REPORT ON GLOBAL WARMING AND ASSOCIATED IMPACTS

(PHASE IV)

TATA ENERGY RESEARCH INSTITUTE
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REPORT ON GLOBAL WARMING AND ASSOCIATED IMPACTS

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Contents

THE ECONOMICS OF CLIMATE CHANGE

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ABSTRACT

The paper discusses some aspects of the use of economics in policy analyses of Climate Change concerns, i.e., the difficulties and limitations of employing Cost-Benefit Analyses (CBA), the issue of uncertainty, the use of formal economic models, the inertia of social and economic systems, the question of choice of domestic and international regulatory instruments, and finally, one way of structuring the equity issue. Very broadly, one may conclude that while no major paradigm shift is necessary, the challenge of policy analysis in the Climate Change context will require a significant sharpening of existing analytical tools of economics, as well as the establishment of deeper interdisciplinary linkages.

1. Introduction:

The issue of Climate Change has emerged as potentially one of the most significant policy questions in the current international arena. This is because the risks of possible Climate Change may be high, and the costs of abatement or adaptation measures also large, and both are likely to fall variably, but uncertainly, on different regions and at different times.

Climate Change is also arguably, one of the most complex global policy issues to have arisen so far. The questions involved relate to numerous disciplines, in the pure and applied natural sciences, positive social science, and political economy, besides ethics and morality. Analysis of the divergent facets of the issue is likely to proceed at the cutting edges of current human knowledge and understanding, and indeed may involve several extensions to the frontiers.

Given the deep and pervasive complexities of the issue, it is a little disconcerting to find that some of the recent literature in the field has tended to focus largely on the technical aspects of Climate Change, in particular on some of the more alarming scenarios generated by Global Circulation Models (GCMs), and gloss over the key question of equity in abatement and adaptation measures. We emphasise at the outset, that in our view, both positive ("what is") and normative ("what ought") questions need to be kept in the spotlight at all times. We have attempted to follow this precept in the present paper.

It is, of course, gratifying that Climate Change has, in just a few years, acquired prominence in both the public mind, as well as that of policy makers throughout the globe. Further, that the world community has acted with commendable despatch in sitting down to substantive multilateral negotiations on regulatory approaches to the issue. However, one may as well recognize that the complexity, and the deep equity implications of approaches to the issue, rule out any quick fixes to the problem. Any multilateral approach which seeks to install a regulatory regime, without allowing for proper analysis and deliberation, or for periodic review of the substantive provisions of the regime, in the light of increasing understanding of the myriad dimensions of the problem, may soon prove to be unworkable, or inequitious, or ineffective.

This paper seeks to summarize some aspects of the current economic understanding of the regulation of Climate Change, in both positive and normative aspects. It is structured in the following manner: Section 2 discusses the application of Cost-benefit methodologies, which have emerged as a major analytical tool for public policy in several countries, to policy analysis for Climate Change. Much of our current knowledge of Climate Change has been revealed by the use of large-scale atmospheric and macroeconomic models, and Section 3 discusses the role, and limitations of employing economic models for predicting greenhouse gases (GHGs) emissions, and the impacts of regulatory and abatement strategies.

Section 4 is about the costs associated with economic and social transformation in different countries, if multilateral regulation for Climate Change is implemented. The choice of policy instruments is a crucial element in designing any regulatory scheme, multilateral or domestic, and Section 5 addresses this question in the Climate Change context, drawing upon both theoretical and experience based insights. Finally, Section 6 attempts to furnish a structure for analysing the key question of equity in Climate Change, drawing upon an existing theoretical framework, and attempts to derive some normative implications from insights gained from several ethical schools.

2. The Development of Cost-Benefit Analyses (CBA): Difficulties and Limitations:

The need for devising global policies for Climate Change arises from the fact that there is no reason to suppose that Providence would ensure that the costs of Climate Change manifestations would be visited exclusively on the polluters, and symmetrically, that benefits would flow exclusively to the environmentally abstinent. Variants of Cost-Benefit analysis have been developed for ranking alternative policy options in a number of situations, including several (local and regional) environmental contexts. However, CBA techniques need to be developed further in several aspects, before they can be applied meaningfully to the analysis of Climate Change options.

Very briefly, in CBA, different policy options are ranked with respect to the present value of the respective streams of benefits and costs over time, reckoned with respect to increase or decrease respectively in a chosen objective function, subject to the resource and technical constraints faced by society. There are two principal types of CBA. The first, i.e., Kaldor-Hicks CBA attempts to rank different policy options on the basis of their respective potentials for increase in national income (GDP) in society. An alternative procedure which is often employed in situations where there is great uncertainty regarding the future streams of benefits, is "cost-effectiveness analysis", in which the policy options are ranked in the order of lower (present value of) resource costs to achieve a given policy goal (for example, a specified level of environmental quality). The second, i.e., Social Cost-Benefit analysis, on the other hand, employs as a ranking criterion the potential increase in a Social Welfare Function (SWF), explicitly chosen by the analyst or the client policy makers, and which incorporates society's distributive concerns, along with efficiency considerations. An example of a SWF is a weighted sum of the aggregate income levels of different social groups, where the weights are the (relative) marginal utilities (cardinal, inter-personally comparable) of incomes of the respective groups ("Utilitarian SWF").

CBA methodologies have evolved for policy evaluations in limited temporal and spatial contexts, and further, for scales of costs and benefits which are not large in relation to the concerned national or regional economies.

Policy options for Climate Change present several challenges to the development of CBA methodologies. First, the "society" is no longer a national or regional entity, but global in a spatial sense. Second, the time-frames of policy options for Climate Change may extend over many human generations, while conventional public policy concerns do

not generally spill-over more than a few decades. Third, the Climate Change issue is characterized by pervasive uncertainties in the timing and nature of environmental impacts, their regional distribution, besides the economic and social effects of the regulatory mechanisms themselves. Fourth, the likely scales of costs and benefits are no longer marginal, but large, so that major restructuring of economic patterns might be involved. Finally, one must confront a fundamental ethical question: Is it appropriate to address dee, environmental issues from an anthropocentric standpoint, i.e., basing policy choices on patterns of human preferences? We discuss below, in brief, each of these aspects:

2.1. Cost-Benefit Analyses for a Global Society:

CBA on the Kaldor-Hicks criterion, conducted for policy options for a national or regional economy, makes an important, if implicit, assumption. That is, either the distributive impacts of each of the policy options are negligible, or alternatively, that the economy has a suite of separate policy instruments which reliably, and costlessly, ensure that the society's preferred pattern of resource distribution is achieved at each level of aggregate societal income. If these assumptions are valid, in that case increases in economic efficiency (i.e., national income) are unambiguously desirable, and candidate policies may be ranked on that basis.

Policy analyses for Climate Change in a global perspective must, however, contend with the fact that neither assumption is tenable. Actual manifestations of Climate Change will almost certainly impose costs, and may confer benefits, unevenly across different regions. For some, the costs may be of catastrophic dimensions. Further, the control measures themselves, may impose highly skewed costs and benefits across different regions. In addition, no human agency yet exists which can be trusted to (costlessly) reassign these costs and benefits, (or indeed any kind of resources), according to any predetermined pattern.

Clearly an exclusive focus on efficiency in policy analyses of global Climate Change options is inappropriate. The analyst has to address the task of devising policies which incorporate mechanisms for redistributing costs and benefits across agents, besides efficiency concerns. In other words, a Social CBA approach is unavoidable in this instance. Conducting a Social CBA however requires the explicit adoption of a SWF at the global level. This is the central aspect of the equity dimension of the Climate Change issue, which is discussed in greater detail below. At this point one may note that the choice of a global SWF is not the task or province of the policy analyst, but is inherently a political act, in which policy makers from different countries, regions, and political and cultural orientations, are the players. At issue is the very nature and process of political authority in the global context.

2.2. CBA in an Inter-Generational Context:

Climate Change is characterized by benefits and costs flowing unevenly across several human generations. Policy analysis employing CBA have encountered few multiple generation situations so far, and accordingly the question of how different generations are to be treated by the present generation, which currently has the power to

unilaterally decide on long-term policy options, is a fertile area for normative policy research.

One possible input to CBA methodologies from inter-generational considerations is the choice of (one or several) social discount rate(s), i.e., how benefits and costs, whether expressed in economic terms, or in relation to changes in a global SWF, are to be discounted over time.

Any strictly positive discount rate applied to economic costs and benefits implies a determination that allocation of resources to the current generation is more important than to future generations. One argument in justification of this position is that because of capital accumulation (and technological advances) by the current generation, future generations will be richer. A typical member of the future generation will therefore, value a unit of income (in utility terms) less than would a typical member of the current generation. Further, they will have greater resources for adapting to adverse impacts of actual Climate Change. On the other hand, arguments have been advanced for zero discount rates, i.e., which would not distinguish between individuals belonging to different generations.

A large volume of literature exists on the choice of a social discount rate in the CBA of conventional policies, i.e., with a time horizon of no more than a few decades. A major problem is revealed by the fact that the application of such conventional social discount rates, typically in the range of 8-12% per year, in an inter-generational context, i.e., with time horizons of, say, 100 years, yields extremely low present values of (postulated) very high future costs. This runs counter to intuitive notions of equity, because it implies that virtually all of the costs of adaptation or abatement measures should be passed on to future generations, even if they are believed to be very high.

Several attempts have been made to incorporate inter-generational concerns in the CBA framework, which are intuitively appealing. These approaches may be summarized as follows:

(a) Imposing sustainability constraints: This approach seeks to allow the maximization of net benefits to the current generation, subject to the requirement that (natural and man-made capital) resources available to future generations would allow them to attain at least the welfare level of the current generation. The major theoretical formulation of the sustainability principle was furnished by Solow (1974), who showed in a simple two-factor model (i.e., natural resources and capital), that a constant level of consumption can be maintained as long as any one of the following conditions are satisfied:

(1) The elasticity of substitution between the factors is greater than unity, or

(2) The substitution elasticity is unity, but the share of capital exceeds that of natural resources, or

(3) that there is sustained resource augmenting technical change.
Of course, important questions arise with respect to whether any of these conditions can

be maintained very far into the future. Little practical headway has yet been made in operationalization of this concept, except for tentative attempts at computing GDP, taking changes in levels of natural resources into account.

(b) Positive approaches: Some attempts have been made to show that even from the perspective of the current generation, social discount rates below private discount rates are appropriate in an inter-generational situation. An argument for considering only the preferences of the current generation, furnished by Arrow and Kurz (1970), is that because the revealed preferences of individuals are accepted in making other social choices, they should be accepted in the inter-generational context as well. The counter argument, of course, is that lack of representation to future generations is the real problem.

One example of a positive approach is that of Marglin (1963). The argument runs that consumption by future generations is a public good to members of the present generation. Accordingly, all members of the current generation are made better off by a social choice in favour of greater savings and investment than would have been the case with individuals acting independently. Such a decision would imply a social discount rate below the private rate. This argument, though intuitively appealing, does not hinge on notions of inter-generational equity, but rests on efficiency considerations.

(c) SWFs embodying inter-generational equity: In this approach, discounting is eschewed in favour of specifying welfare criteria based on the actual welfare levels of different generations. One example of this approach relies on welfare criteria based on the Rawlsian (Rawls, 1971) ethic. Very briefly, this principle ("maximin") states that the welfare of society is the welfare of the worst off member, given that basic freedoms are available equally to all.

A counterintuitive implication of this principle applied inter-generationally was noted by Solow (1974). He looked at the problem of determining the largest sustainable level of consumption for society, subject to constraints on capital accumulation and the stock of an exhaustible resource. The maximin principle would require a large initial capital endowment, and if it is small, then the level of consumption must be small forever, because capital must not be accumulated by sacrificing the consumption of the first generation which is poor.

A way out was suggested by Phelps and Riley (1978). If generations are allowed to overlap, the earlier generation which accumulates capital has a claim to more retirement consumption provided by the labour of the next generation, which has an obligation to work more in exchange for the gift of capital. Such a program can be supported by appropriate debt creation, and growth is further encouraged if the earlier generation derives utility from the consumption of the later generation.

(d) Modifications to the social discount rate: Several examples of this approach exist. One approach seeks to set discount rates to zero, on the ground that one should be impartial with respect to the time at which an individual lives. Such impartiality may be justified, for example in a Rawlsian framework, on the "veil of ignorance" argument. That is, individuals who are unaware of their future place in society and meeting to

decide on a constitutional framework, would be risk averse, and accordingly choose not to place any group at an advantage or disadvantage relative to others. An argument against zero discount rates due to Olson and Bailey (1981) is that discounting proceeds from utility discounting ("time preference") and consumption discounting. They have shown that if time preference is zero, i.e., complete equality exists between generations, and interest rates are strictly positive, individuals should rationally reduce present consumption to zero, which is counterintuitive.

Formulations of consumer discount rates, as well as of producer rates, besides combinations of these also exist (see Pearce, 1991). These approaches are still not theoretically satisfying. Empirical results of the first and second of these approaches remain counterintuitive, and of the third, appear to rest on some strong assumptions.

The long time-horizon of Climate Change also leads to some problems in positive analysis of economic impacts. Long-term predictions are usually based on economic models, and several assumptions must be incorporated, which may drive the models' results. These assumptions may relate to technological change, economic structure, population trends, and other aspects. It is hazardous to assert that any one of the several alternative assumptions will ultimately prove to be valid.

2.3. Uncertainty:

The Climate Change issue is permeated with ubiquitous uncertainties in the types and regional distribution of environmental impacts, besides the economic and social impacts of control or adaptation policies. One way to think about uncertainty in Climate Change is to consider that at each period in the future, the world could experience different sets of such impacts or "outcomes". These possible outcomes may vary with the actual control (and/or adaptation) regime that is implemented, but while for each policy only one of the possible outcomes will be actually realized, there is no way of knowing in advance, which one it will be. Nonetheless, choices among competing policies must be made based on incomplete knowledge.

In an important sense, this notion of uncertainty in Climate Change differs from uncertainty as understood in conventional CBA. In the latter, it is assumed that outcomes of policies depend on "states of nature", i.e., unforeseeable events, but that for any realized state of nature, it is possible to determine unambiguously the outcome of a given policy. For example, whether or not an earthquake occurs is a state of nature, but given that one occurs, one may determine with certainty whether a particular hydroelectric dam, embodying a particular policy choice, will survive. On the other hand, uncertainty in Climate Change implies that the outcomes of policies cannot be determined definitively in any case, because they are insensitive to any intervening states of nature, all of which may be manifest in the long term over which Climate Change may occur. In other words, in Climate Change, "God does not play dice with the world," but that uncertainty arises from inadequate human knowledge and understanding, which could improve with time and effort. For example, uncertainty exists about the predictions of Global Circulation Models (GCMs) of the atmosphere, or of economic models of regulatory policies, on which policies must be based, because they are

sensitive to modelling assumptions or parameter values, whose validity may be in doubt. However, further research may reduce these uncertainties.

In the context of Climate Change, further complexity is introduced by (a) long-time periods involved, on account of which uncertainties in the costs and benefits of policies, and their regional and inter-generational distribution increase; (b) the possibility of catastrophe, meaning that under some equity perspectives the costs of some impacts should be valued as infinite, even if they are remote in time or have a very small probability of occurrence; (c) that knowledge of the uncertainties may change over time, because of gains in scientific knowledge or better modelling (including economic modelling) techniques, meaning that in hindsight, policy choices may be seen to have been mistaken; and finally (d) that there is a hierarchy of policy choice situations, i.e., global, national, and perhaps, subnational, so that policy choices at one level of the chain may impact the outcomes of policies at other levels. This may be the case, for example, with trade and the international division of labour, which may depend on the interactions of global, national, and local regulatory regimes and economic policies. Further, in the multilateral context, the issue of the process of policy choice and of criterion of choosing among alternative policies is reasserted.

Ways of dealing with uncertainty in conventional CBA ultimately rest on subjective judgements. These judgements relate, first, to the choice of a decision criterion. For example, "maximization of expected value", in which the mathematical expectation of net benefits, using subjective probability estimates, is the decision variable). Alternatively, the so-called "maximin returns" rule, in which each candidate policy is evaluated at the minimal net benefit it assures, with the one with the highest such guarantee being chosen. Another option is the "minimax risk" principle, in which the alternative with the smallest "maximum risk", defined for each combination of an alternative and a state of nature, as the excess of the maximum net benefit available in the state of nature and that actually resulting from the given decision in that state of nature, is chosen. Second, judgements of the probabilities of the different outcomes are also inherently subjective, and cannot be formulated as a strictly technical exercise. Before or after an event, no particular probability estimate of the same can be unambiguously validated, even in principle.

In conventional CBA, with a clearly designated policy making authority, the subjective judgements of that authority must prevail. This remains true, even if the tasks of choice of decision rule, or estimating probabilities, are delegated to policy analysts or experts, because it is the decision maker who exercises this choice. In the context of multilateral decision making for global Climate Change policies, each party to the negotiations would make his own subjective choices. In this, there is scope for strategic behaviour by the negotiators. For example, a country may adopt a negotiating strategy of asserting a low probability to adverse impacts in its territory, or conversely, high probability to favourable impacts, in the expectation that this may reduce pressures on it to adopt stringent emissions limits. If enough countries behave in this way, the aggregate global levels of emissions may be negotiated at levels too high to appreciably impact the onset or severity of Climate Change.

2.4. Large Scale of Impacts

Conventional CBA deals with policies whose economic impacts are at the margin, i.e., small in relation to the overall economy, and even perhaps to individual markets. Several assumptions may be justified in such cases. For example, most conventional CBA rests on partial equilibrium analysis, so that only the markets directly impacted need to be studied, maintaining the ceteris-paribus ("all else unchanged") assumption.

Climate Change impacts, or regulatory measures, may however, have to be studied in a more comprehensive manner. For example, since regulation of GHGs emissions will impact patterns of energy use, and energy is a significant input in all industries, regulatory policies may need to be evaluated in a general equilibrium framework, i.e., looking at the inter-dependence of and impacts on all markets, including the traded sectors. Additionally, policies for global GHGs regulation will impact national or regional economies differentially, altering their inter-relationships, for example patterns of comparative advantage and trade.

General equilibrium analyses typically rely on large-scale models of economies, in contrast to the small scale, project or program level focus of conventional CBA. A comparison of such micro level ("bottom up") and model based ("top down") estimates of abatement costs reveals systematic differences in the results. The top down studies, which typically rely on the neo-classical assumption of cost minimizing behaviour by firms, show national economies moving away from an initial equilibrium in which all firms employ resources optimally, so that abatement costs are positive. On the other hand, bottom up studies, employing the assumption of "unfettered penetration of technologies", frequently show negative abatement costs, because the benign technologies may also be more efficient, at least when no changes in relative prices are allowed for. While it is clear that because of the large scale of impacts, general equilibrium effects must be taken into account, one challenge of model development is to realistically incorporate rapid or discrete technological change.

2.5. Is an Anthropocentric Approach Ethical?

Climate Change may impact the major ecosystems of the globe, and thus, all life forms. It may promote speciation through modification of habitats, and for the same reason, may result in the extinction of some species. While several other policy questions have concerned significant local or regional ecological impacts, Climate Change is the one issue in which impacts may be planetary in scope and permanent in duration.

The validity of CBA, or indeed any methodological approach (for example, decision analysis), based on human preferences or valuations, presupposes that an anthropocentric world view is appropriate. The issue may be framed in terms of whether mankind has rights of domination over all Creation (and may therefore employ all of nature as he pleases), or is but one species among many (and accordingly, has no right to disturb the natural order), or has a special responsibility to preserve other living and non-living entities without regard to his own benefit, i.e., stands in relation to the rest of Creation as guardian or trustee. Clearly, no analytical answer to these issues is possible, and the matter is at the heart of ethical philosophy.

Several serious researchers (e.g., Tribe, 1987), have sought to define an environmental

ethic not based on human domination over other "modes of being", including living and non-living entities. Thus, Tribe suggests that "at a minimum, we must begin to extricate our nature regarding impulses from the conceptually oppressive sphere of human want satisfaction, by encouraging the elaboration of perceived obligations to plant and animal life and to objects of beauty in terms that do not falsify such perceptions from the very beginning by "insistent 'reference to human interests'." Some specific proposals in this general direction include:

(a) Legal recognition of a principle that the concept of "rights" is not confined to humans (Stone, 1972). This should not be confused with the idea that their "wants" should be identified and included in a calculus of preferences. Recognizing these rights may be consistent with acknowledging that there maybe circumstances in which such rights may be overridden, as indeed is the case with several "human rights."

(b) The appointment of guardians or trustees for environmental entities, living and non-living, as an embodiment of the recognition of such rights.

(c) Making explicit obligations to nature in environmental surveys and statements, and allocating resources to improving the technical capacity to incorporate such obligations in policy analyses.

The use of CBA, or other analytical techniques based on human preferences, is ultimately based on the doctrine of human domination over nature. Since Climate Change has generated global discourse, it is indeed appropriate that the issue is looked at from alternative cognitive perspectives.

3. The Use of Formal Economic Models:

Policy analysis of Climate Change has relied extensively on formal modelling exercises. Two principal categories of such models are, first, global energy-carbon dioxide prediction models, and second, national or regional economic models focused on energy use and regulation. The next two subsections briefly recount these modelling efforts, and the last subsection considers the possible use of formal models in policy analysis of Climate Change.

3.1. Global Energy-Carbon Dioxide Models:

Numerous attempts have been made at making long-term (i.e., half a century or more) predictions of atmospheric carbon dioxide, employing formal, quantitative models. However, all such predictions are intrinsically uncertain, with the uncertainty increasing sharply with the time horizon. The uncertainty arises both from the tentative nature of economic forecasts of anthropogenic activities which generate GHGs, as well as from inadequate scientific understanding of the various natural processes of the carbon cycle. There are three basic types of such models:

The first type are simple extrapolations of historical trends of energy use, and may be regarded as summarizations of more detailed projections. They may be useful for sensitivity analyses of the carbon cycle and the climate system, but have little intuitive

appeal as systems of comprehensive carbon dioxide accounting. Examples of this type of model include: Keeling and Bacastow (1977), and Siegenthaler and Oeschger (1978).

The second type of global carbon dioxide models are "uncontrolled" (i.e., no regulatory mechanism is embedded), global energy-climate systems models. They include relatively detailed descriptions of global energy supply and demand, and carbon dioxide emissions are an incidental output. Various models of this type vary greatly in design, in the extent to which formal modelling techniques are employed, and in the details of fuels, geography, and other factors. Examples of this approach include: Perry and Landsberg (1977), Edmonds and Reilly (1983), Rotty and Marland (1980), Nordhaus (1977 and 1979), and IIASA (1981).

The third type of models incorporate feedbacks from changes in atmospheric carbon dioxide to the global energy system. They require a basic analysis of a model of the second type as input, but additionally, take into acount changing levels of carbon dioxide, or costs of climate change. In other words, the level of atmospheric carbon dioxide is included as a possible external constraint on the energy system. Examples of models of this type include Nordhaus (1980), Perry et. al. (1982), and Edmonds and Reilly (1983).

The results of all models which are based on reasonably in-depth studies of carbon dioxide emissions project a growth in energy use over the next 40 to 50 years of 2 to 2.5 times the 1975 level (which was 8 Terrawatt-years/year). Whenever such scenarios do not project a large share of non-fossil fuels, they lead to serious concerns about climate change in the next 50 to 100 years.

3.2. National (Regional) Energy Focused Models:

Models of national economies focused on energy supply, demand, and the impacts of policy, have been taken seriously by policy makers from the time of the first oil price shock of 1973. An example is Hudson and Jorgenson (1978). Numerous models in this category have been developed, varying widely in level of modelling detail, assumptions, time-frame, and methodology.

The current generation of this category includes applied general equilibrium models designed to simulate the impacts of price shocks with a high level of causal detail (e.g., Despotakis and Fisher, 1989), or to simulate the impacts of multilateral and domestic GHGs regulatory instruments (e.g., Ghosh, 1990), or to evaluate the costs of environmental quality regulations (e.g., Hazilla and Kopp, 1990). It also includes disaggregated long-term models to evaluate the impacts of pollution regulation on growth (Jorgenson and Wilcoxen, 1989), and long-term macroeconomic models for estimating the economic costs of carbon dioxide emissions limits (e.g., Manne and Richels, 1989). Several of these models attempt to estimate the average or marginal costs of fossil fuel carbon dioxide reductions in the respective countries. The estimates vary widely, reflecting underlying differences in modelling assumptions, structure, and abatement scenarios. A representative sample of these estimates is furnished below:

Table 3.1: The Costs of Carbon Dioxide Reductions: Representative Estimates:

Author(s)	Region	Forecast Year	% CO_2 Reductions	Reference Year	Costs 1989 US$ TC Average	Marginal
Gerbers et.al. (1990)	Nether.	2020	20	1990	31	31
		2020	70	1990	174	889
Yamaji et.al. (1990)	Japan	2005	0	1988	n.a.	281
Manne & Richels (1990)	USA	2030+	20	1990	210	250
Jorgenson & Wilcoxen (1990)	USA	2100	20	1990	n.a.	46
CBO (1990)	USA	2100	20	1988	n.a.	110-440
Morris et.al. (1990)	USA	2010	20	1990	28	39

Source: Adapted from Edmonds and Wuebbles (1991).

3.3. The Use of Formal Models in Policy Analysis of Climate Change:

Typically, the development of formal predictive or policy analysis models requires significant resources of time and effort. Implicitly, the expectation of the modellers in engaging in such intensive research activity is that the simulation results of the models would be taken seriously by policy makers and activists, and actually employed as inputs to policy formulation. An important question that arises is: Why and to what extent should policy makers and other players in the policy game accept analyses which employ such models as credible inputs to the policy making process? The issue of validity of policy modelling is intimately linked to the perceptions of whether these approaches constitute "science". There is general agreement that the scientific method includes (a) the dominant role of empirical testing, (b) the reproducibility of results, (c) of being explicit about uncertainty, (d) of peer review, and (e) of open debate about alternative theories. We discuss below the applicability of each of these attributes of the scientific method to existing policy analysis practices:

(a) Empirical validation: Differences between validation in the natural sciences and policy analysis models are centered on the facts that empirical policy analysis models are contingent on place, time and circumstance, rather than universal, and that validation by the process of controlled experimentation is not possible when the subject of the experiments is society itself (a difficulty common to all social science).

Policy analysis models present some further difficulties which are not encountered in the "hard" sciences. First, policy analysis models often attempt to project the implications of policy decisions far into the future, and direct testing of predictive validity cannot be carried out until long after the analysis is required. Second, such models are frequently designed to simulate the impacts of alternative policies. In such cases, empirical validation of the models in respect of the policies which are not adopted is not possible, even in principle. Finally, when the models can be calibrated against historical data, there is no assurance that past parameter values, or even causal relationships will hold in the future.

It is clear that direct empirical validation is not possible for several types of policy modelling, including those related to long-term Climate Change. This unavoidable situation places a greater burden on policy modellers to observe the other canons of scientific procedure, if the results of the models are to be relied upon even to a limited extent. However, it seems that these conventions are not yet well established among policy analysts, as discussed below:

(b) Reproducibility: Policy analysts have largely neglected the issue of reproducibility, as may be seen, for instance in the frequent lack of adequate documentation that would enable other researchers to reproduce the results. This may be on account of the fact that standardization of methods and tools is not yet sufficiently advanced in policy analysis, so that it is difficult to convey the details of models adequately in typical journal length articles.

(c) Uncertainty: Despite, or perhaps because of, the vast uncertainties inherent in most policy analysis models, it is still not standard practice to treat uncertainties in an

explicit, probabilistic fashion. This contrasts with the practice in the experimental sciences, in which it is usual to report estimates of random or systematic error in measurements or estimates. It is clearly prudent to conduct sensitivity analyses of policy analysis models with respect to parameter values or key assumptions, but this practice, while increasing, is not yet the norm.

(d) Peer review: In conventional science, peer review takes place largely through the refereeing and publication of research reports. For a large and complex policy model, an adequate review can be time consuming and problematic, even if adequate documentation exists. It has also been argued that owing to the time urgent nature of several types of policy analysis, peer reviews are inappropriate, even for models of modest scale. While this may be true in some cases, a general failure to focus on peer reviews has perhaps contributed to the slow development of standards of good analytical practice, as well as a failure to extract generalizable insights from specific analyses.

(e) Debate: Any model used in policy analysis will, at best, be an approximation to the real world. Further, policy analysis almost always deals with situations that are ill-structured. In traditional sciences there are norms about how to conduct experiments, what kinds of theories are interesting, and what questions are interesting: These constitute the prevailing "paradigm" of the discipline. In policy analysis, on the other hand, there seems to be no clearly prevailing paradigm, but rather a number of different contending criteria and methodologies. This lack of agreement on paradigm, and on the focus on ill-structured problems makes the criterion for deciding what is "best" especially difficult. It has been suggested (Mitroff and Mason, 1980) that policy analysis is a dialectical process in which a model is proposed, and counter-models are offered in response. Debate focuses on the relative failings of the competing models, and over time, an improved model may be synthesised from the initial ones. Claims to validity of any policy model, are thus always tentative.

It is likely that the findings of policy research influence policy making, not directly ("instrumental use"), but in a diffuse and indirect manner, without policy makers being able to cite specific research findings employed by them ("conceptual use"). Alternatively, such findings may be employed for reinforcing partisan viewpoints, or as an aid to legitimizing decisions that have already been taken ("symbolic use").

The fact of possible, even probable, symbolic and conceptual use of research findings, casts a special responsibility and need for restraint on the part of policy analysts. The findings of formal models which are not rigorously validated (including those which by their very nature or time frame do not lend themselves to empirical validation) and in which the extent of uncertainty in the results is not determined to specified confidence levels, should not be employed in proposing actual policy measures. This is not to suggest that the findings of such unvalidated models should not be disseminated to policy makers. Provided that the theoretical structure of the models is sound as determined by peer review, that the data employed is believed to be reliable, and that the models are robust as demonstrated through sensitivity analyses over key assumptions and parameter values, the focus of such revelations should be on the causal insights gained. In particular, these insights may relate to mechanisms which are not transparent to the intuition, and in identifying promising policies for further analysis.

4. The Inertia of Social and Economic Systems:

Simple economic models frequently furnish important insights that are difficult to gain from pure intuition. These models are "simple" in the sense that they involve several abstractions from reality, to reduce the number of interacting variables. The construction of such models involve making numerous assumptions, for which economists are notorious. Indeed it has been asserted that economic models are to be judged not by the plausibility of
their assumptions, but solely by their predictive power.

A "standard" assumption in economics is that factors of production are fungible between economic activities, and accordingly, changes in economic patterns are for the most part, costless. Firms may therefore respond smoothly to policy or price changes, although adjustments of different types of inputs may involve different time lags. Thus, in the "very short run", firms may alter materials (and energy) entering process streams, and in the "short run", labour. In the "long-run", capital employed may be changed, and firms may enter or exit a given industry. "Fixed costs" refer to capital (including human capital) stocks which are specific to a given plant (or activity, in the case of human capital), and which cannot be reassigned in any meaningful time frame. Such costs, once incurred, as treated as "sunk." A major theme of neoclassical economics is that only variable costs matter for making economic decisions, and that sunk costs are to be ignored in a rational calculus.

Strategies for reducing GHGs emissions, or in adapting to Climate Change may involve changes in technology, economic structure, and life-styles. The existing patterns are, in each country, the result of historical evolution. Unlike the neo-classical economic assumption, changes in technology and economic structure will not be costless, nor will changes in life-styles be without pain.

Considerable economic and social infrastructure is currently built around energy dependent systems. One example illustrates this assertion. Modes of transport, i.e., whether mass or personal transportation systems dominate, and the vehicular mix in each, determine capital stock and technologies in the sector, besides public infrastructure: railway lines, airports or highways, and patterns of fuel use. Second order linkages include composition of industrial output and trade, besides occupational patterns, human settlement modes, and lifestyles. Clearly, limitations on GHGs use in the transport sector would have pervasive effects throughout the economy. A similar order of economic and social linkages and effects of GHGs regulation may be traced for other energy intensive sectors, for example power generation, industry, agriculture, etc.

In reality, of course, physical capital stocks are not fungible across sectors, or across different technologies in a given sector. In other words, much investment in physical capital is to be regarded as a 'sunk cost', in any significant change in economic structure, including technical change. To an extent, this would also be true of human capital. While some types of workers may be retrained at relatively little cost and deployed in newer lines of economic activity, several skills may become manifestly obsolete and/or because of barriers to labour mobility, the workers may be unable to relocate. The human capital embodied in the skills of such workers must then also be

reckoned as a 'sunk cost.'

Since regulation of Climate Change, as well as its possible impacts may involve major restructuring of the economy, the question of the magnitude of these 'sunk costs' becomes important. Analogously, lifestyle changes may also occur, bringing unhappiness or disutility (and it may be possible to assign monetary values to such disutility, for a given distribution of resources in society). These magnitudes are closely related to the time-frame in which regulatory measures are implemented (or adaptation is necessary). This is because of several reasons:

First, if the required changes are implemented gradually, it may be possible to run down existing (physical and human) capital stocks fully in a given sector, before fresh investments embodying new technology (and skills) are made. A similar situation may prevail for human capital i.e., workers of a given skill may superannuate by the time that new investments requiring new skills are made. Second, if existing capital is not in fact fully depreciated (i.e., in an intrinsic, not financial book value sense), but the period of (premature) replacement is spread out, given positive private discount rates, the present value of 'sunk costs' would be relatively low. Further, one may anticipate that significant technological improvements would occur over time, and this fact may also reduce anticipated adjustment costs if the period of restructuring is spread out. Finally, one may intuitively accept that rapid lifestyle changes may bring greater disutility than gradual changes, and further, if positive time preferences exist with respect to utility, the magnitude of total disutility (perhaps aggregated by monetary imputations) would be lower still.

Several differences exist between industrialized and developing countries with regard to the current age and composition profiles of (physical and human) capital stock. Generally speaking, in many OECD countries, traditional industrial sectors which are GHGs intensive have experienced slow or negative growth in the past several decades. On the other hand, several "sunrise" sectors, i.e., those which have shown relatively high growth rates in recent decades, for example, information intensive sectors such as services, pharmaceuticals, entertainment software, etc., are not GHGs intensive. This means that in industrialized countries, the age of capital stock in GHGs intensive sectors is on the average "high", and that of less GHGs intensive sectors, "low". This situation contrasts with that in many "Newly Industrializing Economies" (NIEs). In these countries industrial capital stock is largely concentrated in GHGs intensive sectors, for example, steel, fertilizer, electric power, and are "new", as compared to similar capital stocks in industrialized countries. A case is therefore apparent, even on cost minimization grounds, i.e., without involving equity considerations, for global GHGs regulatory policies to be focused on the earlier restructuring of OECD economies away from GHGs intensive activity. Equity considerations, taking into account the relative burden of restructuring costs across countries, would seem to only reinforce this conclusion, which dominates the alternatives of restructuring by all countries at the same rate, or a policy of earlier restructuring by developing countries.

5. The Issue of Instrument Choice:

The environmental economics literature distinguishes between two broad classes of

environmental regulatory instruments, i.e., "command and control" or fiat type instruments, and market incentive based instruments. An example of the former is emissions standards (i.e., quantity restrictions on pollution emissions of a given type e.g., SOX, emitted) imposed by directive, and of the latter, pollution taxes i.e., a uniform tax on polluters per unit of pollutant of a given type emitted.

In the case of carbon dioxide whose emissions primarily result from fossil fuel use, the possibility also exists, at least in the context of a national economy, of the use of conventional fiscal and tariff instruments on energy sources and energy intensive sectors. The use of these instruments may, by altering the structure of relative prices perceived by economic agents, impact patterns of energy use by inter-fuel substitution (e.g., substitution of fossil fuels by hydropower for electricity generation), or of factors use (i.e., substitution of energy by capital and/or labor, e.g., by promoting energy conservation), or of industrial and trade structure (e.g., shifts in output and/or trade from energy intensive industrial sectors like steel to (skilled) labor intensive sectors such as services). These shifts in energy use patterns may impact the emissions of carbon dioxide, and perhaps of other GHGs as well.

Some results from the theory of environmental regulation relating to the choice of environmental regulatory policy instruments are summarized in the next subsection.

5.1. Standard Theoretical Results:

In the case of a pollution tax, a necessary condition of economic efficiency in a competitive economy is that the rate of tax is set equal to the marginal damage from pollution. However, and this would very likely be true of Climate Change, the information required to reach efficiency (i.e., the marginal damage at the efficient point to all agents exposed to the pollutant) is unlikely to be available. In that case, a pollution tax will still achieve a given level of environmental quality (e.g., aggregate GHGs emissions levels) at least resource cost, under the assumptions of cost minimization and price taking by firms, which fiat based instruments are unlikely to accomplish. Further, a rigid standard may involve unacceptable control costs if the regulator is misinformed about the magnitude of actual marginal control costs. Another advantage of a pollution tax over a standard under these assumptions is that a tax provides a continuing incentive to polluters to reduce emissions if cost effective means are available, no matter how low they are already. This may stimulate technical change in abatement methods.

On the other hand, while pollution taxes may involve substantial expenditures on monitoring and enforcement, these may be significantly lower for standards if they are imposed by the device of mandated technologies (e.g., a "best available abatement technology" policy). Another disadvantage of a pollution tax is that the level of environmental quality attained cannot be chosen in advance, as it results from the decentralized actions of numerous (and diverse) agents. To achieve a given level of aggregate emissions, tinkering with the pollution tax rate over time may be necessary. However, if an initial level of pollution tax leads to investments in abatement, the costs of adjustment in response to a change in tax rate may be high.

An alternative to pollution taxes that is sometimes suggested is a subsidy to reduce pollution. The argument goes that resource allocation, including the emissions of pollutants, does not depend on the assignment of environmental property rights (i.e., whether agents are taxed or rewarded for abatements does not affect the outcomes, except for the distribution of incomes). Typically such subsidies take the form of payment, at least in part, of the costs of pollution control. Three major problems arise in this approach. First, it is difficult to establish benchmarks for emissions levels (reduction below which will merit lump sum subsidy payments) for each agent without creating incentives for them to misrepresent their actual emissions levels. Second, a subsidy may bias the choice of abatement technology. For example, if capital costs are subsidized, but operating costs are not, capital intensive control methods may be adopted even if they are not efficient (economic). Third, because the subsidy payments can impact agents' profits, while each existing polluter may reduce emissions, an incentive is created to other agents to enter the polluting activity, and in the long-run, the aggregate level of pollution will tend to increase.

In addition, tradeable permits have been proposed by economists as a means of achieving aggregate pollution emissions levels at potentially lower costs than standards imposed on each polluter. Further, tradeable permits also eliminate uncertainty about aggregate emissions levels (or ambient quality, if so desired). However, the monitoring and enforcement costs of tradeable permits may be higher than for pollution tax, because of the need to keep track of trades in permits after the initial assignments. Additional administrative costs may be incurred in operating a scheme for the initial assignments. In the theoretical analysis of tradeable permits, it is assumed that once assigned, a competitive market operates among agents owning these permits.

Two principal ways of assigning these permits are as follows. First, the permits may be distributed among agents on the basis of a political determination of entitlements. In this case, unequal political power of agents may result in "inequitious" distributions of these rights among agents. Second, they may be auctioned by the regulator. In the latter case, if some agents are "large", they may form (buyers' and sellers') cartels and the outcome may differ from that which would be realized if the bidding were perfectly competitive.

A widely shared view among economists is that which of these instruments accomplishes a desired level of control at least cost, including monitoring and enforcement costs, is essentially an empirical one. The following subsection briefly surveys the experience so far with the actual operation of incentive based environmental regulatory instruments at the level of national (and subnational) economies:

5.2. Actual Experience with Environmental Regulatory Instruments:

Pollution taxes (emissions charges), and other similar fee based systems have been operated in Europe, Japan, and the U.S., for at least two decades. These include effluent charges on water pollutants (France, Italy, Germany, Netherlands and U.S.), air pollution charges (France and Japan), taxes on polluting vehicles (Sweden), and on hazardous solid waste (U.S.). Some insights which may bear generalization are as follows:

(1) Charges have been typically designed to raise revenue, rather than to achieve efficient levels of pollution control, or even minimize costs of achieving given environmental standards. The level of improvements appear to be positively related to the level of charges. However, the impacts are low when the revenues are returned to the polluters.

(2) Typically the revenues from charges are used for specific environmental purposes, rather than for reducing reliance on conventional taxes (which may involve greater distortions in resource allocation than pollution taxes).

(3) Where charges have been successful, they have been introduced gradually and increased over time (at rates exceeding the inflation rate).

Tradeable permits schemes have not yet been employed as widely as pollution taxes. Three examples are from the U.S., i.e., trading emissions rights under the Clean Air Act, trading of lead in gasoline, and control of water pollution in a river. A fourth example involves air pollution trading in Germany (for which only very limited information is available). Once again, some insights which might be relevant in other contexts, are as follows:

(1) The market structure and the behavioral norms of the regulated agents are important. In the case of the Wisconsin Fox River, the disappointing results of a scheme of trading discharge permits are traced to (at least) two reasons. First, several of the polluters (pulp and paper plants) are oligopolistic, and may not behave as competitive firms in the permits market. Second, another set of polluters are municipal waste plants subject to public utility regulation, and perhaps insensitive to market incentives.

(2) Where a trading scheme has resulted in large numbers of trades (e.g., as allowed under the "netting" component of the emissions trading program of the U.S. Clean Air Act), significant cost reductions in compliance have resulted (exceeding $ 10 billion in accumulated capital savings under all components of the program). Further, while environmental quality has certainly improved under the scheme, since the emissions trading program is additional to, and not in replacement of the traditional command and control regulatory approach, it is not possible to say how much of the improvement is attributable to the emissions trading scheme.

(3) Effective monitoring and widespread agreement on environmental objectives are important for the success of tradeable permits schemes. This appears to be the case with the lead trading program among refineries in the U.S., which also conforms closely to the notion of a competitive market in permits.

In the next subsection we identify some implications of the above discussion for the choice of multilateral and national level policy instruments for regulation of GHGs emissions.

5.3. Choice of Policy Instruments for GHGs Regulation:

Multilateral level policy instruments which have been suggested for regulation of GHGs

emissions by different countries or regions include variants of standards ("commitments on sources"), as well of pollution taxes ("carbon taxes"), and tradeable permits. While there has been some debate, both in
policy forums as well as in the academic literature, on instrument choice, the question of monitoring and enforcement (M&E) mechanisms has received comparatively little attention. This omission is surprising, both because regulatory schemes are critically dependent on effective M&E, and because the M&E costs of different regulatory strategies may vary widely, impacting the choice of policy instruments.

In the multilateral arena, several political considerations, for example, national sovereignty, may dominate strictly economic criteria (i.e., costs or efficiency), in the choice of regulatory schemes. In addition, the choice of policy instruments may have important distributive (or equity) implications both across and within the regulated agents (countries or regions). Thus, for example, considerations of national sovereignty may preclude the use of emissions standards based on technologies mandated by external authorities. Considerations of sovereignty would also dictate that the choice of domestic regulatory instruments, in fulfilment of multilateral obligations, must be left to national policy makers. However, the feasibility of effective national level regulation would constitute an input into the fixing of multilateral obligations. Equity issues within regulated entities (countries) may, for example, involve changes in relative factor rewards (i.e., interest rates, wage levels, and land rentals), impacting the incomes of different social classes.

If one assumes that any scheme of multilateral regulation of GHGs will be focused on sovereign States, the first question which arises in the context of instrument choice is whether the standard theoretical results would continue to hold in the multilateral context. In particular, we need to enquire whether the assumption of cost minimization by firms has a clearly identifiable counterpart in the case of States. Further, when considering international tradeable permits, whether there is good reason to believe that the resulting permits markets would be competitive.

In attempting to answer the first question we initially proceed in a normative, rather than a positive manner: The minimization of (domestic resource) costs of compliance with a multilateral regulatory regime would result in a gain in efficiency. Public authorities of States "should" however, seek to maximize societal welfare, which has components of both efficiency and distribution across societal classes. Characteristically, policy choices involve tradeoffs between efficiency and distribution. For this reason, gains in economic efficiency may not be unambiguously desirable. Because different (multilateral) regulatory approaches may have varying impacts on efficiency and distribution, it follows that quite rationally, policy makers may not display cost minimizing responses to multilateral regulation. Switching to a positive approach, we note that a sizable literature on the theory of public choice suggests that the maximization of a societal welfare function may conflict with the incentive structure of public officials, and for that reason, is unlikely to occur.

The second question, i.e., whether we may expect an international tradeable permits market to be competitive, may be answered intuitively by looking at the existing

distribution of resources across countries. The facts of vast disparities in the wealth of nations, concentration of wealth in a relatively small number of nations, and great heterogeneity and political differences among a much larger number of poor nations, would suggest that formation of emissions permits cartels by rich nations would be easy. No effective device can be visualized to counter this reality.

The limited experience with operating market based regulatory schemes (discussed above) suggest that deviations from the assumptions on which the theoretical results are based would tend to make these instruments ineffective. Two key theoretical assumptions indeed seem to be violated in the case of market based multilateral instruments. Further, as we have seen, in the case of emissions standards, the option of basing them on mandated technologies, which may reduce M&E costs in their case, may violate notions of national sovereignty. Having said this, one may recognize one advantage of international carbon taxes and (auctioned) tradeable permits over several alternative schemes. These instruments may yield significant net revenues to the multilateral regulatory agency, which may be important in devising practical schemes for financial transfers to developing countries, as may be mandated by a determination of the equity question.

Any multilateral GHGs regulatory regime focused on sovereign States has to be translated by national public authorities to a domestic regulatory framework for domestic emitters, designed to ensure national level compliance with the multilateral responsibilities. In the case of developing countries generally, an important consideration is that a major part of economic activity is in the "unorganized" sector, with little possibility of access by regulatory instruments, including market based instruments. This is because such activity is typically tiny in scale, widely dispersed, and may have little market nexus. It would be unrealistic, accordingly, to subject developing countries to stringent application of multilateral regulatory instruments, and at least in the near term, expect that they would be effective.

Energy is a ubiquitous input in all economic activity, and different energy sources are (partly) substitutable with each other, and in the aggregate are substitutes (or complements) for other inputs to production, i.e., capital, labor, land, and materials. Accordingly, the effects of any domestic policy instrument impacting GHGs emissions through inducing changes in energy use, applied to a single sector (e.g., electricity generation), or a category of economic agents (e.g., consumers) carry over, through changes in relative prices and factor rewards to all aspects of the economy. These include changes in patterns of production, trade, aggregate income and its distribution, consumer welfare, government revenues and expenditures, inflation, savings and investment, and the external balance of payments. Further, global regulation of GHGs may be expected to alter comparative advantage across nations, and relative prices of tradeables, besides financial and investment flows.

It is not likely that all these diverse impacts of GHGs regulation can be predicted intuitively. Some insights may be gained through formal economic modelling techniques. While several limited modelling efforts have indeed been made, we are still far away from an adequate understanding of the impacts of global and national level regulation of GHGs emissions. Clearly there is need for further research on the question of

instrument choice in the multilateral and domestic GHGs regulatory context. Given the present state of knowledge, one would hesitate to unreservedly recommend any particular regulatory arrangement for adoption in the near term.

6. Structuring the Equity Issue:

The key to an eventual international instrument for regulation of Climate Change is the issue of equity or fairness. Equity is involved not only in the distribution of possible benefits of control, but also, importantly, in the costs of abatement responsibilities. A gestalt view of the latter aspect is that since a Protocol would have to limit global emissions, and also apportion entitlements to emissions (or the share of net revenues that might be yielded by the use of international regulatory instruments, such as carbon taxes or tradeable permits), real resource transfers are involved in such schemes. Further, since the sharing of burdens, entitlements, and benefits would occur not only among countries or regions, but also across human generations, equity in the context of Climate Change has both spatial and temporal dimensions. The issue is complex, and in this paper we do not attempt anything more than providing an outline of a framework for analysis of the problem.

Notions of fairness are deeply intertwined with the idea of "equality." The term 'equality' is used in different senses. It may refer to "equality before the law", i.e., equality of treatment by authorities. Alternatively, it may refer to "equality of opportunity", i.e., equality of chances in an economic system. A third meaning is "equality of result", i.e., equal distribution of goods or productive resources. Coleman (1987) seeks to distinguish between these different meanings in the following manner:

Suppose that a system consists of:

(a) a set of positions which have two properties:

(i) when occupied by persons, they generate activities producing valued goods and services;

(ii) the persons in these positions are rewarded for these activities, both materially and symbolically;

(b) a set of adults who occupy positions;

(c) children of these adults;

(d) a set of normative or legal constraints on certain actions.

Equality under law concerns (b), (c), and (d): i.e., the normative or legal constraints on actions depend only on the nature of the action, and not on the identity of the actor. That is, the law treats persons in similar positions similarly. Equality of opportunity

concerns (a), (b), and (c), i.e., that the process through which persons come to occupy positions give an equal chance to all. Ordinarily this means that a child's opportunities to occupy one of the positions (a) does not depend on which particular adults from set (b) are her parents. Finally, equality of result has to do with (a ii), i.e., the rewards given to the position occupied by each person are the same, independent of the activity. These three concepts can also be seen as involving different relations of the "State" to inequalities that exist, or arise in society. Equality before the law means that laws do not recognize distinctions between persons that are irrelevant to the activities of the positions they occupy, but that otherwise policies do not attempt to eliminate inequalities as they arise. Equality of opportunity means that the State intervenes to ensure that inequalities do not cross generations. Equality of result implies that the State periodically or continuously intervenes to ensure that inequalities arising from activities are not accumulated.

In applying these concepts to Climate Change, the first key question is that of the "identification of agents". Ordinary notions of equity involve fairness among human individuals as agents, although often phrased in terms of equity between different groups, or classes. An intuitively appealing notion of "agent" in the Climate Change context would be human beings, irrespective of where or when they happen to live. Alternative notions of 'agent', for example, countries, regions, or defined communities are unappealing, if for no other reason than that they are susceptible to fundamental change in character and composition in the time frame of Climate Change. In that case, (i.e., with agents as individuals as defined above), sovereign States may assume the role of trustees with respect to their citizens in the matter of equity in Climate Change, and an attribute of sovereignty would be that such a claim of trusteeship is not open to challenge.

In the context of multilateral regulation of Climate Change, given that this definition of 'agents' is accepted, how may we identify the other elements of the system described above? 'Legal constraints on actions' may be interpreted as limitations on GHGs emissions. Further, the 'set of positions' would include various occupations (consumption) resulting in GHGs emissions and resulting in economic reward (utility), no matter where or when located. Finally, 'children', would, at any given generation, mean the members of the succeeding generations.

What would 'equality under the law' imply, given these definitions? Since under this principle, no note must be taken of distinctions which are irrelevant to the activities of the agents, a multilateral regulatory framework cannot distinguish between individuals on the basis of nationality, temporal generation, or other attributes, such as race, religion, or colour. Equality under law is generally considered the weakest equity principle, to which even an minimalist State may be expected to adhere, and almost coincident with the notion of "rule of law." It would be difficult to argue against following this principle, in any multilateral context, including of course, Climate Change.

What of 'equality of opportunity'? This principle requires that inequalities (in wealth, welfare) arising from differential levels of GHGs emissions by agents do not carry over across generations. Specifically, at a minimum this principle would seem to require that

the access to GHGs emissions cannot be hereditary, (ruling out "Grandfathering" as a basis for emissions entitlements), and that the incremental wealth accruing to individuals from higher, unentitled GHGs emissions by them, cannot be bequeathed to their offspring. This principle furnishes the basis for the assertion that societies with higher historical per-capita emissions, should compensate societies with lower past per-capita emissions. Ensuring equality of opportunity is a central concern of the welfare State, and (to varying degrees) is sought to be realized in all but avowed legally minimalist States. Little support may be found in international public documents, or current instruments, for abrogating this principle.

Finally, 'equality of result'. Different ethical schools have evolved to address this question, albeit in the context of distribution of the national income between different social classes or groups. In the Climate Change context, this principle should be interpreted as equal per-capita rights to GHGs emissions (which may be voluntarily transferable) across all
agents.

Several philosophical positions take equality of result as 'natural', in the sense that while it needs no justification, deviations from the principle would require it. Rawls (1971), accordingly seeks to address the question: "When can inequalities of result be justified?" The answer, summarized in a sentence, is that "only those inequalities are just, which would make the least well off person in society better off than that person would be, (given ceterus-paribus and that basic human rights are equally assigned to all), in the absence of the inequalities." Rawls' theory of justice would thus cast a strong onus on advocates of differential per-capita GHGs emissions entitlements to demonstrate that any scheme of unequal entitlements would be of greater benefit to the poorest of mankind, than equal entitlements.

Traditional welfare economics based on Utilitarianism, would support the idea of equality of result in income, since declining marginal utility of income would mean that social welfare, an aggregation of individual utilities (cardinal, inter-personally comparable), is maximized when incomes are equal (Pigou, 1932). A progressive per-capita distribution of GHGs emission rights (i.e., emissions rights for the poor are higher than for the rich) might have the effect of equalizing incomes, and thereby, increasing global social welfare. Of course, the underlying assumptions for existence of such a social welfare function are strong. However, there is another objection to the Pigouvian result. That is, if individual welfare is inter-dependent, or in other words, if one person's activities benefit or harm others, even if such external effects are unintended, maximization of social welfare over time would require such external effects to be taken into account. This would mean an allocation of resources (emissions rights) to persons in line with the value of these external effects, justifying some inequalities. Of course, the application of this principle must be comprehensive, i.e., all external contributions of all persons over all time must be accounted for, and it is difficult to see that practical ways of implementing this principle can be devised.

Libertarianism (Nozick, 1973) points out that a preferred (say, equal) societal distribution of resources at one point in time will lead, by the very process by which persons pursue their own welfare, to less preferred (unequal) distributions at later times.

The three ways to prevent this, i.e., preventing economic exchange, or banning economic activities which lead to inequality, or progressive taxation, can each be shown, in the limit, to reduce societal welfare. In other words, continuous interventions by the State to restore the preferred resource distribution may lead to reduction in societal welfare. The Libertarian premise is thus, that interventions by public authorities to promote equality of result cannot increase societal welfare and is thus unjustified. Nozick further asserts that distribution of resources cannot be seen in isolation from the process by which wealth is created. "Whomever makes something, having bought or contracted for all other held resources used in the process (transferring some of his holdings for these cooperating factors), is entitled to it. The situation is not one of somethings getting made, and there being an open question of who is to get it. Things come into the world already attached to people having entitlements over them."

This "historical entitlement theory" would seem, as applied to goods which come into being with pre-existing claims to them, arising for example, from initial property rights over the factors of production, or from the application of one's skill, to deny that equal rights to these goods is natural. However, this would not be the case with resources which are virginal in nature, and Nozick has difficulty in specifying which of several possible methods, for example, through labour, first occupancy, possession, declaration, or some other historical means is appropriate. Steiner (1977) has pointed out that since the process of acquisition of natural resources (which would clearly include environmental resources) creates nothing new, but involves the extraction of pre-existent resources from nature, differential entitlements to virginal resources should be proscribed by the Libertarian. Moreover, the equal right to liberty to which Nozick (apparently) subscribes should imply an initial equal distribution of natural resources. It is thus possible, even from the premises of Libertarianism, to derive the principle of equal per-capita rights to GHGs emissions.

Developing countries assert that their levels of past, current, and (foreseeable) future per-capita GHGs emissions would not aggregatively induce Climate Change. On the other hand, just continuing with the past rates of emissions of industrialized States suffice to ensure increasing concentrations of GHGs in the atmosphere. Further, because of the apparent close linkages between economic growth and GHGs emissions, developing countries cannot accept any commitment with regard to their emissions levels in the foreseeable future. In addition, equity principles, as argued above, would justify compensatory transfers to them for the historically high levels of emissions by industrialized countries, besides equal per-capita emissions entitlements in the future.

The arguments of the developing countries cannot easily be dismissed, even if one urges that in their own self-interest, because of likely adverse environmental impacts, developing countries should eschew GHGs intensive growth paths. However, a determination of the equity issues in Climate Change before the current multilateral efforts to finalize a Framework Convention for regulating Climate Change are concluded, is unlikely. Two possible operative aspects of such a Framework Convention are commitments by industrialized countries to stabilize and then reduce GHGs emissions, within a specified time-frame, and second, financial flows to developing countries to adopt strategies to reduce future growth of GHGs emissions by them. The first aspect is unexceptionable from the point of view of developing countries, as long

as similar commitments are not sought from developing countries before a determination of equity principles. Regarding the second, two considerations are important. One, that such flows must be additional to, and not competitive with, normal aid flows for growth. Second, that financial (and technology) flows, without an equity determination (when these might accrue as of right), must be considered as paternalistic, and no obligation can be cast on anyone to accept such transfers. Accordingly, it would be inappropriate to prescribe binding norms for such financial or technology transfers, and it should be open to individual developing countries to state the conditions under which they would accept such transfers.

Concluding comment:

The past two decades have witnessed a tremendous surge in public concern with the environment. Over time, attention has moved from local environmental quality issues impacting health, recreational amenities, and aesthetics, to global issues which involve the life-support systems of mankind and other living species.

The discipline of economics had, in the earlier phases of environmental awareness, an ambivalent relationship with the policy making process. One view which had some currency earlier, is that economics can contribute little to the resolution of natural resource depletion and environmental quality. This is because the origins of the problems are to be traced in the insensitivity of economic systems to these concerns. Economics was seen as guiding these systems, and the discipline was urged to undergo fundamental restructuring if environmental concerns were to be incorporated into economic policy.

While little paradigm shift occurred in economics in response to this criticism, economists did seek to develop a body of theorems, models and concepts for analysis of resource and environmental issues. Important insights were obtained regarding patterns of depletion or pollution emissions under different market and institutional arrangements. The role of identifying the incentives faced by agents, and their likely responses to these incentives, was identified as a crucial input in designing regulatory policy. Novel policy instruments were devised and to an increasing extent, employed in regulatory frameworks. Policy analysts gradually accepted that economics can indeed furnish useful insights in devising environmental policy.

One conclusion is however, inescapable from the present survey. That is, the challenges of global policy analysis for Climate Change will require a significant sharpening of existing analytical tools of economics. These challenges arise from the very long time frame, extending to the past as well as the future, besides the pervasive uncertainties, both scientific, as well as relating to economic and social impacts, involved in the Climate Change issue. While the basic approach of the discipline, i.e., a behavioral assumption that agents maximize some objective subject to their perceived constraints, remains valid, the global environmental arena calls into question many of the existing formulations of this theme. It is not easy to furnish a listing of the areas where advances of a rather fundamental nature will be required, suffice it to say that they will be over a very broad range, including both positive and normative aspects. It is also clear that the evolving discipline of environmental economics will have to establish

deeper linkages with the theory of social choice, formal ethics, and positive political theory.

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