The Atmosphere as a Global Common: From a Tragedy to a Drama

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Economic Growth in Perspective

The Global Economy, 1–2006 AD

Source: Maddison 2008

Can this really continue???
Growth and Poverty Reduction

- People living in absolute poverty: >1 Billion

- Low economic growth could drastically reduce development in many countries

- Zero growth is not sufficient to reach environmental targets

⇒ Banning growth does not seem to be a feasible solution to protect the environment

Dollar and Kray (2002)
World Map of Wealth

Capital stock per person
- very low
- low
- mean
- high
- very high

Füssel (2007)
World Map of Carbon Debt

Fossil CO2 emissions per person (1950-2003)

- very low
- low
- mean
- high
- very high

Füssel (2007)
Carbon Debt and Wealth

Fitting line: \( \ln P = 0.987 \ln K + c \)
The impact of economic growth on the environment

© IPCC 2007: WG1-AR4
Climate Change: Tipping Points in the Earth System

“Tipping processes of the climate system” show a strong reaction already to small climate changes

Schellnhuber, 1996; Lenton et al., 2008
Cost-benefit Analysis or Risk Management?

- Weitzmann 2009, 2010: The Dismal Theorem
  - Due to „fat-tailed“ climate sensitivity and uncertain tipping points there is a non-trivial probability of catastrophic damages
  - For CRRA utility functions the expected utility converges to minus infinity

\[
U(C) = \frac{C^{1-\phi}}{1-\phi} \quad \text{for} \quad \phi \neq 1 \quad (\phi > 0)
\]

\[= \ln C \quad \text{for} \quad \phi = 1\]

If \( p(C) \) is a fat-tailed distribution:

\[
\int_{-\infty}^{\infty} U(C)p(C)dC \to -\infty
\]
Burning Embers Diagram

Prognosis for 2100 (IPCC 2007)

2°C above pre-industrial level

Climate Change Mitigation as Insurance

In this case the cost-benefit calculus breaks down. With risk aversion, basically the entire income is used to avoid the possibility of catastrophic damages.

Climate policy as insurance against catastrophic climate change!

Table 1—Likelihood (in percentage) of Exceeding a Temperature Increase at Equilibrium

<table>
<thead>
<tr>
<th>Stabilization level (in ppm CO$_2$e)</th>
<th>2°C</th>
<th>3°C</th>
<th>4°C</th>
<th>5°C</th>
<th>6°C</th>
<th>7°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>78</td>
<td>18</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>96</td>
<td>44</td>
<td>11</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>550</td>
<td>99</td>
<td>69</td>
<td>24</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>650</td>
<td>100</td>
<td>94</td>
<td>58</td>
<td>24</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>750</td>
<td>100</td>
<td>99</td>
<td>82</td>
<td>47</td>
<td>22</td>
<td>9</td>
</tr>
</tbody>
</table>

Stern (2008)
Climate Policy as a Hotelling Problem

Cumulative emissions 2000-2050 (GtCO₂)

Meinshausen et al (2009)
Unlimited Resources – Limited Disposal Space

Under BAU more than 1200 GtC are disposed into the atmosphere
Stabilisation of Atmospheric CO$_2$-Concentration

3 stabilisation goals with different probabilities of attaining the 2$^\circ$ goal: 550ppm-eq, 450ppm-eq, 400ppm-eq

CO$_2$ –emissions (energy)

Year

Gt C/yr

Baseline 550ppm-eq 450ppm-eq 400ppm-eq

Negative emissions

~15% prob.
~50% prob.
~75% prob.

Knopf, Edenhofer et al. (2009)
Transformation of the Energy System

Based on IEA Data (1971-2005) and REMIND-R results for 450ppm-eq (ADAM); Graphic by Steckel/Knopf (PIK)
… and What About Energy Efficiency?

Mitigation technologies: 450ppm  World

Luderer et al. 2011
The Atmosphere as a Global Common

Atmosphere: Limited Sink
~ 230 GtC

Resource Extraction
> 12,000 GtC
Managing the Atmosphere with a Sky Trust

1) Determine Magnitude of Atmospheric Disposal Space
   → Balance Costs & Risks of Climate Change with Mitigation

2) Adopt efficient Policy Instruments: Carbon Tax or ETS

3) Distribute the Climate Rent
From Tragedy to Drama: Strategic Options

Country Calculus for Mitigation Program

<table>
<thead>
<tr>
<th></th>
<th>Benefits</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Domestic</strong></td>
<td><strong>Avoided domestic damages &amp; Co-Benefits</strong></td>
<td><strong>Domestic mitigation costs (energy, growth)</strong></td>
</tr>
<tr>
<td><strong>Global</strong></td>
<td><strong>Avoided damages in other regions (ethics)</strong></td>
<td><strong>Costs for other regions (ethics); Access to mitigation in other regions</strong></td>
</tr>
</tbody>
</table>

Demand for Mitigation

Supply of Mitigation
Living in a Second-Best World: Technology Policies

• Supporting Renewables: Fatal Aberration?
• Subsidizing CCS: Almost First Best?
• Combine both Options: A Bridge towards an International Agreement?
The current Global Energy System is Dominated by Fossil Fuels

Shares of energy sources in total global primary energy supply in 2008

IPCC SRREN 2011
The Technical Potential of Renewable Energy

![Chart showing technical potential of renewable energy sources: Electricity, Heat, Primary Energy.](chart)

### Range of Estimates of Global Technical Potentials

<table>
<thead>
<tr>
<th>Source</th>
<th>Max (in EJ/yr)</th>
<th>Min (in EJ/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Energy</td>
<td>1109</td>
<td>118</td>
</tr>
<tr>
<td>Hydropower</td>
<td>52</td>
<td>50</td>
</tr>
<tr>
<td>Ocean Energy</td>
<td>331</td>
<td>7</td>
</tr>
<tr>
<td>Wind Energy</td>
<td>580</td>
<td>85</td>
</tr>
<tr>
<td>Geothermal Energy</td>
<td>312</td>
<td>10</td>
</tr>
<tr>
<td>Biomass</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>Direct Solar Energy</td>
<td>49837</td>
<td>1575</td>
</tr>
</tbody>
</table>

IPCC SRREN 2011
The Costs of Renewables are Often Still Higher Than Those of Non-Renewables. But…

IPCC SRREN 2011
Some RE Technologies Are Already Competitive

- Biomass Electricity
- Solar Electricity
- Geothermal Electricity
- Hydropower
- Ocean Electricity
- Wind Electricity
- Small scale CHP (steam turbine)
- Binary cycle plant
- Domestic pellet heating system
- Palm oil biodiesel

IPCC SRREN 2011
Renewable Energies have a Potential to Lower Costs

- **1976**: [65 USD/W]
- **1981**: [2.6 USD/W]
- **1984**: [4.3 USD/W]
- **2009**: [1.4 USD/W]
- **2010**: [1.9 USD/W]

**Legend**
- Blue squares: Produced Silicon PV Modules (Global)
- Red squares: Onshore Wind Power Plants (Denmark)
- Red pentagons: Onshore Wind Power Plants (USA)
Case 1: Carbon Pricing is Necessary and Sufficient

MC Black Electricity

MC Green Electricity

MC Black Electricity

MC Green Electricity

Social Costs of Carbon

PE$_1$

PE$_2$

PE$_1$

Black Energy

Green Energy

Edenhofer et al. 2007
Case 2: Additional Promotion of Renewables is *not* Reasonable

► Several stable equilibrium points (PE3 and PE1) are possible if the supply curves show a non-convex behavior (PE2 is not stable).

► Without additional policy support, the system will steer towards the neighboring equilibrium point PE3.

► PE3 > PE1: the system is efficient.

Edenhofer et al. (2007)
Case 3: Additional Promotion of renewables is Reasonable

- The internalization of the social costs of energy supply (e.g. via a cap and trade system) improves the competitiveness of renewable energies.

- As long as the cross-over point PE$_3$ does not vanish, this, however, still results in an inefficient state.

Edenhofer et al. (2007)
Consumption losses relative to the 1st-best optimum of optimal and “close-to-be-optimal” instruments that deviate by +1% and -1% from the optimal value.

Kalkuhl, Edenhofer, and Lessmann 2012
2nd Best-Technology Policy

Welfare losses in BGE consumption losses [%]

Compared to optimal carbon pricing policy
Compared to BAU (no policy)

Optimal carbon price
Feed-in-tariff
Carbon Tax
Subsidy
Subsidy + 100$\text{MC}$
Subsidy + 500$\text{MC}$
20-yr Subsidy
40-yr Subsidy
60-yr Subsidy

Kalkuhl, Edenhofer & Lessmann 2011
Carbon Capture and …

…Storage (CCS)

Atmospherical CO₂

Combustion

Bio+CCS / Air Capture

C in Fossil Resources

Geological C storage

Not fully sustainable
The peculiar role of CCS

- Subsidies for CCS create a scarcity rent and an implicit carbon price.

- No leakage and sufficient storage capacities might enable the policy maker to achieve a first-best solution.

- However, these assumptions are highly unrealistic.
Renaissance of Coal?

Prices of Energy Commodities
(U.S. dollars a barrel of oil equivalent)

Asian liquefied natural gas
U.S. gas
Australian coal
Oil

IMF (2011)
Renaissance of Coal?
Combining CCS and Renewables Policy

Welfare losses (in balanced-growth equivalents) of optimal second-best policies compared to the social optimum ($\theta = 100\%$) under a carbon budget. The negative welfare losses of the laissez-faire (business-as-usual) economy indicate the mitigation costs due to the carbon budget constraint.

Kalkuhl, Edenhofer, and Lessmann (2012)
Rent Distribution

Discounted Fossil Resource Rents \([1 = \text{Optimal Policy}]\)

- BAU
- Renewable + CCS Policy
- Renewable Policy
- CCS Policy

Fraction of Optimal Carbon Price \(\vartheta\) [%]

Kalkuhl, Edenhofer, and Lessmann (2012)
Carbon Capture and ... 

...Use (CCU)

Atmospherical CO₂

Combustion + CCS

Gaseous and liquid fuels, e.g. CH₄

C in Fossil Resources

Geological C storage

Renewable electricity

Transitional
Renewable electricity

Gaseous and liquid fuels, e.g. CH₄

Combustion

Bio+CCS / Air Capture

Atmospherical CO₂

Geological or Biological C storage, e.g. charcoal

Sustainable

Carbon Capture and …

…Cycling(CCC)
Linking Climate Cooperation with Technology Policies

- Combine agreement on emission reductions with agreement on research on
  - mitigation technology
  - general (labor) productivity
- Full cooperation can be reached

Lessmann and Edenhofer (2011)
Justification for Trade Sanctions?

CO₂-trade balances for different world regions 1990-2008

Blue: CO₂-Importing
Red: CO₂-Exporting

Peters, Minx, Weber and Edenhofer (2011)
Trade Sanctions Against Climate Non-Cooperators

- Moderate tariffs deter free-riding, enable global cooperation and increase global welfare
- Credible, because climate coalition would gain from it
- Become obsolete once global cooperation is established
- Legitimacy essential: misusage, retaliation, WTO

Lessmann, Marschinski, and Edenhofer (2009)
Creation and ‘Linking‘ of Emissions Trading Systems

⇒ Reduction of mitigation costs by establishing access to low-cost abatement options
⇒ Potential for strategic incentives

Flachsland (2011)
Side Payments: Green Climate Fund

Current standing: For 2010 industrialized countries have earmarked US$ 12 billions

Brunner (2011)
No Regret: Reducing Inefficient Fossil Energy Subsidies

Fossil fuel subsidies have been driven higher by the rebound in international energy prices. They totalled $409 billion in 2010 – about $110 billion up on 2009.

IEA WEO (2011)
Better REDD than dead?

Seeing the wood
A special report on forests
September 25th 2010
Conclusions

• Climate Change is a Global Commons Problem: The atmospheric sink is being overused

• Key Question: Is it possible to transform the „Tragedy of the Commons“ into a „Drama of the Commons“?

• Appears difficult, but there are some promising technological and institutional options

• A world government will not be forthcoming in the next decades: Need to explore options for polycentric governance

www.mcc-berlin.net
Recommended Reading