Economic Analysis of Global Climate Change Policy: A Primer

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What is the point of conducting a detailed analysis of the economics of global climate change policy, some might ask. Surely — the thinking might go — the performance of the economy is largely independent of the quality of the environment, and policy choices regarding environmental quality should be made without attention to economic considerations; moreover, economics cannot shed much light on ways to solve environmental problems.

Quite to the contrary, there are numerous bi-directional linkages between economic performance and environmental quality. Economic considerations can help inform policy decisions regarding environmental protection, and economics provides powerful analytical methods for investigating environmental problems, and hence can provide valuable insights about those problems' potential solutions. The reasons for all of this are essentially two-fold: first, the causes of environmental degradation, at least in market economies, are fundamentally economic in nature; and second, the consequences of environmental problems have important economic dimensions.

Global climate change, perhaps even more than other environmental problems, can be addressed successfully only with a solid understanding of its economic dimensions. First, the fundamental cause of anthropogenic emissions of greenhouse gases, almost by definition, is economic: excessive emissions are an example of an externality, a well-understood category of market failure, where markets left to their own devices tend not to produce social efficiency.[1] Second, economic analysis is clearly necessary to estimate the costs that will be incurred when and if nations take action to reduce the risk of global climate change. Third, because of the large costs that will be involved in any serious climate change strategy, there is considerable interest in economic-incentive or market-based policy instruments that can reduce the costs of addressing the problem. And fourth, turning to the other side of the ledger, the biophysical consequences of global climate change can be evaluated with economic methods in order to identify the benefits, or avoided damages, of global climate policy action.

This chapter consists of six reports, five of which examine specific aspects of the economics of global climate policy. This introduction develops the analytical framework for carrying out economic analyses of policies intended to address the threat of global

The Pew Center and the author appreciate the input of Larry Goulder and Michael Scott, who reviewed this paper and provided helpful comments.

climate change.[2] Along the way, analytical issues particularly germane to climate policy analysis are highlighted,[3] and in a concluding section, the relationships between these issues and the subsequent reports in this chapter are described.

Three broad economic questions are raised by the challenge of addressing the threat of global climate change:[4] what will be the benefits of reducing the risk of global climate change; what will be the respective costs; and how can this information about the benefits and costs of alternative policy regimes be assimilated in ways that are useful to decision-makers?

The Benefits of Global Climate Change Policy

Economics is fundamentally anthropocentric; if an environmental change matters to any person — now or in the future — then it should, in principle, show up in an economic assessment. And environmental changes do matter to people in a wide variety of ways. The economic concept of environmental benefits is considerably broader than most non-economists seem to think.[5] From an economic perspective, the environment can be viewed as a form of natural asset that provides service flows used by people in the production of goods and services, such as agricultural output, human health, recreation, and more amorphous goods such as quality of life. This is analogous to the manner in which real physical capital assets (for example, factories and equipment) provide service flows used in manufacturing. As with real physical capital, a deterioration in the natural environment (as a productive asset) reduces the flow of services the environment is capable of providing.

Note that ecological benefits are very much part of the picture. Here, it is important to distinguish between ecosystem functions (for example, photosynthesis) and the environmental services produced by ecosystems that are valued by humans, since it is only the latter that are potential benefits in an economic framework (Freeman 1997). The range of these services is great, including obvious environmental products such as food and fiber, and services such as flood protection, but also including the quality of recreational experiences, the aesthetics of the landscape, and such desires (for whatever reasons) as the protection of marine mammals. The economic benefits of global climate change policies range from direct and specific impacts, such as those on agricultural yields and prices, to less direct and more general effects on biodiversity.

Protecting the environment usually involves active employment of capital, labor, and other scarce resources. Using these resources to protect the environment means that they are not available to be used for other purposes. The economic concept of the "value" of environmental goods and services is couched in terms of society's willingness to make trade-offs between competing uses of limited resources, and in terms of the sum of individuals' willingness to make these trade-offs.[6] Economists' tools of valuation were originally developed in a more limited context — one in which policy changes mostly caused changes in individuals' incomes and/or prices faced in the market. Over the last 30 years, however, these ideas have been extended to accommodate changes in the quality of goods, to public goods that are shared by individuals, and to other non-market services such as environmental quality and human health.[7]

The economist's task of estimating the benefits or loss of benefits resulting from a policy intervention is easiest when the benefits and costs are revealed explicitly through prices in established markets. When it comes to measuring environmental impacts, however, placing a value on benefits is more difficult, and requires indirect methods. With markets, consumers' decisions about how much of a good to purchase at different prices reveal useful information regarding the benefits consumers anticipate receiving from various items. With non-market environmental goods, it is necessary to infer this willingness to trade off other goods or monetary amounts for additional quantities of environmental services by using other techniques. Environmental economists have developed a repertoire of techniques that fall broadly into two categories: indirect measurement and direct questioning. Both sets of valuation methods are relevant for assessing the anticipated benefits of global climate change policies.

Economists prefer to measure trade-offs by observing the actual decisions of consumers in real markets, using so-called revealed preference methods. Sometimes the researcher can observe relationships that exist between the non-marketed (environmental) good and a good that has a market price. Thus, individuals' decisions to avert or mitigate the consequences of environmental deterioration can shed light on how people value other types of changes in environmental quality (averting behavior estimates). In other cases, individuals reveal their preferences for environmental goods in the housing market (hedonic property value methods), or for related health risks in labor markets (hedonic wage methods). In still other cases, individuals reveal their demand for recreational amenities through their decisions to travel to specific locations (Hotelling-Clawson-Knetsch and related methods). These various estimation techniques are well established for measuring the conceptual trade-offs that are the basis of environmental valuation. However, they are applicable only in limited cases.

In many other situations, it is simply not possible to observe behavior that reveals people's valuations of changes in environmental goods and services. This is particularly true when the value is a passive or non-use value. For example, an individual may value a change in an environmental good because she wants to preserve the option of consuming it in the future (option value) or because she desires to preserve the good for her heirs (bequest value). Other people may envision no current or future use by themselves or their heirs, but still wish to protect the good because they believe it should be protected or because they derive satisfaction from simply knowing it exists (existence value). With no standard market trade-offs to observe, economists must resort to surveys in which they construct hypothetical markets, employing stated preference, as opposed to revealed preference methods. In the best known stated preference method, commonly known as contingent valuation, survey respondents are presented with scenarios that require them to trade off, hypothetically, something for a change in the environmental good or service in question.

Although great uncertainty exists regarding the magnitude (and, in some cases, even the direction) of regional climate impacts, global climate change is anticipated to have a variety of impacts that will affect human welfare, including: changes in resource productivity (for example, in some cases, lower agricultural yields, and scarcer water resources); damages to human-built environments (including coastal flooding due to sea-level rise); human-health impacts (such as increased incidence of tropical diseases in more temperate climates); and damages to various ecosystems.[8] The uncertainties surrounding these various physical impacts are very great, and those uncertainties are compounded by imprecise estimates of respective economic consequences.

Whereas impacts on marketed goods and services (such as agricultural output) can be estimated with some reasonable degree of precision, monetary estimates for non-marketed goods are notoriously imprecise. Furthermore, existing economic estimates in both categories come from industrialized nations, particularly the United States. Much less is known about anticipated economic damages in developing countries, which is especially troubling because they are particularly vulnerable to the impacts of global climate change.[9]

The Costs of Global Climate Change Policy

The task of estimating the costs of global climate change policies may seem straightforward, compared with the conceptual problems and empirical difficulties associated with estimating the benefits of such policies. In a relative sense, this is true. But as one moves toward developing more precise and reliable cost estimates, significant conceptual and empirical issues arise. More attention has been given by economists to analyzing the costs than the benefits of global climate policy action (largely because of existing uncertainties regarding regional biophysical impacts of climate change). Hence, my treatment of the cost side of the ledger is proportionately more extensive.

The economist's notion of cost, or more precisely, opportunity cost, is linked with — but distinct from — everyday usage of the word. Opportunity cost is an indication of what must be sacrificed in order to obtain something. In the environmental context, it is a measure of the value of whatever must be sacrificed to prevent or reduce the chances of an environmental impact. These costs typically do not coincide with monetary outlays — the accountant's measure of costs. This may be because out-of-pocket costs fail to capture all of the explicit and implicit costs that are incurred, or it may be because the prices of the resources required to produce environmental quality may themselves provide inaccurate indications of the opportunity costs of those resources.

Hence, the costs of global climate policies are the forgone social benefits due to employing scarce resources for global climate policy purposes, instead of putting these resources to their next best use.[10]

A taxonomy of environmental costs can be developed, beginning with the most obvious and moving toward the least direct (Jaffe, Peterson, Portney, and Stavins 1995). First, many policy-makers and much of the general public would identify the on-budget costs to government of administering (monitoring and enforcing) environmental laws and regulations as the cost of environmental regulation. This meets the economist's notion of (opportunity) cost, since administering environmental rules involves the employment of resources (labor and capital) that could otherwise be used elsewhere. But economic analysts would also include as costs the capital and operating expenditures associated with regulatory compliance. Indeed, these typically represent a substantial portion of the overall costs of regulation, although a considerable share of compliance costs for some regulations fall on governments rather than private firms.[11] Additional direct costs include legal and other transaction costs, the effects of refocused management attention, and the possibility of disrupted production.

Next, there are what have sometimes been called "negative costs" of environmental regulation, including the beneficial productivity impacts of a cleaner environment and the potential innovation-stimulating effects of regulation.[12] General equilibrium or multi-market effects associated with discouraged investment[13] and retarded innovation constitute another important layer of costs, as do the transition costs of real-world economies responding over time to regulatory changes.

In the give-and-take of policy debates, abatement costs of proposed regulations have sometimes been over-estimated (Harrington, Morgenstern, and Nelson 2000; Hammitt 2000). This may partly be due to the adversarial nature of the policy process, but it is also a natural consequence of employing short-term cost analyses that do not take into account potential future cost savings due to technological change, some of which may be a consequence of the regulatory regime.

Although the task of estimating the costs of environmental protection efforts might be somewhat more straightforward than that of estimating environmental protection benefits, costs seldom can be estimated with great precision, and producing high-quality cost estimates requires careful analysis. Conceptually, there are four steps required to appraise empirically the cost of an environmental-protection measure. First, it is necessary to identify the specific policy instrument that is associated with the measure. For example, is a conventional instrument, such as a technology standard, or a market-based instrument, such as an emissions charge, to be employed? This can be important because the same target, such as a given reduction in carbon dioxide (CO_2) emissions, may be achieved at very different total costs with different policy instruments. The second conceptual step is identifying the specific actions that sources will take to comply with the statute or regulation, as implemented with the given policy instrument. Some of these actions may involve the adoption of a new piece of equipment, but others may involve a change in process. Third, it is necessary to identify the true cost of each action, which requires more than assessing required monetary outlays. Fourth, it is often necessary to aggregate these costs across society and over the relevant time frame.

In the case of climate change, the opportunity cost of taking action may include: direct outlays for control (for example, the incremental cost of employing natural gas rather than more carbon-intensive coal for energy generation); partial equilibrium costs to both producers and consumers (for example, accelerated depreciation of fixed capital); and general equilibrium costs that arise in related markets as prices adjust (Hourcade et al. 1996). In this last regard, it is important to keep in mind that the ultimate consequences of a given environmental policy initiative depend on interactions between the new policy and existing regulations or tax policies. In particular, additional costs can arise from interactions between climate policies and pre-existing distortions in the economy, such as those due to taxes on labor (Goulder 1995).

The baselines, or anticipated business-as-usual paths, utilized for climate policy cost (and benefit) analyses are very important. Indeed, a striking finding from a wide range of integrated assessment models (which layer economic models upon underlying scientific models of climate change relationships) is that differences in welfare impacts[14] across plausible baseline assumptions are greater than the welfare impacts attributable to climate policy itself (Goulder 2000). These baselines are built upon various assumed time paths of future economic growth, encompassing overall rates of growth plus relevant sectoral changes, and a particularly important aspect of alternative baselines is the assumed rate and direction of technological change.

The cost of achieving any given global climate target depends critically upon the "physical scope" of policy action. Does the policy being analyzed affect only emissions, for example, of CO_2 by encouraging fuel switching? Or does the policy also provide mechanisms for: increased biological uptake of carbon through carbon sequestration, presumably through changes in land use (Sedjo, Sampson, and Wisniewski 1997; Stavins 1999); carbon management, that is, removal and storage of CO_2 in the deep ocean or depleted oil and gas reservoirs (Parson and Keith 1998); and/or geoengineering, such as various means of increasing the earth's reflectivity (National Academy of Sciences 1992)? More broadly still, do the cost estimates allow for adaptation policies, which in many cases may be less costly than "equivalent" measures that work through emissions reduction, sequestration, management, or geoengineering (Pielke 1998; Kane and Shogren 2000)? Finally, does the policy being assessed focus exclusively on CO_2 or is a larger set of greenhouse gases being targeted? This is a crucial question, since broader targets enhance flexibility, and, in some cases, can reduce costs of achieving a given climate goal substantially (Hansen et al. 2000).

Just as the allowed physical scope of policy response will affect the costs of achieving any given climate target, the policy instrument chosen to affect change will have profound impacts on costs, both in the short term and the long term. On the domestic front, the portfolio of potential policy instruments includes conventional technology and uniform performance standards (so-called command-and-control approaches), as well as the newer breed of economic-incentive or market-based policy instruments, such as taxes, tradeable permit systems, and various information policies (Stavins 1997).[15] And at the international level, the set of instruments that have been subjected to analysis include international taxes, harmonized domestic taxes, international tradeable permits, joint implementation, and the Clean Development Mechanism of the Kyoto Protocol (Fisher et al. 1996). These two sets of climate policy instruments — domestic and international — should not be thought of as functioning independently of one another. Indeed, the relative cost-effectiveness of what may be one of the most promising mechanisms, the international tradeable permit system recognized by Article 17 of the Kyoto Protocol, will depend greatly upon the particular set of domestic policy instruments adopted by participating nations (Hahn and Stavins 1999).

The outcome of any cost comparison among greenhouse policy instruments also depends upon the sophistication of the underlying analytical models. With many environmental problems, relatively simple analytical models can be employed for comparing policy instruments, since it is reasonable to utilize static (short-term) cost-effectiveness as a criterion for comparison. But the long-term nature of global climate change and related policies means that it is important to employ a dynamic (long-term) cost-effectiveness criterion for comparisons. In this context, the intertemporal flexibility provided by some policy instruments, such as banking and borrowing in a tradeable permit system, can turn out to be very significant (Manne and Richels 1997).

More importantly, the very long time horizons typically employed in global climate policy analysis mean that it is essential to allow for the effects of alternative policy instruments on the rate and direction of relevant (cost-reducing) technological change (Jaffe, Newell, and Stavins 1999, 2000). Three stages of technological change (Schumpeter 1939) can be analyzed: invention, the development of a new product or process (Popp 1999); innovation or commercialization, the bringing to market of a new product or process (Newell, Jaffe, and Stavins 1999); and diffusion, the gradual adoption of new products and processes by firms and individuals (Hassett and Metcalf 1995; Jaffe and Stavins 1995). Most large-scale analyses of global climate policy have not allowed for technological improvements in response to economic stimuli, but this is beginning to change (Goulder and Schneider 1999; Nordhaus 1999; Goulder and Mathai 2000).[16]

Since the compliance costs associated with most climate policies are initially incurred by private firms, it is important to analyze correctly the behavioral response of such firms to various policy regimes. Most economic analyses treat firms as atomistic profit-maximizing or cost-minimizing units. This is satisfactory for many purposes, but it can lead to distorted estimates of the costs brought about by some policies. For example, one potentially important cause of the mixed performance of implemented market-based instruments is that many firms are simply not well equipped internally to make the decisions necessary to fully utilize these instruments. Since market-based instruments have been used on a limited basis only, and firms are not certain that these instruments will be a lasting component on the regulatory landscape, most companies have not reorganized their internal structure to fully exploit the cost savings these instruments offer. Rather, most firms continue to have organizations that are experienced in minimizing the costs of complying with command-and-control regulations, not in making the strategic decisions allowed by market-based instruments (Hockenstein, Stavins, and Whitehead 1997).

The focus of environmental, health, and safety departments in private firms has been primarily on problem avoidance and risk management, rather than on the creation of opportunities made possible by market-based instruments. This focus has developed because of the strict rules companies have faced under command-and-control regulation, in response to which companies have built skills and developed processes that comply with regulations, but do not help them benefit competitively from environmental decisions (Reinhardt 2000). Absent significant changes in structure and personnel, the full potential of market-based instruments will not be realized. Economic models may thereby underestimate the relative costs of employing such instruments to achieve global climate targets.

Finally, the costs of achieving any given global climate target, indeed the very feasibility of achieving such targets, will depend upon the nature of respective international agreements and the institutions that exist to support those agreements. This is an area where economic analysis (along with political science and legal scholarship) can also contribute. A principal issue is the architecture of such agreements and the breadth of the coalitions that are parties to them (Jacoby, Prinn, and Schmalensee 1998; Schelling 1998). From an economic perspective, a fundamental challenge is the necessity of overcoming the strong incentives for free riding that exist with a global commons problem (Carraro and Siniscalco 1993; Barrett 1994; Cooper 1998). More specifically, there is a pressing need to design international policy instruments that can provide incentives over time for more nations — in particular, developing countries — to join the coalition and take on binding targets or other responsibilities (Manne and Richels 1995; Rose, Stevens, Edmonds, and Wise 1998; Frankel 1999; Bohm and Carlén 2000).

Assimilating Benefit and Cost Information

The next analytical challenge, after the benefits and costs of proposed global climate change policies have been assessed, is to assimilate this information in ways that are useful for decision-makers. Two major categories of analysis are required: one is to provide an overall characterization of a policy in terms of its likely benefits and costs (aggregate analysis); and another is to describe the distribution of those benefits and costs across relevant populations, defined, for example, by geographic location, economic sector, income level, or time period (distributional analysis).

Aggregate Analysis

It seems reasonable to ask whether the gains (to the gainers) outweigh the losses (to the losers) of some public policy, and thus determine, on net, whether society as a whole is made better or worse off as a result of that policy. Benefit-cost analysis is the standard technique used to carry out this comparison of the favorable effects of risk reductions (the benefits) with the adverse consequences (the costs). A policy that achieves maximum aggregate net benefits is said to be an efficient one. Although efficiency is surely an important criterion for sound policy analysis, most economists think of benefit-cost analysis as no more than a tool to assist in decision-making. Virtually all would agree, however, that the information in a well-done benefit-cost analysis can be of great value in helping to make decisions about risk reduction policies (Arrow et al. 1996).

Time is a critical and prominent dimension of global climate change policy. First, greenhouse gases accumulate in the atmosphere over very long periods (up to hundreds of years), because of their very slow natural decay rates. Second, changes in the capital stock that are made in response to the threat of climate change have long lives: for example, 50 to 70 years for electricity generators, and 60 to 100 years for residential buildings (Jaffe, Newell, and Stavins 1999). Third, technological change is a long-term phenomenon that has great bearing on global climate change and policies to address it. For all three reasons, benefit-cost analyses of global climate policies must involve the dimension of time, and over very long intervals, at that.

When adding the value of net benefits over time, it is essential to recognize that people are not indifferent to receiving a given economic benefit (or paying a given economic cost) today as opposed to 10 or 20 years from now. For this reason, all future net benefits are typically discounted (expressed in terms equivalent to the time-value of today's net benefits); that is, the present value of net benefits in each year is computed before aggregating net benefits over time.[17]

While the concept of discounting has a sound rationale, it can lead to conclusions that many people, including economists, find unpalatable. For long-run policy problems, such as global climate change, little weight will be given in an analysis to the long-term benefits of taking action, compared with the up-front costs of those actions. This conundrum has stimulated an active area of research (Portney and Weyant 1999), as economists have considered how best to address the apparent dilemma. One avenue of this research has suggested a theoretical basis for employing lower discount rates for longer run analyses (Weitzman 1999). Considerations of time can thus have profound effects on aggregate analysis of the benefits and costs of alternative climate policies.[18]

In addition to time, uncertainty is a prominent feature of global climate change, on both the benefit and the cost side of the ledger. In effect, the risks of premature or unnecessary actions need to be compared with the risks of failing to take actions that subsequently prove to be warranted (Goulder 2000). Because of this, many economic analyses have indicated that climate change may best be addressed through sequential decision-making, with policies being modified over time as new information becomes available and uncertainties are reduced. Because such new information is potentially of great value, flexible policies that adapt to new information have very significant advantages over more rigid policy mechanisms.

The significant uncertainties associated with global climate change interact with the intertemporal nature of the problem to yield another important dimension — irreversibility (Kolstad and Toman 2000). It is well known that when uncertainty is combined with long-lived impacts (economic, if not physical, irreversibility), there is a value (called quasi-option value by economists) in delaying those impacts until more information is available (Hanemann 1989). This value should, in principle, be included in the calculation of benefits and costs. In the global climate context, the irreversibilities include both the accumulation of greenhouse gases in the atmosphere and the accumulation of capital investments that cannot easily be reversed. These two effects push a stochastic benefit-cost analysis of global climate policy in opposite directions. Which is dominant? Although it has been argued that the second effect is more important (Kolstad 1996), it is ultimately an empirical question (Ulph and Ulph 1997; Narain and Fisher 2000).

Distributional Analysis

This discussion of benefits and costs, as well as the way the two are compared, has glossed over an important point, and one that is exceptionally important in the context of global climate change policy. Specifically, benefit-cost analysis is silent about the distributional implications of policy measures. Although considerable thought has been given by economists over the years to the possibility of using weights to incorporate distributional considerations into determinations of efficiency, there is no consensus, nor likely to be one, on what those weights ought to be. It seems reasonable, instead, to estimate benefits and costs, and also provide as much information as possible to decision-makers about gainers and losers.

Assessments of national, intra-national, and intergenerational distributions of the benefits and costs of alternative policy regimes are necessary for the identification of equitable climate strategies. A number of criteria merit consideration (Goulder 2000). First, the criterion of responsibility would suggest that — other things equal — nations that are most responsible for the accumulation of greenhouse gases in the atmosphere should take on the greatest burden for containing the problem. Second, the criterion of ability to pay is premised on the notion that wealthier nations possess greater capacity to respond to the problem. Third, the criterion of the distribution of benefits suggests that nations, which stand to benefit most from action taken ought to take on greater shares of the cost burden. The first two considerations suggest that industrialized nations should bear the principal burden for dealing with the prospect of climate change, while the third consideration favors action by developing countries.

Because of the long time horizon of global climate policy analysis, important issues of intergenerational equity arise. But it should be noted that the use of discounting in benefit-cost analysis has ambiguous effects. For example, some have called for not discounting future costs and benefits at all when time-horizons are very great. At first, this might seem to be a course of action that would favor future generations. In an important sense, however, it does not. If, by using a zero or very low discount rate, we adopt policies that do not pay off until the distant future, we are favoring climate policy action over other policies for which a standard (higher) discount rate is used. As a result, we may pass up opportunities to employ other, non-climate policies that could benefit future generations. Thus, it is not clear that we make future generations better off by using a low rate of discount. More broadly, Schelling (1998) has highlighted the trade-off that may exist between policies to address intergenerational equity and those that address (current) distributional equity: by taking actions to protect future generations (who presumably will be better off than current ones), we reduce the resources available to help today's poor in developing countries.

The Path Ahead

Global climate change — perhaps even more than other environmental problems — can be addressed successfully only with a solid understanding of its economic dimensions. A substantial body of economic literature can be brought to bear on the three broad questions that are raised by the threat of global climate change: what will be the benefits of global climate policies; what will be their costs; and how can this information about alternative policies be assimilated in ways that are ultimately most useful for decision makers? Although the existing literature from decades of economic analysis is helpful in addressing these questions, the truth is that global climate change policy — because of the magnitude of its anticipated benefits and costs, its great time horizons, massive uncertainties, and physical and economic irreversibilities — presents unprecedented challenges to economic research, as it does to the other social and natural sciences.

The five reports that follow this one stake out a number of the frontiers of that research, addressing in turn five particularly timely and important aspects of the overall puzzle. First, in an overview of economic models, John Weyant provides a much-needed user's guide to the large-scale integrated assessment models that continue to be central to much of the research and many of the policy debates on global climate change. Weyant reviews the structure, data, and findings of 14 of the most prominent large-scale economic models, and explains how the models differ, how they do not, and how their results relate to one another.

One of the key determinants identified by Weyant — the role played in respective models by technological change — becomes the sole focus of the second report, "Technological Change and its Effects on Mitigation Costs," by Jae Edmonds, Joseph Roop, and Michael Scott. These authors emphasize that understanding the way technologies evolve and penetrate the market is essential to understanding methods of addressing global climate change. Their focus, then, is on the ways in which technological change is captured by climate change policy modelers, with particular attention to two idealized approaches: top-down and bottom-up. Their conclusion is consistent with Weyant's, namely that in order to understand the implications of large-scale economic models of the climate change problem, it is essential to understand first the assumptions that have been made regarding the path of technological progress.

Much of the analysis of technological change in the global climate policy context has focused directly on products and processes related to the generation and use of energy, because of the prominence of fossil-fuel combustion and consequent CO_2 emissions as a major contributor to the accumulation of greenhouse gases in the atmosphere. The area of technological change that has been most dramatic over the past decade, however, has surely been information technology. What effects, if any, will the emergence of the related "new economy" have on the costs of achieving global climate targets?

This question is the topic of the third report, "The New Economy: Implications for Climate Change Policy," by Everett Ehrlich and Anthony Brunello. Drawing upon both economic theory and empirical evidence, they first argue that with the marginal cost of processing information falling, there will be substitution of information and information-related activities for energy in the production of goods and services. Second, they find that this will lead to more specialization and greater outsourcing of energy service management. Third, empirical analysis suggests that consequent changes in the capital stock will mean that policies intended to reduce CO_2 emissions will have more benign effects on the economy than otherwise. Their overall conclusion is that the information revolution will cause the economic costs of climate change policies to be lower than previously thought.

If there is one lesson that has been learned from the 30 years of environmental policy experience that began with the first Earth Day, it is that flexible environmental policies cost less than more rigid ones. In particular, market-based instruments, such as taxes and tradeable permit systems, can enable governments to achieve their environmental targets at lower aggregate costs than via conventional, command-and-control approaches. Given the magnitude of the global climate change problem, the potential for cost savings with such instruments is enormous, and this is documented in the fourth report, "International Emissions Trading," by Jae Edmonds, Michael Scott, Joseph Roop, and Christopher MacCracken.

With some simple, but powerful numerical examples, and with a review of the results from eight models of carbon trading, the authors are able to document the degree to which international greenhouse gas emissions trading would lower overall mitigation costs. They highlight the fact that the cost savings will increase if greater flexibility is provided in trading mechanisms, such as by allowing trade among the major greenhouse gases, across types of sources, and over time. But the authors also note that the full economic potential of these trading regimes will be reached only if crucial issues of program design and institutional structure are successfully addressed.

Finally, as I emphasized above, because climate policy compliance costs are initially incurred by private firms, it is essential to analyze the behavioral response of such firms to various policy regimes. Nearly all economic analyses treat firms as atomistic profit-maximizing or cost-minimizing units, but firms are vastly more complex. Although such simplifying assumptions are satisfactory for many purposes, it is useful to go inside the black box of the firm to understand private industry's approach to the climate problem and potential solutions. This is precisely the purpose of the final report in this chapter, "A Business Manager's Approach to Climate Change," by Forest Reinhardt and Kimberly Packard.

The authors address a key question: how can managers reconcile the goals of improving both shareholder value and environmental performance? This is a question that has generated considerable debate in the past, but that debate has all too often been dominated by extreme and misleading views: on the one hand, by wishful thinkers who see "win-win opportunities" even where there are severe tradeoffs between environmental and private financial goals; and, on the other hand, by ideologues who portray all environmental regulations as crippling for business. Packard and Reinhardt make sense of this confused and confusing debate, and thus describe a more sensible path for business managers in the face of real concerns about global climate change and the new policies that such concerns may bring forth.

Overall, the five reports that follow provide instructive examples of how economics can offer powerful analytical methods for investigating the problem of global climate change, and how economic analysis can thereby provide valuable insights about potential solutions to this very challenging problem.

Endnotes

1. Looked at somewhat differently, but still well within the framework of conventional economics, the problem is that the atmosphere is treated as "common property," and hence a freely-available receptacle for waste products.

2. A generic, but more detailed treatment of the basic analytical framework can be found in U.S. Environmental Protection Agency (1998).

3. For a more extensive treatment of some of these issues, see Kolstad and Toman (2000).

4. Although the pace of economic research on global climate change has accelerated greatly in the past decade, the earliest work appeared more than 25 years ago. See, for example, Nordhaus (1977, 1982).

5. For a summary of myths that non-economists seem to have regarding economics, and a set of responses thereto, see Fullerton and Stavins (1998).

6. Reference is typically made to "willingness-to-pay" for environmental improvement or "willingness-to-accept" compensation for environmental degradation.

7. For a comprehensive treatment of the theory and methods of environmental benefit estimation, see Freeman (1993).

8. In assessing these economic damages, economists recognize that humans typically adapt to risk — to some degree — in order to lower their anticipated losses.

9. A review of the likely economic damages of global climate change is provided by Pearce et al. (1996).

10. Costs and benefits are thus two sides of the same coin. Environmental benefits are created by taking some environmental policy action, while other benefits are thereby foregone. Hence, the cost of an environmental-protection measure may be defined as the gross decrease in benefits (consumer and producer surpluses) associated with the measure and with any price and/or income changes that may result (Cropper and Oates 1992).

11. One example in the United States is the (federal) regulation of contaminants in drinking water, the cost of which is borne primarily by municipal governments.

12. The notion that environmental regulation can foster economic growth is a controversial one among economists. For a debate on this proposition, see Porter and van der Linde (1995); and Palmer, Oates, and Portney (1995). It is also important to recognize that good economic analysis can be used (and has been used) to identify circumstances where policies involve real "negative opportunity costs," such as policies that increase energy efficiency by reducing distortionary energy subsidies. In these cases, economic analysis can identify true "win-win" policy options.

13. For example, if a firm chooses to close a plant because of a new regulation (rather than installing expensive control equipment), this would be counted as zero cost in narrow compliance-cost estimates, but it is obviously a real cost.

14. This is measured by net benefits: the difference between benefits and costs.

15. For a comprehensive review of worldwide experiences with market-based instruments for environmental protection, see Stavins (2000).

16. As mentioned earlier, climate policy instruments can impose additional costs through their interaction with pre-existing distortionary taxes. This raises another issue for cost comparisons since some policy instruments, such as taxes and auctioned permits, generate revenues, which can be used by governments to reduce pre-existing taxes, thereby reducing what the overall costs of the policy would otherwise be (Goulder 1995).

17. What rate should be used to carry out this discounting? There is extensive literature in economics that addresses this question. A comprehensive summary was provided by Lind (1982), and a more recent exploration was organized by Portney and Weyant (1999).

18. The time dimension is also crucial, of course, in one type of distributional analysis, namely intertemporal distribution, as is discussed below.

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