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Issues in Climate Change

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Issues in Climate Change

Global climate change is one of the nation's most significant long-term policy challenges. Human activities are producing increasingly large quantities of greenhouse gases, particularly carbon dioxide (CO_2). The accumulation of those gases in the atmosphere is expected to have potentially serious and costly effects on regional climates throughout the world. The magnitude of such damage remains highly uncertain. But there is growing recognition that some degree of risk exists for the damage to be large and perhaps even catastrophic.

Reducing greenhouse-gas emissions would be beneficial in limiting the degree of damage associated with climate change. However, decreasing those emissions would also impose costs on the economy—in the case of CO_2, because much economic activity is based on fossil fuels, which release carbon in the form of carbon dioxide when they are burned. Most analyses suggest that a carefully designed program to begin lowering CO_2 emissions would produce greater benefits than costs.

Employing incentive-based policies to reduce CO_2 emissions would be much more cost-effective than using more-restrictive command-and-control approaches (such as imposing technology standards on electricity generators). Incentive-based policies use the power of markets to identify the least costly sources of emission reductions. Thus, they can better reflect technological advances, differences between industries or companies in their ability to make low-cost emission reductions, and changes in market conditions.

Policymakers can choose between two general forms of incentive-based policies—those that limit the overall level of emissions (so-called quantity instruments) or those that reduce emissions by raising their price (so-called price instruments). The simplest price-based mechanism would be a tax on emissions. Under a tax, a levy would be imposed on each ton of CO_2 emissions or on each ton of carbon that is contained in fossil fuels (and which is ultimately released in the form of CO_2). The simplest quantity-based mechanism would be a cap-and-trade program. Under such a program, policymakers would set a limit (cap) on total emissions during some period and would require regulated entities to hold rights, or allowances, to the emissions permitted under that cap. After allowances were initially distributed, entities would be free to buy and sell them (the trade part of the program). Reducing emissions to the level required by the cap would be accomplished mainly by reducing demand for carbon-based energy through increasing its price.[1] Those price increases could provide an effective financial incentive for firms and households throughout the economy to take actions that would decrease emissions.

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1. Emissions could also be reduced to some extent through carbon sequestration, which is the capture and long-term storage of CO_2 emissions underground (geological sequestration) or in vegetation or soil (biological sequestration). For more information, see Congressional Budget Office, *The Potential for Carbon Sequestration in the United States* (September 2007).

The size of the required price increase would depend on the extent to which emissions had to be reduced—larger reductions would require larger price increases to reduce demand sufficiently.

Policymakers would have several key decisions to make in designing a cap-and-trade program. One such decision would be whether to sell emission allowances or give them away. Policymakers' decisions about how to allocate the allowances could have significant effects on the overall economic cost of achieving a given cap on CO_2 emissions, as well as on the distribution of gains and losses among U.S. households. Another key decision for policymakers is determining the appropriate level at which to set the cap. More stringent caps would lead to lower emissions, which in turn would reduce future risks but raise near-term costs. The choice of stringency is further complicated by the fact that the benefits (reductions in future damage) and costs of alternative levels of stringency are both uncertain.

Trends in Emissions and Temperatures

Human activities—industry, transportation, power generation, land use—are producing large quantities of greenhouse gases, particularly carbon dioxide. Those gases are accumulating in the atmosphere more rapidly than natural processes can remove them. Atmospheric concentrations of carbon dioxide have risen from 280 parts per million (ppm) in the pre-industrial era to about 380 ppm today. Concentrations of other greenhouse gases have also risen, but so have concentrations of gases that have a cooling effect. The overall net increase in warming potential is currently roughly equivalent to that of CO_2 alone.

Rising concentrations of greenhouse gases are gradually warming the global climate, contributing to an increase of about 1.4°F in the average global temperature since the middle of the 19th century. Concentrations will continue to rise—and the climate will probably continue to warm—unless global emissions are reduced well below their current levels. Stabilizing emissions (that is, the amount of greenhouse gases released each year into the atmosphere) is merely the first step in a long process of stabilizing concentrations (that is, the total amount of greenhouse gases remaining in the atmosphere).

At present, however, global emissions are rising rapidly, and depending on the growth of emissions and the climate's response, the global climate could warm by another 2°F to 12°F or even more over the next century. Roughly 1°F will result from accumulations that have already occurred. At the higher end of the range of projections, the amount of warming to come would be at least as great as the amount that has occurred since the depths of the last ice age and could produce unexpected, rapid, and very costly changes in the Earth's climate.

Uncertainty About Potential Damage

The climate problem is substantially complicated by uncertainty. Those uncertainties make it difficult to determine the full range of possible outcomes, the likelihood of particular outcomes, and the most appropriate policy response to address such potential outcomes. The important uncertainties include these:

- *Future levels of greenhouse gas emissions and concentrations* that will result from global population trends, technological developments, and economic growth. As a result of those uncertainties, any projection of cumulative emissions of greenhouse gases (measured in terms of CO_2 equivalent) over the next century could easily err by plus or minus 50 percent. The accumulation of those gases in the atmosphere also depends on how rapidly they will be absorbed by the oceans and forests—another source of significant uncertainty.

- *The magnitude and timing of the global climate's response* to rising concentrations of greenhouse gases. Given current scientific uncertainties, any projection of the climate's full response to a given increase in greenhouse-gas concentrations could err by plus or minus 50 percent. Moreover, that full response will unfold at an uncertain pace over decades to centuries.

- *The types, magnitude, and timing of damage* that will result from changes in climate. Some of the changes from warming are likely to be beneficial in some regions—for example, milder winters, longer growing seasons, and greater rainfall. However, many of the changes are likely to impose economic and social costs in other regions—for example, by melting ice caps and ice sheets; raising sea levels; altering agricultural seasons, ecological zones, and the range of infectious diseases; affecting the acidity of the oceans; increasing the variability of weather patterns; and increasing the severity of storms and droughts. All of those types of effects are likely to be more severe the greater (and more rapid) the degree of warming. In addition to those largely expected effects, experts argue that there is a small but uncertain chance that warming could trigger abrupt and unforeseen changes in climate that could be associated with unexpectedly large economic costs. Finally, some effects, such as the extinction of species, are not only difficult to project but difficult to quantify in economic terms.

Choosing Policy Goals in the Face of Uncertainty

The significant uncertainties about potential future damage and the presence of possible catastrophic risk complicate the process of setting realistic goals for climate policy: Targets for emissions cannot guarantee that concentration goals will be reached, and even choosing a target for atmospheric concentrations of greenhouse gases will not guarantee that a temperature target will be achieved, let alone guarantee that the amount of damage will be limited. For example, if policies were implemented to keep concentrations from rising above 550 ppm of CO_2 equivalent by 2100, warming over the next century would most likely be around 4°F, but there is a small probability that warming could be nearly twice as large.

An important implication is that effective climate policies should consider not only the most likely outcomes near the middle of the range, but also the less likely but more damaging possible consequences of climate change. The possibility of unlikely outcomes involving extreme costs provides an economic motivation for greater action to moderate the growth of emissions than might be justified by more likely outcomes. Just as individuals tend to avoid risky behavior and buy insurance to reduce the harm from unlikely but extreme events, some of society's resources may best be devoted to addressing the most severe risks associated with climate change even if the worst outcomes ultimately do not materialize.

In the context of climate change, reducing the risk of future damage involves reducing the trajectory of future emissions: The amount of damage that would be likely to result from a ton of emissions today would be less if the trajectory of future emissions was expected to stabilize the atmospheric concentration of greenhouse gases at a relatively low level. However, reducing emissions would impose economic costs. The difficulty for policymakers is to determine the appropriate cost to be incurred today to reduce what may be a small risk of a potentially catastrophic event in the future.

Different methods of incorporating information about risks and calculating their present value can lead researchers to come up with very different estimates of the benefits of reducing greenhouse-gas emissions even when they assume a similar trajectory of future emissions. For example, one well-known, recently updated study, by William Nordhaus, estimates that the benefit of reducing a ton of emissions today under a trajectory of emissions that would lead to a concentration of 550 ppm would be just over $9 per metric ton of carbon dioxide.[2] In contrast, a comprehensive report by the British government, the Stern Review, estimates that, given the same trajectory, the benefit of reducing a ton of emissions would be over three times as high. The difference in the two estimates stems largely from different ways of incorporating and valuing small probabilities of large future damage.

Policies that stabilize the atmospheric concentration of CO_2 at lower levels reduce the potential for larger damage in the future but also impose greater costs in the near term. Differences in the measurement and evaluation of potential future damage lead researchers to come to different conclusions about what targets to aim for. For example, the Nordhaus study concludes that an ideal policy, pursued by all countries simultaneously, would involve gradually raising the price of emissions and would ultimately limit CO_2 concentrations to about 650 ppm, resulting in a 50 percent chance of limiting the ultimate increase in global temperature to a little

2. Value inferred from estimates of optimal emissions price for carbon in 2015 in William Nordhaus, *The Challenge of Global Warming: Economic Models and Environmental Policy* (September 11, 2007), available at http://nordhaus.econ.yale.edu/dice_mss_091107_public.pdf.

over 6°F. The Stern Review, in contrast, suggests that it would be most appropriate to aim to stabilize the atmospheric concentration of greenhouse gases at between 450 ppm and 550 ppm of carbon dioxide equivalent. Such lower concentrations would be much more likely to keep global temperature increases below 6°F than the level recommended by Nordhaus but are also likely to be considerably more expensive.

Climate policy is further complicated by issues of timing, geography, international political economy, and history. *Timing* matters because unlike short-term investments whose costs and benefits are enjoyed by the same individuals, climate policy could impose significant costs on current generations who will not live to see the vast bulk of the benefits, which will instead accrue to generations that have not yet been born—and who are likely to be much richer than the current generations. *Geography* matters because much of the cost is likely to fall disproportionately on fossil-fuel-producing regions and on developed regions with extensive infrastructure based on fossil fuels, but much of the benefit would tend to accrue to developing countries in tropical and subtropical regions, which would be expected to bear much of the damage associated with climate change. *International political economy* issues are central because countries can directly control only their domestic emissions; as a consequence, managing the atmospheric stock of greenhouse gases will require ongoing, long-term cooperation among all countries with significant emissions. Finally, *history* matters because developed countries are responsible for the bulk of emissions that have already occurred, and developing countries—which will contribute most of the growth in emissions over the coming century—may be unwilling to incur significant costs in restricting emissions unless developed countries bear the bulk of the costs, at least until developing countries have achieved substantial income gains.

Comprehensive Policy Design

Designing policies to address climate change is complicated by uncertainty about the damage that might result from unchecked emissions and uncertainty about the cost of reducing those emissions. The cost of reducing emissions will depend on various factors, including the magnitude of future emissions (which, in turn, depends on the pace of population and economic growth), relative prices for fossil fuels, the development of new technologies for producing energy without creating emissions, and the willingness of individuals to adopt those technologies.[3] A pragmatic climate policy will probably involve a sequence of decisions based on the

3. For a more detailed description of the sources of uncertainty associated with the cost of reducing emissions (as well as the benefits), see Congressional Budget Office, *Uncertainty in Analyzing Climate Change: Policy Implications* (January 2005).

gradual accumulation of information and the resolution of uncertainties.[4] For such an approach, policies that can be easily modified over time would offer advantages.

A flexible approach to dealing with climate change could include three different policy strategies:

- Researching the problem and developing technologies to address it,
- Adapting to a warmer climate, and
- Reducing greenhouse-gas emissions.

In addition, a comprehensive climate policy would inevitably involve coordinating U.S. policies with those of other countries that are major emitters of greenhouse gases.

Research and Development

Research is an essential part of any comprehensive strategy to address potential changes in the climate. Research is likely to provide benefits by helping to resolve uncertainties (including uncertainties about the physical damage that might result from climate change as well as the substantial uncertainties about how to evaluate that damage) and by leading to the development of technologies to cut emissions. Such technologies could include improvements in energy efficiency; advances in low- or zero-emissions technologies (such as nuclear, wind, or solar power); and the development of sequestration technologies. Federal support would probably be most cost-effective if it went toward basic research on technologies that are in the early stages of development. Such research, which often creates knowledge that is beneficial to other firms but does not generate profits for the firm conducting the research, is likely to be underfunded in the absence of government support.

Adaptation

Some degree of warming is inevitable from emissions that have already occurred, and even very aggressive emission restrictions are unlikely to stabilize concentrations for many years to come. In light of the potential for future temperature increases, adaptation could play an important role in any effective climate strategy. Unlike mitigation policy, which could be implemented largely with a single instrument—for instance, a tax on emissions or an aggregate emissions cap—efforts to promote adaptation are likely to be more diffuse, involving numerous policies that

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4. That sequence is sometimes referred to as an “act, then learn, then act” process. A discussion of that approach is provided in A.S. Manne and R.G. Richels, *Buying Greenhouse Insurance: The Economic Costs of CO_2 Emission Limits* (Cambridge, Mass.: MIT Press, 1992). Another useful discussion is found in L. James Valverde A. Jr., Henry D. Jacoby, and Gordon M. Kaufman, “Sequential Climate Decisions Under Uncertainty: An Integrated Framework,” *Journal of Environmental Modeling and Assessment*, vol. 4, no. 2-3 (1999), pp. 87–101.

address different areas. Those policies, many of which are likely to yield benefits even if climate change proved to be relatively benign, could include the following:

- Promoting the efficient use of water resources (which are likely to become scarcer in some regions) through prices that reflect scarcity or through the establishment of markets for water;

- Encouraging the development of low-cost technologies for desalinating seawater;

- Encouraging the preservation of green corridors that would allow plant and animal species to migrate as their habitat changed;

- Facilitating the relocation of people living in low-lying areas that are prone to increased flooding;

- Improving health care and pest control; and

- Encouraging the development and use of drought-resistant crops.

Reducing Emissions

Policy choices about how much to reduce greenhouse-gas emissions involve significant trade-offs: If left unchecked, emissions could ultimately lead to costly and perhaps even catastrophic damage, yet emissions restrictions impose economic costs. Reducing carbon dioxide emissions could be particularly challenging because carbon-based fossil fuels are an integral part of the global economy, accounting for almost 90 percent of global energy use. As a result, policies for reducing CO_2 emissions must be designed in a way that facilitates a smooth, cost-effective transition to a less fossil-fuel-dependent economy, or to the sequestration of fossil-fuel-related emissions. (The design of efficient policies for reducing CO_2 emissions is discussed below.)

International Coordination

Because the causes and consequences of climate change are global, the most cost-effective policy approaches require a coordinated international effort. In particular, reductions in emissions could be achieved most cost-effectively if low-cost opportunities for mitigation were taken advantage of, regardless of where those opportunities were located around the globe. Despite the need for international cooperation to address climate change, the nature of the climate problem may make international agreement difficult to reach because the distribution of likely costs and benefits leaves countries and regions with considerably divergent interests. Furthermore, developing countries, which contributed a relatively small share of historical emissions but are expected to contribute a growing share of future ones, may object to having their development constrained by emissions restrictions. Finally, the challenges associated with enforcing a global solution may make some nations reluctant to participate, adding a source of uncertainty about how cost-effective the policies will be. Regardless of the challenges, U.S. policies will be most effective if they are part of a global effort.

Incentive-Based Policies for Reducing CO_2 Emissions

Any effort to limit CO_2 emissions would have two principal effects: It would produce long-term economic benefits by avoiding some future climate-related damage, and it would impose immediate economic costs by reducing the use of fossil fuels.

Employing incentive-based policies to reduce emissions would help minimize the cost of reducing emissions by any given amount because they would use the power of markets to identify the least expensive sources of emission reductions. Thus, they can better accommodate technological advances, differences between industries or companies in their ability to make low-cost emission reductions, and changes in market conditions.

Two alternative incentive-based approaches for reducing CO_2 emissions are to tax them or to establish a cap-and-trade system for them. Either a tax or a cap would be most efficient (that is, would best balance expected benefits and costs) if it was designed to gradually become more stringent over time—meaning the tax would gradually rise or the cap would become tighter. Such an approach would best reflect the present value of avoided future damage (the benefit of reducing a ton of emissions), which would take on greater weight as larger potential damage became closer in time. Further, such an approach would allow a smooth transition to a less carbon-intensive economy, allowing firms and households time to gradually replace capital equipment with alternatives that are more efficient, use less carbon intensive fossil fuels (such as natural gas rather than coal) or use renewable energy sources (such as wind or solar).

Efficiency Advantages of a Tax on CO_2 Emissions

Although both types of incentive-based approaches are significantly more efficient than command-and-control policies, studies typically find that over the next several decades, a well-designed and appropriately set tax would yield higher net benefits than a corresponding cap-and-trade approach. A tax creates relative certainty about the *cost* of emission reductions each year, because firms will undertake such reductions until the cost of decreasing emissions by another ton just equals the tax on an additional ton of emissions. A cap-and-trade program, by contrast, creates relative certainty about the total *quantity* of emission reductions each year, because the cap limits total annual emissions. In terms of the impact on the climate, however, it does not matter greatly whether a given cut in emissions occurs in one year or the next.[5]

From that perspective, a tax has an important advantage: It allows more emission reductions to take place in years when they are relatively cheap. Various factors can affect the cost of emission reductions from year to year, including the weather, the level of economic activity, and the availability of new low-carbon technologies (such as improvements in wind-power technology). By shifting emission-reduction efforts into years when they are relatively less expensive, a tax can yield a given quantity of emission reductions at a lower cost than can a cap-and-trade program with specified annual emission levels. In addition, by avoiding the potential volatility of allowance prices that might result from a rigid annual cap, a tax could be less disruptive for affected companies. Provided that the tax was set at a level that reflected the expected benefit of reducing an additional ton of CO_2 emissions, the tax would provide a motivation for firms and households to reduce emissions up to the point at which the cost of doing so was equal to the resulting expected benefits.

The relative advantages of a tax and a cap-and-trade program could change over time as new information became available. For example, because a cap creates relative certainty about the level of emissions, it could become more efficient than a tax if scientists determined that additional emissions were likely to trigger a sharp increase in damage, or if new technologies offered the opportunity to make extremely large cuts in emissions at a low and fairly constant cost. Analysts who have tried to define more precisely the conditions under which a cap would be more efficient than a tax have found those conditions to be quite narrow and not likely to be relevant in the near term. Specifically, scientists would need to have fairly precise knowledge about the level of an emissions threshold—beyond which additional emissions would trigger a sharp increase in total global damage—and such a threshold would have to be sufficiently close that policymakers would want to make very large cuts in emissions each year to avoid crossing it.[6] In the absence

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5. Although it is difficult to measure, the long-term cumulative nature of climate change implies that the *benefit* of emitting one less ton of CO_2 in a given year—referred to as the marginal benefit—is roughly constant. In other words, the benefit in terms of averted climate damage from each additional ton of emissions reduced is roughly the same as the benefit from the previous ton of emissions reduced, and shifting the reductions from one year to another does not materially affect the ultimate impact on the climate. In contrast, the *cost* of emitting one less ton of CO_2 in a given year—the marginal cost—tends to increase with successive emission reductions. The reason is that the least expensive reductions are made first and progressively more-expensive cuts would then have to be made to meet increasingly ambitious targets for emission reductions.

6. See William A. Pizer, *Climate Change Catastrophes,* Discussion Paper 03-31 (Washington, D.C.: Resources for the Future, May 2003).

of those conditions, a tax offers a more efficient approach for reaching a multiyear emission-reduction target.

Although a tax is generally a more efficient policy, the efficiency of a cap-and-trade approach can be enhanced by various design features. In addition, some participants in the policy discussion believe that analytical comparisons of a tax and a cap-and-trade system ignore the idea that policymakers may be more inclined to set a tight cap than a correspondingly high tax.

Enhancing the Efficiency of a Cap-and-Trade System

Policymakers could capture some of the efficiency advantages of a tax, while maintaining the structure of a cap-and-trade program, by adding features that would help keep the price of allowances in line with the anticipated benefits of emission cuts. For example, a price cap—typically referred to as a safety valve—and a price floor could keep the price of allowances from climbing too far above or falling too far below the anticipated benefits of emission reductions. The government could implement a safety valve by agreeing to sell as many allowances as firms wanted to buy at a specified price. (If the safety valve was triggered, emissions would exceed the level of the cap.) A price floor could be implemented if policymakers decided to sell a significant fraction of the allowances in an auction and set an auction reserve price. Alternatively, rather than setting a price floor, policymakers could allow firms to "bank" allowances when the cost of reducing emissions was low and to use those allowances in the future when costs were higher. Banking would keep the price of allowances from falling too low, provided that prices were expected to be higher in the future.

Key Decisions in Designing a Cap-and-Trade Program

By establishing a cap-and-trade program, policymakers would create a new commodity: the right to emit CO_2. The emission allowances—each of which would represent the right to emit, say, one ton of CO_2—would have substantial value. Based on a review of the existing literature and the range of CO_2 policies now being debated, the Congressional Budget Office (CBO) estimates that the value of those allowances could total between $50 billion and $300 billion annually (in 2006 dollars) by 2020. The actual value would depend on various factors, including the stringency of the cap (which would need to grow tighter over the years to keep CO_2 from continuing to accumulate), the possibility of offsetting CO_2 emissions through carbon sequestration or international allowance trading, and other features of the specific policy selected.

Policymakers would need to decide how to allocate the allowances that would correspond to each year's CO_2 cap. One option would be to have the government capture their value by selling the allowances, as it does with licenses to use the electromagnetic spectrum. Another possibility would be to give the allowances to energy producers or some energy users at no charge. The European Union has used that second approach in its two-year-old cap-and-trade program for CO_2 emissions, and nearly all of the allowances issued under the 12-year-old U.S. cap-and-trade program for sulfur dioxide emissions (which contribute to acid rain) are distributed in that way.

Consequences of Allowance-Allocation Decisions

Policymakers' decisions about whether to sell the allowances or to give them away would have significant implications for the distribution of gains and losses among U.S. households and for the overall cost of the policy (for a given level of stringency).

Distributional Consequences. The ultimate distributional impact of a cap-and-trade program would be the net effect of two distinct components: the distribution of the cost of the program (including the cost of paying for the allowances) and the distribution of the allowances' value (because someone will pay for them, someone will benefit from their value). Market forces would determine who bore the costs of a cap-and-trade program, but policymakers would determine who received the allowance value. The ultimate effect could be either progressive or regressive.

Obtaining allowances—or taking steps to cut emissions to avoid the need for such allowances—would become a cost of doing business for firms that were subject to the CO_2 cap. However, those firms would not ultimately bear most of the costs of the allowances. Instead, they would pass along most such costs to their customers (and their customers' customers) in the form of higher prices. By attaching a cost to CO_2 emissions, a cap-and-trade program would thus lead to price increases for energy and energy-intensive goods and services that contribute the most to those emissions. Such price increases would stem from the restriction on emissions and would occur regardless of whether the government sold emission allowances or gave them away. Indeed, the price increases would be essential to the success of a cap-and-trade program because they would be the most important mechanism through which businesses and households were encouraged to make investments and behavioral changes that reduced CO_2 emissions. The rise in prices for energy and energy-intensive goods and services would be regressive—that is, they would impose a larger burden, relative to income, on low-income households than on high-income households.

In addition to imposing relatively large burdens on low-income households, the higher prices that would result from a cap on CO_2 emissions would reduce demand for energy and energy-intensive goods and services. Thus, those price increases would create losses for some current investors and workers in those sectors. Such investors could see their stock values decline, and workers could face the risk of unemployment as jobs in those sectors were cut. Stock losses would tend to be widely dispersed among investors, because shareholders typically have diversified portfolios. In contrast, the costs borne by existing workers would probably be concentrated among relatively few households and, by extension, their communities.

Although the price increases triggered by a cap-and-trade program for CO_2 emissions would be regressive, the policy's ultimate distributional effect would depend on policymakers' decisions about how to allocate the emission allowances. Those allowances would be worth tens or hundreds of billions of dollars per year. Who received that value would depend on how the allowances were distributed.

Lawmakers could more than offset the price increases experienced by low-income households or the costs imposed on workers in particular sectors by providing for the sale of some or all of the allowances and using the revenue to pay compensation. Conversely, giving all or most of the allowances to energy producers to offset the potential losses of investors in those industries—as was done in the cap-and-trade program for sulfur dioxide emissions—would exacerbate the regressivity of the price increases. On average, the value of the CO_2 allowances that producers would receive would more than compensate them for any decline in profits caused by a drop in the demand for energy and energy-intensive goods and services that cause emissions. As a result, the companies that received allowances could experience "windfall" profits, with the government regaining only part of that windfall through corporate income taxes.

Those profits would accrue to shareholders, who are primarily from higher-income households, and would more than offset those households' increased spending on energy and energy-intensive goods and services. Low-income households, by contrast, would benefit little if allowances were given to energy producers for free, and they would still bear a disproportionate burden from price increases.

Overall Economic Cost Consequences. The ways in which lawmakers allocate the revenue from selling emission allowances could affect not only the distributional consequences but also the total economic cost of a cap-and-trade policy. For instance, the government could lessen the cost by using the revenue from auctioning allowances to reduce existing taxes that tend to dampen economic activity—primarily, taxes on labor, capital, or personal income. Research indicates that a CO_2 cap would exacerbate the economic effects of such taxes: The higher prices caused by the cap would lower real (inflation-adjusted) wages and real returns on capital, which would be equivalent to raising marginal tax rates on those sources of income. Using the allowance value to reduce such taxes could help mitigate that adverse effect of the cap. Alternatively, policymakers could choose to use the revenue from auctioning allowances to reduce the federal deficit. If that reduction lessened the need for future tax increases, the end result could be similar to dedicating the revenue to cutting existing taxes. The decision about whether or not to sell the allowances and use the proceeds in ways that would benefit the economy could have significant impacts for the economywide cost of a cap-and-trade program.

Consequences of Stringency Decisions

Researchers have produced a large number of studies of the near-term and long-term costs of achieving various levels of stringency in reducing emissions. Several recent analyses focus on the likely costs to the U.S. economy of various legislative proposals put forward in recent years. Within the federal government, both the Environmental Protection Agency and the Department of Energy's Energy Information Administration have analyzed some versions of those legislative proposals at the request of Members of Congress. In addition, researchers at the Joint Program on the Science and Policy of Global Change at the Massachusetts Institute of Technology (MIT) have produced a comprehensive analysis of several long-term emission targets that approximate some of the legislative proposals currently under consideration. The National Commission for Energy Policy has also proposed a comprehensive energy policy strategy that would include restrictions on greenhouse-gas emissions, and Duke University's Nicholas Institute has analyzed at least one of the bills.

Like the proposals themselves, the scenarios analyzed in those studies specify a number of different levels of stringency. In general, all of the proposals involve an increasing level of stringency over time. Some impose hard caps, but others provide for a price limit or safety valve. Most allow for at least some degree of banking and borrowing of emission allowances. Many scenarios involve limited sectoral coverage, usually exempting most emissions from nonelectric energy use in buildings (such as home heating). Many proposals and scenarios allow covered entities to purchase offsets from one or more types of sources—in uncovered sectors, through sequestration of carbon in domestic forests and soils, or from international sources—as a substitute for their own actions.

Most of the models used for those studies are of a type referred to as general-equilibrium models, in which idealized households supply labor and capital to idealized firms that supply a variety of goods and services back to the households. Most of the models incorporate forward-looking behavior; that is, the idealized agents in the model correctly anticipate future developments in the model and adjust their behavior accordingly. With such assumptions, most of the models implicitly assume that households and firms respond rather quickly, rationally, and flexibly to changes in policy—an assumption that may overstate many people's abilities to accommodate such changes.

Many models include considerable detail about the different types of technology in the energy sector. One model, the Energy Information Administration's National Energy Modeling System—NEMS—is not a general-equilibrium model, but is instead a highly detailed representation of the energy sector integrated with a macroeconometric model of the U.S. economy. Some models include the entire global economy, linking countries through international trade flows; others include only the domestic economy and include only rather cursory representations of international linkages. Most of the modeling efforts draw on the Environmental Protection Agency's estimates of abatement costs for carbon dioxide from nonenergy sources and for other greenhouse gases, though most other groups modify those estimates in some way. Those models estimate only the policies' costs; they do not provide for feedbacks from the mitigation policies to climate benefits.

Different models provide somewhat different types of cost estimates for the modeled policies. All of them provide estimates of the annual prices of allowances and offsets (which can differ, depending on whether the use of offsets is restricted or not), or of the level of the annual tax rate on emissions necessary to achieve a given level of emissions. All provide estimates of macroeconomic impacts, such as changes in inflation-adjusted gross domestic product and personal consumption expenditures. Some models provide more comprehensive estimates of changes in households' economic well-being—what economists refer to as welfare impacts.

Even for a given policy proposal, the models' cost estimates can vary because of differences in their assumptions about future economic growth and emission trends, about how firms and households will respond to changing prices, and about what types of technologies are likely to be available and accepted at different times. None of the models explicitly provides for a channel through which policies might influence the pace of development of new technologies, although in some models, such influences are modeled implicitly. The models also differ in whether or not they consider the effects on domestic costs of climate policies pursued in other countries; such effects can be quite important.

Considering the extraordinary complexity of the domestic and global economies and the wide range of activities associated with greenhouse-gas emissions, no single modeling framework or modeling scenario provides a fully comprehensive treatment of all the potential effects. A realistic assessment of the results requires modelers and users to consider a range of models and results to draw broader conclusions.

With a wide range of modeled policies, a wide range of baseline projections, and a wide range of reasonable differences in assumptions about how the economy might respond to policies, the results vary considerably. Nevertheless, a few robust insights emerge:

- First, there is significant uncertainty about the price required to induce a specific level of emission reductions, and significant uncertainty about the level of reductions that would be induced by a specific price. Higher prices induce greater reductions in emissions; conversely, greater stringency in constraining emissions requires higher prices and imposes greater welfare impacts.

- Second, even substantial reductions in emissions are generally associated with relatively modest impacts on consumption—especially compared with the expected growth in consumption over the next few decades.

- Third, in the near term—that is, roughly through 2025—many reductions are likely to come from relatively inexpensive sources of greenhouse gases outside the energy sector. Within the energy sector, reductions in overall energy use are likely to be relatively modest; instead, reductions are likely to come predominantly from the electric utility sector, mainly by shifting fuel use away from coal and toward natural gas and nuclear power. Sequestration and international offsets could yield significant reductions at relatively modest cost, assuming moderate administrative costs.

- Finally, over the longer term, domestic and international offsets are likely to become increasingly less important, and most reductions are likely to come from the energy sector. Technology will play a critical role in that process, but current understanding provides little consensus as to which technologies will dominate. It appears likely that a combination of several technologies could play a role: carbon capture and sequestration, nuclear power, and biofuels. Other renewable energy sources and conservation appear likely to play relatively limited roles.