Cold War, Global Warming: A Tale of Two Dilemmata

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Multi-model Averages and Assessed Ranges for Surface Warming

Globally averaged warming (°C)

-1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0

B1 A1T B2 A1B A2 A1FI

Year 2000 Constant Concentrations

20th century

Globally averaged warming (°C)

1900 2000 2100

Multi-model Averages and Assessed Ranges for Surface Warming
Key Message 1 - Climatic Trends

„Recent observations show that [...] many aspects of the climate are changing near the upper boundary of the IPCC range of projections.“
Sea level follows upper limit of IPCC projections (scenario „including land ice uncertainty“).

Figure 1 Synthesis Report (Rahmstorf et al. 2007 Science)
Accelerated Greenland Melt-Down

Melt of Greenland ice sheet contributes ~0.5 mm year\(^{-1}\) to total global mean sea level rise of 3.1 mm year\(^{-1}\).

Box 1 Synthesis Report (Steffen and Huff 2009)
Key Message 2 - Social and Environmental Disruption

„Temperature rises above 2°C [...] are likely to cause major societal and environmental disruptions through the rest of the century and beyond.“
Updated Reasons for Concern

Figure 8 Synthesis Report (Smith et al. 2009 PNAS)
Tipping elements in the Earth’s climate system

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In this issue

Climate change and the fate of the Amazon

Papers of a Theme Issue compiled and edited by Yadavinder Malhi, Richard Betts and Timmons Roberts
Large $\text{N}_2\text{O}$ emissions from cryoturbated peat soil in tundra

Arctic nitrous oxide emissions could amount to 4% of the global warming potential of Arctic methane emissions at present.
The new estimate of frozen carbon stored in permafrost soils of the circumpolar region is over 1.5 trillion tons, about twice as much carbon as contained in the atmosphere. (Tarnocai et al. 2009 Global Biogeochemical Cycles)
Interdependency Between Tipping Points

(Kriegler et al. 2009 PNAS)
„Mass loss on Himalayan glacier endangers water resources“ (Kehrwald et al. 2008 Geophys Res Lett)
Key Message 3 – Long-Term Strategy: Global Targets and Timetable

„Rapid, sustained and effective mitigation based on coordinated global and regional action is required to avoid dangerous climate change.“
THE COMING CLIMATE CRUNCH

- The trillionth tonne of carbon
- How disastrous can it get?
- Engineering alternatives

1 TRILLION TONNES

NATUREJOBS
Immunology
Emissions Peaking After 2020:
More than 1 Kyoto per Year

(Meinshausen et al. 2009)
Emissions Peaking After 2020:
More than 1 Kyoto per Year

(Meinshausen et al. 2009)
Emissions Peaking After 2020: More than 1 Kyoto per Year

(Meinshausen et al. 2009)
G8 and Emerging Economies Agree on 2°C Long-term Target

Constitutes the most comprehensive assessment of the science. We recognise the [broad] scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2°C. Because this global challenge can only be
“World Formula” for Climate Policy

Total global CO₂ budget in period \([T_1, T_2]\) that keeps global warming below 2°C with probability \(p\)

\[
C_{glob}(p) = \int_{T_1}^{T_2} E_{glob}(t) \, dt
\]

Integral over global profile of CO₂ emissions

National CO₂ budget in \([T_1, T_2]\)

\[
C_{nat} = \int_{T_1}^{T_2} E_{nat}(t) \, dt = C_{glob}(p) \frac{M_{nat}(T_M)}{M_{glob}(T_M)}
\]

Fraction of global CO₂ budget as determined by ratio of national population \(M_{nat}\) to world population \(M_{glob}\) at time \(T_M\)
“World Formula“ for Climate Policy

Illustration

Global carbon budget
Share in world population
National carbon budget

E_{\text{glob}}(t)
C_{\text{glob}}(p) / (T_2-T_1)
E_{\text{nat}}(t)
C_{\text{nat}} / (T_2-T_1)

Gt CO_2/a
T_1
T_2
t

Gt CO_2/a
T_1
T_2
t

Share in world population:
- China
- India
- United States
- Brazil
- Mexico
- Remaining America
- Australia/Oceania
- Other
- Russia
- Germany
- Remaining Europe
- Nigeria
- Remaining Africa
- Japan
- Philippines
- Vietnam
- Bangladesh
- Pakistan
- Indonesia
- Remaining Asia

Other
Inter-Temporal Flexibility

National emission profiles respecting national CO$_2$ budgets
Inter-Regional Flexibility
Scenario 1: Historic Responsibility

\[ T_i = 1992, T_2 = 2050, T_M = 1994, p = 0.75 \]
Scenario 2: **Climate Compromise**

\[ T_1 = 2010, \quad T_2 = 2050, \quad T_M = 2010, \quad p = \frac{2}{3} \]
Scenario 2: Climate Compromise

$T_1 = 2010, T_2 = 2050, T_M = 2010, p = \frac{2}{3}$
Scenario 2: Climate Compromise

\[ T_1 = 2010, \; T_2 = 2050, \; T_M = 2010, \; p = \frac{2}{3} \]

Emission paths per capita for selected countries

- Germany
- USA
- China
- India
- Burkina Faso

Global budget per capita assuming constant annual emissions
Potsdam Memorandum

Main Conclusions
from the Symposium 8 – 10 October in Potsdam

“We are standing at a moment in history when a GREAT TRANSFORMATION is needed to respond to the immense threat to our planet. This transformation must begin immediately and is strongly supported by all present at the Potsdam Nobel Laureates Symposium.”
MILESTONES of the Great Transformation

An effective and just global agreement on climate change

A low carbon infrastructure

Forest protection, conservation and restoration

“[…] we should confine the temperature rise to 2°C to avoid unmanageable climate risks. This can only be achieved

• with a peak of global emissions of all greenhouse gases by 2015

• at least a 50% emission reduction by 2050 on a 1990 baseline. […] developed countries have to aim for a 25-40% reduction by 2020.

[…] a total carbon budget […] should be accepted as the base for measuring the effectiveness of short-term (2020) and long-term (2050) targets“
“Many warnings have been uttered by eminent men of science [...] We have not yet found that the views of experts on this question depend in any degree upon their politics or prejudices. They depend only [...] upon the extent of the particular expert's knowledge. We have found that the men who know most are the most gloomy.”
“The mission […] is to bring scientific insight and reason to bear on threats to human security arising from science and technology in general, and above all from the catastrophic threat posed to humanity by nuclear and other weapons of mass destruction.”

Nobel Peace Prize 1995

Professor John P. Holdren
Chairman, Pugwash Executive Committee
Prisoners' Dilemma

• Partners in crime with 2 options:
  – remain silent
    (no strong evidence)
  – confess
    (maybe as chief witness)

• Game characteristics:
  – simultaneous move
  – «one-shot» game

• Nash Equilibrium:
  – best response to other players
  – best strategies
  – in «math»: strategies \( s^* \) such that

\[
\begin{align*}
  s^* &= \left( s_i^*, s_{-i}^* \right) \\
  \pi_i(s_i^*, s_{-i}^*) &\geq \pi_i(s_i, s_{-i}^*)
\end{align*}
\]

\( s \) – strategy, \( \pi \) - payoff
Cold War As a Prisoners’ Dilemma

- Payoffs:
  - Peace: no adverse effects: 0
  - Unilateral strike:
    - security gain for aggressor: +1
    - destruction for the attacked: -2
  - Bilateral strikes:
    - destruction, but at least it’s mutual: -1

- Equilibrium outcome:
  Nash Eq’m (strike, strike)
Cold War As a Repeated Prisoners’ Dilemma

- Mutually Assured Destruction (MAD)
  - First strike and
  - Second strike weapons (retaliation)

- Threat of mutual destruction as a trigger strategy:
  - Keep peace
  - If defection is detected, then retaliate forever

- Prospect of being punished forever suffices to stabilize the cooperative (peace,peace) outcome
MAD Triggered Arms Race

US and USSR nuclear stockpiles

(Wikipedia 2009)
Climate Change as a Prisoners’ Dilemma

- Payoffs:
  - Abatement costs: 7 for abater
  - Avoided damages: 5 for all players

- That is:
  - Abate: no climate change: 3
  - Pollute:
    - Polluter: enjoy benefit for free +5
    - Pollutee: high costs, little benefit -2
  - All pollute:
    - Business as usual: 0

- Equilibrium outcome:
  Nash Eq‘m (pollute,pollute)

\[
\pi_i(a_i, a_{-i}) = -7a_i + 5(a_i + a_{-i})
\]

\[a_i \in \{0,1\}\]
Climate Change as Multi-Player Game

2 players

<table>
<thead>
<tr>
<th></th>
<th>Pollute</th>
<th>Abate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollute</td>
<td>0</td>
<td>-2</td>
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<tr>
<td>Abate</td>
<td>5</td>
<td>3</td>
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</table>

Moving from 2 to N players:

\[ \pi_i = -7a_i + 5 \sum_{j=1}^{N} a_j \]

N symmetric players

<table>
<thead>
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<th>Number of abating nations other than i</th>
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<tr>
<td>0</td>
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<tr>
<td>Nation i pollutes</td>
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<tr>
<td>Nation i abates</td>
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Equilibrium outcome: Nash Eq'm (all pollute)
Learning From the Cold War Analogy?

Cold War

Mutually Assured Destruction → trigger strategy
Outcome: tense but stable peace

Global Warming

Possible trigger strategies to punish “climate change sinners“:

• threat of unabated emissions: pollution by one triggers end to mitigation by all
• trade sanctions (bans, tariffs): polluters are punished

Outcome: cooperative emission reduction

Mutually Assured Decarbonization
Three Ways of Going MAD

• MAD 1: Mutually Assured Destruction

• MAD 2: Mutually Assured Decarbonization

• MAD 3: Mitigation, Adaptation, Development
Food for a Week, Darfur Refugees, Chad
Food for a Week, Germany
Exhibit 3.0.1

Global GHG abatement cost curve beyond business-as-usual – 2030

**Note:** The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO$_2$e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

**Source:** Global GHG Abatement Cost Curve v2.0
Degradation of Freshwater Resources
Increase of Storm and Flood Catastrophes
Decrease of Food Production
Migration

Climate Change Security Risks
Selected Hotspots

(WBGU 2007)
## Scenario 1: Historic Responsibility

\[ T_1 = 1992, T_2 = 2050, T_M = 1994, p = 0.75 \]

<table>
<thead>
<tr>
<th></th>
<th>Share in population (%)</th>
<th>Total budget (GtCO₂)</th>
<th>Used up budget (GtCO₂)</th>
<th>Remaining budget (GtCO₂)</th>
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Scenario 2: **Climate Compromise**

\[ T_1 = 2010, \ T_2 = 2050, \ T_M = 2010, \ p = 2/3 \]

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<th>Share in population (%)</th>
<th>Total budget (Gt CO₂)</th>
<th>Mean annual budget (Gt CO₂ / a)</th>
<th>Annual emissions (Gt CO₂ / a)</th>
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