Embracing dynamic complexity in climate economics

The DSK agent-based integrated assessment model

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1 Why Agent-based models?
The problem of Integrated Assessment Models

Thou shalt annually raise CO2 abatement by 1.9%!

For this, thou shalt impose a carbon tax, so that mankind shall follow the optimal emission trajectory…

but…
Abatement cost in DICE

The problem of Integrated Assessment Models

Thou shalt annually raise CO₂ abatement by 1.9%, so that mankind shall follow the optimal emission trajectory…

but...

1990ies

Ongoing emissions:
Apparently, we don’t act optimally...

Annual total CO₂ emissions, by world region, 1751 to 2017

Source: Carbon Dioxide Information Analysis Center (CDIAC); Global Carbon Project (GCP)
Note: The difference between the global estimate and the sum of national totals is labeled “Statistical differences”.
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY
### Problems with Integrated Assessment Models

<table>
<thead>
<tr>
<th>IAMs typically contain (several of) the following assumptions</th>
<th>Real socioeconomic systems...</th>
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<td>-- perfect rationality (social planner, representative agent)</td>
<td>-- consist of heterogeneous agents</td>
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<td>-- perfect information (on prices, climate sensitivity…)</td>
<td>-- which can act irrationally / boundedly rational (rule of thumb)</td>
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<td>-- perfect market equilibrium</td>
<td>-- make use of imperfect insight</td>
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<td>-- interactions may allow several equilibria, or disequilibrium, and endogenous crises</td>
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**Agent-Based Models can mimic this behaviour!**
Agent-Based Models (ABMs)

What is an Agent?
An agent is a persistent thing which
-- has some state you find worth representing
-- interacts with other agents, mutually modifying each others states

-- ABMs were successfully used, for example, to study financial crisis
-- relatively rare in climate economics

Here, we present an Agent-Based Integrated Assessment Model.

Goal:
-- not: computing optimal policy
-- but: study how policy affects economic system
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2 The Dystopian Schumpeter-Keynes model
The Dystopian Schumpeter-Keynes model

DSK model:

-- industrial sector of one homogenous country:
   little “toy model” economy with interacting banks, firms, government, workforce

-- coupled to a simple climate model, C-ROADS
   (assuming that our little economy has a constant share of global emissions)

-- and an agent-based damage function
The DSK model: firms + workforce

-- Agents: 2 types of firms
- 50 machine firms create tools
- 200 consumption good firms use tools
  + make (homogenous) consumption good

-- Machine firms invest in Research & Development.
  -> improves machines (stochastic process)

-- machine firms send “brochures” to some consumption good firms, who buy
  best + cheapest machines they know of

-- consumption good firms have “market share”
  depending on prices and previous sales.

-- households provide labour + consume all wages... or unemployment aid
The DSK model: banking

- Banks provide finance to consumption good firms (if they can; otherwise: credit-rationing)
- Mach.firms need no credit, are paid in advance
- Banks also buy government bonds
- Banks that fail are bailed-out by government
The DSK model: energy firm

-- extra agent: 1 energy firm

-- has 2 types of power plants:
  - “dirty” (no building costs, but fuel costs)
  - “green” (high building costs, no fuel costs)

-- energy firm likewise does R&D to improve plants
  more R&D money for well-used plant types

-- when energy demand unfulfilled, new plants
  (either “green” or “dirty”) are built,
  dependent on expected building + operation costs

-- when supply>demand, cheapest (i.e. green) plants are used.
Abatement cost in DICE

The DSK model: climate

-- CO2 emissions cause global warming

-- Warming causes climate damage, which can be

- long-term (think of costs for building dikes)
- short-term: warming increases the likelihood and severity of shocks

-- damage can hit in many ways, e.g.
- destroy firm’s product
- destroy firm’s capital stock
- reduce worker’s productivity …
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3 Results & ongoing work
Results I: agent-based damages

Climate change causes shocks affecting firm’s store of product, firm’s stock of machines (capital), firm’s energy efficiency, or firm’s labour productivity.
Results I: agent-based damages

Climate change causes shocks affecting firm’s store of product, firm’s stock of machines (capital), firm’s energy efficiency, or firm’s labour productivity.
Results I: agent-based damages - summary

Results: (using very stylised shock functions)

-- climate shocks can hit the economy in various ways

-- these shocks can propagate through the economic system

-- “target” of shocks (i.e. who is hit how?) greatly influences on macro-economic impact

Open tasks:

-- consider long-term damage, non-market damage

-- tune more thoroughly to real-world climate events
Recall:
-- Electricity firm’s Research&Development (R&D) depends on current energy sources
  -> lock-in: using coal plants -> much R&D for coal plants -> coal plants more competitive
-- But: success of R&D is also stochastic.

-> Can the electricity firm be decarbonised by a carbon tax?

Set-up:
-- Initially, 10% energy from green sources; green plants slightly more expensive.
-- carbon tax starts in 2005 and is constant (inflation-corrected) afterwards.
-- Results from 7 example Monte-Carlo members are shown
Results II: Carbon lock-in vs green transition

Low carbon tax: Initial advantage of coal plants is not overcome.
Results II: Carbon lock-in vs green transition

Medium Carbon tax: Green transition happens in some Monte-Carlo members, Depending on “luck” with (stochastic) innovation.

Tax = 1.0 * $T_{critical}$

Tax = 0.7 * $T_{critical}$
High carbon tax: All members are pushed to green transition. Transition can take time, as old infrastructure (coal plants) need to be replaced.

Tax = 0.7 * T_{critical}

Tax = 1.0 * T_{critical}

Tax = 1.3 * T_{critical}
**Ultimate aim:**
-- Investigate how various policy measures (carbon tax, regulations, R&D subsidy…) affect the economic system
-- Find policy mix which brings about green transition without hurting the economy

**Ongoing steps:**
-- allow for intermittency in the electricity sector (solar cells do not work at night…)
-- include fuel use in firms (currently: only electricity use)

**Possible future expansions:**
-- Trade / multi-region model
-- coupling with agriculture model
-- …
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References

Integrated Assessment Models vs Agent-Based Models:
-- Farmer et al., 2015: A third wave in the economics of climate change

The original Keynes & Schumpeter model (without climate change):
-- Dosi et al., 2010: Schumpeter meeting Keynes: a policy-friendly model of endogenous growth and business cycles.

The Dystopian Schumpeter-Keynes model:
-- Lamperti et al, 2017: Faraway, so Close: Coupled Climate and Economic Dynamics in an Agent-Based Integrated Assessment Model  [->agent-based damage function]
-- Lamperti et al., 2018: And Then He Wasn’t a She: Climate Change and Green Transitions in an Agent-Based Integrated Assessment Model  [green transition vs carbon lock-in]