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William D. Nordhaus

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ALTERNATIVE POLICIES AND SEA-LEVEL RISE IN THE RICE-2009 MODEL

By

William D. Nordhaus

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COWLES FOUNDATION FOR RESEARCH IN ECONOMICS
YALE UNIVERSITY
Box 208281
New Haven, Connecticut 06520-8281

http://cowles.econ.yale.edu/

Alternative Policies and Sea-Level Rise in the RICE-2009 Model[1]

William Nordhaus
Yale University
August 25, 2009

Abstract

The present study extends earlier research by presenting the results of a new and updated version of the RICE model (Regional Integrated model of Climate and the Economy), labeled the RICE-2009 model. The model is a regionalized, dynamic model that incorporates an end-to-end treatment of economic growth, emissions, climate change, damages, and emissions controls. The model allows projections of what will occur with no policies, with efficient policies be, how nations can undertake policies to limit climate change (in the current runs to 2 °C), and the impacts of limited participation. These new estimates indicate that coordinated international policies have a substantial economic benefit. The optimal carbon tax is estimated to be \$29 per ton carbon (\$8 per ton CO_2) for 2010 in 2005 prices. The economic optimum would limit global temperature rise to an average of 2.5 °C over 1900 levels for the 22nd and 23rd century.

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[1] This research has been supported by the National Science Foundation, the Department of Energy, the Glaser Foundation, and particularly by Yale University. The author is grateful for research assistance of Xi Chen and Mark Longhurst. Comments and suggestions from colleagues, especially Zili Yang, have been essential to the improvements in the models. This version reflect RICE model RICE-2009.beta.082509. This analysis supercedes the earlier working paper dated July 30, 2009. The main difference is that the earlier version used a different scaling procedure for combining countries.

The economics of global warming has become particularly salient with the engagement of the Obama Administration with proposals to undertake sharp cuts in carbon dioxide (CO_2) emissions. The present study extends earlier research by presenting the results of a new and updated version of the RICE model (Regional Integrated model of Climate and the Economy), labeled the RICE-2009 model. The model is a regionalized, dynamic model that incorporates an end-to-end treatment of economic growth, emissions, climate change, damages, and emissions controls. The model allows projections of what will occur with no policies, with an efficient set of policies, with policies to limit climate change (in the current runs to 2 °C), and with limited participation.

I. The RICE-2009 Model

I begin with a succinct description of the RICE model, beginning with the economic sectors and then discussing the geophysical sectors.[2]

The approach used here is to view climate change in the framework of economic growth theory. In the optimal growth model, or Ramsey model, society invests in tangible capital goods, thereby abstaining from consumption today, in order to increase consumption in the future (Ramsey 1928, Koopmans 1965). The DICE/RICE models are the extension of the Ramsey model to include climate investments. The capital stock of the conventional neoclassical growth model is extended to include investments in the environment. Emissions reductions in the extended model are analogous to investment in the mainstream model. That is, we can view concentrations of GHGs as "negative natural capital," and emissions reductions as lowering the quantity of negative natural capital. Emissions reductions lower consumption today but prevent economically harmful climate change and thereby increase consumption possibilities in the future.

The world is divided into 12 regions. Some are large countries (such as the U.S. or China); others are large regions (like the European Union or Latin

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[2] The model is available as an Excel spreadsheet on the author's web page at http://www.econ.yale.edu/~nordhaus/homepage/DICE2007.htm. These results are based on the "beta" version as of August 25, 2009.

America). Each region is assumed to have a well-defined set of preferences, represented by a social welfare function, which optimizes that regions consumption, greenhouse gas policies, and investment over time. The social welfare function is increasing in the per capita consumption of each generation, with diminishing marginal utility of consumption. The importance of a generation's per capita consumption depends on its relative size. The relative importance of different generations is measured using a pure rate of time preference, and the shape of the utility function is given by the elasticity of the marginal utility of consumption. These parameters are calibrated to ensure that the model real interest rate is close to the average real interest rate in real-world markets (Nordhaus 1994, IPCC Second Assessment, Economics 1995).

The model contains both a traditional economic sector found in many economic models and geophysical relationships designed for climate-change modeling. We first describe the traditional sector of the economy — the economy without any considerations of climate change.

A. Economic sectors

Each country or region is assumed to produce a single commodity which can be used for either consumption or investment. Each region is endowed with an initial stock of capital and labor and with an initial and region-specific level of technology. Population data are from United Nations 2004 updated with more recent estimates through 2008. Output estimates are purchasing power parity in 2005 U.S. international prices from the World Bank and the International Monetary Fund and are through 2008 with projections to 2014. CO_2 emissions are from the U.S. Energy Information Administration and are generally through 2006.

Population growth and technological change are exogenous in the baseline model, while capital accumulation is determined by optimizing the flow of consumption over time. Output is produced with a Cobb-Douglas production function in capital, labor, and carbon-energy inputs. Technological change takes two forms: economy-wide technological change and carbon-energy-saving technological change. Economy-wide technological change is Hicks neutral, while energy-saving technological change is modeled as reducing the ratio of CO_2 emissions to carbon-energy inputs. Technological change is projected for a frontier region (the U.S.), and other countries are assumed to have partial convergence to the frontier. For convenience, both carbon-energy and industrial emissions are measured in the same units of carbon weight (Nordhaus 1994, Nordhaus and Boyer 2000).

We calibrate the energy-related parameters using data on historical and projected GDP and CO_2 emissions, and particularly the CO_2-GDP ratio by region. We specify a cost function for CO_2 emissions reductions that is drawn from more detailed models at the national and regional levels from IPCC Fourth Assessment, Mitigation 2007. Additionally, there is a backstop technology which can replace all carbon fuels at a relatively high price ($1200 per ton C, declining over time, drawn from IPCC Carbon Capture 2001 and other sources). The supply curve allows for limited (albeit huge) long-run supplies of carbon fuels. Because of the optimal-growth framework, emissions are efficiently allocated across time, which implies that low-cost carbon resources have scarcity prices (called "Hotelling rents") and that carbon-energy prices rise over time (Hotelling 1931).

Solution of a multi-country general-economic equilibrium model poses major modeling issues (see Rutherford 2009). We have used a modification of the Negishi procedure introduced in Nordhaus and Yang 1996. The modification is that the welfare weights are set to equalize the period-by-period marginal utilities using the weighted average marginal utility, where the region-period weights are the region's share of the global capital stock.

B. Geophysical sectors

The geophysical part of the model contains a number of geophysical relationships that link together the different forces affecting climate change. This part contains a carbon cycle, a radiative forcing equation, climate-change equations, a climate-damage relationship, and a new sea-level rise module.

In the current vintage of models, endogenous emissions are limited to industrial CO_2. Chlorofluorocarbons (CFCs) are now outside the climate-change control strategy. Other contributions to global warming are taken as exogenous. These include CO_2 emissions from land-use changes, non-CO_2

greenhouse gases, and sulfate aerosols (Hansen et al. 2006, IPCC Fourth Assessment, Science 2007).

The model uses a three-reservoir model calibrated to existing carbon-cycle models to calculate the carbon cycle. Climate change is represented by global mean surface temperature, and the relationship uses the results of the Fourth Assessment Report of the IPCC to estimate the lag structure and the equilibrium (IPCC Fourth Assessment, Science 2007). The current version assumes that the equilibrium temperature-sensitivity coefficient is 3 °C per CO_2 doubling. The model has also been checked by comparing results with those of MAGICC 2009.

Understanding the economic impacts of climate change continues to be the thorniest issue in climate-change economics. The estimates of damages come from Nordhaus 2007. It assumes that the damage-output ratio is a quadratic function of global temperature increase. The damage ratio is 2.6 percent global output at a 3 °C increase and 10.2 percent at a 6 °C increase.

The current version of the RICE-2009 model does not differentiate the damage functions by regions because of the uncertainties associated with the damage estimates. We plan to introduce region-specific change functions in the next version.

There have been many recent studies concerned with abrupt and catastrophic climate change (Oppenheimer 1998, National Research Council, Committee on Abrupt Climate Change 2002, Oppenheimer and Alley 2004). Estimates for the economic costs of abrupt and catastrophic climate change are included in the damage estimates in the RICE model, but the model does not build in a precise tipping point at a given temperature increase because that has not be reliably determined.

C. Sea-level Rise

The RICE-2009 model contains a new module with calculations of sea-level rise (SLR).[3] This experimental model contains estimates of the SLR

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[3] The derivation of the SLR module as well as a spreadsheet showing the calculations are available on the author's web page at http://www.econ.yale.edu/~nordhaus/homepage/DICE2007.htm.

associated with different temperature trajectories. The SLR module has five sources: thermal expansion, small glaciers, Greenland Ice Sheet, West Antarctic Ice Sheet, and Other Antarctic Ice Sheet. The first two of these are relatively well modeled in current AOGCMs, while the latter three are subject to major uncertainties.

The model begins with the SLR-equivalent ice in each of the five components. Thermal expansion is a function of the temperature of the upper level of the oceans. For the ice sheets and glaciers, we assume a minimum melt threshold and a linear melt rate as a function of the difference between global mean temperature and the melt threshold.

Thermal expansion has been calibrated to both short-run and long-run model results of OAGCMs and is reasonably consistent with those. Estimates for the GIS are consistent with the model runs in AR4. The estimates for the WAIS are more speculative but are consistent with the consensus rather than the pessimistic views of the potential for disintegration of the WAIS. The details of the SLR module will be provided in an associated study.

II. Policy Scenarios

In the runs developed here, we present four alternatives:

1. Baseline: No climate change policies.
2. Optimal: Climate change policies maximize economic welfare with no participation or other constraints.
3. Limit temperature to 2 °C: The optimal policies are taken subject to a constraint that global temperature would not increase more than 2 °C above the 1900 average. This run is of interest because it has been widely supported by environmental activists.
4. Optimization with limited participation: A final run examines a cost-beneficial policy such as in 2 in which realistic timetables are placed for the participation of middle-income and developing countries.

The baseline can be interpreted as complete inaction and stalemate on climate policy. In this scenario, there are no climate policies. However, it is assumed that a zero-carbon backstop technology becomes competitive with current technologies in 2250, so emissions after that time are zero. The Optimal run provides the most efficient, or best possible, climate-change policies; in this context, efficient involves a balancing of costs of abatement and benefits of reduced climate damages. While it is unrealistic, it provides an economic benchmark against which other policies can be measured. The Limit policy is a variant of the Optimal which builds in a precautionary constraint that a specific temperature increase cannot be exceeded.

The limited-participation run reflects the likely reality that low-income countries will be relatively slow to participate in a global-warming regime. Table 1 shows the assumed year in which each region is assumed to join and the fraction of the emissions of that region which is assumed to be covered in these runs. See Nordhaus 2007 for a further description and discussion of these cases.

Region	Participation rate first year	Year first participation
US	0.95	2010
EU	0.95	2010
Japan	0.95	2010
Russia	0.80	2010
Non-Russian Eurasia	0.75	2010
China	0.75	2040
India	0.60	2050
Middle East	0.50	2050
Africa	0.50	2080
Latin America	0.80	2040
Other High Income	0.90	2010
Other Asia	0.60	2050

Table 1. Participation rates in limited participation runs

III. Major Results

A. The major cases

There are too many results to report comprehensively on the estimates. The program and results are available in a spreadsheet format at the author's website at http://www.econ.yale.edu/~nordhaus/homepage/DICE2007.htm.

The major results for the model are shown in Figures 1 through 12. Figure 1 shows the emissions under the four policies. Unrestrained emissions are estimated to grow very rapidly. Emissions under the optimal and temperature-limited paths are essentially flat for the next two to six decades and then decline after that. The optimal path finds a cut in global emissions of 50 percent from 2005 in 100 years, while the 2 °C temperature limit path prescribes zero emissions at about 2085.

Note that these are global figures. Proposals before the international community relate only to high-income countries and are substantially smaller on a global level. For example, if high-income countries reduce their emissions to *zero* in 2035 but no measures are taken in other countries, the RICE model indicates that the global temperature increase will peak at 5.3 °C rather than 6.2 °C in the baseline case

Atmospheric concentrations of CO_2 rise sharply under the baseline path, reaching 760 ppm by 2100 (see Figure 2). The two control paths have some slight continuation in the rise of concentrations from current levels, peaking between 500 and 600 ppm. (Note these refer to CO_2, not to CO_2-equivalent.) Radiative forcings shown in Figure 3 (which do include non-CO_2 GHGs) peak at 4.3 W/m^2 in the optimal path and at 3.4 W/m^2 in the temperature-limit path.

Global temperature projections, shown in Figure 4, rise sharply under the baseline, reaching 3.3 °C in 2100, 5.3 °C in 2200 and peaks at 6.2 °C (all relative to 1900). The other two paths rise for the early 21st century because of the momentum of past emissions. They then bend down as emissions reductions take place, peaking at 2 °C (obviously) for the temperature limit path and 2.7 °C for the optimal path. One important point to note is that the optimal path has a relatively low maximum temperature, and that the temperature increase averaged over the 2100-2300 period for the optimal case is 2.4 °C.

Figures 5 and 6 as well as Table 2 show the carbon prices in the different runs. The baseline carbon prices (which are the Hotelling rents on carbon fuels) are essentially zero. The optimal and temperature-limit prices start at $29 to $42 per ton carbon for 2010 in 2005 prices. The optimal prices grow sharply until they reach the projected backstop price. Note that the limited-participation run has only a slightly higher optimal carbon price because the marginal damages are only marginally higher with limited participation.

Figures 7 and 8 show the projected SLR. These are tentative at this point because they have not been compared with other integrated assessment models, although they have been compared with AOGCMs. Figure 7 shows that SLR in the base case is projected to be 0.65 meters from 1900 to 2100. The projection for 2200 is 1.6 meters – with about one-half of that coming from thermal expansion and the balance from the large ice sheets. Figure 8 compares the different policies. Any of the three policy runs limit SLR substantially because they keep the temperature rise under 3 °C. The two policy cases have projected SLR around 0.8 meters between 1900 and 2200.

Table 3 shows the stakes involved in the overall costs and benefits of a global warming program. Using our model discount rates, the optimal program raises the present value of world income by $2.46 trillion, or 0.16 percent of discounted income. This is the equivalent to an annuity of $12 billion per year. Note that in the optimal case, adding the constraint of 2 °C is relatively inexpensive, costing a present value of $1.10 trillion. Limited participation in the optimal case reduces the benefits by $0.73 trillion. Note that these are not additive factors, however, because a rigid target *plus* limited participation can be very costly (not shown).

B. Comparison with earlier results

It will be useful as well as humbling to compare the current round of results with earlier RICE/DICE models. These models have almost two decades of track record, with major revisions in science, economics, modeling, and software along the way (Nordhaus 1994, Nordhaus and Yang 1996, Nordhaus and Boyer 2000, Nordhaus 2007).

Figure 9 shows the projected global temperature increase for the next century. While the estimates have varied, the latest estimate is actually relatively close to the estimates in the Nordhaus 1994 model. The model's geophysics is relatively stable.

Figure 10 shows the calculated optimal carbon price. The numbers are corrected for inflation but not for other changes in the models or projections. The near-term estimates are similar to those in the last round while the longer term estimates are considerably higher. There are several reasons for the upward revisions. Some are technical issues, such as moving to PPP exchange rates (see Nordhaus 2007, 2007a). Others come from the "stagnationist" assumptions about output in earlier rounds. Additionally, there have been major upward revisions in the projected emissions path of developing countries, particularly China and India. The increase in the long-horizon prices is due to a much more rapid growth in global output. (Some of these were reviewed in detail in Nordhaus 2007.)

C. A warning about Panglossianism

We discussed above the importance of global participation in any climate-control program. This point is also emphasized by an examination of abatement costs. One of the advantages of the RICE model is that it can show regional costs as well as global costs. Figure 11 shows the estimated abatement costs under the optimal program for several regions. The costs rise sharply over time under the optimal program. The most heavily burdened regions are China and United States, while Japan is relatively lightly burdened.

We can also see the difficulty involved in implementing a global program by examining the sum of abatement costs of middle- and low-income countries (these comprise countries outside Japan, the US, the EU, Russia, and other high income countries). Suppose that high income countries endeavored to compensate developing countries for their abatement costs in the optimal program. As shown by the upper line in Figure 12, these costs would be relatively modest in the near-term decades, but rise to $150 billion per year by mid-21st century. The questionable political feasibility of these large transfers suggests either that climate control programs will be limited to incomplete participation (with the unhappy results discussed above) or that a consensus among poorer countries will need to develop rapidly in the near future. Figure 12 also shows the abatement costs of the non-participants (non-Annex I) countries under the limited-participation runs. While abatement costs are relatively small in the early years, they become substantial as countries join the abatement regime.

This point emphasizes that the "optimal" and even the "limits" runs analyzed here are somewhere between optimistic and Panglossian. They assume a well-managed world, globally designed environmental policies, with all countries contributing, with decision makers looking both to the best geosciences and to sound economic policies, and with rich countries bringing the poor, the unenthusiastic, and the laggard along sufficient with carrots and sticks to ensure that all are onboard with no free riding. Human history suggests that this is an unlikely political environment. Where the actual outcomes will lie between the optimistic optimum and the fatalistic baseline will depend upon how these various political factors play out in the years ahead.

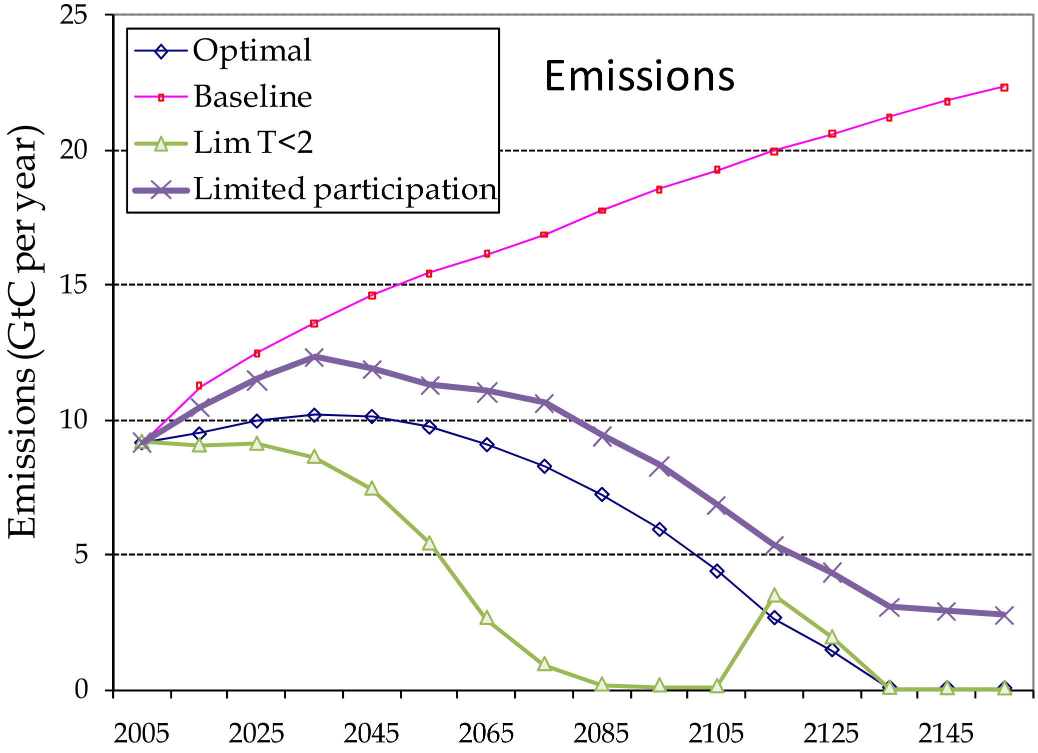

Figure 1. Emissions of CO_2

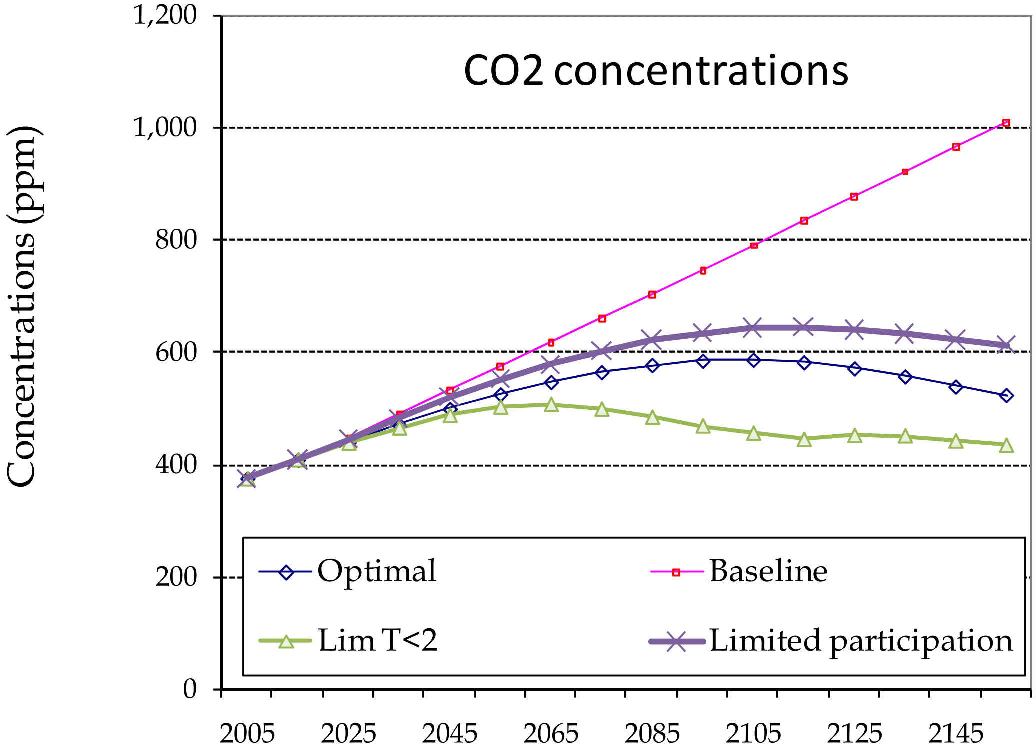

Figure 2. Atmospheric concentrations of CO_2

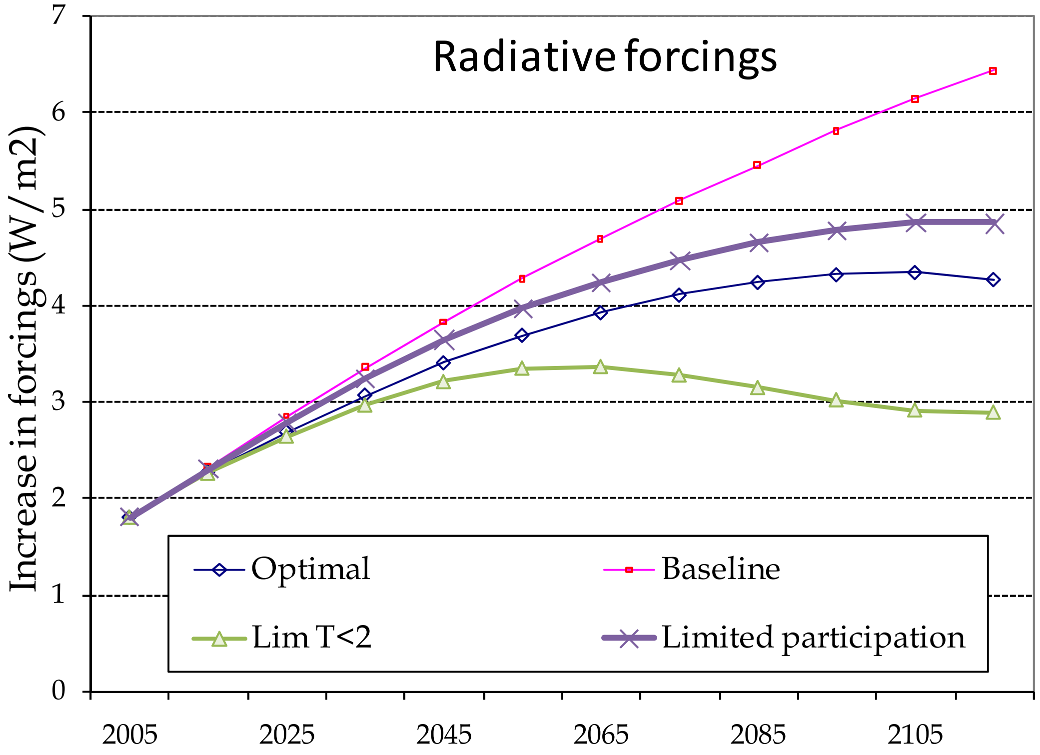

Figure 3. Radiative forcings of greenhouse gases

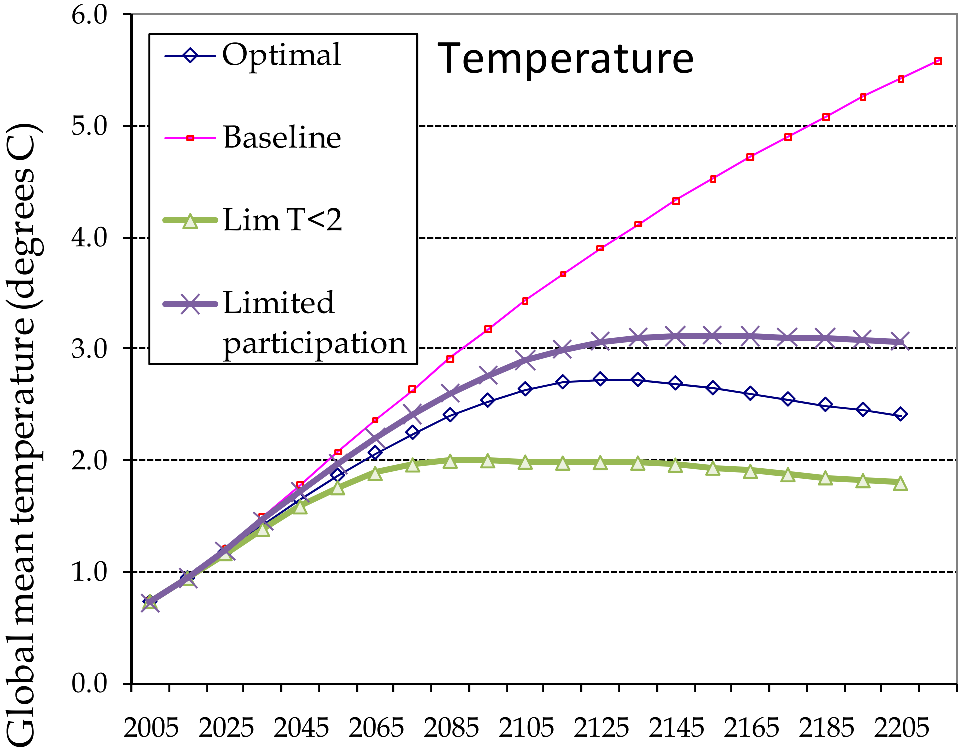

Figure 4. Global temperature increase (°C from 1900)

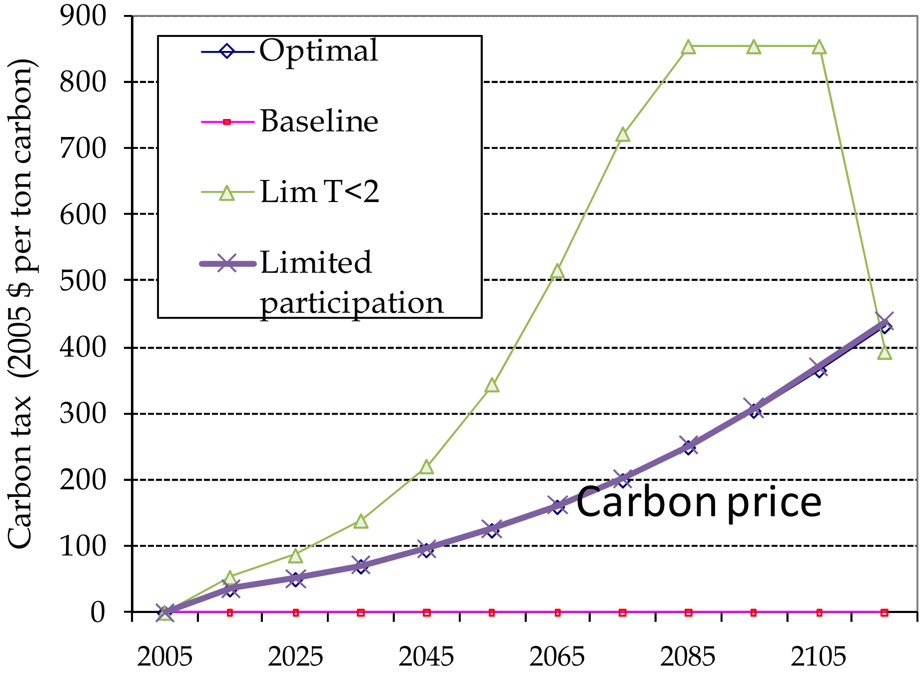

Figure 5. Market price of carbon emissions

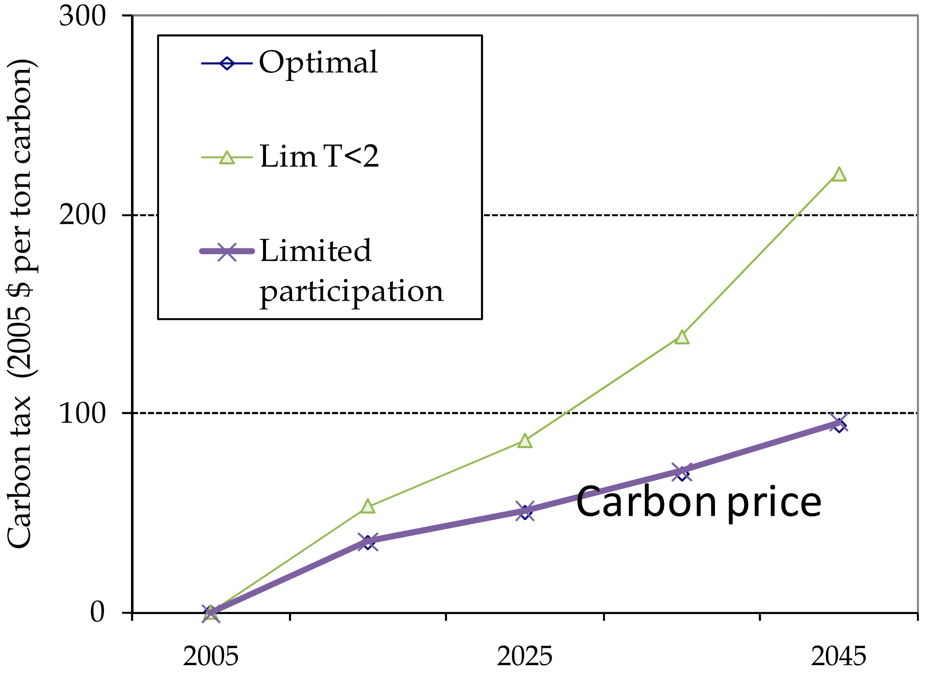

Figure 6. Market price of carbon emissions

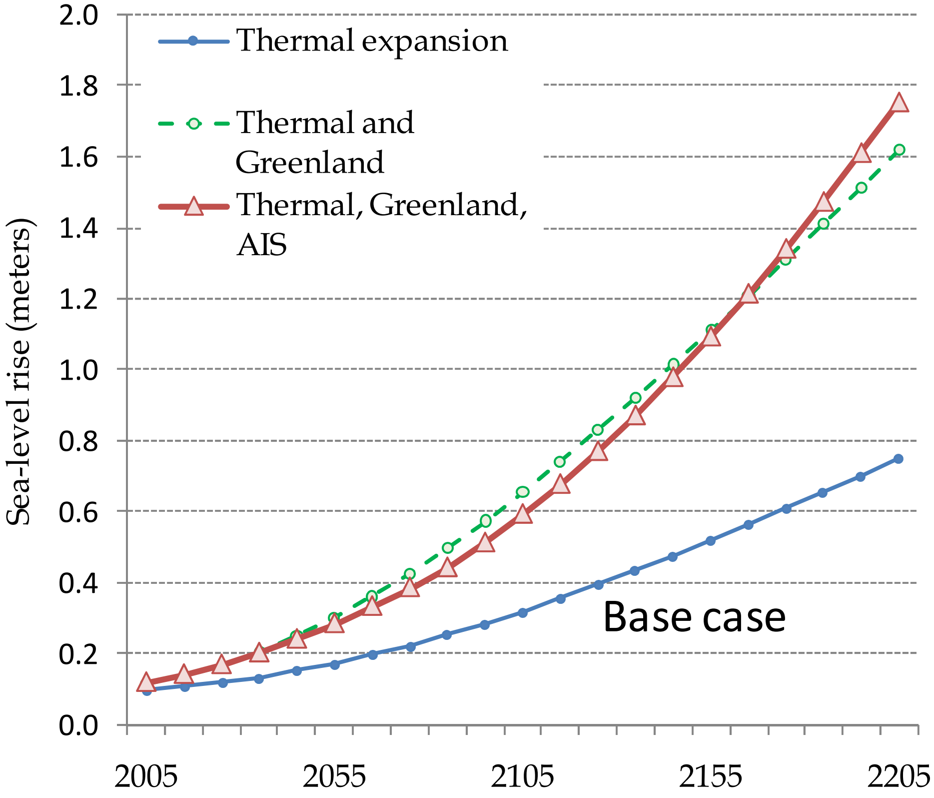

Figure 7. Components of sea-level rise for base case

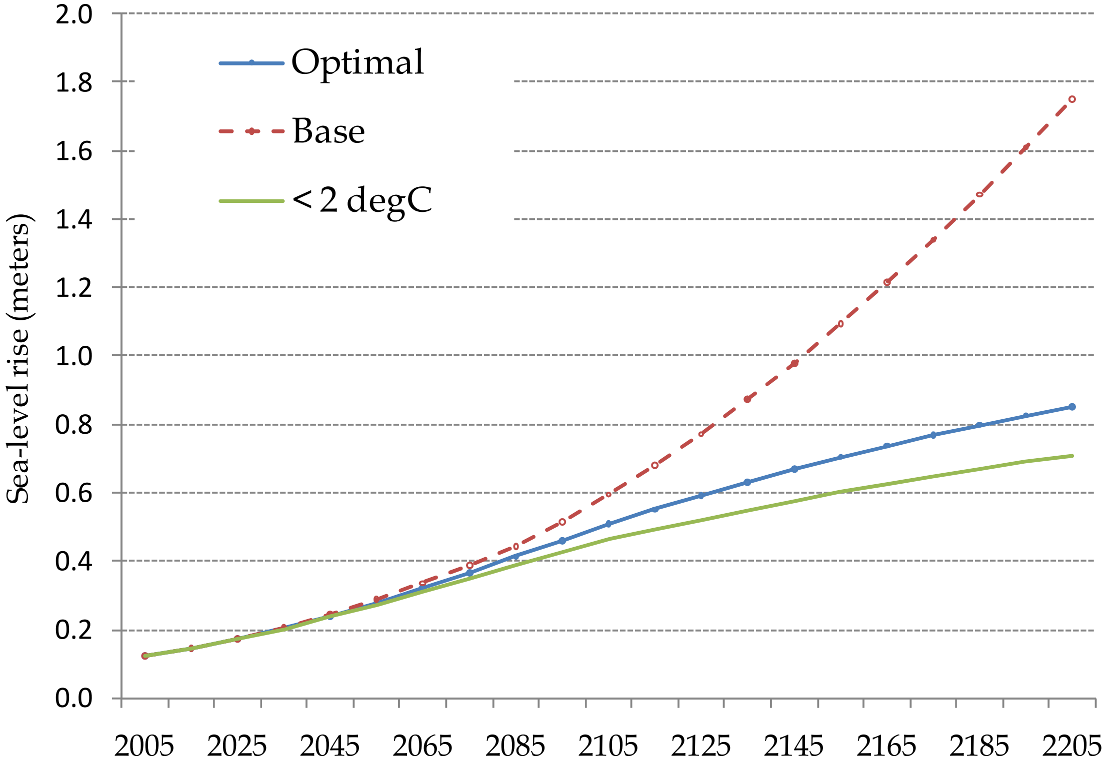

Figure 8. Projected sea-level rise for alternative cases through 2205

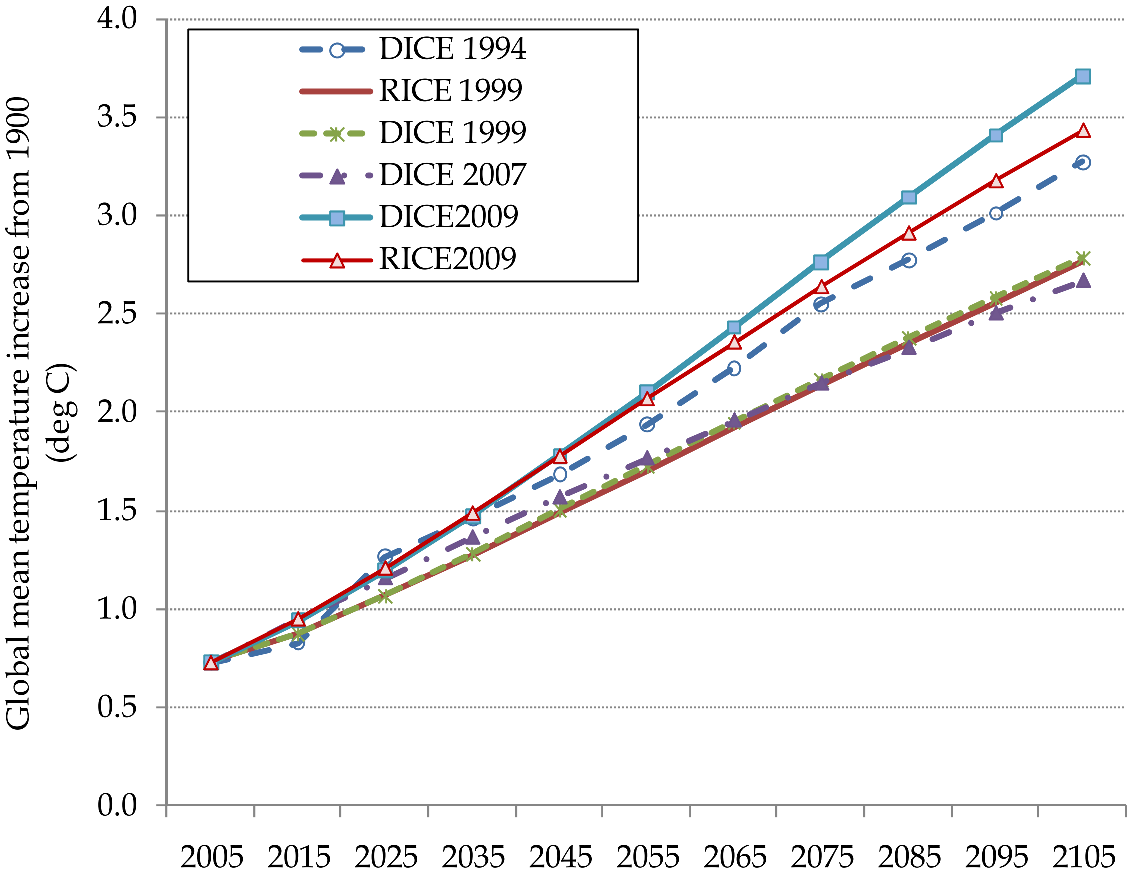

Figure 9. Baseline temperature projections for various vintages of DICE/RICE models

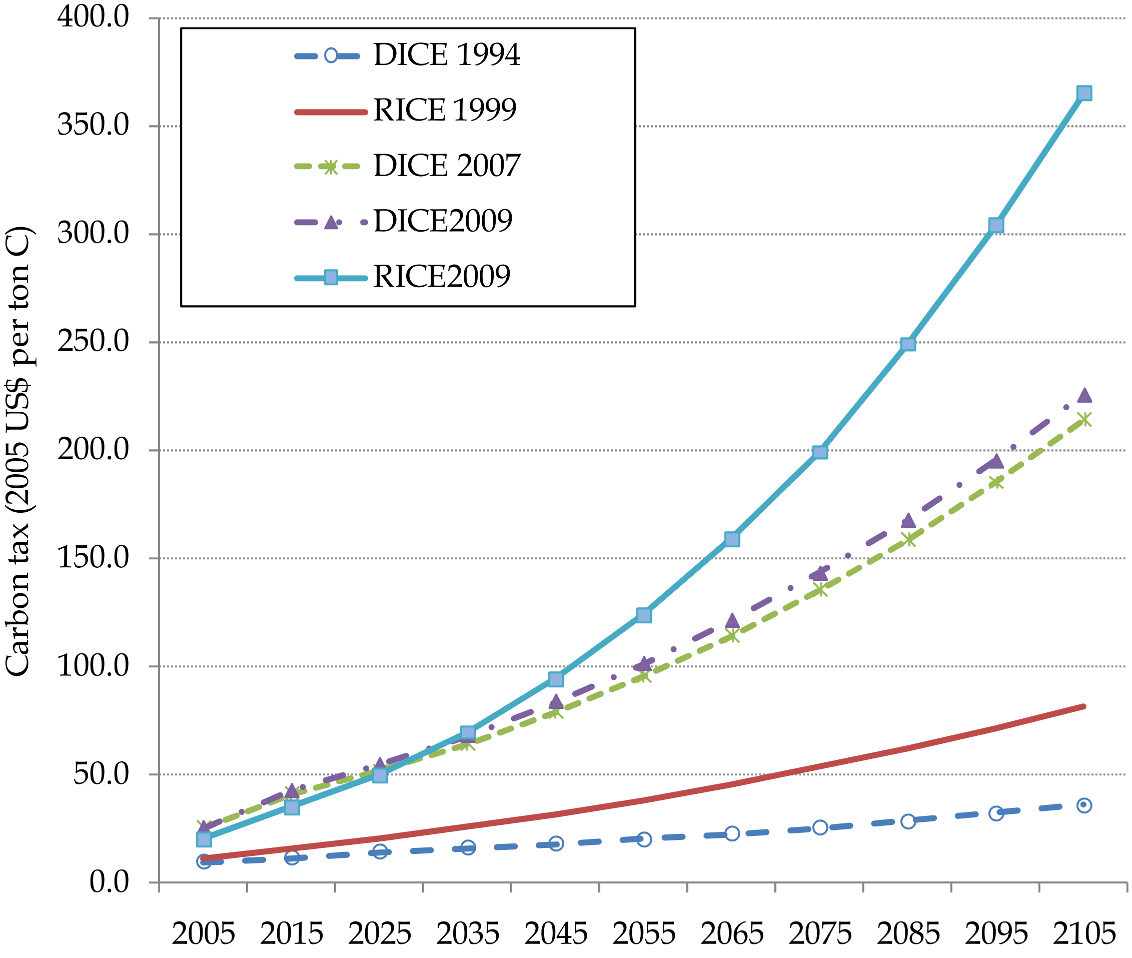

Figure 10. Estimated efficient carbon prices for various vintages of DICE/RICE models

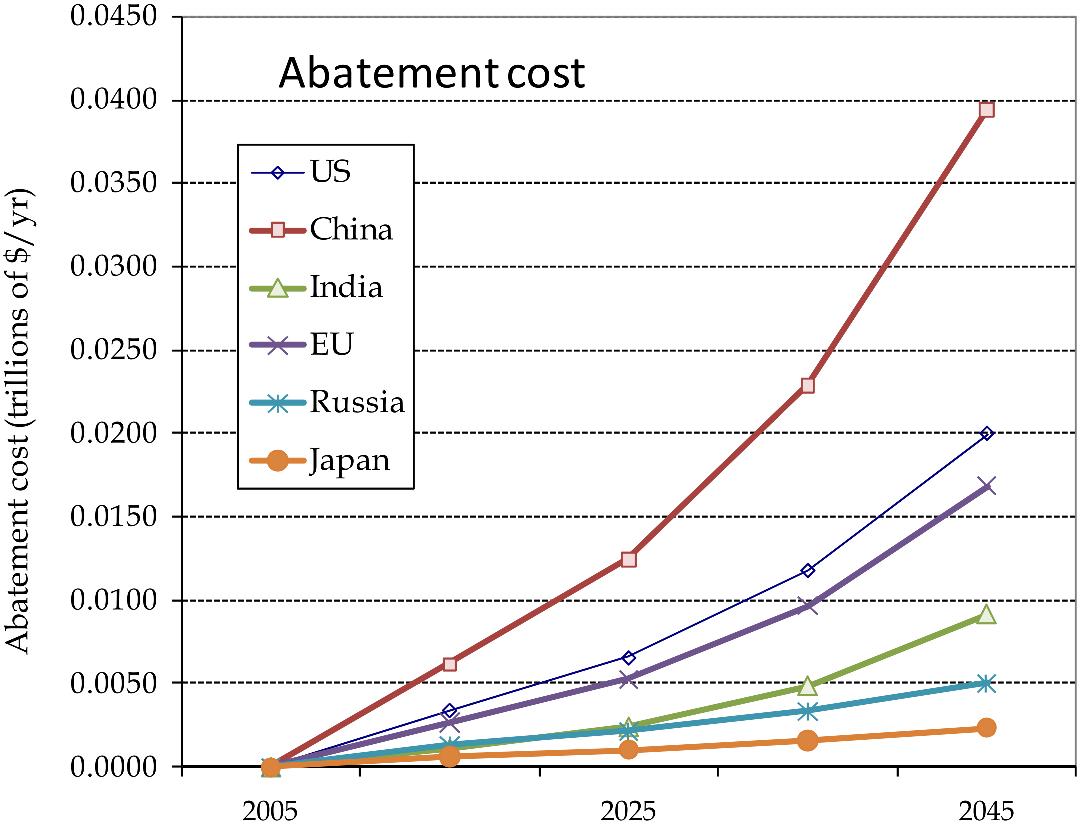

Figure 11. Abatement costs by region in optimal case

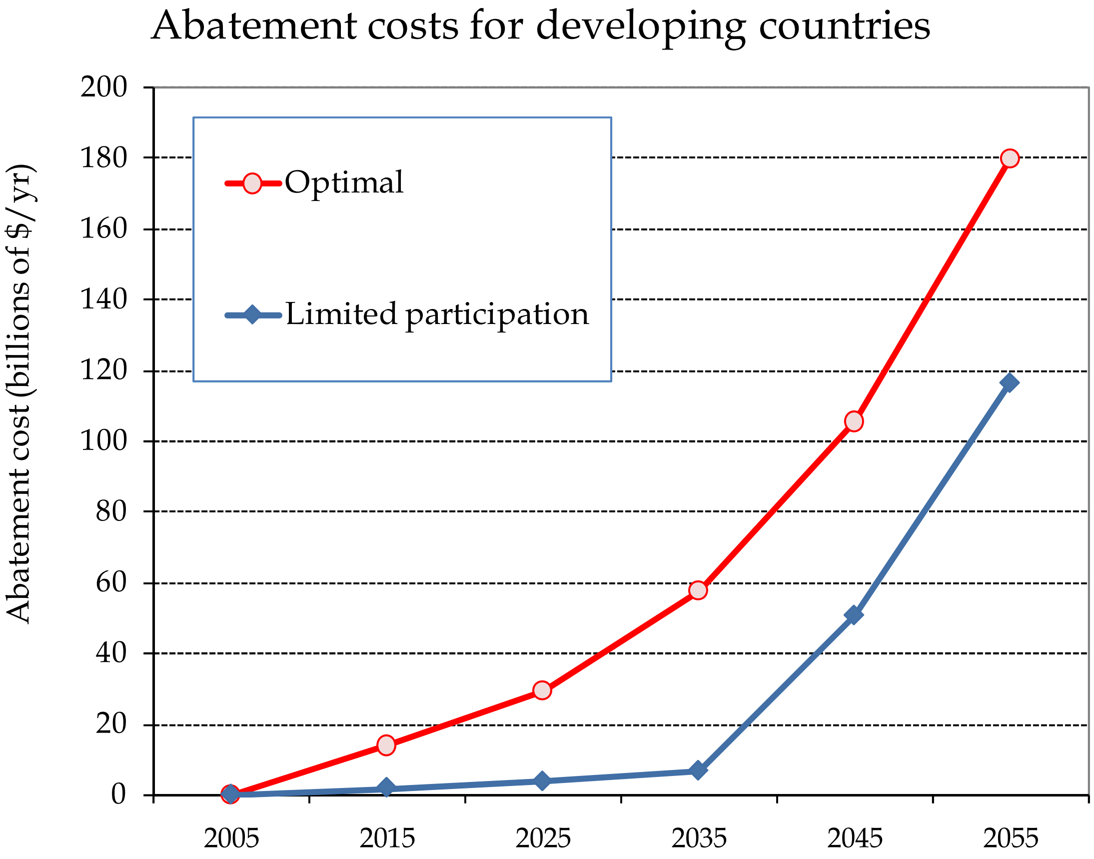

Figure 12. Abatement costs by region in optimal and limited-participation cases for developing countries

(2005 prices per ton C)

Carbon prices	2005	2010	2015	2020	2025	2055	2105
Optimal	0.00	29.33	35.09	41.98	50.23	123.74	364.79
Limit T ≤ 2 °C	0.00	42.17	53.60	68.13	86.60	344.59	854.59
Limited participation	0.00	30.09	35.95	42.96	51.34	125.66	370.31

(2005 prices per ton CO2)

Carbon prices	2005	2010	2015	2020	2025	2025	2025
Optimal	0.00	8.00	9.57	11.45	13.70	33.75	99.51
Limit T ≤ 2 °C	0.00	11.50	14.62	18.59	23.62	94.00	233.11
Limited participation	0.00	8.21	9.81	11.72	14.00	34.28	101.01

(2009 prices per ton C)

Carbon prices	2005	2010	2015	2020	2025	2055	2105
Optimal	0.00	32.26	38.60	46.18	55.26	136.11	401.27
Limit T ≤ 2 °C	0.00	46.39	58.97	74.95	95.26	379.05	940.05
Limited participation	0.00	33.10	39.55	47.26	56.48	138.22	407.34

(2009 prices per ton CO2)

Carbon prices	2005	2010	2015	2020	2025	2055	2105
Optimal	0.00	8.80	10.53	12.60	15.07	37.13	109.46
Limit T ≤ 2 °C	0.00	12.65	16.08	20.44	25.99	103.40	256.42
Limited participation	0.00	9.03	10.79	12.89	15.41	37.70	111.11

Table 2. Carbon prices in the different runs

Policy scenario	PV Utility	Difference		Annualized*	
	[Trillions of 2005 $]	[Trillions of 2005 $]	Percent of base	[Billions of $ per year]	Percent of base
Base	1,577.0	0.00	0.00	0.00	0.00
Optimal	1,579.4	2.46	0.16	12.32	0.16
Limited participation	1,578.7	1.74	0.11	8.68	0.11
Limit T $\leq$ 2 °C	1,578.3	1.36	0.09	6.81	0.09

* Annual value of consumption at discount rate of 5 percent per year.

Table 3. Present value of consumption, different policies (scaled to 2005 US international dollars, 2005 prices)

References

Hansen, James, Makiko Sato, Reto Ruedy, Ken Lo, David W. Lea, and Martin Medina-Elizade [2006]. "Global temperature change," *PNAS,* 103: 14288-14293.

Hotelling, Harold [1931]. "The Economics of Exhaustible Resources," *Journal of Political Economy,* Vol. 39, pp. 137-175.

International Monetary Fund [2009]. *World Economic and Financial Surveys, World Economic Outlook Database,* April 2009 Edition, available online at http://www.imf.org/external/pubs/ft/weo/2009/01/data/index.aspx .

IPCC Carbon Capture [2001]. *IPCC Special Report on Carbon dioxide Capture and Storage*, Eds., Bert Metz, Ogunlade Davidson, Heleen de Coninck, Manuela Loos, and Leo Meyer, available at http://www.ipcc.ch/activity/srccs/index.htm.

IPCC Fourth Assessment, Impacts [2007]. Intergovernmental Panel On Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability, Working Group II Contribution to the Intergovernmental Panel on Climate Change, Summary for Policymakers,* April, available online at http://www.ipcc.ch/.

IPCC Fourth Assessment, Mitigation [2007]. Intergovernmental Panel On Climate Change, *Climate Change 2007: Mitigation, Working Group III Contribution to the Intergovernmental Panel on Climate Change, Summary for Policymakers,* April, available online at http://www.ipcc.ch/.

IPCC Fourth Assessment, Science [2007]. Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis,* Contribution of Working Group I to the Fourth Assessment Report of the IPCC, available online at http://ipcc-wg1.ucar.edu/wg1/wg1-report.html.

IPCC Third Assessment, Science [2001]. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. *Climate Change 2001: The Scientific Basis.* Ed. J. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P. J. van der Linden, and D. Xiaosu, Cambridge: Cambridge University Press.

IPCC Second Assessment, Economics [1995]. *Climate Change 1995 – Economic and Social Dimensions of Climate Change*. Eds. Bruce J., H. Lee, and E. Haites. Cambridge, UK: Cambridge University Press, 125–44.

Koopmans, Tjalling C. [1965]. "On the Concept of Optimal Economic Growth," *Academiae Scientiarum Scripta Varia* 28(1): 1-75 (available for download at http://cowles.econ.yale.edu/P/au/p_koopmans.htm).

MAGICC [2009]. Model for the Assessment of Greenhouse-gas Induced Climate Change, Tom Wigley, Sarah Raper, Mike Salmon and Tim Osborn, developers, available at http://www.cgd.ucar.edu/cas/wigley/magicc/index.html.

National Research Council, Committee on Abrupt Climate Change [2002], *Abrupt Climate Change: Inevitable Surprises,* National Academy Press, Washington, D.C.

Nordhaus, William D. [1994]. *Managing the Global Commons: The Economics of Climate Change*, MIT Press, Cambridge, MA, USA.

Nordhaus, William D. [2007]. *A Question of Balance: Economic Models of Climate Change*, Yale University Press, New Haven, CT, USA.

Nordhaus, William D. [2007a]. "Alternative measures of output in global economic-environmental models: Purchasing power parity or market exchange rates?" *Energy Economics,* **29,** 3, pp. 349-372.

Nordhaus, William D. and Joseph Boyer [2000]. *Warming the World: Economic Modeling of Global Warming*, Cambridge: MIT Press.

Nordhaus, William D. and Zili Yang [1996]. "A Regional Dynamic General-Equilibrium Model of Alternative Climate-Change Strategies," *American Economic Review,* 86: 741-765.

Oppenheimer, Michael [1998]. "Global Warming and the Stability of the West Antarctic Ice Sheet," *Nature*, vol. 393, pp. 325–332.

Oppenheimer, Michael and Richard B. Alley [2004]. "The West Antarctic Ice Sheet and Long Term Climate Policy," Climatic Change, vol. 64, 1–10.

Ramsey, Frank P. [1928]. "A Mathematical Theory of Saving," *Economic Journal.* vol. 38, pp. 543–559.

Rutherford, Thomas F. [2009]. "Strategies for Calibrating Ramsey Models with Non-Stationary Growth," Lecture Notes, May 24, 2009.

Stern Review [2007]. *The Economics of Climate Change: The Stern Review,* Cambridge University Press, Cambridge, UK and available on the web at http://www.hm-treasury.gov.uk/independent_reviews/ stern_review_economics_climate_change/ sternreview_index.cfm.

United Nations [2004]. Department of Economic and Social Affairs, Population Division, *World Population to 2300,* United Nations, ST/ESA/SER.A/236, New York.