ECONOMICS FOR EQUITY & ENVIRONMENT

Towards Greater Transparency in Climate Economics: Deconstructing DICE-2007

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a brief prepared for
Economics for Equity and the Environment Network[1]
April 2009

- William Nordhaus' DICE model, one of the best-known and most influential climate economics model, is very sensitive to changes in its underlying assumptions.
- A slight modification to the damage function results in a much higher estimated cost of allowing climate change to continue.
- A slight modification to the abatement function results in a much lower estimated cost of stopping or slowing climate change.

Today's scientific models of climate change have achieved remarkably detailed forecasts of future climatic conditions, with a gradually increasing degree of consensus between models. In the realm of economics, however, there is much less agreement about the laws and patterns that will govern future development. Numerous economic models weigh the costs of allowing climate change to continue against the costs of stopping or slowing it, and thus recommend a "best" course of action: one that, given the assumptions of the model, would cause the least harm. But there is little indication of an impending accord among climate economists.

The results of climate economics models depend on facts about the physical world, on theories about economic growth, and on ethical and political judgments. To the extent that climate policy relies on the recommendations of economic models, it is vulnerable to assumptions hidden in their inner workings. It is, therefore, of paramount importance that the economic models that shape our climate policy be not only as accurate and up-to-date as possible in their scientific content, but also as transparent as possible in their ethical, political, and economic content.

Perhaps the best-known and most influential climate economics model, William Nordhaus' Dynamic Integrated model of Climate and the Economy (DICE), links a simple representation of the climatic impacts of greenhouse gases to a simple representation of economic growth,

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[1] Economics for Equity and the Environment Network (E3) is a nationwide network of economists developing arguments for environmental protection with a social equity focus. For more information, please contact Kristen Sheeran, Director, at ksheeran@e3network.org. E3 is a program of Ecotrust.

driven by a process designed to maximize economic well-being. The DICE climate and economic models share two feedback mechanisms: a damage function, relating temperature increase to economic and social costs; and an abatement function that describes the costs associated with reducing carbon emissions. The recent update (2007) of DICE yields a basic forecast of the "social cost of carbon" (SCC) – the combined current and future impacts of an additional ton of carbon – of $21/tC in 2005 or $216/tC in 2105. The implication is that any abatement policy that cost less than this would result in a net benefit to society. DICE recommends a gradual increase in emission controls to achieve completely carbon-free production in 2235, with the increase in global mean temperature reaching 3.3º (above year 1900) in 2215 before beginning to decline. Following this policy prescription, 45 percent of world production would be carbon-free in the year 2100.

The DICE climate model and economic model are relatively unremarkable (although the choice of discount rate – the value that we place on costs and benefits in the future – and the assumed pace of economy-wide technological advancement have powerful impacts that dominate the model's policy recommendations). The basic structure of DICE is flexible and can accommodate a wide assortment of assumptions about damage and abatement costs. These feedback mechanisms are also the most conjectural parts of the model: Who can know with any certainty what economic impacts will transpire at 1º, 2º, or 3º increase in global mean temperature, or 50, 100, or 150 years in the future? How can we predict with any accuracy the costs of technology not yet invented? Yet these judgments are all-important to the model: as described below, DICE is extremely sensitive to small changes to the set of assumptions that makes up its damage and abatement functions.

Costs of Allowing Climate Change to Continue

In DICE, damage costs as a share of gross world output grow in proportion to the square of increases in global mean temperature (relative to 1900). The damage function's parameter and exponent are cited as having been set with the goal of matching as closely as possible Nordhaus' two point estimates of damages from climate change: at 2.5°, 2 percent, and at 6°, 11 percent of gross world output. The damage costs for a 1° increase from 1900 implied by this function are 0.3 percent of gross world output.

The 2.5° damage costs on which the DICE damage function is based are the sum of six categories of non-catastrophic climate change damage and an additional estimate for catastrophic damage. These include three kinds of market impacts: agriculture, other vulnerable markets, and damage to coastal property from rising sea-level. Damage costs also include monetary values for three categories of non-market impacts: lives lost to climate change, the pleasure derived form living in a warmer climate, and damage to human settlements and natural ecosystems. Similar explanations of the damage costs assumed for catastrophic impacts at 2.5º and for both non-catastrophic and catastrophic impacts at 6º are not included in the DICE materials.

Revising the DICE damage function to approximate Richard Tol's (2002) higher estimated damage costs of 2.7 percent of world product at 1.7º increase since 1900 (maintaining the rate of increase) results in an impressive change to the model recommendations: an initial SCC of $59/tC and an abatement path that reaches zero industrial emissions in 2145.

Costs of Stopping or Slowing Climate Change

The DICE abatement cost function makes the strange assumption that the price of carbon-free technologies will decline over time regardless of the amount of investment in abatement. The costs, as a share of gross world output, of abating greenhouse gas emissions are the "backstop" costs (the extra cost of using emission-free technology) weighted by a rapidly increasing function of the emissions control rate. This formula results in marginal costs rising as the control rate rises (and the easiest and cheapest abatement strategies are exhausted) and average costs falling autonomously over time. Backstop costs are a function of the CO_2-equivalent-emissions output ratio (or carbon intensity), which decreases autonomously over time, and an assumed decline rate in the cost of the backstop technology over time. The initial cost of abatement for a 100 percent emissions control rate is assumed to be 5.2 percent of world product.

Making backstop costs a function of cumulative abatement costs, assuming a 15 percent return from learning by doing to a doubling of cumulative abatement costs (in keeping with recent literature), can be achieved with a small change to the abatement cost function. The use of this revised abatement function results in no change in the initial SCC but a much more rapid path to total abatement than in the DICE recommendations, reaching zero industrial emissions in 2175. Alternatively, making the assumption that just 8 percent of carbon emissions can never be eliminated is enough to keep temperatures from dropping in centuries to come. Thus, the long-run behavior of DICE also depends on unobservable features of the abatement and damage cost functions.