Embracing dynamic complexity in climate economics

The DSK agent-based integrated assessment model

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1 Why Agent-based models?

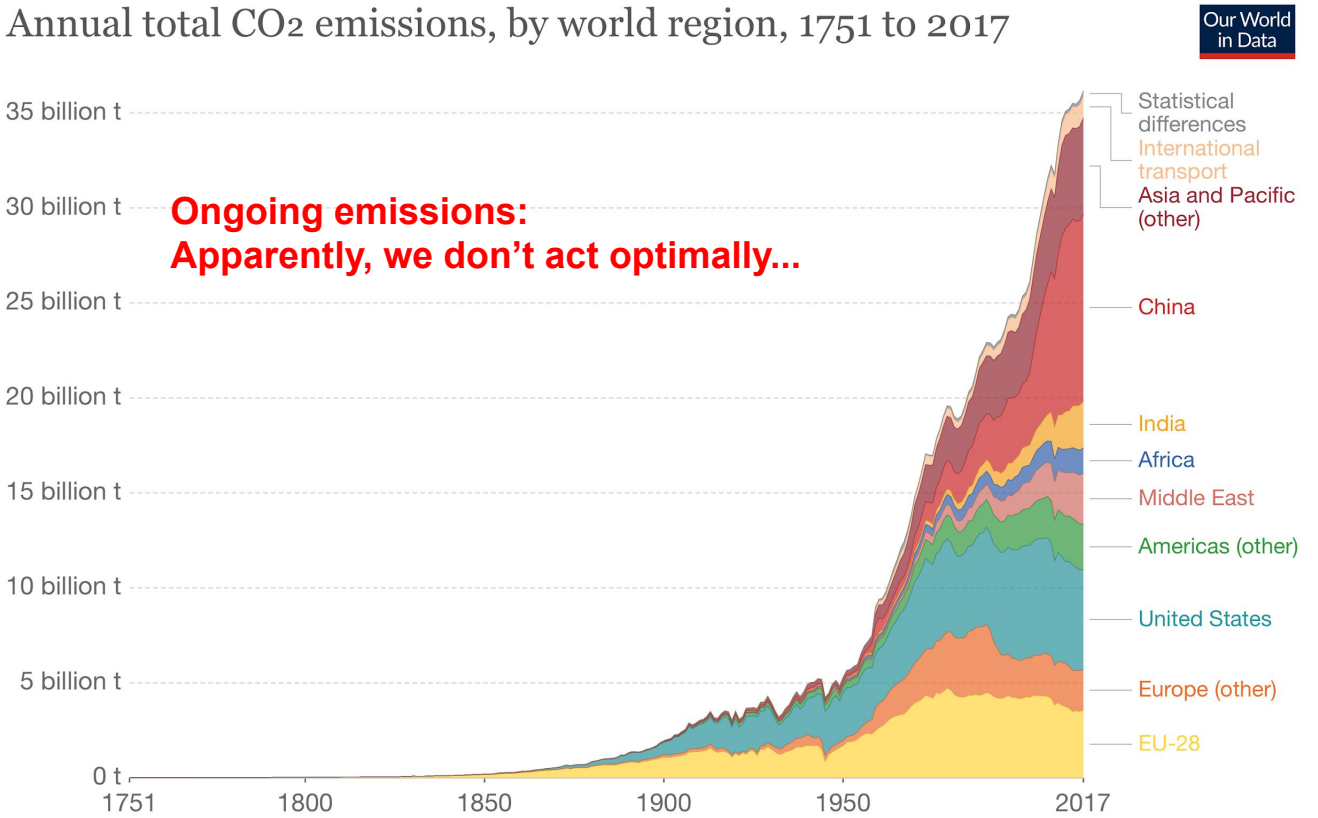
The problem of Integrated Assessment Models

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...

The problem of Integrated Assessment Models



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

Problems with Integrated Assessment Models

IAMs typically contain (several of) the following assumptions

-- perfect rationality
(social planner, representative agent)

-- perfect information
(on prices, climate sensitivity…)

-- perfect market equilibrium

Real socioeconomic systems...

-- consist of heterogeneous agents

-- which can act irrationally / boundedly rational (rule of thumb)

-- make use of imperfect insight

-- interactions may allow several equilibria, or disequilibrium, and endogenous crises

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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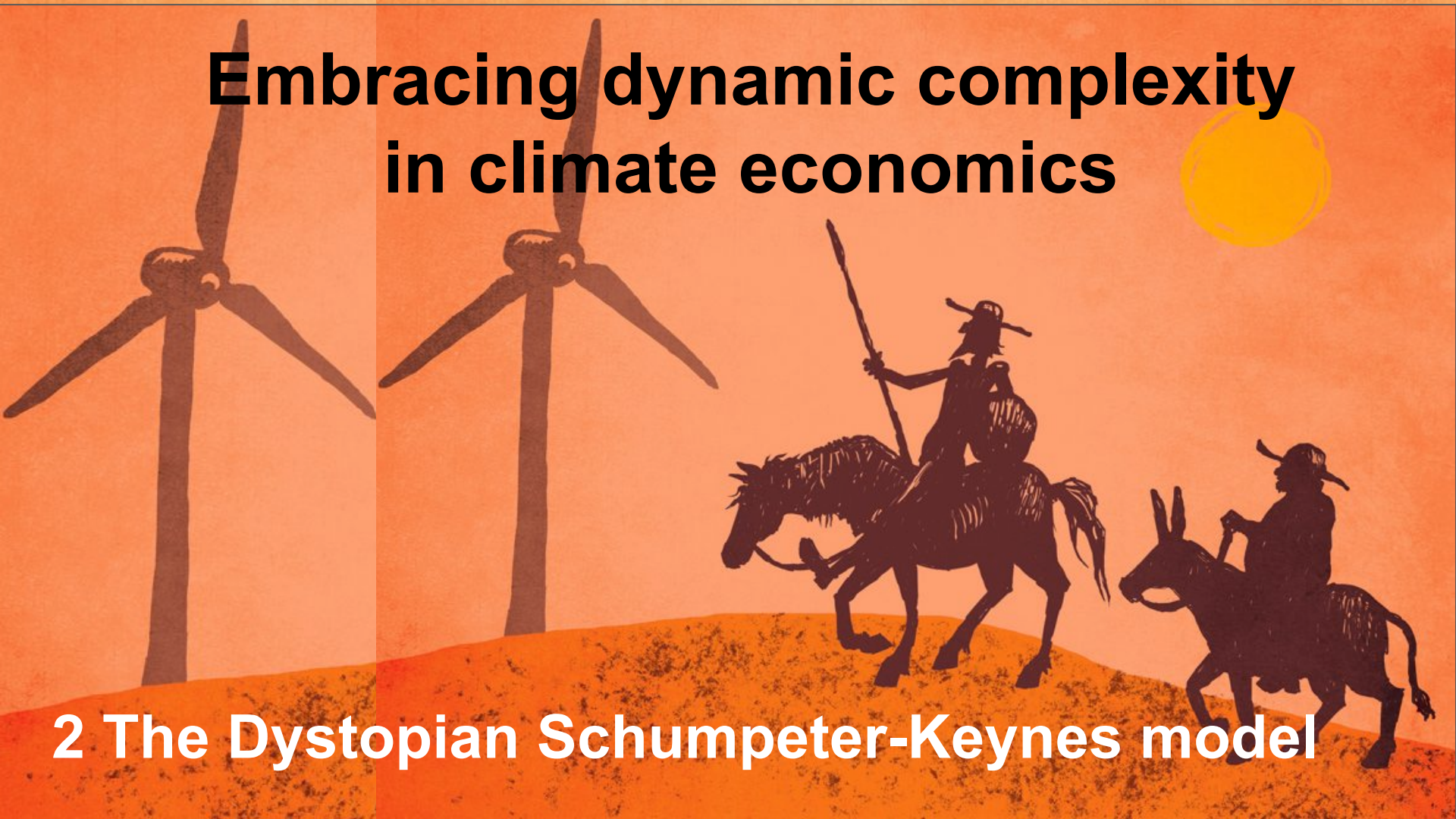


2 The Dystopian Schumpeter-Keynes model

The Dystopian Schumpeter-Keynes model

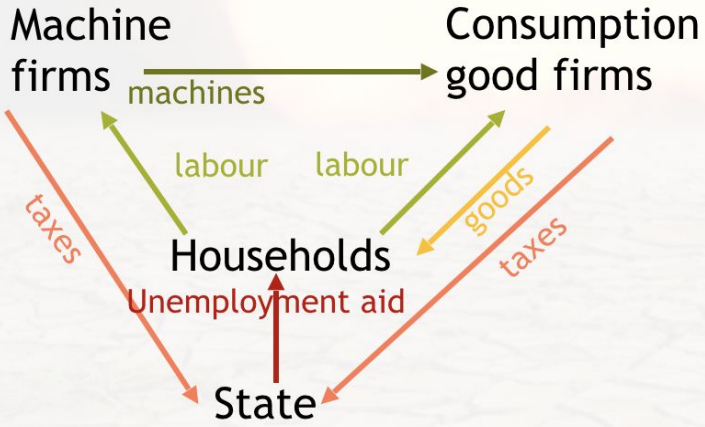
DSK model:

-- 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

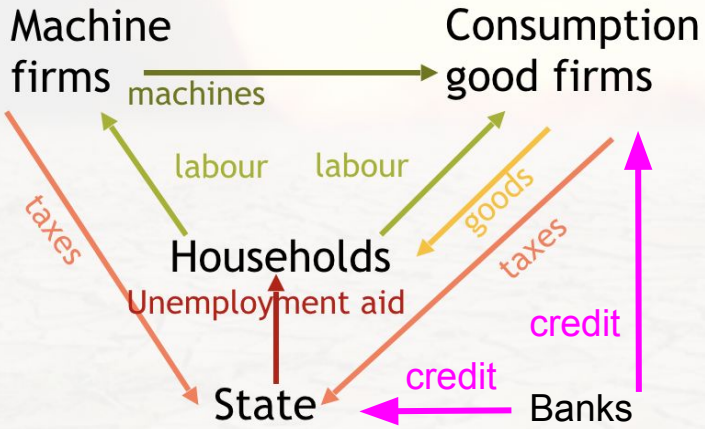
-- Machine firms invest in Research&Development.
-> improves machines (stochastic process)

-- 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



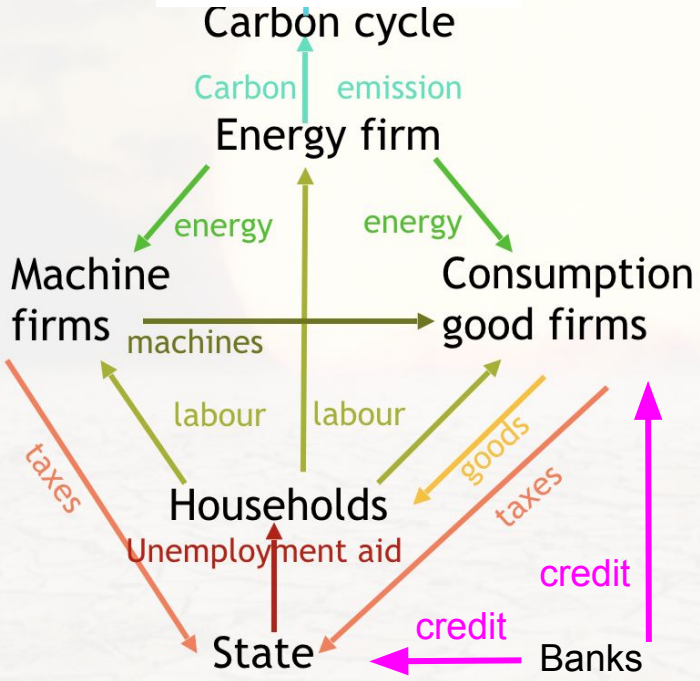
-- Banks provide finance to consumption good firms
(if they can; otherwise: credit-rationing)

-- 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

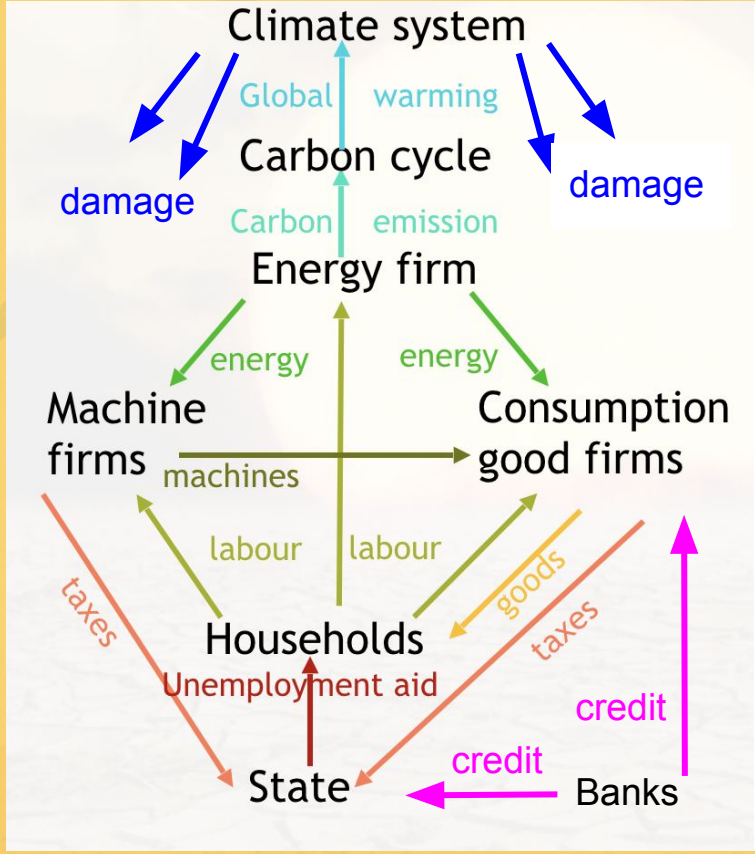
-- has 2 types of power plants:
- "dirty" (no building costs, but fuel costs)
- "green" (high building costs, no fuel costs)

-- 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.

The DSK model: climate



-- CO_2 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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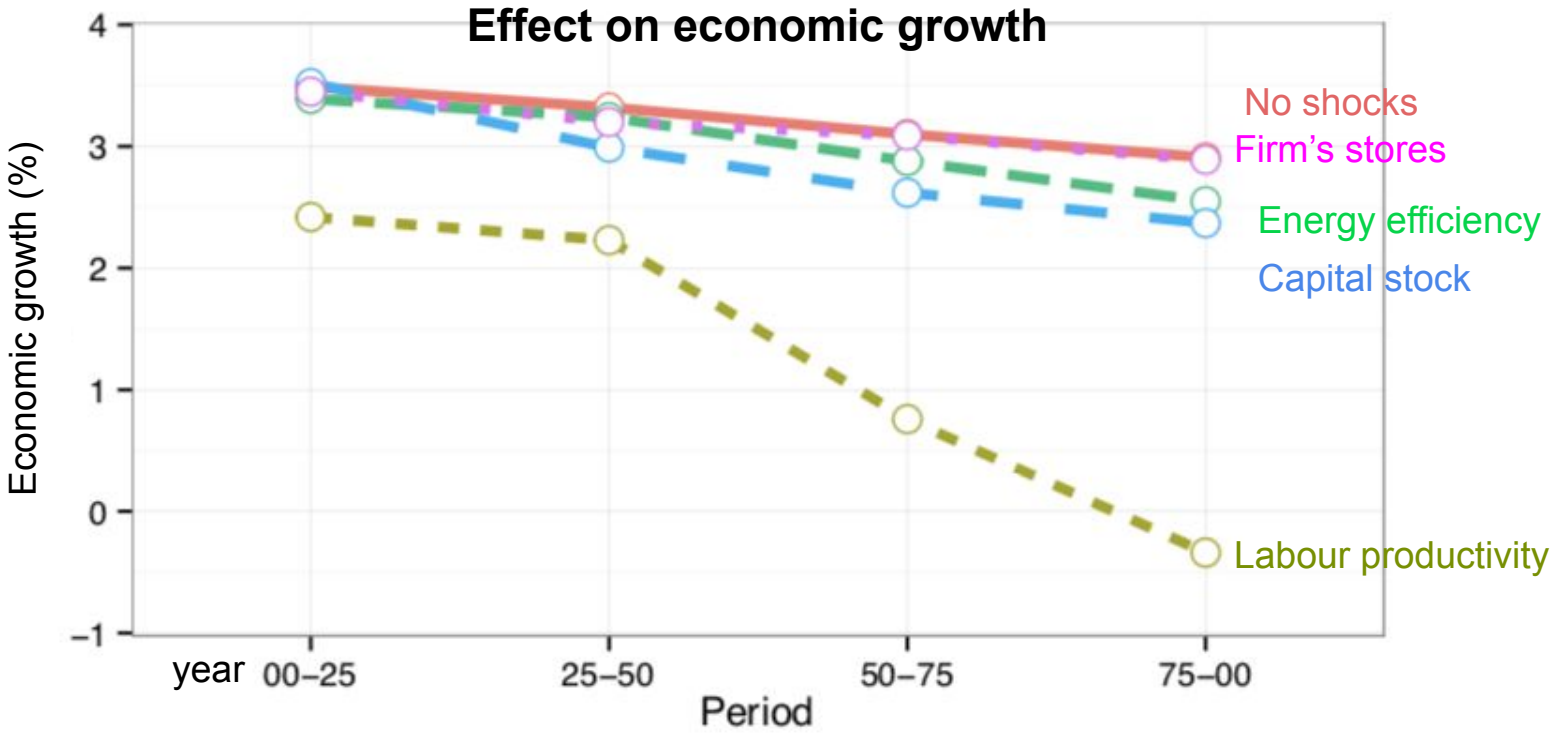
3 Results & ongoing work

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.



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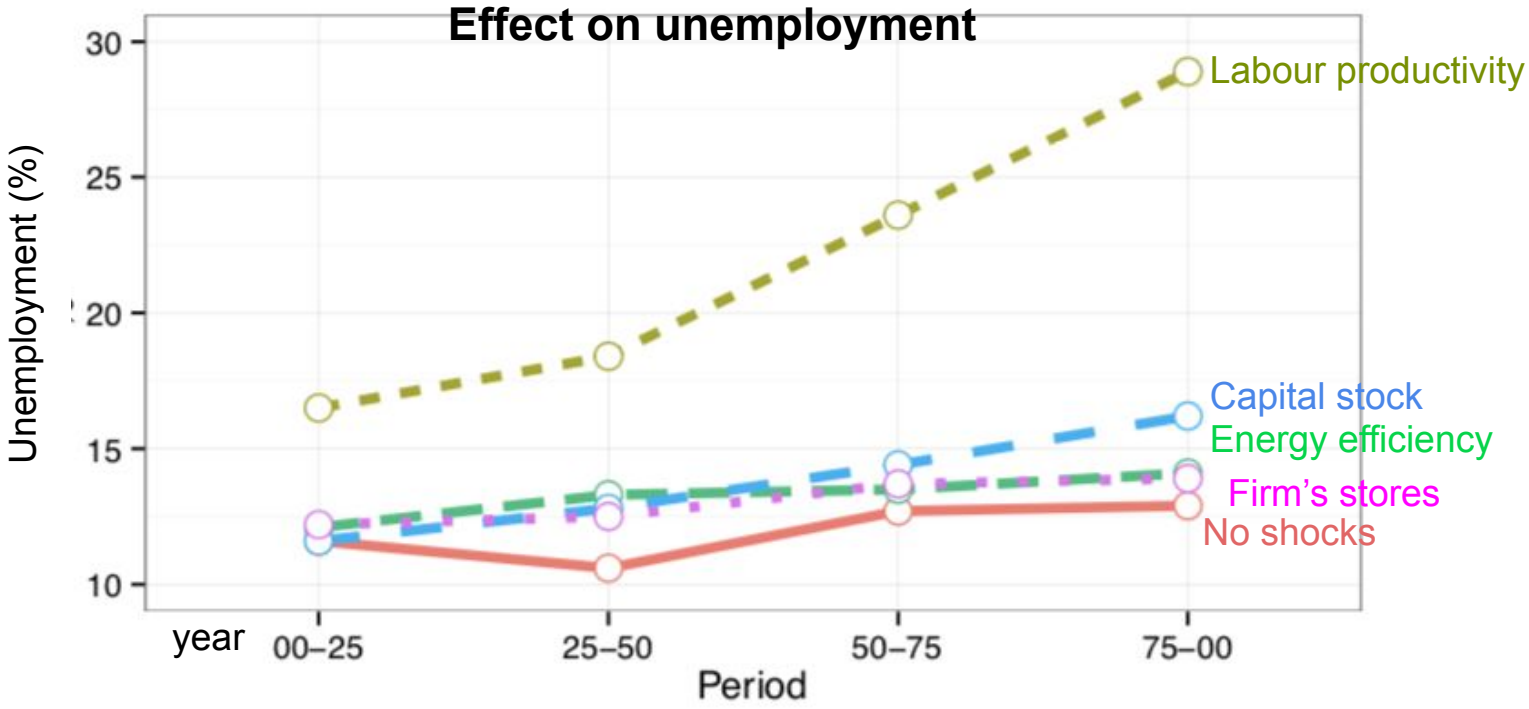


Results I: agent-based damages - summary

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

Results II: Carbon lock-in vs green transition

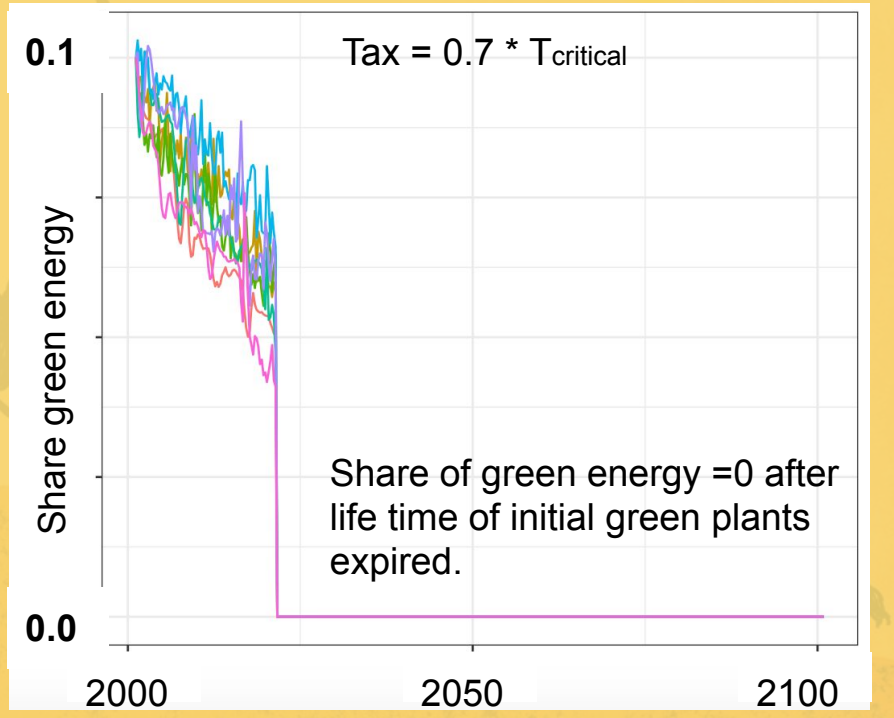
Recall:
-- Electricity firm's Research&Development (R&D) depends on current energy sources
    -> lock-in: using coal plants -> much R&D for coal plants -> coal plants more competitive
-- But: success of R&D is also stochastic.

-> 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

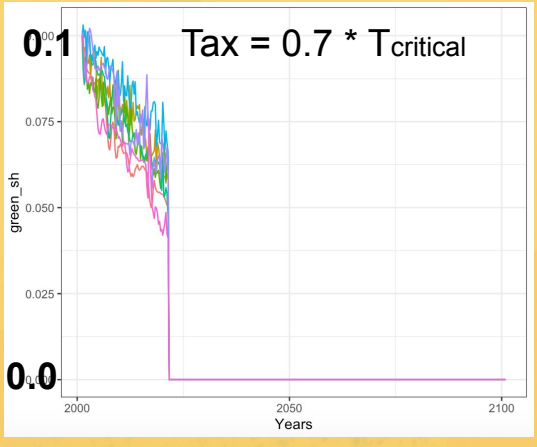
Results II: Carbon lock-in vs green transition

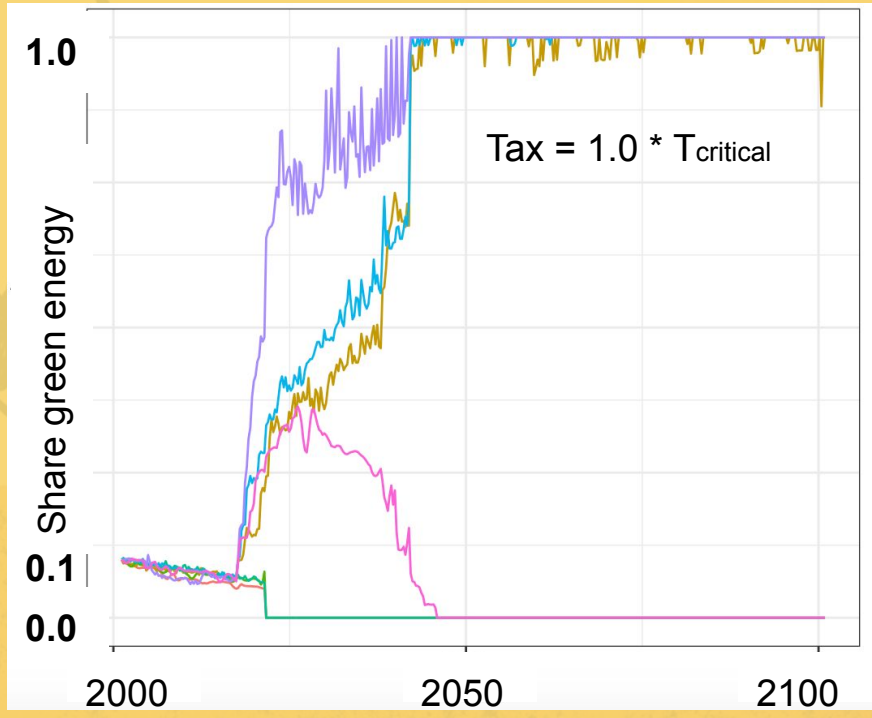
Low carbon tax: Initial advantage of coal plants is not overcome.



Results II: Carbon lock-in vs green transition

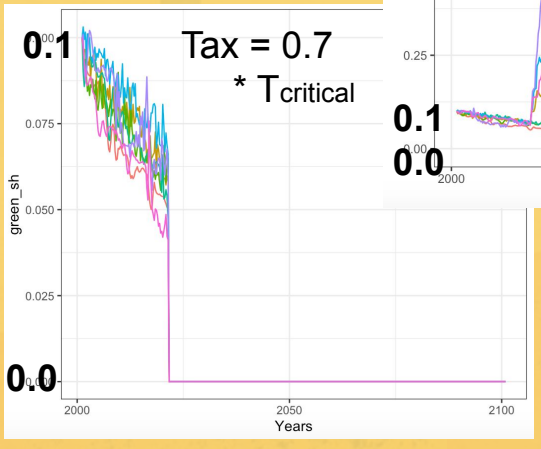
Medium Carbon tax: Green transition happens in some Monte-Carlo members, Depending on "luck" with (stochastic) innovation.

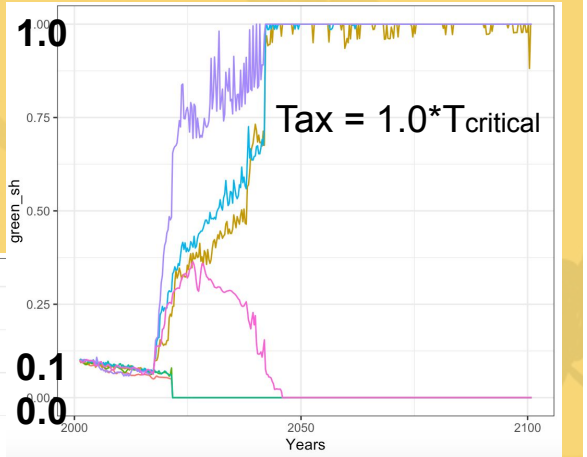


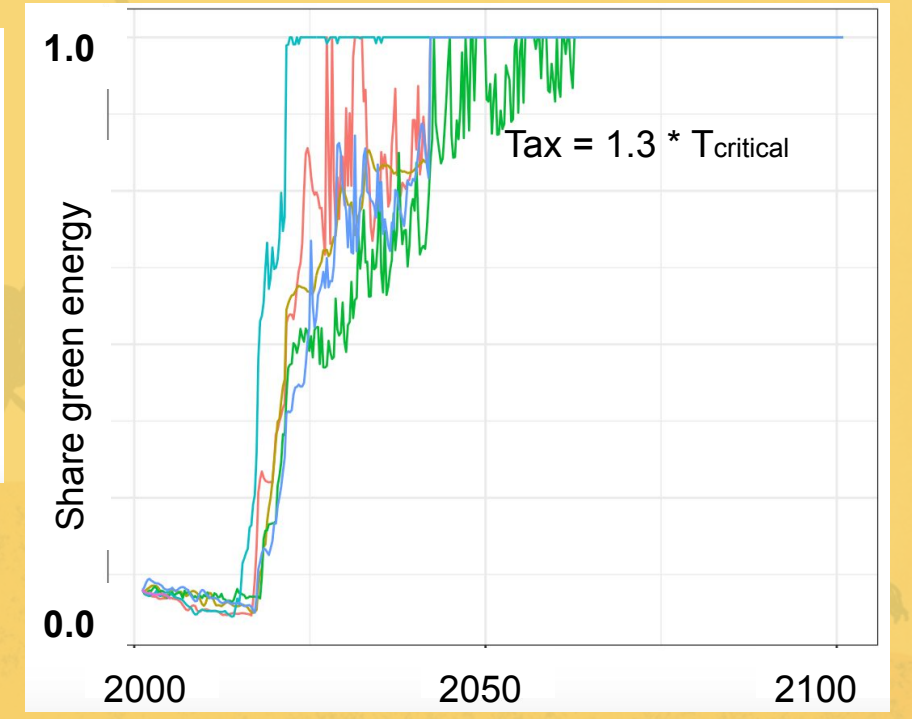


Results II: Carbon lock-in vs green transition

High carbon tax: All members are pushed to green transition. Transition can take time, as old infrastructure (coal plants) need to be replaced.







Ongoing work: Policy mix

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]