Nordhaus on the Impacts of Climate Change

1. Four points are noted about first-generation studies of the impacts of climate change. These studies conclude that the monetized damages for the U.S. lie between 1.0 and 1.5 percent of GDP for 2.5 to 3.0°C warming.

   (1) There is a deceptive degree of consensus to the estimates. They add up to the same amounts, but the details are highly divergent.

   (2) The early studies (particularly for agriculture and sea level rise, and energy) were extremely pessimistic about the economic impacts. More recent studies, which include adaptation, are not so gloomy.

   (3) Coverage of regions outside of U.S. is sparse. Very little work in China, India, and Africa.

   (4) Many of most pressing concerns, particularly the concern with catastrophic risk, have not been adequately studied.

   Also, in more recent work only agriculture and sea-level change have been studied on a regional basis. It is very difficult to say much about ecosystems and human health because of uncertainties about underlying physical and biological impacts and the potential for adaptation. Valuation is extremely difficult, and there are not established methodologies for valuing catastrophic risks.

2. The present approach differs in three respects from earlier studies.

   1. All regions are considered.
   2. More emphasis on non-market aspects.
   3. Present study relies on willingness to pay.

   Scholars are gravitating toward the view that it is the risks that are major cause of concern about future climate changes. So, willingness to pay approach tries to estimate what societies are willing to pay to prevent climate change.

3. Thirteen regions and 7 areas of concern are considered. The mean annual temperature varies from 3°C (Russia) to 26°C (India) and 13.4°C (U.S.).

4. Agriculture
   More recent studies have allowed extensive adaptation. No allowance for CO_2 fertilization effects.

Estimated damages on agriculture from CO_2 doubling (benefits are negative while damages are positive)

	2.8°C increase	
	Billions, 1990 U.S. Dollars	% Of GDP
United States	3.90	0.07
China	-3.00	-0.51
Japan	-17.20	-0.55
OECD Europe	42.10	0.58
Russia	-2.88	-0.87
India	5.11	1.54
Other high income (Canada, Australia)	-10.40	-1.14
High-income OPEC	0.00	0.00
Eastern Europe	2.26	0.58
Middle income (Brazil)	19.51	1.43
Lower middle income	0.65	0.06
Africa	0.10	0.06
Low income	0.30	0.06

5. Sea-Level Rise
   First generation studies for the U.S. was between 0.1 and 0.2 of GDP. More recent estimates are significantly lower. But three factors - storms, undeveloped land, and cost of resettlement – have not been accounted for. During 1987-95, damage from tropical storms in the U.S. was 0.083 percent of GDP. If storm damage were to double, this would be a noticeable impact. Nordhaus asserts that 0.1 percent of income is a reasonable WTP (willingness to pay estimate) for preventing a 2.5°C warming for the coastal sector of the U.S.

   There is little work on sea level rise outside the U.S. Nordhaus constructs an index of coastal vulnerability – for other regions, which depends on the land along the coast relative to total land area. So while the coastal impact (% GDP, 1990) is 0.10 for the U.S., it is 0.47 for Japan and 0.52 for Western Europe.

6. Other Vulnerable Market Sectors
   More than 90 percent of the economy is not likely to be significantly affected by climate change. Earlier studies show inconsistent estimates for these sectors. Nordhaus rates the impact of this sector to be zero in temperate climates. For cold climates, energy consumption will decline by 5 percent. For tropical and semitropical sub regions, it is estimated that energy expenditures go up by 8 percent.

7. Health
   There are no comprehensive studies of health impacts of global warming. Though there are estimates of climate related diseases such as malaria and a broad group of tropical diseases, dengue fever, and pollution. Various assumptions have been made about the impact of climate and as expected, most of the impact will be in sub-Sahara Africa, and to a lesser extent in warmer climates such as Latin America, India, and south-coast Asia. The mortality

in established market economies will be little affected.

8. Nonmarket Amenity Impacts (other than health)
   one early tabulation shows that climate sensitive to time was less than 5 percent of non-market time. Activities that can definitely be identified as outdoor recreation (outdoor recreation, walking, and hiking) to 0.8 hours or 2 percent of free time. A recent survey of those participating in sports activities found that of 235 million participants, only 24.3 percent participated in activities (skiing, hockey) that would be adversely affected by warming.

   A more recent study is based on diaries for various outdoor activities for different states and months. Two conclusions are: (1) Time spent on climate related activities increases with warmer weather (the time spent on camping with warm weather outweighs the time loss through skiing). (2) The estimated value of a 2.5°C warming in the U.S. is modest, but positive for the U.S., about 0.30 percent of GDP. The net amenity value of climate change is positive for temperate and cold subregions and negative for warm subregions. More work is necessary, particularly for tropical and semitropical subregions.
9. Human Settlements and Ecosystems
   There will be special problems in Venice and in low-lying countries such as Bangladesh, Maldives, or the Netherlands. But a more fundamental problem exists with valuing natural ecosystems. As there are no systematic estimates, it is assumed that the capital value of climate-sensitive human settlements and natural ecosystems range from 5 to 25 percent of regional output. For the U.S., this value is $500 billion in 1990. This number is estimated to be higher in Europe in island countries such as Japan, in small countries, and in countries with sensitive ecosystems. It is assumed that each region has a willingness to pay of 1 percent of the capital value of the vulnerable system.

10. Catastrophic Risks
    Severe events include a sharp rise in sea level, shifting monsoons, a runaway greenhouse effect, collapse of the West Antarctic Ice Sheet, and changing ocean currents that would have a major cooling effect on OECD Europe.

11. The results differ markedly by the region. The impact of a 2.5°C warming range from a net benefit of 0.7 percent of output for Russia to a net damage of almost 5 percent of output for India. For the world, the damage is 1.5%. The damage is quite modest for the next century. U.S., Japan, Russia, China are essentially zero over this period assuming catastrophic scenarios do not materialize. Europe, India, and many low-income regions, appear vulnerable to significant damages.

    The United States appears to be less vulnerable to climate change than many countries. This is the result of its relatively temperate climate, small dependence of its economy on climate, the positive amenity value of a warmer climate in many parts of the United States, its advanced health system, and low vulnerability to catastrophic climate change. The two most recent studies on the United States are largely in agreement that the economic impact of gradual climate change (that is, omitting catastrophic outcomes) is close to zero for a moderate (2.5°C) global warming.

Outside the United States, it is estimated that Russia and other high-income countries such as Canada will benefit slightly from a 2.5°C benchmark warming; the benefits to these regions come because of significant improvements in the agricultural sector as well as gains from nonmarket time use. At the other extreme, low-income regions – particularly India and Africa – and Europe appear to be quite vulnerable to climate change. The impact on India comes from its extreme vulnerability to climatic shifts because of the importance of monsoons on agriculture, the disamenity of increasing temperatures on nonmarket time use, and the potential for adverse health impacts. For Africa, much of the vulnerability comes from potential health impacts of global warming. Europe appears to be the most vulnerable of high-income regions because of the potential of catastrophic climate change due to shifts in ocean currents as well as significant coastal and agricultural impacts.

Estimates here indicate that for most countries the market impacts are likely to be relatively small; the major concerns are the potentially catastrophic impacts. As table 4.10 shows, the catastrophic costs are estimated to be twice as large as all other impacts combined for a 2.5°C warming. Similarly, catastrophic damages are estimated to dominate impacts for higher temperature increases. Because the estimated catastrophic impacts are so uncertain, this implies great uncertainty about the overall impacts.

A word of caution is necessary before closing. It must be emphasized that attempts to estimate the impacts of climate change continue to be highly speculative. Outside of agriculture and sea-level rise for a small number of countries, the number of scholarly studies of the economic impacts of climate change remains small. Estimates of the regional climatic impacts of global warming are still inconsistent across different climate models, and economic studies have made little progress in estimating impacts, particularly in low-income countries. Much more work is needed to improve understanding of the impacts of climate change.

12. Efficient Global Change Policies
    (1) No controls (baseline).
    (2) Optimal policy – Balances current abatement costs against future environmental benefits.
    (3) Ten year delay of environmental policy. Policy begins 2000-2009.
    (4) Kyoto Protocol. OECD countries plus Eastern Europe and former Soviet Union. Their emissions cut on average by 5 percent relative to 1990 levels.
    (5) Stabilizing global emissions at 1990 levels starting in 2005.
    (6) Limit CO_2 emissions at 560 parts per million of CO_2
    (7) Climate stabilization at 2.5° C or 1.5° C temperature increase.

13. Conclusions
    (a) The optimal policy produces a net benefit gain of $198 billion. This is the present value of the gain to all regions, discounted back to 1995.

    (b) A delay of ten years leads to a trivially small loss from waiting and gathering more information, assuming that action is appropriately taken in the future.

(c) A policy that limits global emissions to 1990 levels has a discounted loss of $3 trillion.

(d) The Kyoto Protocol has a relatively small impact. A small loss of $120 billion because the needed projects relatively low emissions of Annex I countries, emissions, concentrations, and temperature increases are very close to the base policy because it has little impact on global emissions.

(e) A policy of limiting CO_2 emissions to double pre-industrial levels has a net loss of $80.7 trillion.

(f) A policy to limit temperature to 2.5° C is $2.5 trillion, and to limit temperature rise to 1.5° C would cost the world a net of nearly $27 trillion.

(g) The present value of environmental benefits (assuming abatement cost is magically zero) is $4 trillion. Of these benefits, $2.4 trillion, accrue to non-annex countries. Europe gains $1.9 trillion. The U.S. gains $82 billion and China loses $21 billion. In general, Europe is the region which gains most from climate policies. In the optimal case, OECD has three-fifths of the net benefits. The region is highly sensitive to climate change, has a low discount rate, and pays little of the abatement costs.

(h) Under the optimal policy, the carbon tax is $6 per metric ton of carbon for 1990-1999, $13 in 2015, $29 in 2050, and $63 in 2100. A $10 per ton carbon tax would raise gasoline prices by 2 cents, though the percentage increase in the price of coal would be 20%. For the optimal policy, the control rate is 5% at first rising to 10% of baseline. Control rates tend to be twice as high as they are in high income countries as taxes on energy are relatively low in these countries, and so it is less expensive to reduce emissions in the low-taxed regions.

(i) Reason why optimal policy or the more ambitious policies have on concentrations and temperature trajectories. First reason for the modest effect is that the impact of warming is relatively small amounting to around 2% of global output for 2.5° C change and the abatement costs are high. Also, there is a great deal of momentum of climate change given the build up of GHG and the lags in the response of climate to GHG increases. Even with the policy of stabilizing global emissions at 1990 rates, an extremely ambitious policy requiring a reduction of CO_2 emission by over 40 percent and costing $4.5 trillion in abatement expenditures, global temperature would still rise by slightly more than 2° C above 1900 levels by 2100. According to scientific studies, the relationship between equilibrium warming and CO_2 concentrations is approximately logarithmic. This implies that in going from 300 to 315 ppm of CO_2 increases temperature by 0.205° C, while moving from 600 to 615 ppm increases temperatures by 0.104° C. A small decrease in CO_2 concentrations have a relatively small impact on the path of temperature.

Kyoto Protocol

	Global Trade	Trade within Annex I Countries	Trade within OECD	No Trade
Abatement Costs	59	217	611	884
Reduction in Damages	108	96	155	161

Global Trade means that Annex I countries can buy permits from all countries, including less developed countries.

Trade within Annex I Countries means that U.S. and Europe can buy permits from Russia and Eastern Europe.

Trade within OECD means trade within only high-income countries.

No Trade means no trade permits between countries.

In the optimal run concentrations in 2100 are 538 ppm, while in Annex I version of Kyoto Protocol they are 551 ppm. The baseline estimate is 557 ppm. The Kyoto Protocol leaves out low-income regions. The Protocol makes little headway in reducing CO_2 concentrations under any trading scheme.

The U.S. ends up paying most of the costs and reaping little of the benefits. The reason is that CO2 emissions have been increasing more for the U.S. and are projected to increase more rapidly. West Germany merged with energy-inefficient East Germany, and Eastern Europe and the former Soviet Union have large excess credits to sell.

So, for the Annex I trade case, the estimated costs to the U.S. are $325 billion and the estimated benefits are only $12 billion. So, net benefits are -$313 billion. Europe gains $46 billion (it has virtually no costs and Eastern Europe, including Russia, gains $113 billion primarily by selling permits to the U.S.

The major flaws of Kyoto are, first, that it excludes low-income countries, and secondly, that it assigns windfalls to countries which had inefficient energy systems.

Conclusions:
(1) The difference in countries depends on the difference in emissions at a fixed historical benchmark.

(2) The Protocol has no grounding in economics or environmental policy.

(3) The environmental damages do not vary much among variants. The basic difficulty is that it targets only the emissions of high-income countries, which are likely to be a dwindling fraction of global emissions.