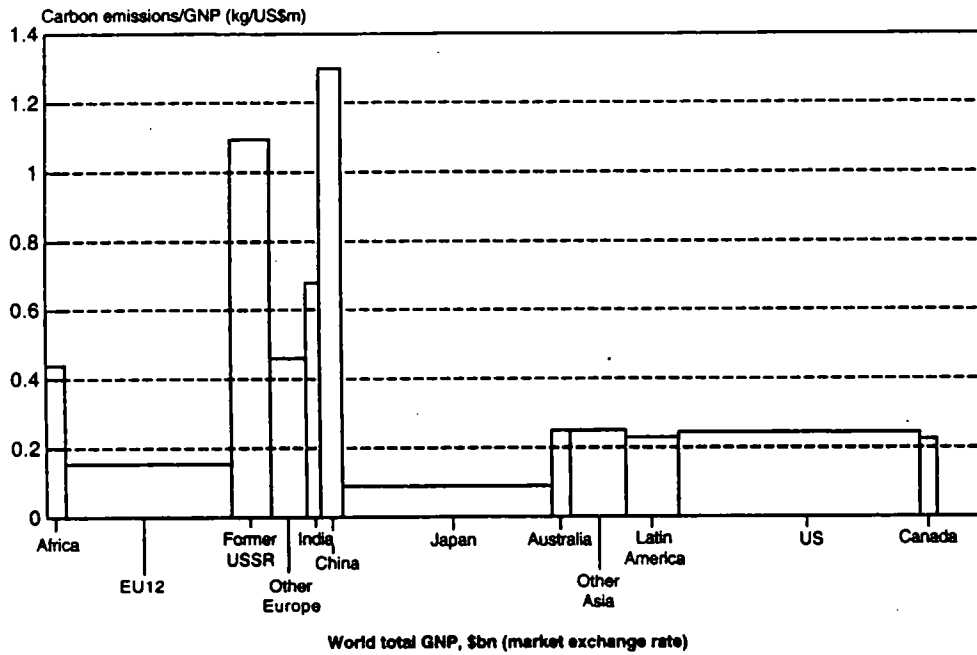


Source: Derived by M. Grubb from BP Statistical Review of World Energy 1994 and World Population Prospects, UN

918005 fig 1/95 ap

Figure 6

Carbon Emissions/GNP and Total GNP, 1992



Source: Chapter 3

Chapter 1

Introduction: Scope of the Assessment

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January, 1995

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SUMMARY

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 variation, and multiple greenhouse gases of concern. The risks of climate change are highly asymmetrical, with a large probability of a small loss, and a small probability of a large loss. Even in the presence of significant uncertainty, this asymmetry, plus the principles of risk aversion and portfolio balancing provide the rationale for going beyond *no-regrets* policies to those that incur net costs.

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

Both public goods and externalities require a legal framework within which the problems they pose can be addressed. No such legal framework now exists for global climate change. Mechanisms for control of international public goods may include the definition of property rights, the definition of limits to emissions and a consensus for distributing the same in a fair and equitable manner. If, on the other hand, each agent acts in its individual interest, the result will be too little of the public good and too much of the externality.

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

Policy measures to reduce risks to future generations include 1) immediate reductions in emissions; 2) R&D on new supply and conservation technologies; 3) continued research on how much change is likely and what its effects will be; and 4) investments to assist in adaptation if significant climate change occurs. A well-chosen portfolio of policies will yield greater benefits for a given cost than any one option undertaken by itself. Striking the appropriate balance requires taking into account costs, benefits, and risks.

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

Issues of efficiency and equity can largely be separated. The Framework Convention on Climate Change calls on all parties to implement cost-effective measures for abatement, enhancement of sinks, and adaptation. The Framework Convention also explicitly requires an equitable sharing of the burdens of response, recognizing the common but differentiated responsibilities of the parties. Different countries will be affected differently by climate change and by policy responses to it. The South is more likely to be adversely affected than the North; moreover, developing countries often lack the financial and technical resources to respond. The Framework Convention does not, however, include a formula for sharing the costs of addressing climate change.

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

Efficiency also calls for international mechanisms such as joint implementation and coordinated economic instruments. Coordinated carbon taxes and tradable carbon emission permits can correct the market failure associated with greenhouse emissions.

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 before the end of the next century and, if unchecked, continue to rise thereafter (IPCC 1990).

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 role of human activity in generating greenhouse gases, the consequences of those changes for humans, and possible responses, lie within the purview of the social sciences.

Climate change impacts are likely to vary dramatically from country to country. A warmer climate could benefit sectors of the economies of some mid- and high-latitude countries. At the same time, a rising sea level and the possibility of increased storm surges could threaten the survival of some small island states and coastal areas, and could increase the risk of midcontinent drought and desertification for inland areas on the periphery of deserts.

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

The commitment of resources to mitigate climate change may rest on one of two arguments. The first arises from fundamental values, the second from decision analysis:

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.
2. The potential exists for sudden, largely irreversible non-linearities with major effects

on the economy, particularly the economy of certain countries or regions.

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

This chapter, and others in this Assessment Report, draw on the findings of Working Groups I and II, and follow the guidelines provided by the Framework Convention. That Convention makes clear that important questions remain to be addressed by subsequent negotiations, including the adequacy of national commitments. 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 agriculture¹, forests², water resources³, the costs of heating and cooling⁴, the impact of a rising sea level rise on small island states and low-lying coastal areas⁵, 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 impacts⁶, including damages to existing ecosystems and the threat of species losses⁷.

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 natural scientists agree that greenhouse gas emissions are rising, they do not agree about the mechanism linking concentrations, and temperature. Further, although natural 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, social scientists do not agree on the size of the behavioral responses or economic effects that would follow, or on the effect of these changes on well-being.

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_0 , then even a small increase in the mean temperature, from m_1 to m_2 , may greatly increase the number of days above the threshold, represented by the area under the curves to the right of T_0 . 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 water formation and the North Atlantic Ocean circulation, responsible for much of the oceans' carbon uptake. Once disrupted, this current might not revert to its original position for centuries⁹.

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 now¹⁰. 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.

Long life of capital stock. 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 easily be rebuilt. For other investments, the cost of change will be small; for diversified agricultural economies, the cost of switching from one annual crop to another will be small if the temperature increase is on the order of 0.2°C. to 0.3°C. per decade, as climate scientists now expect (IPCC 1994). For less diversified economies, the costs may be larger.

Inertia in the climate system. 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. In this respect, the risks of climate change are unlike those of earthquakes or floods. The combination of time lags in the climate system and uncertainty about effects requires taking action before unambiguous information emerges about the 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.

Moreover, whereas economic analysis generally takes the point of view of a single decision maker or government, the important decisions on climate change will of necessity be made by many sovereign governments. Economic and decision sciences are not yet able to predict the outcome of bargaining problems of this type¹¹.

Regional variation. Impacts are likely to vary greatly both within and among countries. Some countries and regions will suffer from warming; others will benefit, at least in some sectors. Some cold countries will benefit from a reduction in heating costs and an increase in the length of growing seasons; some warm countries will see a drop in yields from agriculture and forestry; low-lying states are likely to suffer from increased storm surges and flooding. For the world as a whole, the net effect at any time will be the sum of local effects at many points on the globe, some positive and some negative; analysts have no way to estimate this sum without detailed local calculations (summarized in Chapter 6).

Aggregation. On a priori grounds, there is no reason to believe that greenhouse warming should have in the aggregate, either positive or negative long-run effects (although adjustment implies costs in the short run). Indeed, studies twenty years ago focused on the dire consequences of global *cooling*. It seems unlikely that the earth is somehow endowed at this moment with the *optimal* temperature; the Earth has nonetheless adjusted to its current climate, and readjustments in either direction may be costly.

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 greenhouse gases differ in radiative forcing and atmospheric lifetime, analysts have devised measures of global warming potential (IPCC 1990), making the different gases commensurable¹².

Importance of net emissions. Because greenhouse gas concentrations depend on net rather than gross emissions, changes in forests and other greenhouse gas sinks must be taken into account¹³.

Efficiency vs. Equity. How much to reduce emissions is a matter of efficiency. Who pays is a matter of equity. Economics has much to say about the former, but much less about the latter. Nonetheless, equity considerations will drive many of the policy decisions to be made under the Framework Convention on Climate Change.

1.3 CONTRIBUTION OF ECONOMICS

Economics and the social sciences offer perspectives on climate change not provided by the physical sciences. In the classic definition, economics is the study of the allocation of scarce resources that have alternative uses. Economics emphasizes the importance of 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.

This chapter sets out the logic of cost-benefit analysis as applied to climate change. Standard cost-benefit analysis requires 1) a valuing of costs and benefits over time, using *willingness to pay* as a measure of value and 2) a criterion for accepting or rejecting proposals¹⁴. The standard criterion is the *compensation principle* (Kaldor date, Hicks date), which says that if the project yields positive net benefits, then those made better off could compensate those made worse off with something extra left over. The result is an unambiguous gain in welfare, without the necessity of weighing effects on different individuals.

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

Beyond these fundamental concepts are ideas, originally from 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. Moreover, results available to date from integrated assessment models indicate that **climate change risks are highly asymmetrical**, with a high probability of a small loss and a low probability of a large loss (Manne and Richels 1992, Peck and Teisberg 1993, Nordhaus 1994). In the past thirty years, much new economic research has focused on rational responses to risk¹⁵, including three areas important to a systematic examination and rational response to climate change: portfolio theory, insurance, and decision analysis.

1.3.1.1 Portfolio Theory

A portfolio manager attempts to get the best return for a given level of risk. One 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.

Several responses can reduce the impact of climate change: insurance and precautionary investments¹⁶. Precautionary investments may take the form of mitigation or in actions that enhance the ability of future generations to adapt. 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 benefit for a given cost than any one option undertaken by itself. For an individual country, the issue is how to choose the portfolio of policy measures best suited to its circumstances, and to adjust the portfolio over time in response to new developments. Governments will be making climate change decisions for several decades at least. This means that they will have many opportunities to adjust the size (total resources) and mix (choice of measures) of their portfolio of responses.

1.3.1.2 Insurance

Several concepts from insurance have important applications to climate change: risk aversion, risk premium, and certainty equivalent.

That individuals and societies are *risk averse* means that average utility is increased by pooling risks, or equivalently that people are willing to pay to reduce the risks they face. If society as a whole is risk averse, then some investments with a negative expected return, for example in climate change mitigation, should be undertaken if they reduce the

Risk and Uncertainty

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

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

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

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

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

probability of a loss, or the costs of future adaptation.

The magnitude of those expenditures depends on (a) society's degree of risk aversion; and (b) the magnitude of the risk. The *risk premium*—the extra amount that society is willing to pay to reduce a risk—is small if the stakes (say, the maximum loss) are small, and large if the stakes are large. An investment of a 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. If a possible outcome is a loss of 10%, even though the expected loss is only 3%, then the *certainty equivalent* loss will exceed 3%. A dollar investment that reduces this certainty equivalent loss by more than a dollar should be undertaken; such an investment could either reduce the average loss, e.g. by reducing the probability of the loss occurring (through mitigation actions) or reduce the variance of the loss. For example, some actions that reduce extreme losses will have more than proportionate returns.

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

The economic principles of risk aversion and portfolio theory provide the rationale for going beyond *no-regrets* policies. Naturally, actions that reduce greenhouse gas emissions at zero or negative costs should be undertaken. But a prudent response to the risk of greenhouse gas warming goes beyond *no-regrets* policies to some policies incurring net costs.

Traditional insurance involves pooling a large number of diversifiable risks. Insurance exist when people differ in their ability to bear a given risk, or would be affected differently by the risk. Insurance markets *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 risk¹⁷. By transferring risk, traditional insurance can address one aspect of the risk from climate change: the large differences in expected regional impacts. This holds irrespective of who pays the cost, because wealthier individuals and countries are better able to bear risk¹⁸, 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 South¹⁹.

Traditional insurance will not, however, address all risks from climate change. Shipowners can buy insurance against storm loss because shipping risks are diversified: one storm is unlikely to sink all the ships covered by the insurer. But because climate change

is global by nature, and therefore undiversifiable, traditional (intragenerational) insurance cannot fully insure against climate change risks. Rather, some form of intergenerational insurance is likely to arise as a way to redistribute more of the risk.

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.²⁰

1.3.1.3 Precautionary investments

A business makes precautionary investments to reduce the total risk of its portfolio. Numerous policy measures are available to reduce risks to future generations from climate change. Four have dominated discussions in recent years: 1) immediate reductions in emissions to slow climate change²¹; 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.

Precautionary investments may also enhance the ability of future generations to react. An important reason that people establish savings accounts is to reduce the impact of unfavorable events in the future. Similarly, a society may elect to accumulate capital against the possibility of a large loss from climate change. This is one thread of the debate over discount rates in Chapter 3. Those who argue for a discount rate close to the opportunity cost of capital point out that society may choose between immediate greenhouse gas mitigation, at a cost, and delayed mitigation, with some of the money saved put aside as a savings account for our grandchildren in the event of large climate-induced damages.

1.3.2 Sequential Decision Making

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

A more useful formulation is: "Given current knowledge and concerns, what actions should we take over the next one or two decades to position ourselves to act on new information that will become available?" (Lind 1993) For example, decisionmakers would like to know if the possibility of irreversible damages²² justifies immediately undertaking an aggressive abatement program²³.

Climate change demands a decision process that is sequential and can incorporate new information. Timing will be a key element, and the date of resolution of uncertainty an important element of the analysis. Figure 1 shows schematically the progression from a simple decision to a sequence of linked decisions. The simple decision is sometimes referred to as the "learn, then act" model, the second as "act, then learn"; or, in the case of the decision depicted, "act, then learn, then act."

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

For example, the choices might be 1) immediate investment in new plant and equipment 2) aggressive R&D on greenhouse abatement technology or 3) deferring large investment for 10 years, until the nature and size of the threat is better understood, and when costs will presumably have dropped and the job can be done more efficiently.

Because of the high cost of being wrong in either direction, the value of information about climate change is likely to be great. In particular, the value of information about the sensitivity of temperature to CO₂ increases, the temperature damage function, the GDP growth rate, and the rate of energy efficiency improvement is likely to be high (Chao 1991, Peck and Teisberg 1991, Manne and Richels 1992, Nordhaus 1994)²⁴.

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

1.3.3 Dynamics

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

Dynamic analyses have 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 are likely to be less costly. This suggests large potential gains from flexibility in timing of emission reductions²⁵.

1.3.3.1 Kaya Identity

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

$$\begin{array}{lcl} \text{CO}_2 & = & \text{CO}_2/\text{E} \quad \text{E}/\text{Q} \quad \text{Q}/\text{L} \quad \text{L} \\ \text{carbon dioxide} & & \text{carbon dioxide} \quad \text{energy} \quad \text{output} \quad \text{population} \\ \text{emissions} & & \text{emissions per} \quad \text{per unit} \quad \text{per} \quad \\ & & \text{unit energy} \quad \text{output} \quad \text{capita} \end{array}$$

or, expressed in rates of change:

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

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 population²⁶.

This identity clarifies different approaches to reducing emissions. For a developed country with a stable or slowly growing 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 second term on the right-hand side, for example from cars to public transportation, from less to more fuel-efficient cars and homes²⁷. Fuel switching (for example, from coal-based electricity to oil, gas, hydroelectric, wind, and geothermal), represented by the first term, also offers the potential to limit CO₂ emissions in many countries.

For many developing countries, emissions will increase unless energy efficiency and greenhouse gas emissions per unit of energy change to offset growth in per capita output and population. For many developing countries with rapidly growing populations, pressures for economic development will make it difficult to direct capital from investments with higher greenhouse gas emissions to those with lower greenhouse gas emissions²⁸.

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., how much does aggressive emission reduction depress economic growth? Order-of-magnitude calculations suggest the presence of only limited trade offs, at least for the near term; (b) do developing countries have the institutional capacity to achieve the desired increases in emissions efficiency?

1.3.3.2 *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 itself²⁹.

The central problem with natural resources, whether renewable or not, is timing. Many renewable resources 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 flows later³⁰.

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 postponed³¹. Conversely, research on "learning effects" shows that if actions taken today will lower costs faced tomorrow, then these dynamic benefits should be included in the calculus (Arrow 1962, Atkinson and Stiglitz 1969). In the context of climate change, if emissions constraints stimulate technical or other developments that help to lower the costs of continuing or additional emission abatement, then reductions should be accelerated (Grubb 1993, 1995). If discount rates are high, the costs borne by future generations will carry less weight than if discount rates are low. In the presence of risk, non-linearities, or irreversibilities, the principle of risk aversion suggests a strategy of early mitigation.

The theory of non-renewable resources has a second set of lessons for climate change policy. Among the four energy categories -- coal, gas and oil, biomass and non-carbon

sources -- gas and oil are exhaustible; this limits total emissions from gas and oil. With exhaustible natural resources, the question is not how much will be consumed, only when³².

Figure 2 depicts fuel use in 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 oil and gas 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 sources³³. 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 coal-rich countries 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.

1.3.4 *International Public Goods*

The atmosphere is an *international public good* in that atmospheric concentrations are the result of combined actions by all countries. A pure public good (Samuelson, 1954) has two properties: 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*).³⁴ The atmosphere has both characteristics. One country's greenhouse gas reductions affect all other countries as well. If this thwarts

climate change, all countries benefit³⁵.

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 emissions³⁶.

1.3.4.1 Property rights

An important strand of economic thought associates externalities with a failure to assign property rights (Coase 1990). Assigning property rights to the atmosphere is particularly difficult, since this would require the agreement of many sovereign states. 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.

1.3.4.2 Paying For An International Public Good

Who should pay for a global public good? every country faces this question internally in determining who should pay for the public goods it provides. Who should, for instance, pay for pollution control within a country?

Economists generally agree on 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.

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.

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

Economists agree less about the framework for deciding the burden of financing mitigation and adaptation. At least four approaches have been proposed to determine how the burdens of taxation should be shared. One approach looks at *benefits*: just as those who benefit from private goods must pay for them, those who benefit from a public good should be made to pay for 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.

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

A third approach is based on contribution to the problem. Because the North has contributed more than two-thirds of the stock of greenhouse gases in the atmosphere today, this approach seems to suggest a large responsibility for the North. On the other hand, by the time greenhouse gas concentrations double from preindustrial levels, the developing countries are projected to be contributing more than half of annual emissions, and roughly half of the total stock in the atmosphere (IPCC, 1990; Cline 1992). Thus under this criterion, the developing countries might eventually pay far more of the mitigation costs than under the other principles described earlier.

Economists have turned to a fourth approach -- the social welfare function -- to answer the question of how much extra different parties should pay, as well as the question of how to distribute the surplus. The discussion of equity below differentiates between the Rawlsian and utilitarian approaches. In this case, both approaches yield similar results: In the absence of incentive problems, both imply that all of the surplus should be allocated to the poorer countries, or that the burden of effort be borne by the richer countries³⁷.

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 obtained³⁸; and (b) that the outcome is independent of how property rights are assigned³⁹. Coase also emphasizes the importance of transactions costs, which will often influence the choice of policies.

A simple approach that yields efficiency but does not require redistribution (and is thus consistent with the two principles enunciated above) requires coordinated tax rates so that all countries face the same energy prices. This approach makes the cost of emitting an extra ton of carbon equal across all countries, and each country retaining the revenues thus generated⁴⁰. 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 countries⁴¹.

Accounting for past damages. The Framework Convention on Climate Change directs the Annex I countries to take the lead in responding to the threat of climate change. Some have argued in addition that because the North has been the major contributor to current levels of greenhouse gases, it should bear most of the costs of mitigation. This view says that costs should be borne not in proportion to benefits expected, but in proportion to contribution to pollution. This argument, however, is not based on efficiency, which requires that incentives be prospective (forward looking), not retrospective⁴². 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. Moreover, many have challenged the ethical basis for assigning responsibility based on past damages⁴³.

The controversial issue of population growth, while central to the question of economic development, bears on climate change largely through its effect on emissions. This chapter will limit its treatment of population to this one effect⁴⁴.

1.3.4.3 Enforcement

Both externalities and public goods need a legal framework within which the problems they pose can be addressed. Without compulsory taxation, there is an incentive for each individual to be a free rider, though there is some empirical evidence that the free rider effect may not be as significant as economists have previously assumed (Bohm [date]). In the absence of compulsory taxation, externalities can only be addressed with well defined property rights (Coase 1990)⁴⁵ 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. For example, the incentive for free riding is great, whether through delay, nonagreement, or noncompliance. 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 compliance⁴⁶.

1.3.4.4 Knowledge

A key element in addressing the problem of climate change 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 some mechanism, possibly including joint implementation, must exist for sharing research plans results, and for ensuring that the fruits of this research are made freely available.

1.3.5 Efficiency

With some exceptions noted below, issues of efficiency and equity can be separated⁴⁷. Analysts agree that any actions responding to climate change should be cost-effective: no matter who bears the cost of emission reductions, reductions should occur where their cost is lowest⁴⁸. 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 11. All of these approaches, however, attempt to confront all individuals and producers in all countries with the same cost of emissions. Emission control is an international public good in that greenhouse emission reductions have the same effect, wherever they occur. Just as efficiency in the production of steel or any other commodity requires that all consumers and producers face the same price, so too with emissions. 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, will significantly reduce its effectiveness. The growth of international trade has resulted in important links between the developed and developing countries, and the total effects of any policy undertaken in the North can only be evaluated in terms taking into account the systemic responses, including responses from the South, as discussed under "General

Equilibrium," below⁴⁰.

1.3.5.1 Bankable permits

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

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

1.3.5.2 Exchange/risk efficiency.

When different parties to an agreement hold widely differing views about risk and the probability of loss, significant efficiency gains can result from transferring risk among parties. An earlier section discussed the importance of establishing an international insurance market for those facing the threat of losses under climate change, and noted the advantages of establishing a market within which countries who are less concerned about the economic risks associated with climate change 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 lifetimes⁴⁰), 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; 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 may relocate outside the OECD. Further, if greenhouse mitigation puts an economic drag on the developed countries, developing countries would be affected through trade.

If different countries have different obligations to reduce greenhouse emissions, different implicit tax rates will result. This will interfere with world economic efficiency--decreasing world real output--possibly with little effect on total greenhouse gas emissions. For example, the most energy intensive activities--such as aluminum production--may well relocate to developing countries⁴¹.

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)⁴². Thus, estimates of carbon "leakages" are based only on commodity substitution⁴³. But allowing for relocation of industries -- as would occur in the very long run, the time span of interest for an analysis of climate change-- leakages may well be higher. No consensus now exists on the magnitude of long-run leakages.

1.3.6.1 Intertemporal Substitution

General equilibrium issues also arise when production can be shifted from one period to another. For example, in a partial equilibrium analysis, a tax on gas or oil raises the price of the fuel taxed, thereby reducing its consumption, and thus associated emissions. But 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)⁵⁴.

1.4 EQUITY

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

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

[Account must be taken of] the differences in their starting points and approaches, economic structures and resource bases, the need to maintain strong and sustainable economic growth, available technologies and other individual circumstances, as well as the need for equitable and appropriate contributions by each of these Parties to the global effort regarding [the Convention's] objective⁵⁵.

1.4.1 General Issues

Within the limits of cost-benefit analysis, equity arises because of the principle of compensation, discussed in section 1.3, above. For example, suppose it could be shown that a business-as-usual path produced higher total benefits than a path with lower greenhouse emissions. We could not from this evidence conclude from this that the world as a whole would be better off. Suppose that costs of warming fall predominantly on one group or one generation, while benefits accrue to another. (For example, some have speculated that the costs of damages from warming would fall largely on the South, without a compensating increase in benefits (Parikh date).) Unless the gainers actually compensate the losers for their losses, cost-benefit analysis cannot conclude that the change has been on balance good for society. Compensation is particularly difficult if future generations would bear most of the costs, because no "Fund for Future Greenhouse Victims" exists (Steer 1992). Thus, some have argued that in the absence of mechanisms to make these transfers, we should not rely on possible future transfers from gainers to losers, but should instead

insist that the gainers pay the costs up front. An alternative explanation addresses these equity concerns by assigning different weights, perhaps based on economic status, to changes in consumption of different individuals (Atkinson date).

No consensus exists among either economists or philosophers about the appropriate ethical responses to the changes that would come with climate change. 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? Economists have often argued no, for several reasons. First, some wealth is not a reward for productive activity, but merely an accident. It is not because country X did something that \$200 billion worth of minerals or oil was discovered to lie beneath its territory. 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. Another view denies that government policies would be taking away value from assets that by right should be there; until now, according to this view, 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.⁵⁶

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

Many of these impacts will be reflected in capital costs. Thus, the value of land in temperate climates is likely to rise, and the value in extreme climates to 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, residents of colder climates are likely to consume less heating fuel, but perhaps at a higher price, which would leave them on balance about where they started. Energy prices are likely to rise, and land rents to fall, in an almost offsetting way. On the other hand, current owners of land would bear the full brunt of the present discounted value of all future increases in taxes (or the tax-equivalent cost of regulations designed to reduce energy utilization.) As a result, unless policy changes are introduced gradually, dramatic changes in land values may occur, with possibly large effects on financial institutions and the economy as a whole. Anticipation of these policies would partially offset these dramatic changes in land values³⁷.

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

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 climate change, 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 lost; 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 sulfur dioxide, 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 3 addresses directly the most important issue in intergenerational equity: choice of an appropriate discount rate.

This argument also applies to actions with differential impacts on different regions. If greenhouse warming turns out to be a major threat to countries of the South, and if the North fails to reduce emissions aggressively now, countries of the South might suffer additional damage later. Alternatively, if the North chooses to embark on an aggressive control regime now, and if this cuts into Northern growth rates, the result would shrink exports markets for the South, and thus reduce growth there; in addition, if the North views its greenhouse efforts as, in effect, development aid for the South, it might cut back on other programs (sanitation, water, education for women, etc.) with a greater impact on life expectancy, health, and well-being.

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 workers⁵⁸.

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 possibly 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, or save an extra dollar of 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 (including the social costs of implementing the policy) 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 least-cost methods of reducing greenhouse gas emissions? What does the cost curve look like⁵⁹? 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 future⁶⁰. 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 lunch⁶¹.

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

1.5.2 Policy Reform

A variety of government reforms could enhance energy efficiency, including removing energy subsidies, reforming or clarifying property rights, reducing 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 countries⁶². 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%. Agricultural subsidies also distort the outcome, especially affecting the size of forests.

1.5.2.2 Property Rights Reform

One responsibility of governments is to define property rights and enforce contracts.

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

7 8 **1.5.2.3 Administrative Reforms**

9
10 Defining property rights and eliminating energy subsidies are two important actions
11 governments can take to reduce greenhouse emissions. At the same time, many less
12 sweeping reforms can improve economic efficiency and simultaneously reduce greenhouse
13 gas emissions. For example:

14
15 *Pricing of government produced electricity.* Many governments price electricity not at the
16 market price but at the cost of production. Economists generally recommend that
17 electricity, like any good, be priced not at its cost of production, but at the competitive
18 price. In countries with a mix of plants, this means that electricity from all sources should
19 be priced the same--at the highest marginal cost of production⁶³.

20
21 *Land use and other regulation.* Changes in land use policy can also reduce energy
22 consumption (especially for transportation and space conditioning), and thus greenhouse gas
23 emissions⁶⁴.

24 25 **1.5.2.4 Regulating Non-greenhouse Externalities**

26
27 Many activities producing greenhouse emissions also generate pollution of other types.
28 For example, fossil fuel combustion releases conventional air pollutants; rush-hour auto use
29 contributes to road congestion. In the presence of these spillover effects or externalities,
30 market solutions will not properly reflect the externalities generated, leading to the
31 overconsumption of environmental resources. Energy taxes, congestion pricing, or tradable
32 permits can correct these market signals, resulting in lower emissions of both greenhouse
33 gases and other pollutants. Some reforms, such as congestion pricing, also reduce the need
34 for roads and other physical capacity.

35 36 **1.5.2.5 Special Problems of Economies in Transition**

37
38 The economies in transition provide special opportunities for mitigating greenhouse
39 emissions. In the old Soviet bloc, high energy subsidies and other price distortions affected
40 energy usage directly, as well as indirectly through the composition of output. Spotty
41 environmental regulation meant that Eastern Bloc nations lacked the environmental controls
42 common in the OECD. The capital shortage of the past decade has contributed to the
43 problem, through a general deterioration of physical capital stock.

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

8 9 **1.5.2.6 Examples of Efficiency-Increasing Policies**

10
11 Policies that cause individuals not to take into account the full social costs of their
12 actions often result in greater energy use and greenhouse emissions. The National Action
13 Plans of many countries have revealed examples of such policies, and have suggested
14 remedies, including:

15
16 *Unit pricing of waste disposal to encourage recycling:* The *life-cycle* social cost of
17 consuming a good includes its costs of production plus disposal. Most consumers, and
18 many businesses, pay a flat fee for trash disposal; with a flat fee, the marginal cost of
19 throwing away an extra pound of trash is zero. By moving from flat fees to unit pricing,
20 the actual price consumers pay to buy and dispose of a good will more closely match its
21 full life-cycle social cost.

22
23 *Pay-at-the-pump automobile insurance:* In most countries, drivers pay automobile
24 insurance yearly or monthly. Once the premium is paid, the marginal insurance cost of
25 driving an extra mile is zero, even though driving more does increase the chance of being
26 in an accident. As an alternative, drivers could be required to pay a portion of their
27 insurance bill at refueling. With pay-at-the-pump insurance, a tax would be levied on
28 gasoline and earmarked to pay for insurance premiums. This would raise the cost of
29 gasoline at the pump, but lower auto insurance premiums.

30
31 *Subsidized parking.* In some industrialized countries, many employers provide parking to
32 employees at no cost or lower-than-market cost, thus lowering the relative price of
33 commuting by car relative to public transportation. A distortion arises when governments
34 tax income spent on public transportation, but not income implicit in the parking subsidy.

35
36 *Subsidized housing.* In some industrialized countries, home mortgage interest is
37 tax-deductible. In all but a few countries, the implicit income on owner-occupied housing
38 is not taxed. These tax provisions encourage individuals to consume more housing than
39 they otherwise would. In cold or hot climates, where more housing space requires more
40 energy, this tax treatment increases CO2 emissions.

41
42 *Subsidized trucking.* Studies suggest that virtually all road damage is caused by heavy
43 trucks, which pay only a portion of the expense of building and maintaining the road
44 system. Many countries thus subsidize trucking compared with rail or barge transport,

probably increasing greenhouse emissions⁶⁵.

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

The substantial differences in practices both within and between countries 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 1982). 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 companies⁶⁶.

Moreover, both theory and evidence support the view that markets, on their own, do not provide an efficient level of disclosure of information⁶⁷. Indeed, some evidence indicates that markets may try to obfuscate relevant information⁶⁸. This provides the rationale for government provision of information, or laws that in many countries require disclosure of interest rates and other consumer-relevant information, including appliance energy consumption.

Bureaucratic structure, limited scope of attention. In recent years, economic and organizational theory⁶⁹ 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 attention⁷⁰. How managers direct their attention has much to do with what the firm does⁷¹. 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 place⁷².

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 firms⁷³. Studies of implicit discount rates consistently show that households and firms use discount rates substantially above market rate for long-term government bonds.

Two explanations have been offered: 1) Risk: Interest rates facing firms and households reflect the risk premium that lenders require to compensate them for the probability of default. Firms often use discount rates that include a risk premium to reflect the riskiness of projects; 2) Capital constraints: Individuals and firms often face rationing in capital markets, both for credit and equity. Recent research has provided a rationale for this rationing based on the fact that information is imperfect and costly⁷⁴.

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.⁷⁵ Higher risks should not result in higher discount rates.⁷⁶ Similarly, capital constraints should be reflected in the shadow price of capital, not in the discount rate.⁷⁷ Because of limited information (and a version of the "winners' curse"⁷⁸) 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.⁷⁹ 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.⁸⁰

1.5.3.1 *Revising national accounts*

Some have suggested revising the conventional systems of national accounts to incorporate full social pricing of resources. An early contribution suggested a new measure of economic welfare based on consumption that increases quality of life (Tobin and Nordhaus, 1972). These authors and others recognized that national income accounting, widely adopted after World War II, measures aggregate income and expenditure flows, but does not incorporate environmental costs and benefits.

Conventional national income accounting does not fully report three categories of resource expenditures: a) defensive expenditures, either for pollution prevention before the fact or for cleanup after the fact (although these expenditures are not separately reported, they are counted in GDP); b) consumption of environmental goods (such as exhaustible resources)⁸¹; and c) conflicting uses of environmental services (such as the atmosphere, used by producers as an input into production, and by households as a consumption good).

One proposal would include in GDP the effect of changes in quality of the environment. In Eastern Europe and the former Soviet Union, steady increases in reported post-war GDP masked the effects of decades of environmental degradation; for part of that period, environment-adjusted GDP almost certainly declined.⁸²

However, important conceptual problems in defining levels and changes of environmental assets, complicate the task of modifying national accounts. First, the stock

of natural resources has no obvious definition. While most geologists would agree on the size of coal stocks -- their location is known and their in situ value can be estimated -- this cannot be said for oil or minerals⁸³. Second, environmental assets--such as air quality--present another set of problems, because no market prices exist to value the asset.

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

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

Another measure of broad-based welfare, although not including environmental amenities, is the UN's human development index or HDI (UNDP, 1990). The HDI gives a composite measure of human development by combining three key indicators: longevity (measured by life expectancy at birth), education (measured by adult literacy and mean years of schooling), and income (real GDP per capita adjusted for purchasing power). Although the HDI is not directly related to global environmental issues, both climate change and abatement policies may affect it⁸⁴.

1.5.4 *Innovation*

Standard competitive analysis argues that *given all required information and technology* market economies produce efficient outcomes. But recent economic analyses have shown that, in general, market economies need not result in the efficient allocation of resources 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 less 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 innovation⁸⁵. 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.⁸⁶ 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. In the same way, the high cost of establishing intellectual property

rights impedes the transfer of technology to developing countries.

Still, there is a general consensus among economists that the patent system provides a better basis of financing applied research than do 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 reduced⁷⁷. (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 change⁷⁸.

1.5.5 Carbon Taxes and Tradable Permits.

Economic efficiency requires all agents in the economy to pay the full marginal social costs of their actions. But firms and households are not charged for the additional warming potential they add to the atmosphere, and so do not pay the full social costs they impose. Two economic instruments can correct this market failure: carbon taxes and tradeable permits.

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

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

can sell excess permits on the market and generate revenue.⁷⁹

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 actions⁸⁰. Permits are better for regulating large sources; carbon taxes are better for small sources. In principle, both could be adjusted to achieve the desired level of emissions desired, although adjustments of this sort are likely to be difficult in practice.

The initial allocation of permits will largely determine the distribution of costs of abatement (Chapter 3 discusses these issues of equity at greater length), and at the same time influence the growth path of participants' economies. For example, an allocation based on population at a given date would provide an incentive for population control⁸¹.

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, by embarking on an ambitious program to reduce emissions, a firm may qualify for fewer permits than it would otherwise. Not only does this violate ordinary notions of fairness, but anticipation of granting permits in this way would, accordingly, have strong adverse effects on emissions⁸².

That a tax has large distributive consequences, while presenting a political impediment to its introduction, is not necessarily an argument against it. Some argue that those who failed to pay the full social costs of their actions earlier are not therefore entitled to special allotments now⁸³.

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 existing 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 commodities⁹⁴.

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 target⁹⁵.

1.5.5.2 Energy Taxes

Energy taxes as a means of controlling greenhouse emissions must be viewed as "second best" taxes in that they do not directly tax the externality, greenhouse emissions. 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 for permit banking (storage) or brokerage (trading) to facilitate trades between private parties. These services would prove especially useful in the more complex international context.

1.5.5.4 Combining taxes with tradeable permits

While carbon taxes and tradeable permits are typically presented as alternatives, policy makers may prefer to combine them. 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. Another possible combination is permits for large sources and a tax (set to equal the permit price) on small sources.

1.5.5.5 Intertemporal patterns of taxation

If the target is the long-run atmospheric concentrations of greenhouse gases, then climate change damages will be approximately the same for emissions in any particular year, although the optimal carbon tax must be adjusted for differences in costs, discounting, and risk⁹⁶. The focus on concentrations also implies that early reductions are more valuable than later reductions.

For exhaustible natural resources, such as oil, economic efficiency requires that those deposits with the lowest cost of extraction be extracted first. Hotelling (1931) argued that competitive equilibrium implies that rents (price minus costs of extraction) must rise at the rate of interest. The price of the backstop technology (an energy source assumed to be available in unlimited quantities at a certain price after a certain date, such as electricity from solar photovoltaic cells) determines the set of resources to be ultimately exploited, 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

Regulation of greenhouse emissions may take many forms, including fuel restrictions, technology standards, and various economic incentives; Chapter 11 discusses these options in detail. Economists have long argued for the use of economic incentives for environmental management, although governments have so far relied on traditional regulations almost exclusively, as traditional approaches have been more acceptable to the public and industry. For example, Corporate Average Fuel Economy (CAFE) standards in the U.S.A. require automobiles to meet certain mileage standards.

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 the claim of technology forcing, however, is equivocal. In several cases in which industry failed to meet the applicable standards, regulators withdrew the standard in the face of unacceptably high economic costs. The apparent advantage of technology forcing -- one large club instead of the subtle and continuous incentives provided by market forces -- is often in fact a disadvantage.

Other disadvantages to the traditional approach are: First, traditional regulations do not in general result in economic efficiency, since those in one sector face implicit or explicit incentives at the margin that differ from those in other sectors. Second, traditional regulations fail to account for offsetting private responses that may neutralize the regulation's intended effects and even cause environmental harm. Third, traditional regulations provide no incentives for exceeding the given target, even when doing so might result in little additional cost⁷⁷.

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

captured by special interest groups⁷⁸.

1.6 SUSTAINABLE DEVELOPMENT

The concept of sustainable development was formulated about 1980 as a response to the apparent conflict between environmental concerns and the need for economic growth, especially in developing countries. At the time, preserving biodiversity and maintenance of environmental quality seemed incompatible with a 5- or 10-fold increase in world output, as would be necessary if per capita incomes of the South were eventually to approach those of the North now. The sustainable development debate rekindled interest in the question of resource scarcity, originally addressed in the economics literature by Malthus (1798), and revived in the policy arena with the publication of *Limits to Growth* (1972). A variety of definitions of sustainable development have been proposed. The Brundtland Commission 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 needs⁷⁹.

Although the Commission clearly had in mind environmental considerations, its report did not spell out exactly what sustainable development included. The Interamerican Development Bank explicitly included environmental concerns in its formulation:

[Sustainable] development distributes the benefits of economic progress more equitably, protects both local and global environments for future generations, and truly improves the quality of life.

1.6.1 The Economic Concept of Sustainable Development

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

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

In practice, sustainability as defined by Solow provides few constraints on growth paths for the developed countries, so long as steady increases in productivity continue. Technical change alone, without further capital accumulation, may well sustain future living standards

and offset any effects of environmental degradation. To see this with a numerical example, note that even if estimates of adaptation costs are taken to be 1 to 3 percent of GDP should significant warming occur, and if even 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. Even with no discounting, it would be hard on this account alone to justify the sacrifice of further consumption by this generation in order to enhance the standard of living of the future generation.

Capital accumulation and substitutability. To what extent can technology, skills, and capital equipment substitute for a decline in exhaustible resource stocks or a decline in per capita environmental amenities? Solow's definition, and much of economic theory to date, implicitly assumes that substitutes exist or could be found for all resources. As formulated by Pearce (1988), if substitution possibilities are high, as most evidence from economic history indicates, then no single resource is indispensable, and intertemporal equity stands as the only crucial issue. If on the other hand, human and natural capital are complements or only partial substitutes (e.g., if because of the irreversibility of extinction¹⁰⁰, capital accumulation is only a partial substitute for biodiversity) then different classes of assets must be treated differently, and some assets are to be preserved at all costs.

Pearce (1992) distinguished between strong and weak sustainability. Weak sustainability requires that any depletion of natural capital be offset by increases in human-produced capital -- the Solow criterion -- or by the substitution of other forms of natural capital, such as renewable assets in place of nonrenewable assets. Strong sustainability requires that some natural capital, being irreplaceable, must be preserved¹⁰¹. It has been argued that there are no close substitutes for the atmosphere and the climate it produces, implying no substitution possibilities and hence the need to preserve the atmosphere.

1.6.2 Implications of Sustainable Development for Developing Countries

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

None of these linked [development] issues can be resolved unless and until there is broad-based development in the South. Only such broad-based development can provide the foundation of international security. The Northern approach is to attack the symptoms, with a residual emphasis on poverty eradication. But the international community must insist on addressing the underlying causes for concern. Development, environmental protection, peace, and security are indivisible¹⁰².

Similarly, the G-77 and China emphasized the need for economic growth in the

following statement on sustainable development and the environment introduced during the INC negotiations in 1991:

Protection of the global climate against human-induced change should proceed in an integrated manner with economic development in light of the specific conditions of each country, without prejudice to the socio-economic development of developing countries. Measures to guard against climate change should be integrated into national development programmes taking into account that environmental standards valid for developed countries may have inappropriate and unwarranted social and economic costs in developing countries¹⁰³.

1.7 CONCLUSIONS

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 variation, and multiple greenhouse gases of concern. The risks of climate change are highly asymmetrical, with a large probability of a small loss, and a small probability of a large loss. Even in the presence of significant uncertainty, this asymmetry, plus the principles of risk aversion and portfolio balancing provide the rationale for going beyond *no-regrets* policies to those that incur net costs.

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

Both public goods and externalities require a legal framework within which the problems they pose can be addressed. No such legal framework now exists for global climate change. Mechanisms for control of international public goods may include the definition of property rights, the definition of limits to emissions and a consensus for distributing the same in a fair and equitable manner. If, on the other hand, each agent acts in its individual interest, the result will be too little of the public good and too much of the externality.

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

Policy measures to reduce risks to future generations include 1) immediate reductions in emissions; 2) R&D on new supply and conservation technologies; 3) continued research

on how much change is likely and what its effects will be; and 4) investments to assist in adaptation if significant climate change occurs. A well-chosen portfolio of policies will yield greater benefits for a given cost than any one option undertaken by itself. Striking the appropriate balance requires taking into account costs, benefits, and risks.

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

Issues of efficiency and equity can largely be separated. The Framework Convention on Climate Change calls on all parties to implement cost-effective measures for abatement, enhancement of sinks, and adaptation. The Framework Convention also explicitly requires an equitable sharing of the burdens of response, recognizing the common but differentiated responsibilities of the parties. Different countries will be affected differently by climate change and by policy responses to it. The South is more likely to be adversely affected than the North; moreover, developing countries often lack the financial and technical resources to respond. The Framework Convention does not, however, include a formula for sharing the costs of addressing climate change.

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

Efficiency also calls for international mechanisms such as joint implementation and coordinated economic instruments. Coordinated carbon taxes and tradable carbon emission permits can correct the market failure associated with greenhouse emissions.

1.8 ENDNOTES

1.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. (1993) 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. Trade in international commodity markets (Ausubel, 1990; Rosenzweig and Parry, 1994; Reilly, Hohmann, and Kane, forthcoming; Kane, Reilly, and Tobey, 1992) can ensure that agricultural prices change only moderately, though particular regions may gain or lose significantly.

2.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.

3.Some analysts conclude that a warmer climate would significantly reduce water supply (Gleck, 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.

4. 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 lowers the cost of heating and cooling in the U.S.. Cline (1992) finds net costs of \$9.9 billion.

5.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), which assumed a disintegration of the West Antarctic Ice Sheet. The current "best

1 estimate" for mean global sea level rise by 2030 under "business as usual" is 18 cm (Warrick, Oerlmans *et al.*
2 1990; Raper *et al.*, 1990).

3

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

11

12 6. Some analysts believe that the justification for costly and more restrictive actions rests on intangible costs
13 (Nordhaus, 1993). Intangible refers to the difficulty to measuring, and include migration, comfort, health,
14 leisure activities, urban infrastructure, and air pollution (Fankhauser 1992; Cline 1992). A warmer climate
15 would improve human comfort in cold areas, and in the winter generally, while decreasing comfort in warm
16 areas. Mearns *et al.* (1984) calculate a threefold increase in heat waves for a 1.7 degree C rise in U.S. mean
17 temperature. It is not yet clear whether net comfort will rise or fall for a given rise in temperature. Chapter
18 6 covers these issues in more detail.

19

20 7. Both the natural rate and human contribution to the process of species loss are difficult to estimate (EPA, 1989).
21 Predicting the effect of climate change on species distribution is more difficult still. The magnitude and even the
22 sign of these intangibles remains in dispute, for uncertainty about the duration and type of environmental changes
23 that would be caused by climate changes make the long-term projection of species change highly complex.
24 Moreover, while some species may have difficulty adapting to climatic changes, opportunities for other species
25 that otherwise may have become extinct may open up. Population pressures have added to pressure on
26 ecosystems, particularly in the third world. Climate change may exacerbate these damages, particularly in Africa,
27 where environmental degradation has been particularly pronounced during the last 15 years (UN, 1989).

28

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

36

37 9. Recent ice core data from Greenland points to earlier temperature rises of several degrees occurring within a
38 few decades (IPCC 1994); reasons for these sudden changes are still not understood, but might have come from
39 changes in deep ocean currents. The other side of this debate holds that on the whole the biosphere is
40 homeostatic or self-correcting; this "Gaia hypothesis" compares the biosphere to a living being: once moved away
41 from equilibrium, self-correcting forces naturally move it back to equilibrium (Lovelock, 1979). The two
42 hypotheses are not necessarily inconsistent. Within a range of variation, homeostatic properties could dominate,
even if stability was not guaranteed outside that range.

43

44 10. Countries make century-long choices implicitly, as when they choose population policies, policies affecting
long-term capital formation and productivity growth, or protection of environmental assets.

45

46 11. Although bargaining theory has contributed some basic principles, such as the importance of threat points.

1 12. Scientists have proposed several methods to measure the warming potential of different greenhouse gases
2 (IPCC Special Report 1994). Although global warming potential (GWP), endorsed by the IPCC, is a useful
3 concept in formulating comprehensive approaches to greenhouse mitigation policies (Stewart and Wiener,
4 1990), some analysts have recently criticized the concept on the grounds that GWP implicitly sets the
5 opportunity costs of an increment in radiative forcing equal for all periods in the future (Schmalensee, 1993).
6 If all greenhouse gases had the same rate of decay, then this problem would not arise.

7

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

10

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

12

13 15. Frank Knight's often-quoted distinction separates risk, for which the probabilities of different outcomes are
14 known, from uncertainty, in which either they are unknown, or some potential outcomes are not specified. Ref.
15 Knight, Frank, 1922, Risk, Uncertainty, and Profit.

16

17 16. This division of responses is from Nordhaus (1994).

18

19 17. While most insurance markets do not reduce overall risk, there are a few exceptions: fire insurance companies,
20 by requiring commercial buildings to install sprinklers, do reduce the overall level of losses.

21

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

26

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

34

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

40

41 19. Chapter 6 provides estimates of expected regional damage.

42

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

47

48 21. Computer modelers participating in the Energy Modeling Forum examined an "accelerated R&D"
49 scenario in which the cost of nonelectric backstop falls from \$100 to \$05 per barrel of oil equivalent, and the
50 cost of the electric backstop falls from 75 to 50 mills per Kwh. The four models used were remarkably
51 consistent in their estimates of economy-wide costs, reporting GDP losses falling by 65 per cent for the 20

1 percent emissions reduction scenario (EMF 1993).

2 22. For example, low-lying states may suffer permanent damage.

3 23. Weitzman et al. (1981), cited in Lind (1993), make these points in formulating a sequential decision strategy
4 for developing synthetic fuels.

5 24. Manne and Richels, Nordhaus, and Peck and Teisberg all report a high value of information on *** and ***
6 in their computer simulations. In addition, *** also reports a high value to information on ***.

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

10 26. Alternatively, the Kaya identity may be written
11
12 Growth rate = growth rate - decline in energy - emissions
13 of CO₂ emissions of output per unit output per unit energy use
14
15 That is, CO₂ emissions will not rise as long as output grows no faster than the combined decline in energy
16 intensity per unit of production and CO₂ emissions per unit of energy use. This formulation applies most usefully
17 to the developed countries.

18 27. Chapter 8, "Evaluating the Costs of Mitigation," treats the important issue of inertia and technology.

19 28. Note that energy efficient development paths for developing countries have been proposed (Goldemberg and
20 Reddy 1988).

21
22 29. That is, for conventional exhaustible resources, there is a stock, S . Welfare depends on flows out of the stock
23 each year:
24 $U(S_1 - S_0, S_2 - S_1, \dots, S_{t+1} - S_t, \dots)$, where S_t is the stock at the end of period t .
25
26 Here, welfare depends *directly* only on the stocks, though indirectly, through the effects on consumption, on
27 emissions, which affect the change in stock:
28 $U(S_0, C_1(S_1 - S_0), S_1, C_2(S_2 - S_1), \dots, S_t, C_{t+1}(S_{t+1} - S_t), \dots)$.
29

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

32
33 For the atmosphere, a sustainable stock of greenhouse gases means stable concentrations. Current emissions are
34 estimated to be about twice emissions consistent with stable concentrations.

35 31. Postponing action may lead to some irreversible damages, for example the flooding of low-lying states.

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

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

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

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

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

8 37. This kind of optimization problem was first studied by Edgeworth, *Mathematical Psychics* (). The
9 importance of incentive effects for the analysis of distributional issues was first emphasized by Mirrlees (1971)
10 and Fair (1970). There are, obviously, important incentive effects: if the LDCs were able to classify any
11 expenditure that had some effect on mitigation as a mitigation expenditure, with the cost borne by the developed
12 countries, they would have an incentive to undertake excess expenditures of this type. The GEF (Global
13 Environmental Facility) directly addresses this issue, by only providing funds for incremental costs, that is those
14 costs that go beyond what would have been the efficient level of expenditures ignoring the public good benefits
15 of greenhouse gas mitigation.

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

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

24
25 A slight extension of this perspective says that social scientists should simply *describe* the outcome of the
26 bargaining process by which property rights are assigned. Beginning with the important work of Nash [], a
27 variety of bargaining theories have been developed, most of which emphasize the importance of "threat
28 points"--the outcomes which arise in the absence of a bargaining agreement-- to the determination of the eventual
29 outcome. In this case, the fact that the net losses of many developed countries may be limited relative to those
30 of many of the less developed countries suggests a bargaining solution in which much more of the costs of
31 mitigation are borne by the less developed countries than under the "social welfare function" allocations described
32 earlier.

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

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

40 42. The *polluter pays principle* endorsed by the OECD is exclusively prospective.

43. 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.

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

45. 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.

46. See Abreu [].

47. In some cases, equity considerations may prevent 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.

48. Chapter 7 discusses this issue at greater length.

49. 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.

50. The precise manner in which this should be done is a technical matter, treated in the literature on Global Warming Potential (see, e.g., IPCC 1990). 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.

51. 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).

52. Only a few models take into account international capital flows. Thus, most models do not address issues of industry relocation (McKibben and Wilcoxon, 1992). Chapter 11 provides a more complete discussion on leakages.

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

54. 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.

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

56. 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.

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

58. 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.

59. 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 GDP. Aggregated models (top-down) have generally reported higher costs, while disaggregated models (bottom-up) have shown lower costs. Chapter 9 contains a more complete discussion.

These GDP losses 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.

60. 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.

61. 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.

62. 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.

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

64. 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.

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

65. 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.

66. 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.

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

68. 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].

69. 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 divergence of interests. See Stiglitz [1988]. A more recent overview is provided by Stiglitz [] and the symposium in the *Journal of Economic Perspectives*.

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

71. 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.

72. 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.

73. 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

1 focus.

2

3 (c) *Variation across individual consumers:* Engineering models generally assume an average consumer; actual

4 consumers may display a wide range of characteristics and usage patterns. Except when demand functions are

5 linear in the relevant variables, the consumption of the "average" individual is not equal to the average

6 consumption; and what is optimal for the average person may not be optimal for a significant fraction of the

7 population.

8 74. For a survey, see Jaffee and Stiglitz []. The basic theory of credit rationing was developed in Stiglitz and

9 Weiss [1981] and the theory of credit rationing is developed in Greenwald, Stiglitz, and Weiss [1984] and Myers

10 and Majluf [1984].

11 75. This generally accepted methodology is, for instance, reflected in the guidelines issued by the Office of

12 Management and Budget in the United States for the evaluation of projects and regulations. The applied literature

13 does not address the question of whether this procedure is appropriate in the presence of certain types of time and

14 risk non-separabilities.

15 76. Though if the variance of the net benefits is increasing over time in a particular manner, the differences in the

16 two methodologies may not be large.

17 77. Again, under certain restrictive conditions, where the shadow value of a capital constraint is changing

18 systematically over time, the differences in the two methodologies may not be great.

19 78. See Wilson . Though the original discussion of winners curse focused around bidding in auctions, it has

20 subsequently come to be applied to a range of other market phenomena. See, e.g. Stiglitz [].

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

22 80. In some industrialized countries, energy efficient home mortgage lending may help correct the problem.

23 Lenders generally set criteria for the maximum loan amount based on the borrowers' ability to repay, which in

24 turn depends on income and wealth. The fact that a particular expenditure which would enhance efficiency and

25 reduce utility bills is not given special attention. Energy efficient mortgages provide funds to households to

26 make energy efficiency enhancing investments intended to pay for themselves, i.e. result in reduced utility bills

27 equal to or greater than the interest payments. With capital constraints, builders may have an incentive to trade

28 off initial capital costs for higher maintenance costs (lower energy efficiency). Building codes specifying minimal

29 levels of energy efficiency and full disclosure of expected life cycle energy costs may help address these market

30 distortions.

31

32

33 81. A country that rapidly depletes its natural resources may show a high rate of growth under conventional

34 income accounting, but a lower rate of growth when resource depletion is taken into account. Repetto (1991,

35 1992) calculated resource-adjusted GDP for several countries rapidly harvesting their stocks of hardwoods and

36 other resources, arguing that conventional measures sharply overstated GDP.

37 82. Cobb and Daley (1989) have even claimed that U.S. per capita GDP, when adjusted for environmental damage,

38 was stagnant between 1950 and 1986. This assertion is hard to reconcile with the steady improvement in most

39 measures of environmental quality since 1970, when measurements standards were established.

1 83. Analysts now use two methods to estimate stocks. The first assumes a fixed stock of a natural resources such

2 as oil. Consumption of oil then depletes the stock by the amount of consumption. The second begins by treating

3 discovered reserves as the asset. Thus, additions to reserves increase the asset, while consumption reduces it.

4 If in any given year, new discoveries match resource utilization, then according to this method no net depletion

5 has occurred.

6 84. Many researchers have noted deficiencies in standard national income accounts. First, national income

7 accounts do not, in general, provide an adequate measure of welfare; second, they do not provide the correct

8 information relevant for making policies relevant to sustainable development. Sustainable development is

9 concerned with society's resources; an economy is growing when its resource base (capital stock combined with

10 natural resources) is growing. GDP does not, and is not intended to be, a measure of resource availability. Firms

11 have two sets of accounts—cash flow (income) statements and balance sheet statements. GDP is a statement of

12 the former type.

13

14 Standard accounting procedures require that firms, in an attempt to present an accurate account of "true income,"

15 take account of depreciation. GDP measures gross output; it does not take into account depreciation, either of

16 natural or physical capital stocks. The reason is simply that it is hard to get accurate measures of depreciation.

17

18 Net national product does take into account depreciation, the change in capital stock. And it is this account which

19 should be most subject to criticism, since it accounts for changes in the physical capital stock, but not in other

20 capital assets, in particular, environmental assets and natural resources.

21

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

23

24

25 First, how should the "stock" of natural resources be defined? Coal poses perhaps the easiest situation. The

26 location of coal reserves is known. Costs of extraction are high, so the rents (the value of coal *in situ*) is low.

27 The depletion can be measured not by the coal used times the market price, but the coal used times the *in situ*

28 value. But for oil and other minerals, information about where reserves are located is vital. Two models have

29 been proposed. One sees the world as having a fixed stock of natural resources (say oil). When one uses oil,

30 one is depleting this stock. Thus, to calculate the value of depletion, one does not need to know the entire stock;

31 the flow (the amount of oil consumed) provides an accurate measure of the change in stock.

32

33 The alternative model looks at the size of discovered reserves. Reserves are treated as the asset. Additions to

34 reserves thus are viewed as increasing the resource base. If in any given year, new discoveries match resource

35 utilization, then there is no net depletion. This is the approach being taken by the U.S. Department of Commerce.

36 This accounting framework would be correct if there were an infinite supply of the resource (reflected in zero

37 rents); the essential "capital" good is information about where the resource is located.

38

39 Environmental assets—such as air quality—present another set of problems, because there are not market prices

40 to value the asset. Dynamic optimization problems of the kind described earlier can be used to calculate shadow

41 prices. How sensitive these shadow prices are to specific assumptions remains to be investigated.

42

43 Accounting systems do not, however, have to aggregate all information together. Just as information about

44 longevity and other indicators of well being (see below) serve to complement information from national income

45 accounts concerning standards of living, so too can information about *physical* environmental measures be used

46 to complement information from the extended national income accounts.

47 85. There is some concern that excessively broad and long patents may actually impede innovation. When

48 technological progress occurs by building on previous innovations, later innovator require permission of earlier

49 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.

86. 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 [].

87. 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.

88. 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.

89. 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.

90. 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, tradable permits are the better option. Here, an erroneous estimation of the optimal tax rate will lead to a relatively large deviation from the optimal level of emissions 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.

91. 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.

92. Similarly, 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?

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

94. 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.

95. 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 GREEN 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.

- 1
- 2 96. Rapid capital stock retirement may add to the cost of immediate CO2 reductions. Also, reductions may be
- 3 cheaper later because of technical changes in the intervening years.
- 4 97. Indeed, the "ratchet effect," a commonly observed phenomena in the command and control economies
- 5 (Stiglitz, 1975, Weitzman, 19) leads firms to just satisfy the target.
- 6 98. Two examples from the United States Clean Air Act: 1) the requirement that coal-burning power plants
- 7 install stack-gas scrubbers even if they burn low-sulfur Western coal; 2) the mandates for ethanol in reformulated
- 8 gasoline.
- 9 99. World Commission on Environment and Development, Our Common Future, Oxford: Oxford University Press,
- 10 1987.
- 11 100. It has been argued that new species and varieties produced by genetic engineering may be able to more than
- 12 offset the loss in genetic variability from climate impacts, particularly because of the increasing capacity to direct
- 13 those mutations toward socially desirable objectives.
- 14 101. Other views represented in the debate on sustainable development but not generally accepted in the
- 15 economics profession include those of Daly (1977, 1980) and Daly and Cobb (1991), and those of the new field
- 16 of ecological economics (Costanza 1991).
- 17 102. Tariq Osman Hyder, "Climate Negotiations: the North/South Perspective," in Mintzer, ed. Hyder has headed
- 18 the Pakistani delegation at meetings of the INC, and GEF (Global Environment Facility).
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