Working Papers in
AGRICULTURAL ECONOMICS

March **91-5**

A Critical Analysis of Climate Change Policy Research

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Abstract

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After more than a decade of warning from scientists, the policy community has begun to take up the challenge of global climate change. This paper considers some of the recent efforts to analyze policymaking in this area. Several shortcomings are seen in the present policy research, including: inconsistencies in the data and methods used in some of the analyses, a myopic vision of options available, an overly anthropocentric focus on estimating costs and benefits, inadequate treatment of uncertainty and irreversibility, and the lack of recognition of differential motives of developing and developed countries. We also have concerns with how results of the analyses have been presented and interpreted, and the limited amount of peer review that has taken place.

A Critical Analysis of Climate Change Policy Research

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INTRODUCTION

After more than a decade of warning from scientists, the policy community has begun to take up the challenge of global climate change. The last few years have seen an explosion in policy research related to this issue.[2] This paper considers some of the recent efforts, focusing on those which attempt to estimate the costs and/or benefits of various policies. These represent the research that has received the most attention within the policy community and that has been at the center of much of the policy debate in the U.S. The paper is not intended to be a summary of work to date[3]; rather its purpose is to raise several concerns about the questions that are being addressed, how the research is being performed, and how the results are being presented to the policy community and the public in general.

Much of the research reviewed here reflects preliminary effort to address issues in this area and includes several works in progress. We recognize that we have not evaluated all of the work that has been, or is being done. Nevertheless, it is our opinion that it is the appropriate time to raise these sorts of questions and concerns. The reader should, for the most part, interpret our conclusions as general critiques and not as criticisms of the specific works reviewed.

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[1] Resource Economics, Department of Agricultural Economics, Cornell University, Ithaca, NY 14583. A shorter version of this paper will be published in the conference proceedings for Global Climate Change: The Economic Costs of Adaptation and Mitigation, Dec. 4-5, 1990, Washington, D.C. Special thanks is given to Peter Taylor and Tom Drennen for extensive reviews of earlier versions of this paper, and to Melissa Duffy for her assistance. This work was supported in part by the U.S. Department of Agriculture.

[2] Significant policy analyses in an earlier period include Nordhaus (1979), Kellogg and Schware (1981), Changing Climate (1983), and Edmonds and Reilly (1983).

[3] For more general surveys of estimates of the costs and benefits associated with global climate change policy, the reader is referred to Nordhaus (1990d), DOE (1990), Hoeller and Nicolaisen (forthcoming), and Edmonds and Wuebbles (forthcoming).

We begin by laying out the basic concepts that several authors have suggested should be considered in climate change policy research. This is followed by a catalogue of the concerns that we have with the present body of research. The paper concludes with a summary of our major conclusions and our perception of desirable future research in this area.

CLIMATE CHANGE POLICY RESEARCH: WHAT SHOULD BE STRESSED?[1]

> One approach would be to take a 'certainty equivalent' or 'best guess' approach, ignore uncertainty and the costs of decisionmaking, and plunge ahead. ... It is appropriate as long as the risks are symmetrical and the uncertainties are unlikely to be resolved in the foreseeable future. Unfortunately, neither of these conditions is likely to be satisfied for the greenhouse effect. (Nordhaus 1990c)

> These features - cost-benefit thinking, appropriate behaviour under uncertainty and incentives to cooperate - define what we call 'thinking economically about climate change'. (Barbier and Pearce, 1990)

At a very fundamental level, the evaluation of policies to address potential global climate change must include a careful weighing of costs and benefits. (It would be imprudent after all to pursue policies for which the costs of the policy clearly outweigh the benefits.) Climate change presents major challenges, however, calling for innovative analyses. This section considers some of the difficulties, principally the wide range of costs and benefits that must be considered, the importance of uncertainty, risk, and irreversibility, and finally the global and intertemporal aspects of climate change policy.

In analyzing policies to address global climate change, a full account must be made of the costs and benefits. Indirect costs, i.e. impacts on international trade patterns and other aspects of the macroeconomy, should be included as well as direct costs, i.e. tax rates on fuels, or subsidies for conservation or reforestation. Estimates of the benefits of climate change policy need to incorporate joint benefits, such as benefits from reductions in levels of other pollutants, and improved levels of energy efficiency. Researchers must be careful to recognize both costs and benefits that are not

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[1] For a further consideration of some of the issues expressed in this section, the reader may wish to refer to Barbier and Pearce (1990) and Nordhaus (1990c).

easily monetized, as these are likely to be significant for any policy related to global climate change.

Global climate change policy research must face the issues of uncertainty, risk, and irreversibility. Uncertainty refers here to a lack of knowledge that can be improved with further information. Currently, there remain significant gaps in our understanding of the climate system and how it may be affected by increasing concentrations of greenhouse gases. Similarly, our understanding of the natural and socio-economic systems which both determine and bear the effects of global climate change is incomplete; so even if we were to completely decipher the climate system, we would be left with uncertainties concerning how many of the forces driving it might change and what might be the impacts of this change. Some of the uncertainty is expected to be reduced with further study, but this may take a long time and some of it may not be reducible. The concept of risk encompasses this irreducible uncertainty, but it also includes the idea of inherent variability. An example of this would be the interannual variability of rainfall and temperature in a particular region. With better knowledge it may be possible to determine how these might change with global climate change, but the underlying variability will remain. A simpler example would be rolling a fair die. Even if it were determined that the die is fair, the number showing on the die when rolled would still remain an uncertain event. Irreversibility is important because many of the effects that continuing emissions of greenhouse gases imply for natural and social systems cannot be undone once they occur, at least not in the time scales which are considered for climate change policy. This introduces an important assymetry into the analysis of uncertain events.

Global climate change is not limited to a single nation or region of the world, nor to a single generation. Actions taken today in one part of the world have repercussions that will be felt throughout the globe and for many years to come. This causes severe difficulties in evaluating future costs and benefits, regional differences in costs and benefits, and international implications of climate change policies. It also raises important questions concerning the effectiveness of unilateral action, and of intergenerational and regional equity which cannot be ignored.

taxes. Similarly, Morris, et.al. (1990) and Jorgensen and Wilcoxen (1990), using more disaggregated models, find much lower estimates of the marginal costs of achieving similar reductions in CO_2 emissions in the United States than do Manne and Richels (1990a).[1]

The bottom-up analyses take a more micro perspective. Individual technologies or specific actions that either reduce or offset greenhouse gas emissions (i.e. by planting trees) are analyzed to make an estimate of the costs. Drennen and Chapman (1990), Dudek and LeBlond (1990), and Geller (1990) provide examples of this approach. Wider effects on the economy, and feedbacks such as changing relative prices as the technology enters into the market on a large scale are generally ignored. Also, bottom-up analyses normally include estimates of benefits as well as costs. For these reasons, bottom-up analyses tend to provide lower estimates of costs, sometimes even showing a negative net cost of reducing greenhouse gas emissions. For example, Drennen and Chapman (1990) estimate the cost of reducing CO_2 emissions by using compact fluorescent light bulbs to be -$56 per ton of CO_2 equivalent, and Geller (1990) has calculated that increased efficiency standards on automobiles and refrigerators in the past fifteen years have produced net costs of carbon avoidance of -$60 and -$90 per ton of CO_2 equivalent, respectively. Geller (1990) further argues that similar initiatives could reduce carbon emissions in the U.S. by 10% from 1988 levels by the year 2000, at a net savings of $75 billion per year. Specific policies may be found to be quite expensive, however; for example, Drennen and Chapman (1990) estimate that the reduction of greenhouse gas emissions by altering the diet of cattle has a cost of over $350 per ton of CO_2 equivalent.

Future research should consider trying to link these two approaches, or at least to narrow the gap. More detailed models, as employed by Morris et.al. (1990) and Jorgensen and Wilcoxen (1990) may or may not be the proper direction to take, but they need to be considered if large scale modelling is

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[1] Morris et.al.(1990), in their base case, estimate the marginal cost for the U.S. to reduce its CO_2 emissions to 20% below 1988 levels by the year 2010 to be under $40/ton carbon. Jorgensen and Wilcoxen (1990), in a remarkably similar result, determine that a tax of just over $40/ton carbon is sufficient for the U.S. to achieve a reduction of 20% from 1990 levels by the year 2005. Manne and Richels (1990a), however, estimate that for the U.S. to achieve reductions of 20% from 1990 levels by the year 2020, and holding steady thereafter, would require a tax that would rise to nearly $600/ton carbon before settling at a level of $250/ton in the long-run.

to be used. For the moment, as Zimmerman (1990a) and Wuebbles and Edmonds (forthcoming) point out, one must be careful when comparing costs across studies to recognize the differences in the two approaches.

THE IMPORTANCE OF ASSUMPTIONS: CARBON TAXES AND GNP LOSSES

Too often the results of policy analyses, especially those that involve the use of computer models, are taken at face value without a consideration of the assumptions that underlie the analysis. The following two examples illustrate how a few assumptions can directly determine key results.

The first example focuses upon the long-run equilibrium carbon tax estimated by Manne and Richels as necessary to maintain a level of emissions that is 20% below current levels in the United States, other OECD countries and the Soviet Union and Eastern Europe; elsewhere the tax limits the growth in emissions to 100% above current levels. The equilibrium value that they present is \$250/ton of carbon (Manne and Richels 1990a,1990b). This number is determined by three assumptions: the cost of synthetic fuels - \$10/million British Thermal Units (mmBTU), the cost of a non-electric backstop technology with no carbon emissions - \$20/mmBTU, and the carbon emission rate for synthetic fuels - 0.04 tons carbon/mmBTU:

Cost Differential/Carbon Differential = (\$20-\$10)/(.04 tons) = \$250/ton

Manne and Richels do recognize the dependence of this number on these assumptions, particularly the cost differential, but do not present evidence to indicate that they have done extensive tests or sensitivity analysis in this area. This number has also been cited by others, with little or no acknowledgement of the importance of the underlying assumptions.[1]

The second example involves Edmonds and Barnes' (1990) estimates of GNP losses that may occur as a result of policies that aim to reduce emissions of greenhouse gases. They estimate the global "GNP penalty" to be 3% for a

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[1] See Nordhaus (1990d), CBO (1990), N.Y. Times (19 November 1989), Wuebbles and Edmonds (forthcoming), and Hoeller and Nicolaisen (forthcoming). Of these, only Nordhaus (1990d) notes that the value of \$250/ton "is purely a product of the assumption about the cost of carbon-free technologies."

Richels has indicated that he and Manne have come across model scenarios where the long-run tax is not determined by the non-electric sector in certain regions of the world. Also, he emphasizes that the key assumption is the cost differential between the carbon-based and non-carbon-based technologies, rather than the absolute value of either one. (Richard Richels, personal communication, Nov. 1990) global effort to stabilize CO_2 emissions at current levels in the year 2025, and 8% for a global effort to reduce emissions by 50% in the same year. If only OECD countries act, the GNP penalty for these countries is a staggering 17% to simply stabilize global emissions at current levels.

Before we get too excited by these results though, we must recognize how they are derived. Edmonds and Barnes use a "GNP feedback elasticity parameter which reduces actual GNP as the cost of energy services rise" (Edmonds and Barnes, 1990). The authors do not say what the value of this parameter is, but in an earlier piece by Reilly, Edmonds, Gardner, and Brenkert (1987) the mean values provided are -0.14 for OECD countries, 0.05 for Mideast countries, and -0.20 for other countries. A value of -0.14 implies that a 1% increase in the costs of energy services will result in a 0.14% decline in GNP. Edmonds and Barnes recognize that this simplistic estimation of costs is one of the major limitations of their present analysis:

> The importance of the GNP feedback results should not be overemphasized. These results are based on a single equation relationship whose key parameter values reflect the results of analysis on the 1970's period. The period of analysis was too brief to allow a full analysis of long-term adjustment responses and **small changes in this highly uncertain parameter can lead to large changes in dollar value of GNP, even if percentage changes are small.** (Edmonds and Barnes, 1990; our emphasis)

It would seem wise to heed the caution expressed here. Care must be taken to acknowledge the limitations of analysis in the presentation of results. This leads us to our next question: given that much of our knowledge concerning the physical and social science aspects of global climate change are uncertain at best, do the analyses try to address these uncertainties?

MEASURING COSTS FROM THE WRONG BASELINE[1]

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[1] This subsection reflects a concern raised by Mary Beth Zimmerman (1990b) of the Alliance to Save Energy at the conference Global Climate Change: The Economic Costs of Mitigation and Adaptation, Washington, D.C., December 4-5, 1990. Her argument was disputed by David Montgomery of the Congressional Budget Office and principal author of the CBO (1990) study referenced in this paper, who expressed the opinion that it is proper to separate costs and benefits in the manner presently done in most studies.

A common measure of part of the costs of policies to address global climate change is lost economic output.[1] This is generally expressed as a reduction in Gross National or Gross Domestic Product (GNP or GDP). The procedure employed is to run the economic model (most of these studies are top-down) without policies to project a baseline path of economic growth; the model is then run with the climate change policies. Since policies represent an added constraint on the economy, the resulting path of economic growth is expected to be lower than the baseline. The difference between the two paths provides an estimate for the costs of the policies.

The flaw in this method lies with the baseline path. It is estimated under the assumption of no climate change, and therefore no impact on economic growth from changing climate. If this impact is not zero (it is generally assumed to be negative), then the baseline estimates of economic growth are incorrect, and the resulting cost estimates are measured inappropriately.

IGNORING THE COSTS OF DELAYING ACTION

> Delaying the policy response to the greenhouse gas buildup would substantially increase the commitment to global warming. (EPA, 1989)
>
> [T]he risks of delaying action appear to be large, and the costs of reducing emissions are likely to increase as the time allowed for these reductions is shortened. (EPA, 1989)
>
> The longer emissions continue to increase at present-day rates, the greater reductions would have to be for concentrations to stabilize at a given level. (IPCC, 1990)

As the above quotes illustrate, it is well recognized that there may be significant costs associated with delaying action to address global climate change. These costs can take more than one form. The longer that action to prevent or reduce global climate change is postponed, the larger will be the eventual climate change. Also, delaying either mitigative or adaptive action today may require more extreme action in the future that will need to be accomplished over a shorter period of time, thereby implying larger costs. A

[1] For just a few examples see Manne and Richels (1990a, 1990b), Edmonds and Barnes (1990), Jorgensen and Wilcoxen (1990), CBO (1990), and Nordhaus (1990e).

perverse result, described by Cline (1989b) and Oppenheimer and Boyle (1990), is that delaying action now may lead to costs in the future that surpass the ability of the society to take action at that time.

The cost of delaying action has escaped the purview of studies which set out to estimate the costs and benefits of climate change policy, however. A single example of research addressing this cost has been found: Manne and Richels in "Buying Greenhouse Insurance" (1990c). In this paper, the authors present a decision-analysis framework for determining the optimal level of near-term emissions reductions in the face of scientific uncertainty, in their words -- "optimal hedging strategy". Although, Manne and Richels are primarily interested in seeing how the optimal hedging strategy varies with: "(a)the probability of eventual carbon limitations, (b)the accuracy and timing of the climate research program, and (c)the prospects for new supply and conservation technologies", their tentative results do underscore the value of pursuing some level of emissions reductions in the face of uncertainty, and may provide some estimates of the costs of delaying action (Manne and Richels, 1990c). Hopefully, more research will be pursued addressing this issue.

DE-EMPHASIZING BENEFITS IN COST-BENEFIT ANALYSIS

Very few of the studies to date have addressed the benefits side of the cost-benefit calculus. Some authors have pointed to the large degree of uncertainty in current knowledge concerning the social and economic impacts of global climate change as a justification for focusing only on the costs of policies.[1] Should this be considered acceptable? By emphasizing only the costs of policy do we not introduce a bias into our decisionmaking? The emphasis of a recent conference, as reflected in the title, "Global Climate Change: The Economic Costs of Mitigation and Adaptation", reflects this bias.

Many of the studies that have tried to explicitly estimate benefits from global climate change policy have been summarized by William Nordhaus (1990c).[2] His procedure is to identify sectors of the US economy which are

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[1] Nordhaus likes to refer to our knowledge of potential climate change as terra infirma, implying unstable terrain, and our knowledge of the social and economic impacts of such change as terra incognita, or unknown terrain to indicate how much greater are the uncertainties in this aspect of climate change research (Nordhaus 1990c, 1990e, 1990f, 1990g).

[2] These include EPA (1988) and the Coolfront Workshop (1989).

highly or moderately sensitive to climate, using the 1981 sectoral breakdown of the US economy. Based upon detailed studies done by the EPA (1988), the Coolfront Workshop (1989), and Binkley (1988), he then estimates the total damage to the US economy that would result from a 3°C increase in the global mean surface temperature. His final estimate is that the net economic damage of such a warming would be on the order of 0.25% of national income for the U.S. Recognizing that a number of factors are missing in his analysis, he estimates that this number may really be as high as 1%, with his "hunch ... that the overall impact upon human activity is unlikely to be larger than 2 percent of total output" (Nordhaus, 1990c). Later, he states that "climate change will lead to a combination of gains and losses with the likelihood of but a small impact on the overall economy and with no strong presumption that modest and gradual global greenhouse warming will on balance be harmful" (Nordhaus, 1990c).

William R. Cline (1990b) provides several reasons why Nordhaus' estimates of the benefits from global climate change policy are likely to be too low. He argues that: 1)the net impact on agriculture will be negative, especially in developing countries, not zero as Nordhaus assumes for his central estimate, 2)the land loss resulting from rising sea levels will be much higher than that estimated for the U.S., 3)costs associated with species and forest loss, human disutility, and storm intensity have been ignored[1], and 4)the estimates do not consider the effects beyond a doubling of CO_2 (Cline, 1990b).

NEGLECT OF JOINT BENEFITS

Even considering Cline's critique, we have other concerns with analyses regarding the benefits of global climate change policy. The first of these is that many of the benefits that may occur as a result of global climate change policies have been omitted. Whereas many of the studies address the indirect negative impacts that policies may have, i.e. reduction in the growth of GNP, very few try to account for the indirect positive impacts that may also occur.

[1] See Cline (1990c) for a discussion of the costs of increased hurricane damage due to global warming. He provides a conservative estimate of $750-1000 million annually with a doubling of atmospheric CO_2.

These include health and other benefits associated with reduced levels of other atmospheric pollutants due to lowered consumption of greenhouse gases and economic gains from increased expenditures on renewable technologies. Metz (1990) states that a primary reason that the European Community is pursuing policies related to global climate change is that they provide significant benefits with respect to acid rain, smog, and other environmental problems; including these ancillary benefits results in only slight negative or positive effects on the economy.

ANTHROPOCENTRIC NATURE OF BENEFIT ESTIMATES

> Fair assessment of the trade-offs among policy options will therefore require a thorough analysis of both monetized and non-monetized costs and benefits. (Barbier and Pearce 1990)

Most of the analysis of benefits to date has been overly anthropocentric. It is recognized that many natural ecosystems are likely to suffer severe damage as a result of the pace and extent of the expected global climate change in the next century and beyond (EPA, 1989). Recognition of the benefits from preventing species loss and forest destruction, even when present, tends to focus only on the advantages to human society - "[s]pecies diversity enlarges the options open to future society for medicines and agricultural varieties" (Cline 1990b).

Is it proper to include in our analyses only those items that can be measured in terms of their direct impact on the economy, specifically only those aspects that are valued by humans? Recently the U.S. EPA has been requested to give greater emphasis to the health of natural ecosystems affected by climate change as distinct from the human consequences of that change (EPA, 1990; "E.P.A. Acts to Reshuffle", 1991). We should encourage this development in ourselves and other researchers.

INCORRECTLY COMPARING MARGINAL COSTS AND BENEFITS: FOCUSING ON AN EQUIVALENT DOUBLING OF CO_2

> Accumulation of trace gases and consequential global warming is a continuous process that would not stop with the mere doubling of CO_2 but, in the absence of policy action, would persist into the indefinite future. . . . [P]olicy analysis of global warming will tend erroneously toward inaction if it remains focused on the damages that might be expected from a doubling of carbon dioxide,

and considers only the next fifty years or so. Consideration of a longer time horizon and much greater global warming can reverse the benefit-cost calculus toward an outcome favorable to preventative action. (Cline 1990d)

The principal analyses of the benefits associated with global climate change policy have concentrated on the potential impacts of an equivalent doubling of CO_2 (Nordhaus 1990c, EPA 1988, Coolfront Workshop 1989, Binkley 1988). Cline (1990d) argues, however, that rather than considering a doubling of CO_2 levels with a warming around 3°C, policy analyses should really take a longer-term view and consider a more than seven-fold increase in CO_2 levels with a warming of over 10°C. Here, we would like to point out a more fundamental concern in any comparison of marginal costs and benefits.

Nordhaus (1990c) has developed curves showing rising marginal costs and constant marginal benefits of reducing emissions; the latter is calculated assuming an equivalent doubling of the CO_2 concentration in the atmosphere. He then uses these estimates to determine an efficient level of greenhouse gas reductions of 17% by finding the point at which these curves cross.[1] This methodology is fundamentally flawed. First, a 17% reduction in greenhouse gas emissions will not result in a stabilization of atmospheric concentrations at the level of an equivalent doubling of CO_2. For example, the IPCC estimates that more CO_2 emission reductions of 50% below 1985 quantities would be required to stabilize atmospheric concentrations of CO_2 at twice their preindustrial levels. Secondly, the social and economic damage resulting from global climate change is likely to increase at an accelerating pace as greenhouse gas concentrations increase beyond an equivalent doubling, so the marginal benefit from reducing emissions is not constant. Therefore, with emission reductions of only 17%, the marginal benefit will be much higher than those estimated using an assumed equivalent doubling of CO_2. A more proper

[1] This is his estimate for a medium damage scenario. Using low and high damage scenarios, the optimal levels of reduction are 10% and almost 50%, respectively (Nordhaus, 1990c). In this paper, Nordhaus does describe a greenhouse damage function that increases with greenhouse gas concentration, but he indicates that he has little confidence in this assumption, and does not use it in further analysis.

More recently, Nordhaus (1990g) has sketched out an intertemporal general-equilibrium model of global climate change. This model does include an economic damage function which rises at an increasing rate with global climate change, and is used to determine optimal levels of emissions controls. Only preliminary results have been presented at this time.

comparison of marginal costs and benefits would accordingly lead to a higher level of reductions.

INADEQUATE TREATMENT OF UNCERTAINTY/LACK OF SENSITIVITY ANALYSIS

A common element in our knowledge concerning all aspects of global climate change, from the scientific to socio-political-economic, is some degree of uncertainty. The further out into the future that we look, the more that this uncertainty influences the results of the research. Earlier, a few examples were given of the importance of assumptions in many of the models employed. Little of the climate change policy research on estimating costs and/or benefits seen to date has included extensive sensitivity analyses or attempts to incorporate uncertainty, however.

Nordhaus and Yohe (1983) and Edmonds et.al. (1986) do provide us with examples of using uncertainty analysis in the forecasts of future emissions of GHGs, and Nordhaus (1990a) uses probabilistic scenario analysis to estimate possible likely paths of future warming. Edmonds et.al. (1986) use a Monte-Carlo analysis to generate 400 model scenarios by drawing independent samples from the distributions of 79 important input parameters. Nordhaus and Yohe (1983) use a similar technique. In both of these studies, the results are summarized as subjective probability distributions for future emissions, GNP, etc. Nordhaus (1990a) uses statistical techniques to combine the distributions of the important parameters in his model to directly arrive at a probability distribution for future global warming.

Very little of this sort of analysis has been done in the area of estimating the costs of adaptation or mitigation, however. Scenario analysis is employed by a few studies, but these are limited to only a few scenarios and consider only different policy options and do not specifically test model assumptions (Edmonds and Barnes 1990; Manne and Richels 1990a, 1990b; Morris et.al. 1990). Studies which do include sensitivity analyses of input assumptions test only one or two assumptions. Still, the results show that small changes in input parameters can have large effects (Manne and Richels 1990a, 1990b; Morris et.al. 1990; Edmonds and Barnes 1990). These conclusions should make us conscious that more effort needs to be expended in this area.

Manne and Richels (1990c) have updated their Global 2100 modelling system to be probabilistic. Hopefully, this will allow them to incorporate more uncertainty into their analysis in the future. The decision-analysis framework which they present also looks to be a step in the right direction with respect to incorporating risk and irreversibility directly into their analysis.

PEER REVIEW

The policy research on climate change should be subject to the same level of scrutiny and peer review as is the scientific research. Since most of the research reviewed here is recent and/or ongoing, it is understandable that much of the work is yet to be published. However, this does not lessen the need for the underlying research used to formulate policy recommendations to be made available, and in sufficient detail to allow for adequate review. Although most researchers are willing to disseminate details and drafts of unpublished research, or work in progress[1], very little of the analysis has been presented in sufficient detail to allow for careful checks on assumptions, calculations, etc.

INCONSISTENCY/IRREPRODUCIBILITY OF ASSUMPTIONS, METHODS, AND RESULTS

Our review of work that is presented in sufficient detail has uncovered several inconsistencies in assumptions, results, and methods. The details of our findings, specifically related to the work of William Nordhaus, are included as an appendix to this paper. This is not to imply that these inconsistencies are pervasive or that they drastically alter major conclusions. The very presence of these problems is troubling, though, and should lead us to be cautious about accepting the results of analyses.

CONCLUSIONS

This paper has presented a set of concerns that we have with current climate change policy research, particularly that research which has focused on estimating costs and benefits of climate change policy. We have cited the

[1] One notable exception that the authors have encountered is with the McKinsey and Co. study prepared for the November 1989 Ministerial Conference on Atmosphere Pollution and Climatic Change, held in Noordwijk, the Netherlands. Goldemberg (1990) cites the results of this study. He reports costs of controlling greenhouse gas emissions are significantly lower than estimated in other studies; a tax of just $1 per barrel of oil-equivalent, or $6 per ton of coal-equivalent used to fund CFC phase-out, forest management, and energy conservation would reduce global emissions by 20%. When the authors contacted McKinsey and Co., they were told that the report could not be made available.

need for more effort in certain areas: combining top-down and bottom-up approaches, benefits estimation, incorporation of indirect costs and benefits, sensitivity analysis, testing of assumptions, inclusion of uncertainty, risk, and irreversibility, and peer review. We have also noted cases where some of the current analysis is logically flawed: specifically measuring costs from the wrong baseline and improperly comparing marginal costs and benefits. It is our hope that this effort will stimulate further discussion on these topics and result in better and more appropriate research in the future.

APPENDIX

INCONSISTENCY/IRREPRODUCIBILITY OF ASSUMPTIONS, METHODS, AND RESULTS

DETAILED EXAMPLES

In the body of the paper, we have referred to cases where we have found inconsistent assumptions and results, and also irreproducible results. This appendix provides three detailed examples of problems that we have found.

Inconsistencies in Assumptions

One of the more important assumptions in climate change policy research which considers the relative contribution of different greenhouse gases is the effective atmospheric lifetime of CO_2. The cycling of carbon in the atmosphere and the oceans is sufficiently complicated that it is inappropriate to talk about a single atmospheric lifetime for CO_2. However, several estimates have appeared for an "effective" lifetime, ranging from 120-500 years.[1] Throughout most of his analyses, Nordhaus uses a value of 200 years for the effective lifetime of CO_2 (Nordhaus 1990b, 1990c, 1990d). For some unexplained reason, though, he chooses to use a value of 500 years for converting Chlorofluorocarbon (CFC) emissions into CO_2 equivalents for the purpose of estimating the mitigation costs of reducing CFC emissions in $ per ton of CO_2 equivalent.

The effect of using 500 years instead of 200 years is to provide a lower estimate for the tons of CO_2 equivalent per ton of CFC. For example Nordhaus, using a lifetime of 500 years for atmospheric CO_2, calculates a conversion factor of 1849 tons CO_2 per ton CFC-12; using a lifetime of 200 years, we calculate this value to be 2642 tons CO_2 per ton CFC-12. This in turn results in a larger estimate for the cost of reducing CFC emissions, expressed in $ per ton of CO_2 equivalent. To see this assume that the costs of reducing the emissions of CFC-12 by one ton is $10,000. Using a conversion factor of 1849 tons CO_2 per ton CFC-12, this values translates into $5.41 per ton CO_2 equivalent; using a conversion factor of 2642, the cost is only $3.78 per ton

[1] For various estimates see Wuebbles and Edmonds (1988) - 500 yrs, Rodhe (1990) - 120 yrs., and Lashof and Ajula (1990) - 230 yrs. The uncertainties inherent in these numbers and the danger in using them to estimate a CO_2-based greenhouse warming potential for all GHGs is also discussed in Victor (1990), "Greenhouse Numbers", and Allen (1990).

CO_2 equivalent, a difference of 30%. Elsewhere in this paper, Nordhaus has emphasized the relative cost-effectiveness of reducing CFC emissions vis a vis reducing CO_2 emissions. One is left then with the question as to why it would make sense for him to inflate the costs of reducing CFC emissions other than it serves to inflate the overall costs of reducing all greenhouse gas emissions.

Inconsistency in Methods/Irreproducibility in Results

In "Contribution of Different Gases to Global Warming: A New Technique for Measuring Impact" (Nordhaus 1990b), Nordhaus outlines his method for calculating the total future warming potential for the four primary GHGs: CO_2, CH_4, N_2O, and CFCs. In the body of the paper he provides the formulas that are used to calculate the total future warming for the various greenhouse gases (see p.6 in Nordhaus 1990b for details). Using the provided information, we can obtain the following per unit values of total warming for the four major GHGs:

CO_2 : $8*10^{-4}$ (°C-years/ppb)
CH_4 : $1.7619*10^{-3}$
N_2O : 0.15
CFCs : 7.50

Using these values, we obtain the same results as he does for the total warming potential for 1985 emissions as presented in Table 3 of the paper:

CO_2 : $8*10^{-4}$ (°C-years/ppb) * 1150 (ppb) = 0.92 (°C-years)
CH_4 : $1.7619*10^{-3}$ * 15 = 0.0264
N_2O : 0.15 * 0.7 = 0.1050
CFCs : 7.50 * 0.247 = 0.18525

and for the total warming potential for estimated total emissions over the period 1985-2100 for N_2O and CFCs:

N_2O : 0.15 (°C-years/ppb) * 40 (ppb) = 6.00 (°C-years)
CFCs : 7.50 * 2.28 = 17.10

However, when we try to do the same thing for the total emissions of CO_2 and CH_4 over the time period 1985-2100, we get markedly different answers from

Nordhaus:

CO_2 : $8*10^{-4}$ (°C-years/ppb) * 282000 (ppb) = 225.60 $\neq$ 487.67 (°C-years)
CH_4 : $1.7619*10^{-3}$ * 1425 = 2.51 $\neq$ 4.33

If something has changed in the methodology, it is not mentioned in the text, and the results for N_2O and CFCs were not affected.

The discrepancies in this table are disconcerting since these results are used to generate the following set of results:

Percentage Contribution to Radiative Warming, No Feedback, for Change in Concentrations, 1985-2100

Gas	Nordhaus (1990b)	Our Estimates
CO_2	94.67	89.16
CH_4	0.84	1.71
N_2O	1.16	2.37
CFCs	3.32	6.76

This table is cited in subsequent papers that Nordhaus has written in order to emphasize the relative importance of the different greenhouse gases (Nordhaus 1990c, 1990d, 1990e, 1990f, 1990g). Although CO_2 is dominant in both estimates, the relative contributions of the gases other than CO_2 is significantly smaller using Nordhaus' estimates.

Inconsistencies in Results

In three different studies, Nordhaus provides estimates for the emissions of the four primary GHGs in CO_2 Equivalent Emissions for the year 1985 (using a 5% discount rate for effect of future emissions).[1] These values are not consistent between the studies. In particular, the estimates

[1] See Nordhaus (1990b) for his description of the methodology used to calculate these values. He refers to this earlier paper in the latter two papers cited in the table.

that he presents are as follows:

Gas	CO_2 Equivalent Emissions (billions of metric tons) Nordhaus (1990b)*	Nordhaus (1990d)	Nordhaus (1990c)
CO_2	6.50	6.50	6.50
CH_4	0.87	0.65	0.28
N_2O	1.00	0.68	0.85
CFCs	2.51	1.46	1.75
Totals	10.89	9.29	9.37

* We calculated these values using the same methodology that he used for calculating equivalent emissions using 0%, 1%, and 4% discount rates.

There is no indication in the latter two papers that there has been a change in either the assumptions or the methodology used to calculate these values. Therefore, one is left to wonder what has happened, and why the other gases have been "de-emphasized" relative to CO_2.

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