What is wrong with very long-run economic modeling for climate change?

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My storyline
Reflecting on economic modeling for climate change

- Obvious failures of economists in dealing with climate change
- Some reasons for that
- There are grounds for hope
„Economics is the only field in which two people can share a Nobel Price for saying the opposite thing“
Sea level rise
according to Richard Tol

England and Wales today

... and after sea level rise
Floods of 2002 in AT
Are there any economic impacts?

Damage about 1% G

But:
Positive (?!?) impacts on GDP
Extreme events in DCs
No impacts on economic activity?

Tsunami 2005

„... no impact on stock market since no major production facilities were affected“.
What went wrong?
Modeling the very long-run

- Economic modeling has been fundamentally challenged when asked to deal with a time horizon of at least 100 years.

- This means modeling the very long-run.

- The first generation of models used was just not adequate.
The Nordhaus paradigm for economic modeling of climate change
Production – Potential output
Factors of production

Q production is determined by

\[ Q = A(t)K(t)^\gamma L(t)^{1-\gamma} \]

A technical progress
K produced capital
L human capital
I investments

\[ A(t) \text{ exogenous} \]
\[ K(t) = K(t-1)(1-\delta_K) + I(t-1) \]
\[ L(t) \text{ exogenous} \]
Emissions
Abatement efforts

**E emissions are determined by**

\[ E(t) = (1 - \mu(t))\sigma(t)Q(t) \]

- \( \mu \) abatement effort
- \( \sigma \) abatement effort
- \( Q \) output
Actual output
Impact of emissions damages and abatements

**Q actual output** is lower than potential output because of

- **Ω** damages from emissions
- **µ** abatement efforts

\[
Q(t) = \Omega(t) \left(1 - b_1(t)\mu(t)^{b_2}\right) A(t)K(t)^\gamma L(t)^{1-\gamma}
\]

\[
\Omega(t) = \Omega(E)
\]

E emissions
Consumption and investment
Limited by actual output

actual output is available for

\[ Q(t) = C(t) + I(t) \]
The fundamental interactions
Policy variables determine consumption

\[
\Omega(t) \left( 1 - b_1(t) \mu(t)^b_2 \right) A(t) K(t)^\gamma L(t)^{1-\gamma} = C(t) + I(t)
\]

Control variables

\( \mu \) abatement efforts
\( I \) investment

Key output variables

\( C \) consumption
Searching for “optimal” policies
Evaluating policies

W welfare measured by

C/L per capita consumption

ρ discount rate

\[ \max W(t) = \sum U \left( \frac{C(t)}{L(t)} \right) (1 + \rho_t)^{-t} \]
Controversies within the Nordhaus paradigm
Why economists disagree on climate change

- Doubling of atmospheric concentrations of CO2 would cost between 1% and 2.5% of global GDP

- But:
  - costs of abatement today
  - benefits after decades or centuries

- The crucial role of discounting

  1.00 € in 50 years
  0.61 € if 1% discount rate
  0.23 € if 3% discount rate
  0.05 € if 6% discount rate
Why the Nordhaus paradigm is not adequate for modeling the very long-run

- Problems with impacts of climate change
  - Extreme events
  - Sea level rise
  - Loss of natural capital
  - Loss of human lives

- Problems with analyzing abatement policies
  - Low energy technologies
  - Low carbon technologies

\[
\Omega(t) \left(1 - b_1(t) \mu(t)^{b_2}\right) A(t) K(t)\gamma L(t)^{1-\gamma} = C(t) + I(t)
\]

\[
\max W(t) = \sum U\left(\frac{C(t)}{L(t)}\right)(1 + \rho_t)^{-t}
\]
The deficiencies of the Nordhaus paradigm when used for modeling the very long-run

Damage and abatement are extremely difficult to evaluate

Technological change is the issue

Welfare results also from stocks

\[
\Omega(t) \left(1 - b_1(t)\mu(t)^{b_2}\right) A(t)K(t) \gamma L(t)^{1-\gamma} = C(t) + I(t)
\]

\[
\max W(t) = \sum U \left(\frac{C(t)}{L(t)}\right) (1 + \rho_t)^{-t}
\]
A stimulus from outside
The Pacala-Socolow paradigm
A paradigm shift
The Pacala-Socolow proposal

“Humanity already possesses the fundamental scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half-century and climate problem over the next half-century.”

S. Pacala and R. Socolow
Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies
Current technologies for GHG stabilization in 50 years

**Graph A**
- BAU (business as usual) line
- WRE500 line

**Graph B**
- Stabilization triangle
- Continued fossil fuel emissions
Current technologies for GHG stabilization in 50 years

- Efficiency and conservation
  - Cars (4x -> 2 billion cars)
    - 60 instead 30 miles/gallon
    - 5000 instead 10000 miles per year
  - Buildings
    - -25% energy
  - Power plants
    - from 40 to 60% efficiency
Current technologies for GHG stabilization in 50 years

- Decarbonization
  - Electric power plants
  - Gas substitutes coal
  - New renewables
    - Wind, thermal, and photovoltaic solar

- Carbon capture and hydrogen storage
  - Post-combustion carbon capture and storage in electricity generation
  - Pre-combustion carbon separation and hydrogen storage as substitute for fossil fuels

- Carbon sinks
Searching for the next generation of economic models for the very long-run
Key issues for next generation of long-term models

- **Structure**
  - **Additions**
    - Extended concept of *production*
    - Recycling and production in households
    - Extended list of *capital stocks*
    - Reproducible capital in firms and households
    - Exhaustible, knowledge and natural capital
  - **Links**
    - Stock-flow relationships
    - Endogenous technical change

- **Measuring welfare**
  - From stocks and flows

- **Mechanisms**
  - Price (market based) mechanism
  - Non-price mechanisms
Extended production activities
Re-generated and knowledge goods

Production and investment activities

$q$ reproducible goods
$g$ re-generated goods (recycling)
$k$ knowledge goods
Extended capital stocks
Reproducible and non-reproducible

Reproducible capital stocks

\[ K^q \] reproducible goods – production
\[ K^g \] re-generated goods - recycling
\[ K^c \] reproducible goods – consumption

Other (capital) stocks

\[ E \] emissions (concentration)
\[ N \] natural capital
\[ R^r \] renewables resources
\[ R^e \] exhaustible resources
(Technological) Knowledge stocks

Stocks of (technological) knowledge

- $T^q$: reproducible goods – production
- $T^g$: re-generated goods – recycling
- $T^c$: reproducible goods – consumption
- $T^e$: emissions
Investment activities

\[ i^q \] reproducible goods – production
\[ i^g \] re-generated goods - recycling
\[ i^c \] reproducible goods – consumption
\[ i^k \] knowledge goods
Production in companies

$q \quad$ reproducible goods – production
$g \quad$ re-generated goods - recycling

$q = q(K^q, L^q, T^q, e^q)$

$g = g(K^g, L^g, T^g, e^q)$
Production in households

$$s = s(c, K^c, L^c, T^c, e^c)$$

consumer services – household production function (housing, nutrition, mobility, information)
Investment activities

- $i_q$: reproducible goods – production
- $i_g$: re-generated goods - recycling
- $i_c$: reproducible goods – consumption
- $i_k$: knowledge goods
Flow equilibria

Flow equilibrium
Flows of demand and supply include recycling

\[ c + i^q + i^g + i^c + i^k = q + g \]
Stock equilibria (1)

Reproducible capital

\[ K^q = K^q (K_{-1}^q, i^q) \]
\[ K^g = K^g (K_{-1}^g, i^g) \]
\[ K^c = K^c (K_{-1}^c, i^c) \]
Stock equilibria (2)

(Technological) Knowledge capital

\[ i^k = i^{kq} + i^{kg} + i^{kc} \]

\[ T^q = T^q (T^q_{-1}, i^{kq}) \]

\[ T^g = T^g (T^g_{-1}, i^{kg}) \]

\[ T^c = T^c (T^c_{-1}, i^{kc}) \]
Stock equilibria (3)

Stock of emissions (concentrations)

\[ e = e^q + e^g + e^c \]

\[ E = E(E_{-1}, e) \]
Measuring welfare

Welfare from flows and stocks

\[ W = W(s, E, N) \]

Indicators

- \( E \) emissions
- \( N \) natural capital
Modeling decision mechanisms

**Mechanism**
- Price decisions
- Non-price decisions

**Decisions**
- Consumption
- Investment
- Production
An example
An internet structure for electricity and heat

The shape of grids to come?

Conventional electrical grid
Centralised power stations generate electricity and distribute it to homes, factories and offices.

Energy internet
Many small generating facilities, including those based on alternative energy sources such as wind and solar power, are orchestrated using real-time monitoring and control systems.

Offices or hospitals generate their own power and sell the excess back to the grid. Hydrogen-powered cars can act as generators when not in use. Energy-storage technologies smooth out fluctuations in supply from wind and solar power.

Distributing power generation in this way reduces transmission losses, operating costs and the environmental impact of overhead power lines.
Lessons to be learnt
How to deal with the “very long” run

- Forward-looking perspective for technological change
  - What are the feasible paths for the penetration of certain technologies?
  - Which path should be chosen?
  - What are the adequate instruments?

- Structures before strategies
  - There are no markets for the “very long” run
  - Innovative instruments are needed
An economics limerick

Folks came from afar just to see
Two economists who‘d agreed to agree.
While the event did take place.
It proved a disgrace;
They agreed one plus one adds to three.
“Practical men … are usually the slaves of some defunct economist.”

John Maynard Keynes (1936)
Thank you.

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