Degrees of Change

A Newsletter from the Global Change Integrated Assessment Program

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Making decisions about climate change is difficult. The costs of inaction are uncertain and possibly very large, as are the costs of stringent abatement when only moderation may be needed. Exploring the various aspects of the problem requires careful characterization of what is known about human and natural systems and the interactions between the two systems. Integrated assessment models exemplify a systematic and quantitative approach towards a better understanding of these problems. ICAM 2.0 has been developed to explore the role of uncertainties in climate policy. Some basic findings are presented here.

Insights From ICAM 2.0

The second generation Integrated Climate Assessment Model (ICAM 2.0) was made available to the public in January 1995. More than half a dozen members of the Carnegie Mellon climate group were involved in the development of the new model, which now has more detailed and specific representations of the precursors, processes, and impacts of climate change than ICAM 1.0. As with the previous versions, ICAM 2.0 is designed to reflect parameter and model uncertainties. Providing decision-makers a qualitative measure of the confidence with which various policies can be adopted; ICAM 2.0 also offers scientists an opportunity to identify systematically the areas where our knowledge of the problem and decisions based on that knowledge are suspect.

In the past, we have written about the importance of decision rules and decision-makers in determining policy outcomes. In ICAM 2.0, seven distinct geopolitical regions are modeled where: i) expectations about economic growth, ii) energy use patterns, iii) location, iv) regional landuse and air pollution controls, v) patterns of climate change, as well as decision rules and metrics play significant roles in shaping the desirability of greenhouse gas abatement policies. The role each of these plays in modeled outcomes is considered briefly below:

Economic growth — In general, when considering per capita welfare, the higher the expected economic growth, the lower the weight is on long-term climate change impacts. In our model, China and India are important regions where high expected growth leads to an unfavorable view of GHG controls. In the OECD and E. Europe, where growth is expected to be more modest, the model indicates a greater propensity in favoring GHG controls.

Energy use patterns — Response to GHG abatement policies involves conservation of energy and fuel switching. In regions where there is a high dependence on coal, the model shows the cost of controls to be higher than regions that don't rely exclusively on coal. In the OECD, economic activity is less energy intensive than the rest of the world, and there is less reliance on coal than in the Former Eastern Block or China. These differences contribute to a divergence in "good" policy choices and the consequent outcomes across regions.

Location — Few detailed case studies of climate impacts are available for specific regions. However, expectations are that coastal areas will suffer because of rising sea levels and climate change will be more pronounced at higher latitudes. In addition, climate extremes are equally undesirable throughout the world. GCMs suggest greater climate change at high latitudes, but these regions are generally more industrialized and considered less vulnerable. In the absence of better specified impact models, it appears that the benefits of GHG abatement would not be equally distributed around the world.

Regional landuse and air pollution control — These factors are important determinants of the nature and magnitude of regional aerosol concentrations. Organic and elemental carbon aerosols and sulfur dioxide are the major culprits. Sulfur dioxide emissions are primarily a by-product of fossil fuel combustion. Elemental and organic carbon are associated with incomplete combustion. This can happen when fossil and biomass fuels are used and during land clearing. Elemental carbon aerosols are dark and can lead to a local increase in

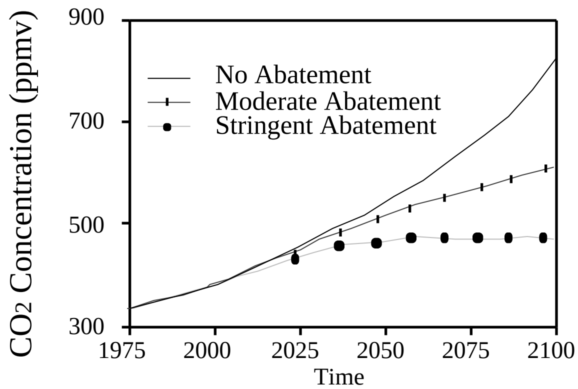

Figure 1a. Mean trajectory of atmospheric CO_2 in response to no, moderate, and stringent abatement policies.

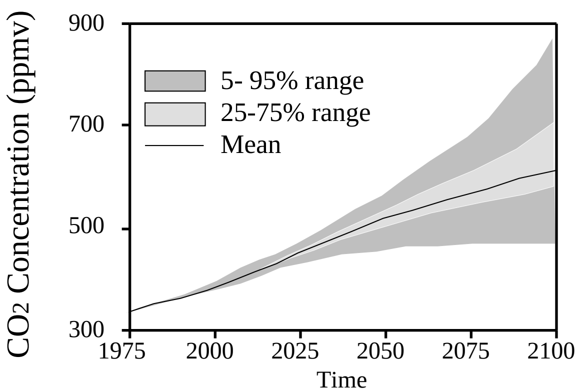

Figure 1b. The Atmospheric CO_2 trajectory is uncertain. Uncertainties about economic growth, response to policy, emissions and the carbon cycle lead to uncertainties in CO_2 concentration. The 25-75% and 5-95% confidence bands are presented along with the mean of the moderate abatement strategy (middle line from Figure 1a). The level of uncertainty is such that the mean trajectories associated with the other abatement options lie within the 5 to 95% range of the moderate abatement policy.

radiative absorption. The other aerosols increase the reflectivity of the clear sky as well as enhance cloud formation and reflectivity. In the OECD, steps have been taken to control all of these air pollutants. The historic sequence of control has been to first slow land clearing and improve combustion efficiencies, then control black carbon and, finally, sulfur dioxide. This sequence is modeled in ICAM 2.0. In the rest of the world, control of carbon emissions would lead to an associated reduction in aerosol emissions. The short atmospheric lifetime of aerosols leads us to expect that the initial consequence of GHG abatement would be a net *increase* in absorption of radiation by the atmosphere and *exacerbated* climate change. The global consequence of different regional loadings of aerosols is not known. However, it can be assumed that perverse climate response to GHG controls is likely to be more pronounced in the northern hemisphere, especially in regions such as China and the former Soviet Union.

In some critical domains of the climate problem, competing hypotheses have been proposed. In ICAM 2.0, these “positions” are treated as model uncertainties. Development of the differing models permit quantification of their impacts on policy outcomes. Two examples are: assumptions about adaptation to climate impacts, and treatment of tropospheric aerosols.

Adaptation — Human beings have distinguished themselves by adapting to a wide range of environments. It is foolhardy to assume that they will not adapt to a changing climate. Should the impacts of climate change be detected and judged undesirable, technical and social capabilities will be harnessed to minimize such impacts (if not the change in climate).

Three versions of the model were exercised: i) with neither adaptation nor aerosols, ii) with adaptations and no aerosols, and iii) with both adaptation and aerosols. Two alternatives to taking no action were considered, both using annually rising carbon taxes starting in the year 2000. In the moderate abatement strategy, the carbon tax rises at $0.5/Ton of Carbon /Yr. In the stringent abatement strategy, the carbon tax rate is four times higher at $2.0/TC/Yr. By 2050, the moderate strategy reduces mean CO_2 emissions from fossil energy use by 40%. The stringent strategy effectively limits emissions below 6 GT/Yr. after 2060. The model was run fifty times to quantify the impact of the various uncertainties. The procedure used in DEMOS involves systematic sampling of uncertainties at each step, and recalculation of all state variables in the assessment. The consequent mean atmospheric CO_2 concentration trajectories are depicted in Figure 1a. The range of possible outcomes (due to the various uncertainties) for the moderate abatement strategy are depicted in Figure 1b. Note that the mean trajectories of CO_2 concentration for the two alternative abatement strategies fall within the 5th and 95th percentile range of the moderate abatement strategy.

Discounting — In this analysis, the payoff of various strategies is in terms of net present value of per capita utility. It is assumed that economic and ecological impacts have equal weighting. The model calculates impacts of policy on market and non-market goods. Thus, the results from each run of the model, once discounted, are a single value for the equivalent discounted net per capita utility for the period from 1975 to 2100. The results in Figures 2a &

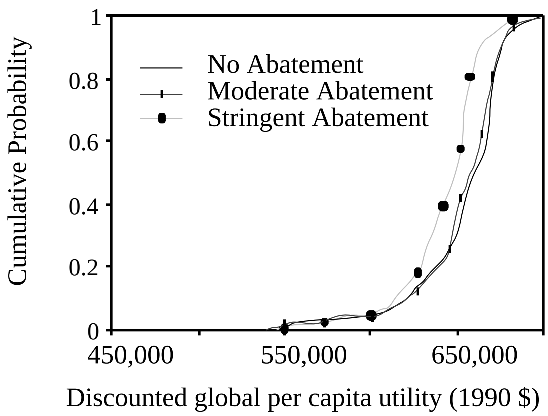

Figure 2a. Cumulative distribution plots for three abatement policies.

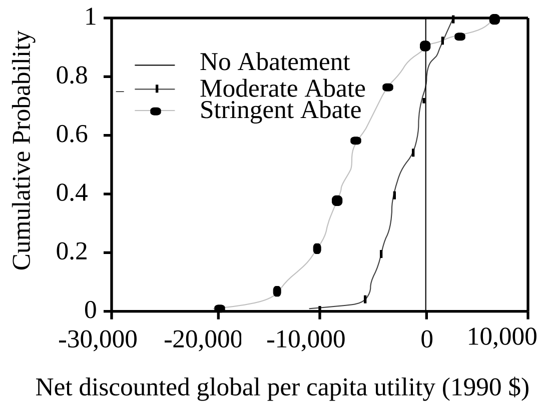

Figure 2b. Net outcomes for moderate and stringent abatement policies

b, and entries in Table 1 were generated using the discounted utility of average citizens. The discounting in these results follows the convention proposed by Thomas Schelling (paper referenced under "Further Reading"). Discount rates differ by region and are based on per capita growths in income. Thus, China has the highest discount rate at approximately 3%. Other regions' discount rates were between 3 and 1% per annum.

In Figure 2a, the discounted globally averaged per capita utility for the three policies is presented as cumulative distribution plots. Each curve corresponds to the range of outcomes associated with a policy option. The range is defined by fifty points corresponding to the fifty runs of the model used to quantify the key uncertainties. The horizontal axis marks the level of discounted per capita welfare. The vertical axis denotes the probability that the outcome is equal to or less than that amount. The range of outcomes (the highest minus the lowest point on each curve) spans about 150 thousand 1990 dollars. This range is due to uncertainties that are largely unrelated to climate change.

Table 1. Probability that the no abatement strategy has the highest payoff

Region	Plain Model	Adaptation	Aerosols & Adaptation
OECD	0.2	0.5	0.8
L America	0.4	0.6	0.7
Africa	0.4	0.7	0.8
E Europe	0.6	0.7	0.9
M East	0.6	0.7	0.9
SE Asia	0.6	0.7	0.9
China	1.0	1.0	1.0

If one curve in Figure 2a did lie clearly to the right of the others, following that policy would ensure the superior outcome. These modeling results show that such a policy cannot be identified for the average global citizen — the curves cross over one another. One way of illustrating this issue more convincingly is to plot the cumulative distribution function of the difference between the policies. By subtracting the outcomes for the business as usual policy (for each run) from the two abatement policies, it is possible to see the relative merits of each policy by keeping other uncertainties the same. This is presented in Figure 2b. The stringent policy yields a net loss in 90% of the cases, but may result in a larger benefit than the moderate policy. The moderate policy only leads to losses in 75% of cases considered. For the world as a whole, none of the considered policies is always superior.

The difference between the three policies (Figure 2b) is only about one tenth the range of outcomes possible for each policy (Figure 2a). This is one way of demonstrating why the issue of climate change policy is so controversial.

Regional calculations from ICAM 2.0 are reported in Table 1. These show that the probability for the preference of no action varies across regions. The table is arranged to show the regions ordered in increasing preference for taking no abatement action. China is the only region where the no action policy is dominant over all circumstances considered.

The results obtained are very sensitive to the assumptions made. This is illustrated in Table 1, where the no abatement strategy grows more favorable with explicit incorporation of adaptation and aerosol effects in the model.

In future issues we will discuss how policy preferences are shaped by both the decision metrics (e.g., do ecosystem damages count or not) and decision rules (e.g., try to avoid extreme impacts on specific communities or just maximize expected outcomes).

Many features of ICAM 2.0, unexplored in this briefing, should be explained to increase understanding of the context of these findings. For example, in ICAM, energy efficiency responds to policies even when there is no lasting price effect. This is based on recent findings at CMU about the Autonomous Energy Improvement index and will be the subject of a future briefing. There is also considerable doubt now about our estimates of oil and gas reserves and resources. For the results reported here, the range of fossil fuel resources were assumed known and did not respond to rising prices due to perceived scarcity. The alternative is also modeled in ICAM 2.0 and can be explored with ease.

Landcover change, a very important aspect of global change, is not represented in ICAM 2.0. Landcover responds to the demands of agriculture, urbanization and environmental forces. Landcover plays an important role in determination of atmospheric chemistry and climate. ICAM 3.0 will include process models that influence landcover and reflect the interactions between landcover and climate change. Preliminary analysis suggests that the feedback from landcover processes on the carbon cycle and local climate may tip the balance towards more active GHG abatement policies. We plan to have ICAM 3.0 ready for distribution by January 1996.

FURTHER READING

More detailed papers on ICAM 2.0 are:

- Dowlatabadi, H., et al. "An Overview of the Integrated Climate Assessment Model Version 2 (ICAM-2)." in Western Economic Association. 1994. Vancouver, BC, Canada:
- Dowlatabadi, H. and M. Kandlikar (1995). "Key Uncertainties in Climate Change Policy: Results from ICAM-2," The 6th Global Warming Conference, San Francisco, CA.

An overview of the integrated assessment modeling efforts around the world:

- Dowlatabadi, H. (1995 in press). "Integrated Assessment Models of Climate Change: An Incomplete Overview." Energy Policy.

An excellent paper on the critical issue of discounting is:

- Schelling, T. C. (1994). "Discounting," International Institute for Applied Systems Analysis, Laxenburg, Austria.

An overview of the Global Change Integrated Assessment Program and our recent publications can be obtained by contacting us.

PLEASE ENGAGE IN THE DIALOGUE

The motivation behind this newsletter is to enhance communication among global change researchers and decision-makers. This goal can be met by facilitating the distribution of findings at the Global Change Integrated Assessment Group and elsewhere to a broader audience. Of equal importance to us is the feedback from decision-makers and other researchers. Such a dialogue is needed in order to remain focused on policy- relevant research, and to bring pertinent research to the attention of policy decision-makers.

As such, we hope that this newsletter is the first stage of many dialogues. In each issue we will present a briefing on recent findings at CMU and elsewhere. We ask you, our readers, to send us your reactions. All of the reactions will be posted on an electronic bulletin board and summarized in subsequent issues of *Degrees of Change*.

QUESTIONS TO CONSIDER

- Is probabilistic treatment of this problem useful, or does pointing out the high uncertainties hinder policy formation?
- How may quantitative analysis be employed to better help decision-making?

HOW TO REACH US

Should you need to reach us in order to: record your reaction, request reprints or a copy of ICAM, you have a number of choices:

On the World Wide Web our URL is:
http://www.epp.cmu.edu/global_change

Send e-mail to:
gc-degrees@andrew.cmu.edu;

Send faxes to:
Hadi Dowlatabadi @ (412) 268 3757;
or call him @ (412) 268 3031.