MITIGATING STRATEGIES FOR CO_2 PROBLEMS

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PREFACE

A question of considerable interest in assessing long-term energy options involves whether burning of carbon, particularly the plentiful resources of coal, will continue increasing. If so, the level of carbon dioxide (CO_2) in the atmosphere may rise substantially, perhaps doubling around the middle of the next century. It is widely believed that such an increase would lead to a significantly different climate, probably one warmer than the earth has experienced for on the order of 100,000 years, and to important consequences for the economy and environment.

What is the appropriate societal response to this prospect? Should nations try to prevent or reduce such change? If they choose to accept the change, what adaptive measures may be effective? These questions have been under study for some years at IIASA, first in the Energy Systems Program (ENP) and more recently in the Resources and Environment (REN) and Management and Technology (MMT) Areas. The REN Area is grateful to Dr. Lave for preparing this paper for his recent visit to the institute expanding the characterization of a policy of adaptation and how it might be successfully developed. Dr. Lave, a Senior Fellow in the Economic Studies Program at the Brookings Institution, has been deeply concerned with these questions through his participation in the climate project of the American Association for the Advancement of Science and the Carbon Dioxide Effects and Assessment Program of the US Department of Energy.

Previous work at IIASA has explored strategies for prevention of carbon dioxide emissions and for physical compensation for carbon dioxide once it has been created. A preventive strategy emphasizing economic tools was developed by Nordhaus. (See Nordhaus, W., *The Efficient Use of Energy Resources*, New Haven: Yale, 1979, and "Thinking About Carbon

Dioxide: Theoretical and Empirical Aspects of Optimal Control Strategies," Working Paper, Yale University, July 1980.) Technical means for compensation have been proposed by Marchetti. (See Marchetti, C., "Constructive Solutions to the CO_2 Problem," pp. 299-311 in Bach, W., J. Pankrath, and W. Kellogg (eds.) *Man's Impact on Climate*, Amsterdam: Elsevier, 1979.) Comparative discussion of arguments for the different societal responses is offered in this paper, as well as by Meyer-Abich. (See Meyer-Abich, K. M., "Chalk on the White Wall? On the Transformation of Climatological Facts into Political Facts," in Ausubel, Jesse and Asit K. Biswas (eds.), *Climatic Constraints and Human Activities*, Oxford: Pergamon Press, 1980.)

Current IIASA research on the CO_2 question is attempting to place the various policy options in a more systematic context, using a gaming approach. The status of this work is described in Robinson J. and J. Ausubel, "A Framework for Scenario Generation for CO_2 Gaming," IIASA WP-81-34.

ABSTRACT

Vast uncertainties surround our ability to predict the physical and social effects of increased carbon dioxide concentrations in the atmosphere during the next century; fossil fuel combustion rates will change, predicting the effects of carbon dioxide on climate is difficult, and predicting the resulting social reactions to these changes is essentially impossible. Furthermore, time must elapse before there is convincing proof of the expected amount of climatic change, before people perceive the magnitude of the problem and accept its existence, before we can act to abate emissions, and before new capital can be put into place. In addition, it will be extraordinarily difficult to convince all nations to abate carbon dioxide, especially since some will gain from climatic changes. Thus, we must focus on adaptation to future climatic change, as it is a more feasible social response than reducing carbon dioxide emissions in order to prevent change.

Unfortunately, the effects of carbon dioxide are likely to be insidious and difficult to connect to climatic change. Myriad effects, both good and bad, are unlikely to be recognized as caused by carbon dioxide.

Conscious adaptation involves explicit decisions or compulsion such as convincing people to change their behavior or punishing antisocial behavior through laws or fines. Unfortunately, such actions cannot be tailored to achieve precise objectives; they are blunt tools that should be used only for important goals and then sparingly. Unconscious adaptation takes place through behavioral changes induced by the market place or social institutions. These mechanisms can be swift and powerful, but are difficult to manipulate.

Monitoring climatic change and informing important groups of the current state of knowledge on carbon dioxide induced climatic changes can help to speed adaptation, as can contingency planning and development of nonfossil fuel technologies. More important are plans that would set unconscious adaptation into motion, such as plans to disseminate information on the problem and on behavior which will help individuals or firms.

Of greatest importance is having a society that can quickly perceive and adapt to the new regime. This means a strong economy with high scientific and engineering capabilities, a well educated population, and a more flexible, resilient capital stock. These social and economics characteristics are desirable from many points of view unrelated to carbon dioxide. Thus, carbon dioxide can serve as a catalyst in promoting policies that are justified for a host of reasons.

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1. Introduction

Atmospheric concentrations of carbon dioxide have been increasing for more than a century due to human activities such as the clearing of forests and combustion of fossil fuels. [1] Since the latter is forecast to accelerate over the foreseeable future, atmospheric concentrations will increase further. The increased carbon dioxide is predicted to warm the earth's climate (an increase in the annual average temperature of about 10 degrees Celsius at the poles and little at the equator), to change precipitation patterns (probably less precipitation in the American Midwest), and to change ocean movements. [2] The atmospheric changes are unlikely to be measureable until at least the turn of the century and the effects probably will not be of substantial magnitude until well into the 21st century. [3]

Uncertainty over four factors complicates efforts to examine the implications of carbon dioxide emissions. The first factor is the amount of fossil fuel that will be burned each year; this depends on world population, economic activity, the costs and availability of each energy source, and technologies for utilizing energy. The second major uncertain factor is the interactions of the ice caps and the oceans with atmospheric carbon dioxide and temperature change: how will various concentrations of CO_2 in the atmosphere affect the oceans and how fast can the oceans absorb CO_2 and heat from the atmosphere? The third factor is the interaction of biota with changes in the atmosphere and oceans. The fourth is the extent to which human behavior and institutions can and will mitigate the adverse effects of the physical and biological changes or even utilize these changes to accomplish individual and social goals

better.

2. Difficulties of Prevention

Policies designed to lessen carbon dioxide emissions are unattractive. Fossil fuels are the cheapest source of fluid and solid fuels at present; proscribing them would be difficult and expensive. More importantly, the effects of increased CO_2 in the atmosphere will be highly uncertain for at least half a century. It would be extremely difficult to convince any nation to bear the higher costs associated with switching to other fuels, particularly since we can neither estimate the magnitude of the changes with assurance nor be certain that the physical changes will be predominantly detrimental to humans. These difficulties of curtailing the use of fossil fuels are so immense that very little is likely to be done to abate carbon dioxide emissions before the middle of the next century; steps will be taken then only if the effects are important, predominantly adverse, and adaptation is unable to mitigate the costs.

The lags associated with recognizing the problem and taking action are further reasons why carbon dioxide emissions are unlikely to be abated before the end of the 21st century. First, there is a recognition lag associated with obtaining convincing proof that carbon dioxide will cause large, adverse effects. As early as 2000, we could receive confirmation that general circulation models (GCMs) are correctly predicting the gross climate effects. However, there will remain considerable uncertainty because the models could roughly predict the effects of small increases in carbon dioxide but be inaccurate on the effects of larger concentrations. Moreover, features of climate that are of second or third order importance under the current climate regime could become of first order importance with large increases in carbon dioxide levels. Even greater uncertainty stems from whether a particular climatic change ends up producing beneficial rather than adverse outcomes.

A second lag is that associated with general recognition of the problem and deciding on a solution. The perceived seriousness of the problem would vary with location, occupation, income, and perceived alternatives. For example, seven years after the abrupt change in petroleum supply resulting from the Arab oil embargo and quadrupling of oil price, there is little agreement within the US or international communities about what policies to pursue. Getting agreement on the carbon dioxide problem and its solution could take decades.

One factor making international agreement difficult is the international nature of the carbon dioxide problem. [4] Atmospheric concentration of CO_2 is a "public good" (or bad) in that no small nation can have a noticeable effect on climatic change by its individual program to abate carbon dioxide emissions. Furthermore, there is every incentive to cheat, since one nation's emissions would not have much effect on climate if every other nation eschewed fossil fuels. Yet, clearly the total emission is the sum of the emissions of each nation. Finally, some nations stand to gain from climatic change and would encourage fossil fuel burning.

The third lag is that required to switch fuel sources once agreement has been reached on policies. Other fuels must be extracted and high investments and retraining of labor are required. Several decades would be required to change fuel sources.

These lags are likely to be so long that it will be the latter part of the next century before carbon dioxide emissions could be curtailed substantially. Absent compelling reasons for relinquishing fossil fuels, we can be virtually certain that substantial climatic change will occur and persist.

3. Identifying Carbon Dioxide Effects

The effect of human activity on climatic change due to CO_2 emissions is likely to be small compared to that stemming from other events. For the next century, wars, economic competition, usual climate fluctuations, and technological change probably will be more important than the long term climatic changes due to carbon dioxide. Carbon dioxide is likely to seem unimportant beside the myriad current, short-lived opportunities and problems.

Nor are the consequences of climatic change easily attributed to the correct cause. Climatic change might cause lifestyle changes, such as forcing a group of farmers to move into cities, which in turn lead to increases in crime or civil disorder. The perceived problem would be the crime and violence, and it would be far from obvious that carbon dioxide was the culprit. Similarly, unemployment, regional strife, or even world war might result from carbon dioxide, but it is unlikely that there would be general recognition of the cause. Alternatively, in regions where growing conditions improved, the change would probably be ascribed to some combination of astute planning and good luck.

While physical changes, such as temperature and precipitation, can be measured, it is more difficult to measure the direct human reactions to climatic change, such as new cropping patterns. Virtually impossible to measure would be the tertiary effects, good and bad, that flow from cascading social adjustment. If social institutions are functioning well, the effects will be beneficial on net, but will be so diverse that they could not be linked to carbon dioxide. If institutions are not functioning well, effects such as urban crowding, crime, and riots are not likely to be perceived as due to carbon dioxide. Thus, it seems unlikely that society will be provided with convincing proof that action must be taken to reduce carbon dioxide emissions because the cnsequences are intolerable -- at least not until climatic changes are very large.

4. Methods for Adaptation

Thus, at least two decades are likely to pass before the first predictions about climatic change can be verified, and much more time may pass before climate effects could be predicted with confidence. Unfortunately, the adverse consequences of climatic change are unlikely to be recognized until they are very large. Since fossil fuels will continue to be attractive, carbon dioxide emissions are unlikely to be abated until there are bad, almost disastrous consequences and only then with a considerable lag. Thus, if we are to do something about this potential problem, the emphasis should be on adapting to climatic change; prevention is

unlikely to succeed, since curtailing emissions would have to occur well in advance of consequences or even confident forecasts of consequences.

4.1. Explicit or Conscious Adaptation

The usual conception of adaptation focuses on actions taken by some institution or individual as a conscious response to a perception of a need for change. [5] These explicit or conscious adaptations result from information and thought; they are rational changes in behavior designed to mitigate damage or take advantage of an opportunity. For explicit adaptation to occur, some authoritative source must present information in an understandable form, convince the decision makers that change is desirable and feasible, and facilitate change.

The hallmark of conscious adaptation is legal compulsion or explicit recognition of a problem and the possible solution; in both cases behavior change results from widespread dissemination of information. The presentations must be such that the problem is readily understood; dissemination must ensure that information gets to decision makers and appears authoritative. [6] However, as the warning on cigarette packs or laws against marijuana indicate, inducing changes in behavior is difficult.

The decisions to be influenced by climatic change include those concerning investments, education and training, migration and location generally, jobs, and the production and purchase of goods and services. The facts that are pertinent, people to be reached, and points of leverage vary with each target.

Explicit government intervention to change behavior might take the form of laws, or licensing and control of conditions of operation. Laws define property rights and tolerable behavior. Violations bring incarceration, fines, or other criminal and civil penalties. In the extreme, execution or lifelong incarceration can prevent proscribed behavior. Laws are a direct way of changing behavior, but often are unsuccessful. Laws work best when there is a clearly identified action, such as murder, which is abhorred. They do not work in attempting to change behavior to correspond to the moral beliefs of a minority, as in the case of prohibition. Unfortunately, mitigating the problems caused by carbon dioxide is likely to require subtle changes in behavior that could not be induced by laws.

Laws can also influence behavior by zoning, declaring areas off limits to various activities (for example, wilderness areas), or generally changing property rights and the conditions under which business can operate. A forecast rise in sea level due to carbon dioxide induced warming might bring about rezoning to prevent new buildings from being constructed in areas which would be flooded. However, current efforts to prevent construction in flood plains are notably unsuccessful.

4.2. Mixed Explicit-Implicit Adaptations

A range of possible government actions, such as taxes, subsidies, and attempts at moral suasion, do not compel changes in behavior, but do exert an influence. [7] These actions stem from conscious decisions by government but need not result in conscious decisions by consumers.

Taxes and subsidies can provide various degrees of incentive to change behavior. For example, the subsidy to gasohol resulted in rapid, large-scale increases in production. Taxes on gasoline which caused vast differences in price resulted in large differences in fuel economy between automobiles designed for use in the US and those designed for use in most European nations in the 1960s. The difficulty is designing taxes and subsidies that will accomplish the intended goal. Professional advisers ensure that taxes and subsidies are used for many purposes other than those intended. For example, Nordhaus has tentatively proposed a tax of $10 per ton of carbon released into the atmosphere. [8] The narrow focus of this proposal might be compared to others such as subsidies for nuclear power or prohibiting synfuels.

Licensing of workers and businesses and regulation of the conditions of operation are used by state and local government to accomplish such purposes as ensuring minimum quality standards and regulating location. Implementation and enforcement of these rules is difficult and limits their applicability. More importantly, there is the temptation to use taxes, subsidies, licenses, and so forth, to reward special groups or accomplish unrelated, often socially undesirable goals, such as raising the income of a group (for example, barbers) at the expense of the public. Economists have learned painfully that legislating any type of tax subsidy or regulation is predominantly a political process whose outcome will have little semblance of economic efficiency. While these tools are available in theory, in practice they are used to accomplish other ends and are largely ineffective. [9]

The effect of moral suasion by the government should not be underestimated. Where it is not against the perceived self-interest of individuals, moral suasion can lead to important changes in behavior, as evidenced by energy or water conservation during crises. Even where the individual is required to make a sacrifice, most will do so if there is a perceived threat to society and a perception that all individuals will share the burden, for example, serving in the armed forces during World War II. If people could be convinced that carbon dioxide is a serious problem, they would probably respond to appeals to conserve energy.

4.3. Implicit or Unconscious Adaptation

Conscious adaptation is a blunt instrument, subject to all of the difficulties of enacting legislation or other formal rules. It is a direct way of compelling changes in behavior and is thus appealing. But, it is subject to major defects, such as speed of enacting change. More important than explicit adaptation is implicit or automatic adjustment. For example, adjustment to changes in consumer preferences for goods and services is done automatically via prices and profits through the market place. Neither the government nor any national organization need recognize the change and prescribe action. Indeed, most shifts in tastes are accomodated without explicit recognition. If fossil fuels became more expensive, due for example to a tax on carbon emitted into the atmosphere, businesses and consumers would be led to an automatic shift toward other energy sources.

This is not to imply that national recognition of a change would not take place or would not serve to expedite adjustment and lower social costs. Current government activity to estimate the effects of carbon dioxide could inform business and consumers, thereby helping them to adjust. However, data collection and analysis, recognition of changes, and dissemination of the information are profitable nongovernmental activities, since they can increase profit opportunities and reduce loss. A number of large US companies, including survey and consulting firms, now specialize in collection of data or making economic forecasts. While some information collection and dissemination is a public good with a role for government, the vast proportion takes place privately.

Early recognition of changes in consumer tastes, climatic conditions, or production opportunities has vast implications for profits. For individuals and organizations that have no capacity to gather and analyze data on carbon dioxide induced climatic change, the market provides unmistakeable signals in the form of crop failure, unemployment, bankruptcy, or more subtly in lower wages and profits for some businesses contrasted with profit increases and higher wages for others. Firms making windfall profits grow and are imitated. Thus, business and workers are led, as if by an "invisible hand," to adjust to the changing market.

The social structure also promotes adaptive behavior. For example, age at marriage and number of children are influenced significantly by social norms. Similarly, job choice, geographical location, time in the labor force, and food preferences are affected by social institutions. Social pressures speeded the diffusion of television in the 1940s and could speed the demise of large cars in the 1980s; they affect family size, total population, total economic activity, and consumption patterns, thus indirectly affecting CO_2 emission rates and adaptation to climatic change.

Unconscious adaptation translates subtle cues into individual and social change. It is purposive in reducing dissonance between the individual and his environment, either by exploiting new opportunities or cutting losses. Whether it is helpful for a community, nation, or the world depends on the aggregation of individual actions. The institutional and technological structure of society determines whether individuals acting in their self-interest speed or impede needed social adjustment. The economic model of perfect competition is one institutional framework where individual nations are perfectly consonant with social objectives.

While there is no doubt of the power of social institutions in influencing behavior, there is vast uncertainty associated with how climatic changes would affect social institutions, thereby affecting behavior. We know almost nothing about how governments could manipulate social institutions so as to facilitate adaptive behavior toward climatic change. Presumably government could influence the media and opinion leaders as a means of influencing social institutions generally.

There should be planned dissemination of results as the carbon dioxide research proceeds, particularly careful education of reporters and environmental and other interest groups. However, care must be taken not to waste goodwill and credibility by dissemination of material that does not have new results or of material so speculative as to have a large chance of being wrong.

5. Enhancing the Capacity to Adapt

Carbon dioxide induced environmental changes may require changes in location of businesses, residences, and such social overhead capital as streets and sewers. Large amounts of plant and equipment must be replaced, workers may have to find new jobs, often in new locations and involving new skills. Firms may have to redesign their products and manufacturing processes. Furthermore, these changes will be in addition to changes due to shifts in taste, technological change, changing availabilities of raw materials, changing patterns of international trade and relations, and vast "normal" variation in climate. The ability to adapt to the carbon dioxide induced changes will be determined by the ability to adapt to the other changes.

Will the automatic mechanisms send the proper signals? Will government and other decision makers perceive the problem and implement policies that will expedite adaptation? If people perceive the need to change their behavior, will they have the resources and knowledge to change? Will the social and economic institutions be able to keep pace with climatic and social change?

Whether society will have the required resources to adapt will be measured by several indices. The first is gross national product (or income) per capita. This is a measure of aggregate economic activity and is a surrogate for the economic resources to build new facilities or move people. [10]

The second is the gross rate of investment or ratio of investment to GNP. A high ratio means that the economy is putting many new facilities into place and turning over its capital stock rapidly. Since new plant and equipment can be designed for the new situations and be built in the right places, rapid turnover means that most of the capital stock can be tailored to the new regime. For example, consider an economy in which capital lasts 50 years, and so only 2 percent of capital is replaced each year. Climatic change could make much of the capital obsolete, but the obsolete capital would remain for a long time. In contrast, consider an economy that turns over its capital stock every decade. As changes are perceived, they could be incorporated into new capital so that little plant and equipment would ever be obsolete.

A third measure of the capacity of the economy to adapt will be the general education level of workers. Educated workers find it easier to acquire the new skills required for jobs. [11] A skilled labor force can redesign products and facilities to respond to new conditions.

For three other characteristics facilitating adaptation, there are no simple measures. One such characteristic is the flexibility and diversity of capital stock. Some plant and equipment is so highly specialized that minor changes in raw materials, product design, or fuels are impossible to accomodate. For example, some oil refineries were built to process only one type of crude oil snd produce a fixed set of outputs. Another example is an electricity generation unit that can be designed to burn natural gas, oil, coal, any two, or all three fuels. The greater the flexibility, the less need to replace the capital and the easier will be adjustment. Diversity of the capital stock gives the economy the resiliency to avoid

disaster in the face of changing conditions such as climate. An analogy is planting a number of varieties of some grain, rather than depending on a monoculture. The monculture can give greater yield under a narrow range of conditions but can lead to crop failure if conditions change. Similarly, building flexible, diverse capital (like a boiler that can use three fuels) increases cost or lowers output (like planting many varieties of grain), but offers insurance against changing conditions. Another example is the inventories, such as grain and oil, held; large inventories are costly but provide a tool for mitigating the effects of climatic and other changes.

A second difficult to measure characteristic is the amount of basic scientific knowledge and the number of technological alternatives currently available or that can be developed quickly. The greater is scientific knowledge, the more opportunity exists to design technology appropriate to the new conditions. The greater the variety of currently available technology, the greater the chance that some "on the shelf" technology will fit the new conditions. For example, agronomists might be set to work immediately breeding plant and animal strains suited to hotter dry or wet climates.

A final characteristic is the capacity of individuals to interpret the signals of changing conditions correctly and to adapt to them quickly. A better educated population and good planning organizations in social institutions will help. The ability and willingness of planners to recognize the signals and interpret them for the population and social institutions that lack this ability is important. This includes collection of the right data so as to recognize change early and to identify its cause. The federal government has an obligation and important role in collecting and analyzing data and disseminating the interpretations.

6. Conclusions

Society can take steps to enhance each of these characteristics of our ability to adapt more easily to carbon dioxide induced changes. Given the rapidity of social and technological change in the 20th century, facilitating adjustment is important. With the exception of data collection and analysis focused on climate, enhancing each of these functions will be to the general benefit of society, but will not be unique to carbon dioxide induced problems. Carbon dioxide issues can provide a rationale, but probably will be more a catalyst, for pushing society to enhance its ability to adapt to and exploit change. Carbon dioxide is but one of many factors which will have an enormous impact on the economy and social institutions of the US and other countries in the 21st century. If carbon dioxide induced changes were as large as now appears possible, and if they were the only major changes, then it would be worthwhile to invest in enhancing education and capital formation so that we could minimize the effects of adverse changes and take advantage of beneficial changes. Since carbon dioxide induced changes are likely to be only one, possibly small, source of change, there is all the more reason to devote resources to making our economic and social institutions more flexible and adaptable.

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[10] The precise variable is "free" economic resources per capita. A poor society, for example, a nomadic one, might be able to adapt more easily than a rich society unwilling or unable to direct resources to implement needed changes.

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