A New Agenda for Global Warming

JOSEPH E. STIGLITZ

Globalization has made the world increasingly interdependent, and increased the need to work together to solve common problems. But as I point out in my forthcoming book, *Making Globalization Work*, it will do us little good to solve our common global economic problems if we do not do something about the most pressing common environmental problem: global warming.

In Kyoto, nine years ago, the world took an important first step to curtail the greenhouse gas emissions that cause global warming. But in spite of Kyoto's achievements, the United States, the world's largest polluter, refuses to join in and continues to pollute more and more, while the developing countries, which in the not too distant future will be contributing 50% or more of global emissions, have been left without firm commitments to do anything. It is now clear that something else is needed. I propose here an agenda to deal first with the United States' pollution and second with developing countries.

Reducing united states emissions

The first step is to create an enforcement mechanism to prevent a country like the United States, or any country which refuses to agree to or to implement emission reductions from inflicting harm on the rest of the world. It is, perhaps, predictable that it would be the United Sates, the largest polluter, that has refused to recognize the existence of the problem. If the United States could go its own merry way—keeping the carbon dioxide it emits over its own territory, warming up its own atmosphere, bearing itself whatever costs (including hurricanes) that result, that would be one thing. But that is not so. The energy profligate lifestyle of the United States inflicts global damage immensely greater than any war it might wage. The Maldives will within 50 years be our own 21st century Atlantis, disappearing beneath the ocean; a third of Bangladesh will be submerged, and with that country's poor people crowded closer together, incomes already close to subsistence level will be further submerged.

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At first, President Bush denied the existence of global warming; when his own National Academy confirmed what every other scientific body had said, he promised to do something—but did little. Some American politicians whine that emissions reduction will compromise America's living standards; but America's emissions per dollar of GDP are twice that of Japan. America not only can afford to conserve more, it actually would enhance its energy security by doing so. It would be good for its environment and for its economy—though not, perhaps, for the oil companies that have prospered so well under the current Administration.

Fortunately, we have an international trade framework that can be used to force states that inflict harm on others to behave in a better fashion. Except in certain limited situations (like agriculture), the WTO does not allow subsidies—obviously, if some country subsidizes its firms, the playing field is not level. A subsidy means that a firm does not pay the full costs of production. Not paying the cost of damage to the environment is a subsidy, just as not paying the full costs of workers would be. In most of the developed countries of the world today, firms are paying the cost of pollution to the global environment, in the form of taxes imposed on coal, oil, and gas. But American firms are being subsidized—and massively so.

There is a simple remedy: other countries should prohibit the importation of American goods produced using energy intensive technologies, or, at the very least, impose a high tax on them, to offset the subsidy that those goods currently are receiving. Actually, the United States itself has recognized this principle. It prohibited the importation of Thai shrimp that had been caught in "turtle unfriendly" nets, nets that caused unnecessary deaths of large numbers of these endangered species. Though the manner in which the United States had imposed the restriction was criticized, the WTO sustained the important principle that global environmental concerns trump narrow commercial interests, as well they should. But if one can justify restricting importation of shrimp in order to protect turtles, certainly one can justify restricting importation of goods produced by technologies that unnecessarily pollute our atmosphere, in order to protect the precious global atmosphere upon which we all depend for our very well-being.

Japan, Europe, and the other signatories of Kyoto should immediately bring a WTO case charging unfair subsidization. Of course, the Bush Administration and the oil companies to which it is beholden will be upset. They may even suggest that this is the beginning of a global trade war. It is not. It is simply pointing out the obvious: American firms have long had an unfair trade advantage because of their cheap energy, but while they get the benefit, the world is paying the price through global warming. This situation is, or at least should be, totally unacceptable. Energy tariffs would simply restore balance—and at the same time provide strong incentives for the United States to do what it should have been doing all along.

In some ways, the United States should welcome this initiative. It has often complained that one of the problems with the Kyoto protocol is that there is no enforcement mechanism. It claims that if it were to sign, it would feel obliged to meet its commitments, but other countries would not, and this would put the United States in a disadvantageous position. With a strong international sanction mechanism in place, all could rest assured that there was, at last, a level playing field.

Getting the developing world to address the problem

There is a second problem with Kyoto: how to bring the developing countries within the fold. The Kyoto protocol is based on national emission reductions relative to each nation's level in 1990. The developing countries ask, why should the developed countries be allowed to pollute more now simply because they polluted more in the past? In fact, because the developed countries have already contributed so much, they should be forced to reduce more. The world seems at an impasse: the United States refuses to go along unless developing countries are brought into the fold; and the developing countries see no reason why they should not be allowed to pollute as much per capita as the United States or Europe. Indeed, given their poverty and the costs associated with reducing emissions, one might give them even more leeway. But, given their low levels of income, that would imply that no restraints would be imposed on them for decades.

There is a way out, and that is through a common (global) environmental tax on emissions. There is a social cost to emissions, and the common environmental tax would simply make everyone pay the social cost. This is in accord with the most basic of economic principles, that individuals and firms should pay their full (marginal) costs. The world would, of course, have to agree on assessing the magnitude of the social cost of emissions; the tax could, for instance, be set so that the level of (global) reductions is the same as that set by the Kyoto targets. As technologies evolve, and the nature of the threat of global warming becomes clearer, the tax rate could adjust, perhaps up, perhaps down.

It would be good if the world could agree to use the proceeds to finance the range of global public goods that are so important for making globalization work better—for instance, for promoting health, research, and development. But that may be too ambitious. Alternatively, each country could keep its own revenues and use them to replace taxes on capital and labor: it makes much more sense to tax "bads" (pollution, like greenhouse gas emissions) than to tax "goods," like work and saving. (Economists refer to these taxes as corrective taxes.) Hence, overall economic efficiency would be increased by this proposal. The big advantage of taxation over the Kyoto approach is that it avoids most of the distributional debate. Under Kyoto, getting the right to pollute more is, in effect, receiving an enormous gift. (Now that pollution rights are tradeable, we can even put a market value on them.) The United States might claim that because it is a larger country, it "needs" more pollution rights. Norway might claim that because it uses hydroelectric power, the scope for reducing emissions is lower. France might claim that because it has already made the effort to go into nuclear energy, it should not be forced to reduce more. Under the common tax approach, these debates are sidestepped. All that is asked is that everyone pay the social cost of their emissions, and that the tax be set high enough that the reductions in emissions is large enough to meet the required targets. The economic cost to each country is small—in some cases, actually negative. The cost is simply the difference in the "deadweight loss" of the emission tax and the tax for which it substitutes; and it is only differences in these differences that determine the divergent effects on various countries.

Concluding thoughts

The world has invested enormously in the Kyoto approach, and the success achieved is impressive. But no one has suggested a way out of the current impasse, and it is time to start exploring alternatives. Global warming is too important to simply rely on the hope that somehow a solution will emerge; and too important simply to rely on the goodwill of the United States, especially given its flawed political system where campaign contributions from oil companies and others who benefit from emissions play such a key role. The well-being of our entire planet is at stake. We know what needs to be done. We have the tools at hand. We only need the political resolve.

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A Meaningful Second Commitment Period for the Kyoto Protocol

SHEILA M. OLMSTEAD AND ROBERT N. STAVINS

In 1997, more than 160 nations agreed on the text of the Kyoto Protocol to the United Nations Framework Convention on Climate Change. Shortly afterward, many economists—particularly American economists—began to condemn the Protocol as excessively costly, environmentally ineffective, or politically infeasible. Indeed, we have written such critiques ourselves. Today, however, even if we have not come to praise the Kyoto Protocol, neither have we come to bury it. Rather, we ask how it can be modified for its second commitment period (2012–2016) so that it will provide a way forward that is scientifically sound, economically rational, and politically pragmatic. We seek to be responsive to two pressing questions that are now being asked: how can the United States be brought on board, and how can meaningful participation by developing countries be financed?

Our answer includes three elements: a means to ensure that key nations are involved; an emphasis on an extended time path of action; and the inclusion of firm-level market-based policy instruments.

WHO—EXPAND PARTICIPATION TO INCLUDE ALL KEY COUNTRIES

Broad participation by major industrialized nations and key developing countries is essential to address this global commons problem effectively and efficiently in the second commitment period and beyond. China will surpass the United States as the world's leading producer of greenhouse gas emissions by 2009, according to the International Energy Agency. Developing countries are likely to account for more than one-half of global emissions well before 2020.

Many argue that the industrialized countries should take the first steps to combat climate change, since they are responsible for the bulk of man-made current greenhouse gas concentrations. But developing countries currently provide the greatest opportunities for low-cost emissions reductions. Furthermore, if developing countries are not included, comparative advantage in the production of carbon-intensive goods and services will shift outside the coalition of participating countries.

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The shift of production of carbon-intensive goods and services to developing countries will counter the impacts of emissions reductions among participating countries (a phenomenon called "leakage"). Moreover, this shift will push non-participating nations onto more carbon-intensive growth paths, increasing their costs of joining the coalition later.

So, on the one hand, for purposes of environmental effectiveness and economic efficiency, key developing countries should participate. On the other hand, for purposes of distributional equity (and international political pragmatism), they cannot be expected to incur the consequent costs.

It turns out that the two issues can be reconciled. Our answer is a set of growth-indexed emissions limits that are set initially at business-as-usual (BAU) levels for respective developing countries, but become more stringent as those countries become more wealthy. Harvard economist Jeffrey Frankel has noted that this would be a natural extension of the allocation pattern in the Kyoto Protocol's first commitment period (2008–2012), where targets for industrialized countries become, on average, one percent more stringent for every ten percent increase in a country's per-capita gross domestic product (GDP).

Joining the international market for emissions trading could make developing countries better off—even in immediate income terms. The reason is tied to the fact that reductions or reduced increases in emissions for these countries often will be cheaper than for the developed world. As a result, the developing world can sell its "right to pollute" to firms in the developed world in a system that allows trade of emissions permits. Such sales could increase the income of developing countries even if the system requires that they reduce their emissions.

Hence, cost-effectiveness and distributional equity can both be addressed. In fact, tradable permits, which make reductions cost-effective, can be used to achieve distributional equity because the allocation of permits determines the distribution of burdens and benefits.

WHEN—USE AN EXTENDED TIME PATH, AND "RAMP UP"

The Kyoto Protocol's targets are "too little, too fast." Global climate change is a long-term problem, because greenhouse gases remain in the atmosphere for decades to centuries. In this setting, economics would suggest that emissions targets to address the problem of greenhouse gas concentrations ought to begin at BAU levels, then depart gradually, so that emissions increase at first but at rates below BAU. These targets should reach a maximum level and then decrease—eventually becoming much more severe than the constraints implied by the Kyoto Protocol's first commitment period targets, which translate to an average five percent reduction from 1990 levels by 2008–2012. Let's take each of these arguments in turn.

Why should targets begin at or close to BAU levels? Moderate targets in the short term will avoid rendering large parts of the capital stock prematurely obsolete. Investment in the capital equipment used in the burning of fossil fuels, like the boilers on electric power plants, have been made in a world of free carbon emissions. Thus, significant emissions reductions today would require the retirement of much of this equipment (how much will depend on the stringency of emissions targets). This equipment, and similar investments by households in automobiles and major appliances, would typically only be replaced every several years, or several decades.

The Protocol's initial targets may sound modest, but they translate into severe 25–30 percent cuts for the United States from its BAU path, because of the rapid economic growth the country experienced during the 1990s. The same is true for other nations that have experienced significant economic growth post-1990, raising the costs of 1990-based emissions targets and making them politically infeasible as well as economically unreasonable. It is not surprising that many signatories to the Protocol are not on track to meet their emissions targets.

Our second argument is that targets should "ramp up" over time, eventually reaching levels much more stringent than the Protocol's targets. This approach, if made clear at the outset, will alter firms' (and households') capital investment decisions, setting countries on a carbon-intensity path that will allow the achievement of long-run targets. Most importantly, stringent long-run targets known today will spur current and future technological change, bringing down costs over time. Of course, the long-term targets should be flexible, because there is great uncertainty throughout the policy-economics-biophysical system, some of which will be resolved over time.

Our proposal is also consistent with a time path of "price" targets—for example, a time-profile of carbon prices (taxes on the carbon content of fossil fuels). In any event, such a long-term time path of targets involving increasingly aggressive action is the most cost-effective and fair approach. It is also a politically pragmatic approach. Politicians in representative democracies are frequently condemned when they yield to incentives to place greater costs on future rather than current voters. This is typically a politically pragmatic strategy, one that is often denigrated as "politics as usual." In the case of global climate policy, however, this may also be the scientifically correct and economically rational approach.

HOW—EMPLOY MARKET-BASED POLICY INSTRUMENTS

Most economists agree that conventional regulatory approaches cannot do the job, certainly not at acceptable costs. To keep costs down in the short term and bring them down even lower in the long term through technological change, it is essential to embrace market-based instruments.

On a domestic level, systems of tradable permits might be used to achieve national targets. This approach was used in the United States to phase out leaded gasoline in the 1980s at a savings of more than $250 million per year over an equivalent traditional regulatory approach, and is now used to cut sulfur dioxide (SO_2) emissions from power plants by half, at an annual cost savings of $1 billion compared to a command-and-control approach. The better policy model for climate change is the upstream lead-rights system in which trading occurred at the refinery level (analogous to trading on the carbon content of fossil fuels), rather than the downstream SO_2 emissions-trading system.

For some countries, systems of domestic carbon taxes (as opposed to permits) may be more attractive. A particularly promising approach is a hybrid of tax and tradable-permit systems—an ordinary tradable permit system, plus a government promise to sell additional permits at a stated price (the "tax" component). This "safety-valve" approach addresses cost uncertainty by creating a price (and thereby cost) ceiling so that if reductions prove more costly than expected there will be a known and limited increase in the cost of carbon emissions.

International policy instruments are also required, and the Kyoto Protocol already includes a system whereby the parties to the agreement can trade their "assigned amounts"—their national reduction targets—translated into emissions terms. In theory, such a system of international tradable permits—if implemented only for the industrialized countries—could reduce costs by 50 percent. If such a system were to include major developing countries as well, costs could be lowered by half again, according to the estimates of Jae Edmonds and his co-authors.

To be effective, however, trading must ultimately be among sources (firms), not among nations per se. Nations are not simple cost-minimizers, nor do they have the information needed to make cost-effective trades. Therefore, an international trading system must be designed to facilitate integration with a set of domestic trading systems.

International carbon trading markets are of course subject to the same problems as any other market and may not work well if transaction costs are high or some nations or firms have a sufficient concentration of permits (or excess permits). The latter concern is a real one in the climate policy context. If, for example, the majority of excess permits (allowable emissions in excess of BAU emissions) is found in a relatively small number of nations, then the possibility increases of collusion among sellers, as a recent *Energy Policy* article by Alan Manne and Richard Richels points out.

In any event, the initial allocation of permits among nations can imply exceptionally large international wealth transfers. Several analysts have identified this as a major objection to an international carbon trading regime, and have endorsed international tax approaches for this and other reasons. However, taxes will also have distributional effects through the recycling of revenues; moreover if tax rates are equalized across countries as efficiency requires, they do not provide control over the wealth transfers. Wealth transfers can be broadly controlled to achieve distributional equity with particular permit allocations. And it is precisely this feature of the permit allocation that allows cost-effectiveness *and* distributional equity to be addressed simultaneously.

THE WAY FORWARD

The three-part global climate policy architecture we propose can form the foundation for the second commitment period (and beyond) for the Kyoto Protocol. But can countries credibly commit to the long-term program that is part of this proposed architecture? Our answer is that once nations have ratified the agreement, implementing legislation within respective nations would translate the agreed long-term targets into domestic policy commitments. Such commitments would send signals to private industry and create incentives to take action. Ultimately, such domestic actions provide the signals that other countries need to see. This represents a logical and ultimately feasible chain of credible commitment.

This overall approach is scientifically sound, economically rational, and politically pragmatic. Without doubt, the challenges facing adoption and successful implementation of this architecture for the Kyoto Protocol's second commitment period and beyond are significant, but they are no greater than the challenges facing other approaches to the threat of global climate change.

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Global Climate Change: A Challenge to Policy

KENNETH J. ARROW

Last fall, the United Kingdom issued a major government report on global climate change directed by Sir Nicholas Stern, a top-flight economist. The Stern Report amounts to a call to action: it argues that huge future costs of global warming can be avoided by incurring relatively modest cost today.

Critics of the Stern Report don't think serious action to limit carbon dioxide (CO_2) emissions is justified because there remains substantial uncertainty about the extent of the costs of global climate change and because these costs will be incurred far in the future. They think that Stern improperly fails to discount for either uncertainty or futurity.

I agree that both futurity and uncertainty require significant discounting. However, even with that, I believe the fundamental conclusion of Stern is justified: we are much better off to act to reduce CO_2 emissions substantially than to suffer and risk the consequences of failing to meet this challenge. As I explain here, this conclusion holds true even if, unlike Stern, one heavily discounts the future.

A PERSONAL INTRODUCTION TO GLOBAL WARMING

I first heard of the effect of industrialization on global temperatures long before the present concerns became significant: in the fall of 1942, to be precise. I was being trained as a weather officer. One course, called "dynamic meteorology," taught by Dr. Hans Panofsky at New York University, dealt with the basic physics of weather systems (pressure variations, the laws determining the strength of winds, the causes and effects of precipitation, and similar matters). One of the first things to understand was what determined the general level of temperature. The source of terrestrial temperature is, of course, solar radiation. But heating of the Earth from the Sun's rays causes the Earth to emit radiation at frequencies appropriate to its temperature, that is, in the infra-red low-frequency portion of the electromagnetic spectrum. Since the Earth radiates into empty space, where the temperature approximates absolute zero, it would appear that in equilibrium the Earth should come to that temperature also, as is indeed the case with the Moon.

What makes the difference is the Earth's atmosphere. The vast bulk of the atmosphere is

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made up of nitrogen and oxygen, transparent to both the visible radiation coming from the Sun and the infrared radiation emitted by the Earth, and hence without effect on the equilibrium temperature. However, the atmosphere also contains, we learned, a considerable variety of other gases in small quantities. These "trace gases" include most notably water vapor, carbon dioxide, and methane, though there are many others. These trace gases have the property of being transparent to radiation in the visible part of the spectrum but absorbent at lower frequencies, such as infrared. Hence, the effect of these gases is to retain the outgoing radiation and so raise the temperature of the Earth to the point in which life can flourish. The effect is strictly parallel to the use of glass in greenhouses, also transparent to visible radiation but not to infrared; hence, the widespread term, "greenhouse effect."

Where do these trace gases come from? The water vapor comes from the passage of air over the large expanses of water in the Earth's surface, particularly when the water is warmer than the air. The carbon dioxide and methane have come from some non-biological sources, such as volcanic eruptions, but also from the respiration of animals and from organic wastes. (Vegetation, on the contrary, absorbs CO_2.)

Our instructor then added one more observation. CO_2 is a by-product of combustion. There are fires due to volcanoes and lightning, and mankind has lit fires for 500,000 years, but the pace of combustion has vastly increased since the Industrial Revolution. So, concluded Dr. Panofsky, we can expect the world temperature to rise steadily as CO_2 continues to accumulate and at an increasing rate with the growth of industry. This was not presented as a jeremiad or as controversial. Indeed, we were clearly being told this rather to vivify the somewhat arid set of facts we had to learn than to move us to action.

As any economist accustomed to general equilibrium theory might guess, the implications of a given increase in greenhouse gases for the weather are mediated through a very complex interactive system with both positive and negative feedbacks. Elaborate climate models have been developed, each admittedly falling short of catching some significant aspect. (Economists will understand.) Nevertheless, serious studies have lead to a considerable consensus, although with a wide range of uncertainty. I will draw upon the most recent report, prepared by a team directed by Sir Nicholas Stern for the United Kingdom Prime Minister and Chancellor of the Exchequer. The mean levels of different magnitudes in this report are comparable to those in earlier work, but the Stern Review is more explicit about ranges of uncertainty.

The current level of CO_2 (plus other greenhouse gases, in CO_2 equivalents) is today about 430 parts per million (ppm), compared with 280 ppm before the Industrial Revolution. With the present and growing rate of emissions, the level could reach 550 ppm by 2035. This is almost twice the pre-industrial level, and a level that has not been reached for several million years.

POTENTIAL CLIMATE CHANGE AND ITS IMPACTS

Most climate change models predict that a concentration of 550 ppm would be associated with a rise in temperature of at least two degrees Centigrade. A continuation of "business as usual" trends will likely lead to a trebling of CO_2 by the end of the century, with a 50% chance of exceeding a rise of five degrees Centigrade, about the same as the increase from the last ice age to the present.

The full consequences of such rises are not well known. Some of the direct effects are obvious: implications for agriculture (not all bad; productivity in Canada and northern Russia will rise, but negative effects predominate where moisture is the limiting factor and especially in the heavily populated tropical regions), and a rise in sea-level, which will wipe out the small island countries (e.g., the Maldives or Tonga) and encroach considerably on all countries. Bangladesh will lose much of its land area; Manhattan could be under water. This rise might be catastrophic rather than gradual if the Greenland and West Antarctic ice sheets melt and collapse. In addition, temperature changes can change the nature of the world's weather system. A reversing of the Gulf Stream, which could cause climate in Europe to resemble that of Greenland, is a distinct possibility. There is good reason to believe that tropical storms will become more severe, since the energy which fuels them comes from the rising temperature of the oceans. Glaciers will disappear, indeed have been disappearing, rapidly, and with them, valuable water supplies.

ARE THE BENEFITS FROM REDUCING CLIMATE CHANGE WORTH THE COSTS?

The available policies essentially are ways of preventing the greenhouse gases from entering the atmosphere, or at least reducing their magnitude. Today the source of 65% of the gases is the use of energy; the remainder arises from waste, agriculture, and land use. A number of behavioral changes would mitigate this problem: (1) shifting to fuels which have higher ratio of useful energy to CO_2 emissions (e.g., from coal to oil or oil to natural gas); (2) developing technologies which use less energy per unit output; (3) shifting demand to products with lower energy intensity; (4) planting trees and reducing deforestation, since trees absorb CO_2; or, (5) pursuing an unproven but apparently feasible policy of sequestering the CO_2 by pumping it directly into underground reservoirs. We can go further and simply restrict output.

Two factors deserve emphasis, factors that differentiate global climate change from other environmental problems. First, emissions of CO_2 and other trace gases are almost irreversible; more precisely, their residence time in the atmosphere is measured in centuries. Most environmental insults are mitigated promptly or in fairly short order when the source is cleaned up, as with water pollution, acid rain, or sulfur dioxide emissions. Here, reducing emissions today is very valuable to humanity in the distant future. Second, the scale of the externality is truly global; greenhouse gases travel around the world in a few days. This means that the nation-state and its subsidiaries, the typical loci for internalization of externalities, are limited in their remedial ability. (To be sure, there are other transboundary environmental externalities, as with water pollution in the Rhine Valley or acid rain, but none nearly so far-flung as climate change.) However, since the United States contributes about 25% of the world's CO_2 emissions, its own policy could make a large difference.

Thus, global climate change is a public good (bad) *par excellence*. Benefit-cost analysis is a principal tool for deciding whether altering this public good through mitigation policy is warranted. Economic analysis can also help identify the most efficient policy instruments for mitigation, but I leave that to other essays in this issue.

Two aspects of the benefit-cost calculation are critical. One is allowance for uncertainty (and related behavioral effects reflecting risk aversion). To explain economic choices such as insurance or the holding of inventories, it has to be assumed that individuals prefer to avoid risk. That is, an uncertain outcome is worth less than the average of the outcomes. As has already been indicated, the possible outcomes of global warming in the absence of mitigation are very uncertain, though surely bad; the uncertain losses should be evaluated as being equivalent to a single loss greater than the expected loss.

The other critical aspect is how one treats future outcomes relative to current ones. The issue of futurity has aroused much attention among philosophers as well as economists. At what rate should future impacts—in particular, losses of future consumption—be discounted to the present. The consumption discount rate, δ, can be expressed by the following simple formula:

$$\delta = \rho + g\eta$$

where ρ is the social rate of time preference, g is the projected growth rate of average consumption, and η is the elasticity of the social weight attributed to a change in consumption.

The parameter η in the second term accounts for the possibility that, as consumption grows, the marginal unit of consumption may be considered as having less social value. It is analogous to the idea of diminishing marginal private utility of private consumption. This component of the consumption rate of discount is relatively uncontroversial, although researchers disagree on its magnitude. The appropriate value to assign to η is disputed, but a value of 2 or 3 seems reasonable (the Stern Review uses 1, but this level does not seem compatible with other evidence).

Greater disagreement surrounds the appropriate value for ρ, the social rate of time preference. This parameter allows for discounting the future simply because it is the future, even if future generations were no better off than we are. The Stern Review follows a considerable tradition among British economists and many philosophers against discounting for pure futurity. Most economists take pure time preference as obvious. Tjalling Koopmans pointed out in effect that the savings rates implied by zero time preference are very much higher than those we observe. (I am myself convinced by this argument.)

Many have complained about the Stern Review adopting a value of zero for ρ , the social rate of time preference. However, I find that the case for intervention to keep CO_2 levels within bounds (say, aiming to stabilize them at about 550 ppm) is sufficiently strong as to be insensitive to the arguments about ρ . To establish this point, I draw on some numbers from the Stern Review concerning future benefits from keeping greenhouse gas concentrations from exceeding 550 ppm, as well as the costs of accomplishing this.

The benefits from mitigation of greenhouse gases are the avoided damages. The Review provides a comprehensive view of these damages, including both market damages as well as non-market damages that account for health impacts and various ecological impacts. The damages are presented in several scenarios, but I consider the so-called High-climate scenario to be the best-based. Figure 6-5c of the Review shows the increasing damages of climate change on a "business as usual" policy. By the year 2200, the losses in GNP have an expected value of 13.8% of what GNP would be otherwise, with a .05 percentile of about 3% and a .95 percentile of about 34%. With this degree of uncertainty, the loss should be equivalent to a certain loss of about 20%. The base rate of growth of the economy (before calculating the climate change effect) was taken to be 1.3% per year; a loss of 20% in the year 2200 amounts to reducing the growth rate to 1.2% per year. In other words, the benefit from mitigating greenhouse gas emissions can be represented as the increase in the growth rate from today to 2200 from 1.2 % per year to 1.3% per year.

We have to compare this benefit with the cost of stabilization. Estimates given in Table 10.1 of the Stern Review range from 3.4% down to -3.9% of GNP. (Since energy-saving reduces energy costs, this last estimate is not as startling as it sounds.) Let me assume then that costs to prevent additional accumulation of CO_2 (and equivalents) come to 1% of GNP every year forever.

Finally, I assume, in accordance with a fair amount of empirical evidence, that η, the component of the discount rate attributable to the declining marginal utility of consumption, is equal to 2. I then examine whether the present value of benefits (from the increase in the GDP growth rate from 1.2% to 1.3%) exceeds the present value of the costs (from the 1% permanent reduction in the level of the GDP time profile). A straightforward calculation shows that mitigation is better than business as usual—that is, the present value of the benefits exceeds the present value of the costs—for any social rate of time preference (ρ) less than 8.5%. No estimate for the pure rate of time preference even by those who believe in relatively strong discounting of the future has ever approached 8.5%.

These calculations indicate that, even with higher discounting, the Stern Review's estimates of future benefits and costs imply that current mitigation passes a benefit-cost test. Note that these calculations rely on the Stern Review's projected time profiles for benefits and its estimate of annual costs. Much disagreement surrounds these estimates, and further sensitivity analysis is called for. Still, I believe there can be little serious argument over the importance of a policy of avoiding major further increases in combustion by-products.

Letters commenting on this piece or others may be submitted at http://www.bepress.com/cgi/submit.cgi?context=ev.

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Climate Change: The Uncertainties, the Certainties, and What They Imply About Action

THOMAS C. SCHELLING

First the uncertainties; then the certainties; then the urgencies; and finally, what do uncertainties imply about waiting for their resolution before acting.

The uncertainties are many and great. How much carbon dioxide may join the atmosphere if nothing is done about it? That depends on projections of population, economic growth, energy technology, and possible feedbacks from warming that reduce albedo—ice and snow cover, for example.

Next, how much average warming globally is to be expected from some specified increase in the concentration of carbon dioxide and other "greenhouse" gases? For a quarter century the range of uncertainty has been about a factor of three. (As more becomes known, more uncertainties emerge. Clouds and oceans are active participants in ways unappreciated two decades ago.)

How will the average warming translate into changing climates everywhere: precipitation, evaporation, sunlight and cloud cover, temperature and humidity (daytime/nighttime, summer/winter) over oceans and plains and mountains, the frequency and severity of storms, of protracted droughts? Will rain replace snow in mountains, and melting of snow cover occur before irrigation can benefit?

What will be the impacts of such changes in climate on productivity, especially in agriculture, fisheries, and forests, and on comfort and health? Both the vectors and the pathogens of disease, especially in the tropics, will be affected, almost certainly for the worst. (Here productivity enters again: will malaria, river blindness, etc., have been overcome by advances in public health technology?) What will happen to ecological systems, to vulnerable species?

How well can people, businesses, governments, and communities adapt to the climate changes, especially in countries heavily dependent on food production, in countries with poor educational and technological attainment, poor fiscal or legal systems?

And of course, what are the likely costs of various mitigation strategies, mainly shifting to

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renewable energy sources and conserving energy, with technologies mostly not yet ready?

Finally, what will the world be like in 50, 75, or 100 years when climate change may become acute? Think back seventy-five years: what was the world like, compared with now? Will the world be as different from now in seventy-five years as it is now from seventy-five years ago? How would we, seventy-five years ago, have predicted the consequences of climate change in today's world, and who are "we" who might have predicted those consequences?

The uncertainties are immense, and I'll draw some conclusions shortly. But what are the certainties?

It has been known for a century that the planet Venus is so bathed in "greenhouse gases" that its surface temperature, hundreds of degrees above Earth's, does not allow water to exist in liquid form, and that Mars is so deficient in greenhouse gases that its temperature is too cold to allow water to exist in liquid form on its surface. Earth has been blessed with such a concentration of gases in the atmosphere that we have a climate consistent with liquid water and terrestrial life.

It has been known for a century that if a glassed chamber of carbon dioxide is subjected to infrared radiation—the radiation by which earth's heat, perpetually renewed by sunlight, is returned to space to keep our temperature even—the energy output is less than the energy input in direct proportion to the rise in temperature of the gas in the chamber. The greenhouse "theory," as it is sometimes disparagingly referred to, is established beyond responsible doubt.

So the basics of global warming are not in scientific dispute. There is serious uncertainty about the quantitative parameters, and there can be doubt whether the experienced warming of recent decades is entirely due to the "greenhouse effect," there being other conjectured possible solar influences. But the "theory" is not in doubt. (Incidentally, actual greenhouses don't work by the "greenhouse effect," but it is too late to change the terminology.)

If we know that the earth is ineluctably warming, with possible drastic effects on climates around the world, but not how fast or how far, what are the most urgent things to do about it? One, of course, is to keep studying the phenomena; huge advances in understanding of the climate phenomena and their ecological impact are occurring. It is a happy coincidence that concern for climate-affected greenhouse gases arose just as earth-reconnaissance satellites became available to study glaciers, forests, sea level, atmospheric and ocean temperatures, snow and ice albedo, sunlight-reflecting aerosols of sulfur, cloud reflectance, and all manner of things we need to understand.

Under "urgencies," I put energy research and development, especially government sponsored research and development (R and D), and most importantly multi-government R and D. We need, urgently, to better understand what alternatives to fossil fuels there will be, how much energy can be conserved, how to extract carbon dioxide from the atmosphere, and if necessary how to increase the earth's albedo, its reflectance of incoming sunlight.

There are two important ways to induce or provide the necessary research and development. One is to use the price system, the "market," letting private initiative finance and direct the work, through appropriate taxes, subsidies, rationing, and—most important—through convincing the private sector, firms and consumers, that fossil fuels are going to become progressively and, probably, drastically more costly as the decades go by.

The other is for R and D to be financed and directed, cooperatively with business, by governments. Some essential R and D will not be undertaken by private interests; the "market" will not induce the necessary outlays; the benefits cannot be "captured" by the investors. Examples are multitudinous, but one or two may suffice.

It has long been understood that carbon dioxide produced in large stationary plants like electric-power stations can be "captured" and piped to where it can be injected into underground caverns (or possibly ocean beds). In fact, carbon dioxide from such sources has been used for decades to stimulate the flow of oil from exhausting oil wells. Twenty-five years ago it was estimated that capturing the CO_2 output from power plants and injecting it underground would double the cost of electricity; it now appears that costs may be more modest. There are experiments underway, only a few, that should help to determine what technologies may prove most economical, not necessarily a single technology, but alternatives for different regions.

If it proves economical to "capture" and "sequester" carbon dioxide from stationary plants, and if adequate underground repositories can be found all over the world, a huge reduction of emissions into the atmosphere may make less drastic the need to curtail the use of coal. China, with huge coal deposits it plans to exploit, could greatly reduce its carbon emissions by this technology.

But the research and development that will be required, not only in the technology of capture, transport, injection, and sealing but in geologic exploration all over the world for sites suitable for permanent storage, will be beyond the purview of any private interest. This is one example of R and D that depends on government involvement, preferably multinational.

Another area of research that deserves attention, and will not receive it from the private sector, goes currently under the name of "geoengineering." (The subject requires an article of its own, but a few words can be offered here.) Some of the sunlight reaching the earth is absorbed by the ocean, the forests, the plains, the urban areas; some is reflected away. Forests absorb more than plains and deserts; arctic ice reflects more away than bare oceans. Some is reflected away by aerosols, particles in the atmosphere that often form the basis for droplets that are reflective.

It has long been known that some volcanic eruptions, namely those that produce lots of sulfur, can cool the earth significantly. Pinatubo, in the Philippines in the 1990s, had a noticeable effect. It is estimated that sulfur currently in the atmosphere, mainly from combustion of coal and oil, may be masking a significant part of the expected greenhouse effect—perhaps a significant fraction of a degree. The question arises naturally, could one offset some of the greenhouse effect, or all of it, by putting something in the stratosphere that could reflect incoming energy?

It has been estimated that to offset a doubling of the concentration of greenhouse gases would require reflecting away something like 1½ to 2 percent of incoming sunlight. (Not all the adverse effects of CO_2 would be offset: ocean acidity would be affected by continuing injections of CO_2.) Sulfur is not an attractive substance; when it comes down it is not healthful for people or fish. But the amount of sulfur that might be required, in annual injection into the stratosphere, is quite small because it stays up there longer compared with what is already being put into the lower atmosphere. It would make sense to do small, reversible experiments to ascertain what substances might, with what lifting technology, be put at what altitude, and to include the results in the global climate models to ascertain where—what latitudes and longitudes—would be most effective and most benign. Needless to say, this is not a task for the private sector, and some international sponsorship might be appropriate.

Now the critical question: what does uncertainty have to do with the question, proceed with costly efforts to reduce CO_2 abatement in a hurry, or wait until we know more?

In some public discourse, and in sentiments emanating from the Bush Administration, it appears to be accepted that uncertainty regarding global warming is a legitimate basis for postponement of any action until more is known. The action to be postponed is usually identified as "costly." (Little attention is paid to actions that have been identified as of little or no serious cost.) It is interesting that this idea that costly actions are unwarranted if the dangers are uncertain is almost unique to climate. In other areas of policy, such as terrorism, nuclear proliferation, inflation, or vaccination, some "insurance" principle seems to prevail: if there is a sufficient likelihood of sufficient damage we take some measured anticipatory action.

At the opposite extreme is the notion, often called the "precautionary principle" now popular in the European Union, that until something is guaranteed safe it must be indefinitely postponed despite substantial expected benefits. Genetically modified foods and feedstuffs are current targets. (One critic has expressed it as, "never do anything for the first time.") In this country the principle says that until a drug has proven absolutely safe it must be deferred indefinitely.

Neither of the two extreme principles—do nothing until we are absolutely sure it's safe; do nothing until we are absolutely sure the alternative is dangerous—makes economic sense, or any other kind. Weigh the costs, the benefits, and the probabilities as best all three are known, and don't be obsessed with either extreme tail of the distribution.

There are a few actions that the uncertainties make infeasible for now, and probably for a long time, and thus not worth attempting. Deciding now, through some multinational diplomatic process, what the ultimate ceiling on greenhouse gas concentrations must be to prevent, in the immortal words of the Framework Agreement, "dangerous anthropogenic interference with the climate system," as a basis for allotting quotas to participating nations, is in contradiction to the acknowledged uncertainty about the "climate sensitivity" parameter, with its factor of three in the range of uncertainty. Individual commentators have strong opinions, often quite low, but any nation's representatives can adduce substantial evidence in favor of twice that level.

The most terrifying possible consequence of global warming that has been identified is the possible "collapse" of the West Antarctic Ice Sheet. This is a body of ice that rests on the bottom of the sea and protrudes a kilometer or two above sea level. It is not floating ice; floating ice, when it melts, does nothing to sea level. This ice sheet is essentially an iceberg that has grown so large it rests on the bottom: there is enough of it above sea level that, if it glaciated into the ocean, it could raise sea level by something like twenty feet.

That would truly be a disaster. We might save Manhattan (expensively!) with dikes, as the Dutch have done for centuries, or Los Angeles or Copenhagen or Stockholm, or Boston or Baltimore. But dikes can't save Bangladesh: not only is there too much coastline, but dikes would produce fresh water floods. (Rivers cannot rise up over a dike to reach the sea.) And tens of millions of Bangladeshi would have to migrate or die.

Estimates of the likelihood of collapse, or the likely time of collapse, of the West Antarctic Ice Sheet have varied for three decades. Recent studies of the effect of ocean temperature on the movement of ground-based ice sheets are not reassuring. It has occasionally been proposed that the collapse might become irreversible before the world has taken action to mitigate warming. In my reading—this is not my profession, I just try to keep up with the latest research—the likelihood of collapse in this century is small. But uncertain!

How should we respond to that kind of uncertainty? Wait until the uncertainty has been resolved completely before we do anything, or act as if it's certain until we have assurance that there's no such danger?

Those two extremes are not the only alternatives!

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California's Bold New Climate Policy

LAWRENCE H. GOULDER

With Governor Arnold Schwarzenegger's signing last fall of Assembly Bill 32, California became the first state to commit to an economy-wide greenhouse gas regulatory program. The state must now lower emissions to 1990 levels by the year 2020—a 25–30 percent reduction from "business as usual" emissions in 2020.

California's initiative is a test case. Success could hasten the arrival of a broader, federal program. Failure could set back further United States policy efforts indefinitely.

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The new law gives the California Air Resources Board (CARB) until January 2009 to develop a draft plan to achieve these reductions. CARB's finalized regulations are supposed to take effect in 2011.

CARB has broad flexibility in deciding how to achieve the AB32 targets. What approaches should CARB take? In this essay I argue that California should adopt a "cap-and-trade" program as part of its effort. I also point out some major challenges that a California cap-and-trade system would need to overcome—challenges that emerge because this effort is being undertaken at the state level rather than at a national or international level.

FIRST: IS A STATE-LEVEL EFFORT MISGUIDED?

Before focusing on implementation, consider the fundamental question of whether it makes sense to undertake climate policy at the state level. Critics point out that California would enjoy relatively little environmental benefit from its own emissions-reduction efforts. Carbon dioxide and other greenhouse gases tend to become dispersed nearly uniformly throughout the globe. Hence the beneficial impacts (avoided climate-change-related damages) from California's reductions likewise would be spread worldwide, with only a small fraction occurring within the Golden State.

So is California leading with its chin? I don't think so. California's efforts should not be viewed in isolation. Its climate policy can be regarded as a demonstration project that (if successful) will speed up the arrival of a broader, national program. Thus a California program could be partly responsible for the additional benefits to the state, the nation, and the globe that would come from an earlier move to a national policy. From this perspective, a state-level approach has some merit.

WHAT POLICIES SHOULD BE INVOKED TO BRING ABOUT CALIFORNIA'S EMISSIONS REDUCTIONS?

The California Air Resources Board (CARB) has full authority to decide how to meet the statewide emissions-reduction target. In recent decades CARB has established an impressive record of reductions in air pollution, water pollution, and various toxins. Most of the reductions have been achieved through direct regulation that includes efficiency standards on buildings and appliances, and required technology improvements on light-duty vehicles.

CARB is now contemplating including another tool—cap-and-trade—within its arsenal of policies to achieve the statewide emissions-reduction target. Cap-and-trade should be given a key role.

The Main Rationale for Cap-and-Trade

The principal argument for cap-and-trade is that, relative to a system with fixed caps on emissions, it lowers the costs of achieving a given emissions-reduction target. Facilities with relatively high abatement costs will prefer to purchase additional emissions allowances, thus avoiding some costs of abatement. Facilities with relatively low abatement costs will prefer to sell some of their emissions allowances, thereby obtaining revenues that more than compensate for the costs of the additional reductions they must now undertake. The system thus rewards both sellers and buyers, while harnessing market forces to bring about emissions reductions where the reductions can be accomplished most cheaply.

If regulators knew exactly how much it would cost each facility to reduce emissions by various amounts, they could set emissions limits for each facility at just the level that would result from cap-and-trade. In reality, however, regulators do not have this information. A cap-and-trade program introduces a market to overcome this information problem.

Cap-and-trade systems are not simply an idea. They are already in place in the Los Angeles region to address local nitrogen oxide and sulfur dioxide emissions, in the Midwest and Northeast to deal with sulfur dioxide emissions from coal-fired power plants, and in the European Union to reduce greenhouse gas emissions from the power sector and some manufacturing industries. In 2008, industrialized nations adopting the Kyoto Protocol will participate in a broad international greenhouse gas cap-and-trade program, and in 2009, ten states in the northeastern U.S. will implement a cap-and-trade program to address greenhouse gases from electric power plants.

The theoretical case for cap-and-trade is buttressed by empirical studies. For example, two major studies of the Midwest-Northeast sulfur dioxide emissions cap-and-trade program—one by Curtis Carlson and collaborators and another by Denny Ellerman—estimate cost-savings of 43–55 percent relative to a system with uniform standards on emissions.

Cap-and-Trade vs. Direct Regulation

Some adherents to direct regulation view cap-and-trade as a threat. In part, this stems from the belief that cap-and-trade must displace existing direct regulation.

In fact, direct regulation and cap-and-trade can work side-by-side, even within a given industry. To see this, suppose emissions from a group of facilities are controlled through direct regulation. Suppose also that an emissions trading system is now introduced, one that spans the sectors in which these facilities are located. The system's limited supply of emissions allowances indicates the permissible total emissions from these and other facilities within the covered sectors. Correspondingly, it necessitates a certain overall emissions reduction. To the extent that the direct regulations continue to restrict or reduce emissions, they help meet the aggregate cap. If the direct regulations' restrictions are not sufficient to bring total emissions down to the aggregate cap, the emissions allowance market will do the rest of the work: the price of allowances will settle at a level that brings the demand for allowances (total emissions) in line with the fixed supply. Thus, a combination of price-incentives (attributable to the allowance price) and direct regulation will bring emissions within the aggregate cap. Direct regulation is not at odds with cap-and-trade. To the contrary, it contributes to meeting the cap.

Of course, the absence of conflict between direct regulation and cap-and-trade is not a reason to use direct regulation. As suggested above, cap-and-trade has some potential advantages over direct regulation in terms of cost-effectiveness. Why not dispense with direct regulation?

There are at least two reasons why direct regulation still deserves a spot in the policy landscape. One is that some types of emissions—for example fugitive emissions of methane from natural gas pipelines—are very difficult to monitor directly, and direct regulation (such as requiring pipelines to meet certain quality requirements) may be the best way to control the emissions involved. A second is the possibility of additional market failures. By putting a price on greenhouse gas emissions, cap-and-trade addresses one market failure—namely, the inability of the market to capture the externality related to damages from climate change. However, some sectors or activities involve other market failures and may require additional instruments to deal with those failures. Building insulation requirements, for example, can address the market failure that results when apartment renters do not pay for marginal heating costs. No single instrument can address all of the market failures involved, and more than one policy tool may be justified.

Cap-and-Trade vs. Technology-Push Policies

Many analysts point out that "solving" the climate change problem will require the development of radically different, clean technologies for supplying energy or using energy for various services (e.g., transportation). Some claim that cap-and-trade is a poor policy for promoting such technologies. They argue that direct technology-promoting policies—such as subsidies to research and development of alternative energy supply technologies (e.g., improved wind turbines)—are a better approach to the climate problem.

In fact, direct technology-promoting policies have a place in dealing with the climate problem—but not to the exclusion of policies like cap-and-trade that address the market failure stemming from the climate externality from greenhouse gas emissions. Other market failures related to the innovation market—such as the inability of inventors to reap all of the rewards from new knowledge generated by their research efforts—justify direct technology promotion. Once again, multiple market failures call for multiple instruments.

Cap-and-Trade vs. a Carbon Tax

Many devotees of market-based approaches to environmental protection nevertheless are lukewarm about cap-and-trade: they regard a carbon tax as superior.

To many business groups, the carbon tax is better because it avoids uncertainty about the marginal price of emissions: the emissions price (carbon tax) is established by the regulator, leaving the quantity of emissions to be determined by the market. In contrast, many environmental groups prefer cap-and-trade because it avoids uncertainty about the quantity of emissions: the quantity of allowable emissions is set by the regulator, while the price of emissions (the allowance price) emerges endogenously from trades.

Some analysts favor a carbon tax on the grounds that it might involve lower administrative costs than cap-and-trade, particularly if allowances in a cap-and-trade program were initially allocated free rather than through an auction. Negotiating and carrying out the rules for free allocation could involve significant administrative costs. On the other hand, others argue that under cap-and-trade it might be easier to bring statewide emissions close to the limit called for by Assembly Bill 32, since the cap-and-trade program reduces uncertainty about the quantity of emissions that will result after the policy is in place.[1]

In my view, neither approach clearly dominates the other. Why did the state embrace cap-and-trade over a carbon tax? The answer may reflect distributional impacts. Many business groups recognize that cap-and-trade has the potential to impose a smaller burden on polluters than a simple carbon tax. To the extent that some emissions allowances are allocated to emitters free (rather than auctioned), it puts a smaller share of the regulatory burden on emitters relative to a simple carbon tax—under which emitters would effectively pay for every unit of emissions.[2] This may help explain the greater political acceptability of cap-and-trade.

SOME DESIGN CHALLENGES

If CARB adopts a cap-and-trade system, it will need to face substantial challenges in the design of such a system. For starters, it will need to determine the size of the total cap, the sectors to be included under the program, and the method of allocating allowances. Some of the most difficult design issues stem from the fact that the effort is at the state level rather than at a broader jurisdictional level.

Leakage

In particular, it will be very important to confront the problem of emissions leakage: increases in out-of-state emissions that offset the California reductions. Emissions leakage can occur two ways. First, some firms experiencing cost increases as a result of California's regulations might move out of state. To the extent this happens, the regulations would simply cause the location of emissions to switch from California to other states or countries, rather than cause total emissions to decline. Second, the regulations could shift consumer demands in a way that undoes the intended impact on emissions. For example, if emissions by electric power generators are capped, this could lead to higher prices of California-generated electricity, which in turn might induce retailers to substitute imported electricity for the electricity generated within the state. While emissions from power generation within California would decline, the overall emissions associated with Californians' use of electricity wouldn't fall—thus defying the emission-reduction goals of recent legislation. California's legislation makes clear that it will not do to simply push its emissions intensive industries out of state, nor to simply shift to the consumption of out-of-state emissions intensive products.

There is no easy solution to the leakage problem. (And note that direct regulation can lead to leakage as well.) But leakage can be subdued. The leakage problem related to imported electricity, in particular, can be addressed by requiring California's electricity retailers to be accountable for all of the emissions associated with the electricity they sell—whether or not it is generated by power plants within the state. This would reduce the ability to avoid the emissions cap through increased imports. Still, it is not possible to account perfectly for the emissions associated with imported electricity. Imported electricity comes from a variety of sources (hydropower, natural gas fired, coal fired) with very different emissions implications per megawatt-hour. There is no way to gauge precisely what source meets California's demands at the margin—that is, what source would not be utilized if California did not import the electricity. However, rough estimates of emissions associated with imported electricity probably would be sufficient to prevent serious electricity-sector leakage.

Linkage

A second crucial issue is linkage. It will be important to decide whether it would be useful to link a California cap-and-trade system with emissions-trading systems elsewhere. The European Union now has an active greenhouse gas emissions market. Should California's market be linked to that one? On the one hand, this could promote greater global cost-savings. On the other, it could lead to California emitters' purchasing a significant number of allowances from European emitters in order to avoid cutting back emissions within the state. Many would find this objectionable.

Convertibility

A final issue is raised by the prospect of passage of a national cap-and-trade program within the next few years. If this should occur, should a California program remain alongside a national program, or should it allow the national program to replace it? I recommend the latter. Maintaining the California program in parallel could lead to unnecessary administrative costs. If allowances from the two systems are not exchangeable across systems, California emission sources would face dual compliance obligations, which would complicate firms' emissions abatement decisions. On the other hand, if allowances can be traded across programs, the California program becomes redundant: its only significance is to enlarge the total number of allowances in circulation. These considerations suggest that California's cap-and-trade system should be designed to allow for easy conversion into a federal program.

FINAL WORDS

In committing itself to significant reductions in greenhouse gas emissions, California has continued its tradition of being a first-mover among U.S. states on environmental policies. Despite the difficulties of pursuing climate policy at the state level, California's initiative still has considerable merit. The major task ahead is to determine the specific policy instruments to be employed to achieve the statewide emissions targets. Here too the state has the opportunity to show leadership—by including a cap-and-trade system as part of the emissions-reduction effort. Such a system needs to be carefully designed to deal with leakage and linkage issues, and it should allow for the smooth conversion to a national system.

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NOTES

1. It may be noted that a Weitzman-type analysis, which can indicate whether a price or quantity instrument is likely to lead to smaller policy errors ex post, does not indicate the relative appeal of a carbon tax or cap-and-trade in the present context. The reason is that the total allowable quantity is already given by AB32. The relevant issue is achieving that quantity with maximal cost-effectiveness, not introducing the policy that has the smallest expected value of efficiency losses due to deviations from the optimal quantity.
2. Note, however, that a cap-and-trade system in which all allowances are auctioned has distributional impacts similar to a carbon tax in that emitters must pay for every unit of emissions. Moreover, a carbon tax in which some inframarginal emissions are exempted can have distributional impacts similar to a cap-and-trade system with free allocation of some allowances.

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Do Voluntary Carbon Offsets Work?

JOSHUA S. GANS

In February, 2007, an organization called the Tennessee Center for Policy Research obtained the electricity bills of former US Vice President Al Gore and reported that his household usage was more than twenty times the U.S. average. Gore countered, saying that his household's emissions were offset through carbon offset purchases and green power consumption. The implication is that it should not matter how much electricity he uses, what matters is his net impact.

Entrepreneurs such as NativeEnergy (an outfit referenced on the website for Gore's film *An Inconvenient Truth*) are selling environmental indulgences. What you do is calculate the tonnage of CO_2 emissions you generate, then you purchase offsets. Those offsets are used to build wind farms, solar panels or biowaste converters; each to generate electricity. Other schemes use offsets to plant trees that take CO_2 out of the atmosphere. The idea is that an individual household or business can offset its emissions and reduce its net impact; in theory, all the way to zero or beyond if it chooses.

Some economists claim that the offsets cannot be taken at face value and may even be counter-productive. It turns out there is some merit in this view but it should not be taken to extremes.

THE CASE AGAINST CARBON OFFSETS

Do offsets change demand in a way that unwinds the desired CO_2 reduction? One possible problem is that the offsets relieve people's guilt and allow them to rationalize more energy consumption. Offsets may alternatively lower the price of energy which in turn increases others' consumption.

Tyler Cowen and Free Exchange (the blog of *The Economist* newspaper) argued, for example, that when offsets are used to invest in clean electricity generation that has a price effect. As the supply of electricity increases (whether clean or dirty) the price of electricity falls and so consumption of electricity—both clean and dirty—rises. Hence, there may not be a one-to-one matching between the offsets and what is offsetted.

But they also went further. This from *The Economist* blog:

> Carbon offsets are even ~~more lunatic~~ less effective as a response to flying. "I am pouring tons of carbon into the air

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> with my transportation needs, so I will therefore ... increase the supply of electricity in Kansas" doesn't exactly have a fine, logical ring, does it? In this case, it should be obvious to most readers that this does not work. The decision to fly marginally increases demand for flying, meaning, if enough people do it, more flights and more carbon; meanwhile, the wind farms you paid to install probably haven't taken a single power plant offline. Net effect: more carbon. In the case of private jets, we don't even need a marginal demand story; every time you fire up the plane, you contribute to global warming. [Strikeout in original]

Here the argument was that offsets would actually cause those purchasing them to *increase* dirty consumption outweighing any reductions achieved by the offsets themselves.

EVALUATING THE CRITIQUES

To consider the economic effects of voluntary offsets, it is useful to consider, first, what drives their demand. We can then proceed to look at the market effects offset holders generate and figure out if voluntary purchases of carbon offsets could really do more harm than good.

WILL CARBON OFFSETS CHANGE BEHAVIOR?

Let's begin with the behavioral impact of carbon offsets. There is no mandatory requirement for households or others to purchase carbon offsets. It is purely voluntary. If you had no concern for your emissions or believed any action you took to be a 'drop in the ocean' you would not purchase offsets.

But some households feel guilt over their environmental impact. This guilt affects their behavior. For example, if you felt guilty by leaving lights on or your air conditioner targeting too low a temperature, you would not do that. The result would be a lower level of electricity usage than those who live guilt-free.

Purchasing offsets should in some measure relieve this guilt—at least if the offset really reduces emissions in net. If you buy offsets, then switching on the lights may not hurt the environment, but it does lighten your pocketbook.

This means that instead of feeling ever-rising guilt with more electricity, you feel a constant dollar cost for each unit of electricity you consume. Because you have voluntarily purchased the offsets, it must be the case that those offsets are 'cheaper' than your guilt. What is more, drop the offset price and the more guilt you will be able to free yourself of.

But the flip-side of this is that guilt is no longer holding back your electricity consumption, the offset price is. And I have already argued that that price is lower. The end result is that when you purchase offsets, you are likely to buy more electricity too. Put simply, offsets and electricity consumption are economic complements.

What this means is that if Al Gore's household is consuming a lot of electricity it may be related to the fact that he purchases offsets. But similarly, if those offsets are doing their job, Gore's net emissions must be lower—otherwise, guilt rather than a cheaper offset price would be driving his behavior.

So far, it seems that criticisms of offsets have some merit but they do not suggest that offsets are actually counterproductive.

WHAT IF ELECTRICITY PRICES FALL?

The complementarity between electricity consumption and offset purchases implies two things. First, as already mentioned, offsets make the demand for electricity higher. This is because 'cheaper' offset prices rather than 'expensive' guilt drives that electricity use. Second, more subtly, they tend make demand more sensitive to price. That is, while before, extra purchases driven by an electricity price drop would have been constrained by guilt, now that restraint is lifted. If your electricity generator had some market or price setting power, those two facts add up to a lower price for electricity.

Will the lower price for electricity cause you to consume so much more that your net emissions rise? Put simply, no. At current prices, you prefer to pay for more electricity with offsets rather than guilt. Lower the electricity price and that is still the case. So a lower price will increase your electricity consumption but will also increase your offsets in lock-step. Net emissions will still be lower.

What about consumers who are not purchasing offsets? A lower price will mean more electricity usage by them. That will increase emissions. But net emissions would only rise if there were many guilt-free consumers. One has to remember that, even before offsets were available, the mix of guilt-ridden and guilt-free consumers was driving electricity prices. So if many consumers were guilt-free, prices would be low to begin with and what is more they would not fall by very much should some consumers buy offsets. I show elsewhere that this fact means that regardless of the mix of consumers, net emissions always fall when offsets are purchased.

WHAT ABOUT INCREASED COMPETITION IN ELECTRICITY?

If offsets are used to invest in wind or solar electricity generation, those plants have low or zero marginal cost and, moreover, commit to running so as to perform their offsetting function. Thus, they will be aggressive competitors in electricity markets. Those who are concerned that offsets may increase emissions point to this competition. They argue it will provoke more production by existing 'dirty' electricity generators who were previously withholding capacity to keep their profits high.

But clean generators' impacts on electricity prices are limited by their capacity and their capacity is determined by the volume of offsets purchased. So if there are only a few consumers purchasing offsets, clean generation will be minimal and there will be no price impact. If there were many consumers purchasing offsets, clean generation would displace 'dirty' generators. Those generators could lower price to maintain volumes but as wind and solar generators have lower marginal costs that will be fruitless. In the end, offsets mean that the demand for 'dirty' generation is decreased and consequently their price and quantity will fall too.

GO HUG YOUR OWN TREE

Simple economics tells us that consumers, who take actions that impact on their own behavior, do no harm. When those consumers are taking actions that mitigate their environmental impact, the notion that this could cause unintended consequences that worsen environmental impacts are simply not plausible. It is true that offsets—because they impact on electricity and other markets—have a complicated series of effects. However, ultimately, supply and demand will drive outcomes. Offsets reduce the net demand for dirty consumption activities and because demand equals supply, the level of dirty consumption supplied also falls.

Letters commenting on this piece or others may be submitted at http://www.bepress.com/cgi/submit.cgi?context=ev.

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Proposal for a New Climate Change Treaty System

SCOTT BARRETT

Addressing global climate change requires international agreement for a simple reason: it is a global problem, riddled through with transnational externalities.

The Kyoto Protocol—the first major international agreement on climate change—is a poor first attempt. It suffers from three deficiencies:

First, it addresses only one dimension of the problem (reducing greenhouse gas emissions) and fails to change the incentives that cause this externality. A more comprehensive approach is required, one that embraces alternative forms of mitigation and is designed to overcome free-rider incentives.

Second, Kyoto offers only a short-run remedy to a centuries-long problem. Addressing climate change will eventually require the adoption of breakthrough technologies worldwide. Kyoto provides modest incentives for innovation, but it provides little or no incentives for countries to carry out fundamental research. Substantial investment in research and development (R&D) is needed; it should be undertaken now.

Finally, Kyoto mistakenly ignores developing countries. It should have aimed to put the fast growing developing economies onto a different kind of development path and assisted the most vulnerable poor countries to adapt to inevitable climate change. Rich countries should finance both of these efforts, in addition to reducing their own emissions.

The scale of the effort required is without precedent. How should we meet this challenge?

PUBLIC GOODS FOR CLIMATE CHANGE

To address global climate change, five different kinds of public good must be provided: First, global emissions of greenhouse gases must be reduced (relative, at least, to a "business as usual" benchmark). Reductions from any country are a public good since greenhouse gases disperse themselves evenly worldwide. Emissions reductions will require some combination of energy conservation, fuel substitution, a shift to renewable energy, and carbon capture from the exhaust gases of power plants that burn fossil fuels.

Second, the knowledge of how to do all of these things on a massive scale is essential. This knowledge is a public good. Fundamental new

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energy and related technologies are needed, the discovery of which will require investment in basic research (to correct the "innovation market failure").

Third, we need to begin to consider the possibility of removing carbon dioxide (CO_2) directly from the atmosphere, by means of new industrial processes. CO_2 can be removed by planting trees, which eat CO_2 as they grow, but large scale tree planting will have environmental consequences, and trees may reduce albedo in the higher latitudes, causing temperatures there to rise. It is more important to prevent deforestation, especially in the tropics. CO_2 can also be removed by fertilizing the oceans with iron, to stimulate growth of CO_2-eating phytoplankton, but current research suggests that this cannot reduce concentrations by very much.

Fourth, we must also contemplate the possibility of reducing the amount of solar radiation that strikes the Earth, to counteract the effects of increasing atmospheric concentrations of greenhouse gases. The eruption of Mount Pinatubo in 1991 did this naturally, lowering the Earth's surface temperature by about 0.5ºC the next year. "Geoengineering" would essentially fabricate a similar effect; the most developed proposals would throw sulfate or engineered particles into the stratosphere, where they would linger for a few years before being "rained out" over the poles. Such an intervention would introduce new risks, but it may help to reduce the risk of abrupt and catastrophic climate change.

Finally, societies will have to adapt to climate change at the local, national, and regional levels, and some adaptation will involve the supply of public goods (for example, augmenting the Thames Barrier to protect London from flooding is a local public good).

All these public goods are interrelated. Emission reductions and the knowledge of how to produce and distribute energy without releasing greenhouse gases are complements. By contrast, efforts to reduce atmospheric concentrations of greenhouse gases, geoengineering, and adaptation are all substitutes. Because of these connections, the provision of these different public goods needs to be coordinated. We don't need one international agreement; we need a system of interlocking agreements, all gathered together under a revised Framework Convention that recognizes the higher need to reduce climate change risk.

Crucially, the provision of these different public goods also involves very different incentives. I discuss these next.

EMISSION REDUCTIONS

Reductions in global emissions depend on the aggregate efforts of all countries. Provision of this kind of global public good is especially vulnerable to free riding. Its provision requires enforcement.

The difficulty of enforcing an agreement is expressed in three different ways. First, participation in a treaty is voluntary, and some countries may decline to participate. The failure of the Kyoto Protocol to get the United States on board illustrates this problem. Second, an agreement must make it in the interests of states to comply after having signed on to (ratified) the international agreement. Canada signed on to the Kyoto Protocol, yet its emissions are on course to exceed Kyoto's prescribed level by 45 percent or more. The government has just announced a policy to cut emissions, but by the government's own admission that policy will not meet the Kyoto targets. Finally, the demands made by an agreement can be diluted so as to ensure that countries participate and comply. China and

India are both parties to the Kyoto Protocol, and they are sure to comply with the agreement, but that is only because the agreement does not require that they limit their emissions.

How to address the enforcement problem? The editor of this journal, Joseph Stiglitz, has proposed using trade restrictions as a means of enforcing participation in the Protocol. So did Dominique de Villepin when he was Prime Minister of France. It is hard to see how substantial mitigation can be achieved without such a mechanism. However, it is just as hard to understand how trade restrictions could be adopted.

Doing so would require an amendment (or a new agreement). To pass, the amendment would have to be adopted by three-quarters of the parties to the Kyoto Protocol. Even then, the amendment would apply only to the countries that ratified it.

To be effective, enforcement would have to apply to compliance as well as to participation—otherwise countries would simply choose to participate, to avoid being subject to a trade restriction, and yet fail to change their emissions. The existing parties may be reluctant to adopt such a measure, especially as at least some of the existing parties are at risk of not complying.

Should trade restrictions be adopted, it cannot be assumed that the rest of the agreement will be left unaltered. The minimum participation level might be increased; the emission reduction obligations might be weakened. Changes like these are to be expected because, to be effective, trade restrictions must be severe, and yet as trade restrictions become more severe they also become less credible (they would hurt the countries imposing them as well as those on the receiving end).

Trade restrictions would be difficult to apply as a practical matter, since the carbon emitted in the manufacture of a good cannot easily be determined.

Finally, the response of the countries targeted by the trade restrictions must also be considered. These countries might respond by acceding to the agreement—the desired response. But they might also respond by applying trade restrictions of their own. The use of trade restrictions to enforce the Kyoto Protocol could provoke a trade war.

Given these difficulties in bringing about trade restrictions, and the reliance of the Kyoto Protocol on such restrictions, it seems likely that the Kyoto approach can only succeed in reducing emissions by modest amounts, supported mainly by domestic enforcement. To do more will require a different approach.

More might be achieved by shifting attention away from emission limits and towards new technologies. Provided these technologies exhibit certain characteristics, such as network externalities or substantial domestic benefits independent of their effects on climate change, it is possible that their adoption can be promoted without the need for international enforcement. Currently, technologies of this kind do not exist. This is just one reason why more knowledge is needed.

KNOWLEDGE

The Kyoto Protocol provides little or no incentive for countries to discover fundamental knowledge (the kind that cannot be patented) into new technologies that can produce energy without releasing greenhouse gases.

Knowledge is a different kind of public good. Discrete knowledge can be supplied by a single best effort, making it less vulnerable to free riding. An example is the ITER project, which aims to sustain a nuclear fusion reaction at full scale—an essential ingredient into demonstrating the technology's scientific and technical feasibility. The ITER is now being built in France, financed by the European Union, China, India, Japan, South Korea, Russia, and the United States.

Though the example of nuclear fusion is relevant, it is also somewhat special; it offers benefits that are unrelated to climate change. The value of knowledge for addressing climate change will in most cases depend on the prospects of this knowledge helping ultimately to reduce emissions. Hence, the willingness of countries to finance R&D will be linked to the likelihood of any new technologies emerging from the R&D being diffused. If the technologies emerging from R&D have little chance of being adopted, the incentive to invest in R&D will be dulled. For this reason, R&D must not only develop technologies that reduce emissions; it must develop technologies that reduce emissions and that are likely to be adopted globally.

AIR CAPTURE

The idea of capturing CO_2 from the air by means of an industrial process (a related but different idea from removing CO_2 from the emissions of power plants) and then storing it in some way has yet to be tried, even as a pilot project. However, the concept has the potential to transform the problem of stabilizing atmospheric concentrations. Air capture can reduce atmospheric concentrations even if global emissions continue to rise. Air capture also has the advantage of being decoupled from our energy systems; the technology can be located anywhere. Finally, it can be undertaken unilaterally or by a small "coalition of the willing."

Preliminary estimates of the economics of air capture suggest that it will not play a role in the near future—it is too expensive. Should current obstacles be overcome, however, the challenge would be political. If individual countries or small groups of countries had the wherewithal and the incentive to reduce atmospheric concentrations independently, should they be allowed to do so? This is a question of governance.

GEOENGINEERING

The economics of geoengineering—which I take here to mean "solar radiation management"—are much more attractive, making its governance a more pressing matter. A number of countries may, in the next few decades, have an incentive to undertake it unilaterally, or as part of a small coalition. The problem is that the consequences of using this technology would have implications for other countries—and not all of them favorable. Geoengineering would entail a large-scale experiment, not unlike the one it is meant to address (climate change caused by rising atmospheric concentrations of greenhouse gases). Some countries may benefit from climate change, at least in the medium run, and geoengineering would harm them (alternatively, these countries may seek to engineer a warmer rather than a cooler climate). Geoengineering may also alter regional climates, even as it stabilizes the global average. Finally, geoengineering would not address the related environmental problem of ocean acidification.

So, which countries should decide whether geoengineering ought to be tried? Ironically, geoengineering has the opposite problem of emission reductions. The latter is limited by free rider incentives. The former is not.

ADAPTATION

The incentive for countries to adapt to climate change—another substitute for mitigation—is also strong. Indeed, much adaptation will occur "automatically," via the market mechanism. Some adaptation, however, will require the provision of local, national, and even regional public goods, like sea defenses, dikes, and large-scale irrigation projects.

Poor countries are relatively the most vulnerable to climate change for three reasons. First, they tend to be located in the low latitudes. In a sense, these countries are already "too warm," and climate change would make them even warmer. Second, poor countries depend on the natural environment for a larger share of their livelihoods. Agriculture as a share of income is much higher in poor countries than in rich ones, and agriculture is especially vulnerable to climate change. Finally, poor countries typically have weak domestic institutions. They are the least able to supply the local, national, and regional public goods of adaptation.

The Stern Review on Climate Change concluded that today's rich countries should cut their emissions (and finance cuts in the emissions of today's poor countries) dramatically in the short run, to assist today's poor countries a century or more from now. However, this reasoning fails to link mitigation to adaptation assistance. Rich countries should also invest today in the adaptation needed to help today's poor countries not only in the distant future but sooner. The most vulnerable countries need to be more robust to climate change.

Consider as an example the connection between climate change and malaria. Climate change is expected to increase malaria prevalence in the future, mainly by extending the range of the mosquito vector to higher elevations. Malaria might increase 5 percent a century from now because of climate change. Mitigation could reduce this increase a little bit, but investment in the R&D needed to discover and develop a malaria vaccine could reduce malaria prevalence across-the-board—and sooner. Similarly, R&D into new agricultural technologies could lift agricultural productivity throughout the tropics and, in the bargain, make the countries in these regions less vulnerable to climate change.

From the perspective of self-interest, the incentives for rich countries to assist poor countries to adapt are weak. However, the moral imperative for them to do so is strong.

A SYSTEM OF AGREEMENTS

How to proceed? The existing international arrangement consists of a framework agreement establishing the objective of limiting atmospheric concentrations and a protocol intended to make a start in meeting that objective, to be succeeded by a sequence of follow-on agreements that achieve even more. This arrangement is too narrow in focus. Atmospheric concentrations do need to be limited, but more needs to be done. The overall objective should be to limit climate change risk, and achieving this will require not a linear sequence of agreements but a system of interlocking agreements.

Though the Kyoto Protocol cannot be enforced internationally, many of its parties will take steps to reduce their emissions. Eventually, all of these actions will probably be organized under an international framework. That framework, however, will do little more than coordinate the activities of different states. To achieve more will require a change in strategy. It will require, in particular, a focus on new technologies.

Poorer countries—especially the fast-growing ones like China and India—must play a part in reducing emissions. Kyoto's project-based clean development mechanism was intended to help with this, but it is burdened by significant transactions costs. It makes more sense for countries to agree to establish technology standards for new investment, and for the richer countries then to finance the adoption of these new technologies in poor countries. The main task for an international agreement on technology transfer will be to specify the technologies to be adopted. Agreement is also needed on cost sharing, but there are precedents for this; cost-sharing arrangements should not be hard to negotiate.

R&D should be a priority, since our ability to reduce emissions substantially in the long run depends on it succeeding. Agreements to produce discrete knowledge already exist—an example mentioned earlier being the ITER. Many more agreements like this will have to be added, with participation in individual agreements depending on the overall cost and the interests of states in particular technologies.

Air capture and geoengineering must also be contemplated. Compared with emission reductions, both of these interventions have certain advantages. Both also introduce new risks. The challenge in these cases is not so much free riding as governance.

Climate change is inevitable, and as mentioned before, the poorest countries are especially vulnerable. They must be helped. Technologies like a malaria vaccine, if provided by the rich countries, would make it easier for poor countries to adapt to climate change, and contribute to their development as well—a kind of compensation for expected climate change damages.

Letters commenting on this piece or others may be submitted at http://www.bepress.com/cgi/submit.cgi?context=ev.

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Time to Change U.S. Climate Policy

ROBERT HAHN AND PETER PASSELL

Washington is about to get serious about climate change. Global-warming deniers have been pushed to the political fringe. And through a combination of grass-roots organizing and savvy coalition-building, a veto-resistant majority has emerged in Congress that can push through market-friendly regulation to limit carbon emissions. Even the Bush Administration is on the defensive: to counter recent calls for a new Kyoto treaty at the United Nations, the State Department staged its own climate change conference to brainstorm ways to involve developing nations in carbon containment.

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But there's still room for a slip between cup and lip. It's true that opponents of action on climate change have lost the battle for public opinion. It's also true that they've suffered major defections, as corporations ranging from Alcoa to Shell to Whirlpool maneuver for advantage in the regulatory regime they expect to come. But new opposition tactics have plenty of potential to distract Congress from the prize.

THE DIVIDE AND CONQUER STRATEGY

Most climate change proposals before Congress are patterned on the approach used successfully to reduce sulfur oxide and nitrogen oxide emissions from power plants. First, cap total emissions, initially assigning limited rights to dump carbon dioxide into the atmosphere by a formula based on past emissions. Then, encourage trading among the rights-holders.

This approach is good economics and better politics. "Cap-and-trade" programs create incentives to reduce emissions at minimum cost, as well as offering rewards to producers nimble enough to cut emissions below their quotas. The cap-and-trade approach also ensures political support from Wall Street, which is already salivating over the money to be made in trading rights. And, not to be forgotten, a cap-and-trade system can be designed to limit the potential costs by adding a "safety valve" allowing emitters to buy all the rights they need from the government at a price fixed in advance.

But conservatives are now touting another, equally efficient way to manage reductions: tax carbon emissions, and let markets adjust to the new costs by switching fuels and employing new carbon-sparing technologies. Indeed, some economists see it as the superior alternative because it may be less complicated to administer and would surely yield a lot of revenue that could be used for anything from subsidizing health insurance to rebuilding bridges.

There's a catch, however. A carbon tax is just that—a tax. And after years of equating taxes with the work of liberals and the devil, Congress would surely be reluctant to make an exception for one aimed at solving a problem that has yet to make any difference in Americans' lives.

Thus, if the carbon-tax alternative gains traction, it could fatally undermine the awkward coalition of businesses and environmental groups now supporting cap-and-trade. That explains why John Dingell of Michigan, the powerful chair of the House Energy and Commerce Committee and political enforcer for the automakers, is introducing a carbon tax. "I sincerely doubt that the American people will be willing to pay what this is really going to cost them," Dingell told C-SPAN.

THE WAIT AND SEE ARGUMENT

Reducing global emissions fast enough to stabilize atmospheric carbon dioxide at an acceptable level, we are now told, could prove far more costly than the take-a-polar-bear-to-lunch bunch assumes. Dependence on electricity from coal, the premier source of carbon emissions, will be hard to break. Nuclear power is expensive, and bitterly opposed by many environmentalists, while alternative energy sources are equally expensive and—as the ethanol-from-corn boondoggle suggests—an invitation to economic dislocation and colossal waste.

Anyway, these skeptics say, even if rich nations do grasp the nettle, China and India can't be jawboned into joining the effort. Indeed, as the Nobel Prize-winning economist Thomas Schelling has pointed out, poor countries have little incentive to divert money to reducing carbon emissions when the cheaper way to save lives and property is to invest in economic growth. After all, the reason so many die when the monsoons flood West Bengal is that they have neither the roads nor the vehicles to get out of harm's way.

This pessimism offers cover to those who are urging us to abandon efforts to slow global warming and learn to cope with the consequences. Americans aren't truly obliged to live near hurricane-vulnerable beaches. And levees (presumably superior to the ones around New Orleans) could protect big coastal cities. There is even the possibility of a low-cost, high-tech fix for climate change, offsetting the greenhouse effect of carbon emissions by blocking sunlight with sulfur dust ejected at high altitudes.

The catch here is that the world will likely have to adjust to global warming even as we fight to slow it down. The high cost of curbing emissions in rich countries is thus no excuse for failing to create an efficient framework for managing the task. By the same token, the fact that poor countries aren't likely to join the effort voluntarily doesn't mean that we couldn't or shouldn't bribe them to cooperate with cash and technology.

Indeed, bringing Asia on board will be far easier if the United States joins Europe in regulating carbon emissions. A multi-country cap-and-trade system, with emissions rights assigned in a way that initially demanded little of China and India but created powerful financial incentives for businesses in rich countries to pay Asians to use clean technologies, could make everyone happy—and at far lower cost than go-it-alone strategies. There are serious challenges in designing such a system—notably, verifying that emission reductions actually take place. But with the potential for reducing the overall cost of a successful climate change policy so high, the risks of learning by doing are surely worth it.

Fending off both sincere and sophistic opposition to cap-and-trade will no doubt require some uncomfortable compromises. Money will be wasted on unpromising R&D; grotesquely expensive renewable fuels may gain a permanent place at the subsidy trough. And, as noted above, there will always be a risk of cheating. But the first priority should be to seize the day, putting a domestic emissions regulation system in place. Without America's political leadership and economic muscle behind it, an effective global climate stabilization strategy isn't possible.

Letters commenting on this piece or others may be submitted at http://www.bepress.com/cgi/submit.cgi?context=ev.

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Letter: The Other Problems with the Stern Report

ROGNVALDUR HANNESSON

Dear Editors:

There is one aspect missing from Kenneth Arrow's comment about climate change, and indeed from the voluminous Stern Report itself: what will stabilization of greenhouse gases at about twice the pre-industrial level (550 ppm) mean for the poor and not-so-rich countries of the world? If these countries are to rise out of poverty, it will take a formidable increase in the GDP of the world, partly because many of them are so far behind, and partly because this is where the major part of humanity lives. It is a fact that growth in GDP and growth in the use of energy go together, especially in an early phase of economic development. The problem is well illustrated by the development in China. The Chinese economy has been growing at close to ten percent per year for many years now, but the Chinese emissions of carbon dioxide have also grown formidably and will soon surpass those of the United States if they have not done so already.

Unless some technological breakthrough happens quickly, stabilization of greenhouse gases at the level recommended by the Stern Report is either unattainable or will doom the poor countries of the world to continued poverty. One may legitimately ask whether the rich countries of the world should not cut their emissions to a level which would accommodate economic growth and increased carbon dioxide emissions in the less affluent countries of the world. A sobering fact is that two-thirds to three-quarters of humanity live in those countries and that share is rising. The necessary cut in CO_2 emissions in rich countries would therefore have to be very large and would probably reduce the standards of living in those countries so much that it would not be politically possible, unless again some miraculous technological breakthrough happens.

Buying insurance against a fall in GDP of 20 percent in 50 years for a one or even two percent decline in GDP in present value terms may be defensible at reasonable discount rates, but how well founded is the proposition that abatement will be that cheap? From reading the Stern Report I find it difficult to decide whether this abatement cost is wishful thinking or reasoned optimism. In any case the cost-benefit analysis of abatement policies in the rich countries of the world will be significantly influenced by what happens in less affluent countries, particularly if they manage to grow out of poverty, as we all would like to see happen.

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Letter: Why Urgent Emissions Reductions are Needed

STEFFEN KALLBEKKEN AND TORBEN K. MIDEKSA

Dear Editors:

Olmstead and Stavins make a good case for a meaningful second commitment period for Kyoto Protocol. Where we differ with them is this: We do not agree that those emissions targets "ought to begin at [business as usual] levels" and then depart gradually. Early and significant emissions reductions are vital.

If the goal is to avoid dangerous climate change, smaller emissions reductions today mean much faster reductions will be required in the future. For instance, if we could reduce global emissions by 1% per year today, but instead wait 20 years, we will then need to cut emissions at a rate that is three to five times faster to reach the same climate target. Climate changes result from cumulative emissions, not the current emissions level. Is it a good strategy to start gradually if this dramatically increases the need for more rapid emissions reductions later?

Their strategy is to avoid making the capital stock obsolete and to wait for technology to make reductions cheaper. Certainly these are important considerations. Power plants, for example, involve large capital investments with an economic life of 30 to 40 years. And, technological change holds great promise for reducing the cost of emissions abatement in the future.

Running against this argument are two factors, though. First, reductions are apt to be increasingly costly, so concentrating reductions in a given time period (even if the future) risks running very high costs. The most important problem, however, is their assumption about technology. Reduction technology could develop if the future commitment is credible, and if investors are far-sighted. However, investors tend to be fairly near-sighted (five years is a long horizon on Wall Street); moreover, how can large costly future reductions be made credible today? What prevents the politico-economic configurations that delay reductions now from resurfacing in the future and lobbying for further delay?

Our view is that delaying emission cuts provides less opportunity for firms to learn how to reduce emissions and to develop the clean technologies we need for further reductions later. Starting deep emission reductions now is important because it sends a credible signal to firms that investing in cleaner technologies will pay dividends in the future. We don't think that an international commitment today to reduce emissions in the future can send a signal as strong as a willingness to reduce today.

The challenge of avoiding dangerous climate change becomes even more difficult if we postpone emission reductions. Near-term targets need to be relatively stringent and certainly much more stringent than the current business as usual levels.

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