The Challenge of Global Warming: Economic Models and Environmental Policy

William Nordhaus (Yale)

April 2007
Overview

- Outlines latest version of the Dynamic Integrated model of Climate and the Economy (DICE-2007)
- Incorporates greenhouse gas emission, climate change and damages into an aggregated Ramsey-style model
- Compares implications of alternative policy proposals to doing nothing and the "optimum"
Objective function:

\[ W = \sum_{t=0}^{T_{\text{max}}} \left( \frac{1}{1 + \rho} \right)^t \left( \frac{c_t^{1-\alpha}}{1 - \alpha} \right) L_t \]

where \( L_t \) follows a "logistic" function converging to 8.4 billion, \( c_t = C_t / L_t \) and \( T_{\text{max}} = 600 \) years (BGP)

Production Function:

\[ Q_t = \Omega_t \Lambda_t A_t K_t^\gamma L_t^{1-\gamma} \]

where \( C_t + I_t = Q_t \) and

\[ K_t = I_t + (1 - \delta_K) K_{t-1} \]
Geophysical Sectors

- Climate damage:

\[ \Omega_t = \frac{1}{1 + \psi_1 T_{At} + \psi_2 T_{At}^2} \]

where global mean surface temperature, \( T_{AT} \) evolves according to

\[
T_{At} = T_{At-1} + \zeta_1 \{ F_t - \zeta_2 T_{At-1} - \zeta_3 [ T_{At-1} - T_{Lt-1} ] \}
\]

\[
T_{Lt} = T_{Lt-1} + \zeta_4 [ T_{At-1} - T_{Lt-1} ]
\]

\[
F_t = \eta \left[ \ln \left( \frac{M_{At}}{M_{A,1750}} \right) \right] + F_{Xt}
\]

and the carbon cycle is represented by

\[
M_{At} = \pi E_t + \phi_{11} M_{At-1} + \phi M_{Ut-1}
\]

\[
M_{Ut} = (1 - \pi) E_t + \phi_{22} M_{Ut-1} + \phi_{32} M_{Lt-1} + \phi_{12} M_{At-1}
\]

\[
M_{Lt} = \phi_{33} M_{Lt-1} + \phi_{23} M_{Ut-1}
\]
• Abatement Costs:

\[ \Lambda_t = 1 - \theta_1 t \mu_t^{\theta_2} \]

where \( \mu_t \) = emission control rate (control variable)

• Total carbon emissions

\[ E_t = E_{lt} + E_{Lt} \]

where emissions from industry are given by

\[ E_{lt} = \sigma_t (1 - \mu_t) Q_t \]

← implicit price of CO\(_2\) :

\[ P_t = \frac{1}{\sigma_t (1 - \mu_t)} \]
Major Contentious Issues

- The subjective discount rate, $1/(1 + \rho)$ and $\alpha r$
- calibrated to long run growth of 1.4% and a real interest rate of 4.3%:
  $$\ln \frac{c_{t+1}}{c_t} \simeq \frac{r - \rho}{\alpha} = \frac{0.043 - 0.015}{2} = 0.014$$
- could have chosen $\rho = 0.001$ and $\alpha = 3$:
  $$\ln \frac{c_{t+1}}{c_t} \simeq \frac{0.043 - 0.001}{3} = 0.014$$
- makes a big difference to optimal policy and welfare implication

- Uncertainty
- Regional disaggregation
- RICE–2008
Alternative Policies Evaluated

- No controls (baseline)
- Optimal policy: $\mu_t$ set to maximize welfare objective
- CO$_2$ concentration constraints: upper limit on CO$_2$ ppm from 1900
- Temperature change constraints: upper limit on rise in °C from 1900
- Kyoto protocol (various versions): one off reduction to 5% below 1990 emissions by 2012
- Stern proposal: choose optimal $\mu_t$ under low discount rate, but evaluated under "observed" rate
- Gore proposal: rapid rise in $\mu_t$ from 15% to 90% by 2050
- Geoengineering?
Figure V-4. Carbon prices for different strategies
This figure shows the globally averaged carbon price of CO₂ under different strategies for the next century. Note the upward tilt of the strategies. Note these are per ton carbon; for prices per ton of CO₂, divide by 3.67. Prices are for 2008 for the first period.
Figure V-6. Global emissions of industrial CO₂ per decade by policy
Figure V-7. Atmospheric CO₂ concentrations by policies
Figure V-8. Projected global mean temperature change by scenario

Note that increases are relative to 1900 average.
Figure V-9. Per capita consumption, major runs
Figure V-1. Present value of alternative policies
The figure shows the difference in present value of a policy under two measures. The first bar is the objective function, and the second is the present value of the sum of abatement and damages. The policies are shown in Table IV-1. Note that the baseline is omitted as it has zero present value.
Figure V-2. Present value of alternative policies
The figure shows the same values as in Figure V-1 with the larger values omitted for clarity.
Figure V-3. Costs and benefits as percent of income
The figure separates costs and benefits for major policies and shows them as a percent of total income (all figures are discounted at the consumption discount rate). Figures are shown relative to the baseline of no controls.
Main Results

- Theoretical optimum implies gradually rising emissions, leveling out by 2100 and rapidly rising implicit carbon price
  - reduces rise in global temperature to $1.7^\circ C$ over next century
  - optimal price per ton of carbon is $23.4$ in 2007

- Alternative versions of Kyoto have almost no impact (both in terms of costs and benefits)

- More ambitious proposals (Stern and Gore): big reduction in emissions, but economically very costly due to initial rate of reduction

- Nordhaus: "Slow, steady, universal, predictable and boring — those are probably the secrets to success for policies to combat global warming."