ECONOMIC ANALYSIS OF CLIMATE CHANGE

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1. Introduction

Economic analyses of climate change seek to establish, first, the appropriate level of greenhouse gas emission reduction and, second, the appropriate way to implement emission abatement. Climate change is a truly global and long-term problem. The uncertainties are large. Climate change and emission abatement interacts with many other issues of environment and development. Greenhouse gas emitting activities are pervasive. Both emission abatement and climate change have substantial ramifications for equity, and affect efficiency as well. Thus, the questions how much and how to reduce greenhouse gas emissions are hard to answer. In addition, climate change cannot be defined as a strictly economic problem. The insights of other disciplines, including climatology, hydrology, ecology, law, anthropology and political science, are equally important. This combination of characteristics makes economic analysis of climate change into a major intellectual challenge.

2. Impacts of Climate Change

The impacts of climate change are manifold. Changes in temperature, precipitation, and wind affect nature, agriculture, diseases, water resources, energy consumption, transport, tourism, and so on. Sea level rise affects coasts. In most cases, changes in weather extremes are more important than changes in the mean. In all cases, impact is a combination of exposure and adaptation. Adaptive capacity depends on the overall health and resilience of an impacted system, on development and institutions and other stresses. Climate change impacts thus vary greatly from system to system, from place to place, and from time to time. However, a number of generalizations can be made.

Climate change has both negative and positive impacts. The negative impacts are associated with sea level rise, worsening droughts and floods, spread of disease vectors, and increases in heat-related problems. The positive impacts are associated with CO_2 fertilization (ambient CO_2 is a limiting factor to plant growth), alleviation of droughts and floods (the hydrological effects of climate change are specific to location and time of year; it is possible that one place experiences heavier floods in spring and worse droughts in summer; other places may see both reduced floods and droughts, while yet other places would see little change; on average, however, the hydrological cycle will be intensified, that is, more precipitation and more concentrated precipitation), and decreases in cold-related diseases and other problems. Currently hot regions are more likely to be negatively affected. Currently cold regions are more likely to be positively affected. Although globally averaged precipitation is likely to increase, local and regional precipitation could go up or down, and seasonal patterns may change. Regions currently plagued by too little or too much water, stand to lose or gain most by changes in precipitation. Drought problems in agriculture are partly alleviated by an increase in ambient carbon dioxide, allowing plants to use available water more efficiently. Overall, positive impacts seem likely to dominate negative impacts for a modest change in climate, say some 2˚C global warming. Negative impacts seem to dominate for more severe climate change, say above about 2˚C global warming.

Climate change impacts reflect adaptive capacity. Highly specialized, resource-scarce, or marginalized individuals, systems, sectors, regions and species are most at risk. In fact, such are at risk from any stress, climate change just adds to other problems. For natural system, this argument implies that unique systems and rare species are most at risk. For humans, it implies that the poor (in income, knowledge, access) are most vulnerable to climate change. The poor here refers to both poor countries and to poor people in richer countries. The poor also tend to depend to a greater extent on primary resources directly affected by climate, particularly agriculture and water.

Adaptation takes time. Systems have to readjust to the changed circumstances. While readjusting, systems will make sub-optimal use of their available resources and will be sub-optimally exposed to weather-related disasters. If climate change is slow, systems have to evolve only slowly, and the distance between actual and optimal resource use and exposure is small. Fast climate change, however, would have more detrimental impacts.

Expressed in money, the overall impact of climate change is unlikely to be dramatic. Estimates of the impact of a doubling of the atmospheric concentration of carbon dioxide on current society suggest that the aggregate world damage lies somewhere in between a positive 0.5% of GDP and a negative 1.5% of GDP.

However, climate change is seldom judged from an efficiency, or cost-benefit perspective. Instead, climate change impacts are often viewed from a precautionary perspective. Uncertainties about future greenhouse gas emissions, about climate change and about its impacts are large. It is also not implausible that large-scale discontinuities would occur, such as major shifts in ocean currents or rapid disintegration of the West-Antarctic ice sheet. The implications of such events have hardly been studied, but are likely to be immense.

3. Impacts of Carbon Dioxide Emission Reduction

The most important greenhouse gas is carbon dioxide. Its main source is fossil fuel combustion. Land use change, particularly deforestation, also emits large quantities of carbon dioxide. Methane is the second most important greenhouse gas. It originates from coal mining, natural gas distribution, wet rice cultivation, and cattle. Nitrous oxide, SF_6, and HCFCs originate from industrial processes. Little is known about the costs of reducing the emissions of other greenhouse gases than CO_2 from fossil fuel combustion. This chapter is therefore limited to the abatement of CO_2 emissions that result from the burning of fossil fuels.

There are two basic ways of reducing CO_2 emissions. First, one can increase energy efficiency. Second, one can switch to alternative energy sources, such as solar, wind, biomass, nuclear, or hydropower. There are a large number of technologies available for both basic options. Some of these are proven technologies, others exist only as a blueprint. Together, alternative technologies can readily meet current and future energy demand. For now, alternative technologies tend to be considerably more expensive than fossil fuel based technologies. Even if alternative technologies were competitive, the energy sector is very inert. Power plants, and other capital investments related to the generation and use of energy, have a life-time of decades. Reducing CO_2 emissions is not merely a technological problem; it is also a significant economic problem.

Engineering studies suggest that many energy saving and alternative energy technologies are economically viable, some in the short term and most in the long term. Such studies may well have overlooked a number of costs and other barriers for implementation. These studies do indicate that large CO_2 emission reductions are possible at a relatively modest cost.

Economic studies confirm this conclusion. It is possible to reduce emissions by a few percent per year (from baseline; emission reduction from a base year (1990, say) would be more expensive as emissions are projected to grow by a few percent per year (this is the baseline)) while only modestly slowing down economic growth. Faster emission reduction is considerably more expensive, for two reasons. First, fast emission reduction would require either modifying or replacing existing means of production. (Slow emission reduction would be limited to newly installed capital.) Second, fast emission reduction would require the use of less mature alternatives, for which large scale, commercial production is more remote.

Although CO_2 emission reduction may be relatively inexpensive for the economy as a whole, this is not the case for each sector, country, or income class. Obviously, those that make a living out of selling coal and, to a lesser extent, oil, would be hit hard. Sellers of natural gas, which yields more energy per ton of CO_2 emitted, may benefit, particularly in the short and medium term. Energy-intensive industries (e.g., chemicals, steel) would face substantial price increases for their major input factors. Other, less energy-intensive industries would barely notice the effects, or may even benefit. The lower income classes, who spend a relatively large share of their income on energy, would be relatively bad off.

Industries and technologies with different energy- and carbon-intensities also have different labor-intensities. It is therefore expected that CO_2 emission reduction have an impact effects on labor markets. Such an impact may be substantial and positive if the revenues of a carbon tax, or the proceeds from auctioning carbon permits, are used to stimulate employment. Emission abatement policies also affect air quality, because air pollutants largely originate from fossil fuel combustion as well. It should be noted that these *double dividends* may reduce the costs of greenhouse gas emission reduction, but that double dividends cannot *justify* greenhouse gas emission reduction.

There are a variety of international effects of domestic carbon dioxide emission abatement. If a country reduces its emissions further than its main trading partners, its export industries' competitiveness may be negatively affected. This would increase the cost of emission reduction, because export losses would be added to the direct costs. It may also lead to a displacement of production, so that emission reductions in one country are partly offset by emission increases in other countries. Such *leakage* may be as large as 20 or 30%. Leakage is likely to be accompanied by a shift in investment from ambitious emission reducing countries to modest reducers. This would stimulate economic growth in the latter countries. Emission reduction would reduce the international demand for coal and oil, negatively affecting exporting countries. This could cause the world market prices to fall, reducing the effectiveness of emission abatement policies, and benefiting coal and oil importers. Because different economies have different sectoral compositions, emission abatement would change the terms of trade. Emission reduction would reduce economic growth, thus reducing import demand. Exporters of primary commodities would be hit hardest by this.

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Biographical Sketch

Professor Dr Richard S.J. Tol is a Senior Research Officer at the Economic and Social Research Institute and also affiliated with Vrije, Carnegie Mellon and Hamburg universities. An economist and statistician, his work focuses on impacts of climate change, international climate policy, tourism, and land and water use. He is the 44^{th}-most prolific economist in the world. He is an editor of *Energy Economics.* He has played an active role in international bodies such as the Stanford Energy Modeling Forum, the Intergovernmental Panel on Climate Change, the Global Trade Analysis Project, and the European Forum on Integrated Environmental Assessment.