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ECONOMICS OF CLIMATE CHANGE AND POLICY RESPONSES FOR STABILIZATION, MITIGATION AND ADAPTATION

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CLIMATE change presents a unique challenge for economics: it is the greatest and widest-ranging market failure ever seen. The economic analysis must therefore be global, deal with long time horizons, have the economics of risk and uncertainty at centre stage, and examine the possibility of major, non-marginal change.

Economics has much to say about assessing and managing the risks of climate change, and about how to design national and international policy responses for both the reduction of emissions and adaptation. The present paper draws on ideas and techniques from most of the important areas of economics, including many recent advances.

Key Words: Climate Change, Mitigation, Adaptation.

Introduction

The prospect of global climate change has emerged as a major scientific and public policy issue. Scientific studies indicate that accumulated carbon dioxide (CO2) emitted from the burning of fossil fuels, along with contributions from other human-induced greenhouse gas emissions, is leading to warmer surface temperatures. Possible current-century consequences of this temperature increase include increased frequency of extreme temperature events (such as heat waves), heightened storm intensity, altered precipitation patterns, sea-level rise, and reversal of ocean currents. These changes, in turn, can have significant effects on the functioning of ecosystems, the viability of wildlife, and the well-being of humans. There is considerable disagreement within and among nations as to what policies, if any, should be introduced to mitigate and perhaps prevent climate change and its various impacts. Despite the disagreements, in recent years we have witnessed the gradual emergence of a range of international and domestic climate change policies, including emissions trading programs, emissions taxes, performance standards, and technology promoting programs.

In past few years climate change economics has focused on diagnosing the economic underpinnings of climate change and offering positive and normative analyses of policies to confront the problem. While overlapping with other areas of environmental economics, climate change economics has a unique focus because of distinctive features of the climate problem – including the long time scale, the extent and nature of uncertainties, the international scope of the issue, and the uneven distribution of policy benefits and costs across space and time.

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Economic Issues of Climate Change

There is a tendency in economics to focus on the big picture and key messages. In the arena of climate change, these might be: a global externality requiring global cooperation, international emissions trading lower costs for all nations, and emissions pricing is the key to the development of new, climate-friendly technologies. Such thinking clearly shaped the design of the Kyoto Protocol, a climate change treaty negotiated by more than 140 nations that establishes a global emissions trading system for greenhouse gases. And even among those who might quibble with the particular targets, timetables, or mechanisms, many would embrace the overall architecture of global cooperation and international emissions trading. But is this the right message for economists to be bringing to the table? To the extent that economics is fundamentally about informing better public policy decisions, as well as understanding economic (and human) behaviour as a means to that end, the discipline must confront three pieces of information in conflict with the earlier message. First, the United States is not part of the Kyoto agreement now and, for many reasons, probably may not ever join a Kyoto-like agreement. Second, developing countries are not lining up behind the Kyoto idea of binding emissions limits, a necessity for conventional emissions trading. Third, the kinds of technologies we need to solve the long-term climate challenge currently are not available at the prices many nations are willing to pay. For economic insight to be relevant to the climate policy debate, these facts need to be embraced.

Economics and the Science of Climate Change

Economist Statements on Climate Change

The review conducted by a distinguished international panel of scientists under the auspices of the Intergovernmental Panel on Climate Change has determined that "the balance of evidence suggests a discernible human influence on global climate." As economists, we believe that global climate change carries with it significant environmental, economic, social, and geopolitical risks, and that preventive steps are justified.

Economic studies have found that there are many potential policies to reduce greenhouse- gas emissions for which the total benefits outweigh the total costs. For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve U.S. productivity in the longer run.

The most efficient approach to slowing climate change is through market-based policies. In order for the world to achieve its climatic objectives at minimum cost, a cooperative approach among nations is required – such as an international emissions trading agreement. The United States and other nations can most efficiently implement their climate policies through market mechanisms, such as carbon taxes or the auction of emissions permits. The revenues generated from such policies can effectively be used to reduce the deficit or to lower existing taxes.

The first point of the Economists' Statement recognizes the essential contribution of the world's leading experts on climate science who made up the scientific assessment panels of the Intergovernmental Panel on Climate Change (IPCC).The basic physics of the greenhouse effect is beyond dispute; indeed, the fundamental mechanism by which anthropogenic emissions of greenhouse gases increase global temperatures was understood in the 19th Century by Arrhenius and others. The presence of trace greenhouse gases in the atmosphere is what makes the Earth habitable, and these gases account for much of the variation in the surface temperatures of the inner planets of the Solar System. Without the carbon dioxide and water vapor that are the Earth's main greenhouse gases, the average surface temperature would be -18° Centigrade, below the freezing point of water, instead of the observed value of 15°C (IPCC, 1990).

Working Group I of the IPCC found that "the balance of evidence suggests a discernible human influence on global climate." While this is perhaps the most quotable of Working Group I's findings, it is not the only relevant one. The IPCC Report also concluded that "a general warming is expected to lead to an increase in the occurrence of extremely hot days and a decrease in the occurrence of extremely cold days" and that "warmer temperatures will lead to a more vigorous hydrological cycle; this translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places. Several models indicate an increase in precipitation intensity, suggesting a possibility for more extreme rainfall events….Further unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature, difficult to predict. This implies that future climate changes may also involve 'surprises.' In particular these arise from the non-linear nature of the climate system…." (IPCC, 1996a).

Even though economists ordinarily are not directly involved in research in atmospheric science, oceanography, biological ecology, or paleoclimatology (some of the disciplines most heavily involved in current work on climate change), economists do have experience that can help them assimilate the findings of the natural scientists. Economists also use some of the same techniques as those employed by climatologists. Working with large mathematical models is one element of common methodology; but economists are also familiar with the effects of feedbacks in complicated systems, with the abrupt changes that characterize non-linear systems, and with the sensitivity of modeling results to choices of assumptions and parameters. Economists are aware of the way progress is made in science – through vigorous debate, peer review, and empirical testing of hypotheses. The deliberations of the IPCC (and voluminous peer-reviewed literature upon which its reports are based) bear the hallmarks of a healthy scientific process. Economists understand that the findings of Working Group I of the IPCC represent a cautious, mainstream consensus on the current state of scientific knowledge about climate change. As such, the conclusions of Working Group I form a suitable starting point for policy analysis.

The Economists' Statement recognizes that although scientific understanding of the climate system is not complete, it is appropriate to take measures now to address potential climate change. Uncertainties may be real, but they do not justify inaction. Economics can provide guidance on how to deal with the uncertainties, and has much to say regarding the effectiveness and efficiency of alternative policies. Economic reasoning and evidence can help delineate the scope of the climate change problem, and can point the way to a rational societal response. But it should always be kept in mind that sound economics is a necessary but not a sufficient condition for good policy; the decisions needed to protect future generations from climate change have ethical and cultural dimensions that extend beyond the narrow boundaries of economics. (IPCC, 1996a,b,c and DeCanio, S.J., 1997, 99*)*

Assessing the Benefits and Costs of Climate Change Mitigation

As noted, the potential consequences of climate change include increased average temperatures, greater frequency of extreme temperature events, altered precipitation patterns, and sea level rise. These biophysical changes affect human welfare. While the distinction is imperfect, economists divide the (often negative) welfare impacts into two main categories: market and non-market damages.

Market damages**:** As the name suggests, market damages are the welfare impacts stemming from changes in prices or quantities of marketed goods. Changes in productivity typically underlie these impacts. Often researchers have employed climate-dependent production functions to model these changes, specifying wheat production, for example, as a function of climate variables such as temperature and precipitation. In addition to agriculture, this approach has been applied in other industries, including forestry; energy services, water utilities, and coastal flooding from sea level rise (Mansur, Mendelsohn and Morrison, 2005). The production function approach tends to ignore possibilities for substitution across products, which motivates an alternative, hedonic approach (Nordhaus, 1991, 2002). Applied to agriculture, the hedonic approach aims to embrace a wider range of substitution options, employing cross-section data to examine how geographical, physical, and climate variables are related to the prices of agricultural land. On the assumption that crops are chosen to maximize rents, that rents reflect the productivity of a given plot of land relative to that of marginal land, and that land prices are the present value of land rents, the impact of climate variables on land prices is an indicator of their impact on productivity after crop-substitution is allowed for.

***Non-market damages*:** Non-market damages include the direct utility loss stemming from a less hospitable climate, as well as welfare costs attributable to lost ecosystem services or lost biodiversity. For these damages, revealed-preference methods face major challenges because non-market impacts may not leave a "behavioural trail" of induced changes in prices or quantities that can be used to determine welfare changes. The loss of biodiversity, for example, does not have any obvious connection with price changes or observable demands. Partly because of the difficulties of revealed-preference approaches in this context, researchers often employ stated preference or interview techniques – most notably the contingent valuation method – to assess the willingness to pay to avoid non-market damages (Smith, 2004).

Cost Assessment

The costs of avoiding emissions of carbon dioxide, the principal greenhouse gas, depend on substitution possibilities on several margins: the ability to substitute across different fuels (which release different amounts of carbon dioxide per unit of energy); to substitute away from energy in general in production; and to shift away from energy-intensive goods. The greater the potential for substitution, the lower the costs of meeting a given emissions-reduction target. Applied models have taken two main approaches to assessing substitution options and costs. One approach employs "bottom-up" energy technology models with considerable detail on the technologies of specific energy processes or products. These models tend to concentrate on one sector or a small group of sectors and offer less information on abilities to substitute from energy in general or on how changes in the prices of energy-intensive goods affect intermediate and final demands for those goods. The other approach employs "top down," economy-wide models, which include, but are not limited to, computable general equilibrium models (see, for example, Jorgenson and Wilcoxen, 1996; Conrad, 2002). An attraction of these models is their ability to trace relationships between fuel costs, production methods, and consumer choices throughout the economy in an internally consistent way. However, they tend to include much less detail on specific energy processes or products. Substitution across fuels generally is captured through smooth production functions rather than through explicit attention to alternative discrete processes. In recent years, attempts have been made to reduce the gap between the two types of models. Bottom-up models have gained scope, and top-down models have incorporated greater detail.

Because climate depends on the atmospheric stock of greenhouse gases and because for most gases the residence times in the atmosphere are hundreds (and in some cases, thousands) of years, climate change is an inherently long-term problem and assumptions about technological change are particularly important. The modeling of technological change has advanced significantly beyond the early tradition that treated technological change as exogenous. Several recent models allow the rate or direction of technological progress to respond endogenously to policy interventions. Some models focus on R&D-based technological change, incorporating connections between policy interventions, incentives to research and development, and advances in knowledge (Nordhaus, 2002). Others emphasize learning-by-doing-based technological change, where production costs fall with cumulative output in keeping with the idea that cumulative output is associated with learning. Allowing for policy-induced technological change tends to yield lower (and sometimes significantly lower) assessments of the costs of reaching given emissions-reduction targets than do models in which technological change is exogenous.

Policy Responses for Stabilization, Mitigation and Adaptation

Point 3 of the Economists' Statement calls attention to the advantages of using market-based policies to reduce GHG emissions, and to the value of international cooperation in achieving the world's climate policy goals. Economic analysis is unequivocal that the kinds of policies implemented to achieve any particular GHG emissions reduction target will have a significant impact on the costs. At one end of the spectrum, mandating particular technologies on a facility-by-facility basis (the traditional "command and control" style of regulation) would be the most expensive way to achieve any particular emissions reduction target. At the other end of the spectrum, eliminating distortionary subsidies that actually encourage greenhouse-gas emissions would improve aggregate economic performance even if there were no benefit to slowing the pace of global warming. Economists since Pigou have understood that taxes on pollution or other activities that have negative external effects can improve general economic welfare. In the case of greenhouse-gas emissions, the most appropriate tax would be a charge on the emission of carbon dioxide or other greenhouse gases proportional to their global warming potential. Such a tax is often referred to as a "carbon tax," although this is really a shorthand phrase to describe a tax on greenhouse-gas emissions of all types. The advantage of a carbon tax is that it conveys information about the adverse effects of an activity (such as burning fossil fuels) in the price of the activity, thereby allowing the decentralized decision-makers to determine their own arrangements for best using their resources to pursue their own ends. Pricing the externality with a carbon tax allows the market and the environment to be mutually supportive – market activities will be guided, as if by Adam Smith's metaphorical invisible hand, to take environmental values into account.

The same marriage of market forces and environmental protection can be accomplished through government issuance of permits to emit greenhouse gases. The government can determine the desired level of emissions on scientific grounds (with a goal of achieving a given atmospheric concentration of greenhouse gases by a particular date, for example) and issue permits that will allow that goal to be met. The permits would be tradable, and would have a price that reflects the cost of meeting the emissions targets in the most economical way. The number of permits could be varied as new scientific information on the effects of climate change is obtained. In either case, the government can use the tax revenues (or the proceeds from auctioning the permits) to reduce other taxes or to reduce the deficit. The choice will depend on the political process shaping public finance; economists are in agreement that judicious use of the tax or permit revenues can reduce the impact of the environmental protection measures on the rest of the economy. For similar reasons, international cooperation is a way of achieving global climate objectives at minimum cost. The cost of emissions reductions varies widely across countries, sectors, and activities. Construction of more-efficient rather than less efficient electricity generation facilities in China will reduce atmospheric greenhouse-gas loadings as surely as removal of an equal amount of CO2 through actions taken in the United States. The cost of reducing the Chinese power plant emissions may be much less than the cost of equivalent emissions reductions in the United States. If both countries can cooperate, a given emissions reduction target can be reached at a lower cost than if each country were to act on its own. Cost minimization is not the only reason for seeking international agreement in climate policy. Growth and equity also provide a basis for multilateral action. World-wide economic growth is beneficial for all countries; increased productivity in developing countries raises demand for the exports of developed countries, and creates the kinds of goods and services consumers in the developed countries wish to buy. If environmental objectives can be met through policies that stimulate growth, everyone benefits. Thus, international cooperation to assure that environmental protection measures are consistent with the development aspirations of the poorer countries will be globally beneficial in the long run. International emissions trading agreement of the type visualized in the Economists' Statement is one kind of mechanism that would promote both efficiency and fairness. One roadblock to negotiating a successful climate protection agreement is the concern expressed by some in the developed countries over whether developing nations will adhere to a schedule of GHG reductions similar to that of the already industrialized countries. It is important to keep in mind that although it is projected that developing countries' annual GHG emissions will match those of the OECD countries by 2020 (IPCC 1996c), the large majority of emissions to date have originated from the developed countries. On a cumulative basis, the OECD countries plus the former Soviet Union have contributed 67% of total global CO2 emissions since 1800. A principle of international equity specifying some sort of cumulative emissions budget for countries (depending on their size, of course) would produce incentives for earlier cuts in emissions by developed countries than by developing countries. It is working out the details and specifics of a global agreement that will call for patience and ingenuity, and some period of learning, institution building, and additional negotiation is likely to be required. It should be kept in mind that neither China nor India signed the original Montreal Protocol in 1987 because they feared that reductions in CFCs would set back their economic development; yet both countries joined the Protocol after the London Amendment in 1990 established a very modest (but symbolically important) Multilateral Fund to compensate them for the incremental costs of adherence to the Protocol. Just as stabilization of the climate can most effectively be accomplished through a coordinated climate policy involving all the major economies of the world, co-operation in the design of that policy is the clearest way to ensure that technology transfer and trade expansion are helped rather than hindered by the environmental control measures. The global environment can be a source of contention or cooperation among nations – contention if climate crises exacerbate international tensions that already exist, cooperation if the interests of all parties are taken into account and respected. The Montreal Protocol shows that cooperation is possible, effective, and mutually beneficial. It is a worthy goal for the 21st Century to seek the same sort of international consensus on measures to protect the global climate (Pizer, 2002).

Conclusion

Climate change economics has produced new methods for evaluating environmental benefits, for determining costs in the presence of various market distortions or imperfections, for making policy choices under uncertainty, and for allowing flexibility in policy responses. Although major uncertainties remain, it has helped generate important guidelines for policy choice that remain valid under a wide range of potential empirical conditions. It also has helped focus empirical work by making clear where better information about key parameters would be most valuable. From 2003 until 2030, the world is poised to invest an estimated $16 trillion in energy infrastructure, with annual carbon dioxide emissions estimated to rise by 60 percent. How well economists answer important remaining questions about climate change could have a profound impact on the nature and consequences of that investment.

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