Transition of Energy Infrastructures

Using ABM to compare CO₂ policies for CO₂ reduction in power generation

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Context of the energy transition

- Complex, highly developed industrial societies
- Interconnected systems, diverse and large
- Infrastructure sector reforms
  - Liberalized energy sectors
  - Increased complexity
    e.g. by unbundling and introduction of new markets
- New requirements, such as for CO₂, renewables,
  - In addition to flexibility, affordability, acceptability
Agent-based model of an energy transition

- Enabling transition in power generation sector to low carbon electricity generation

- Which carbon policy will do the job?
  - Carbon *emission trading*
    - EU implemented, need to acquire rights
  - Carbon *taxation*
    - Need to pay tax
  - No intervention
Relevant actors and their interaction

**Agent (node):**
- Identity / style
- Strategic management: rules for investment in physical assets
- Operational management: control rules for physical assets

**Physical Asset (node):**
- Physical properties
- Economic properties
- Design properties

**Edges:**
- Ownership of physical assets
- Contracts with other agents
- Physical flows to/from other physical assets

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Agents

- Producers and Consumers of Electricity
- Government and Markets

Installations and Products

- Power Plants
- Industrial Facilities
- Consumer Products
Running the Model
electricity prices:
emission trading

carbon taxation

no intervention

CO₂ price
emission trading

CO₂ taxation
Impact is caused by difference in portfolio evolution - no intervention

[Graph showing portfolio evolution over time with different energy sources.]
Impact is caused by difference in portfolio evolution – emission trading
Impact is caused by difference in portfolio evolution - carbon taxation
Observations

The model shows potential *transitions*

The *agents* are the motor of transitions by competition for power generation through ‘the market’.

They are *constrained* and *enhanced* by external trends/properties.

Government can as an actor – to a limited amount – influence this by implementing policy.
Conclusions

• Emission reduction:
  • Carbon policies do deliver in the long run.
  • The first 10-15 years, CO₂ emissions continue to increase.
  • Without intervention, emission levels grow dramatically.

• Electricity prices / investment risk:
  • A fundamental difference in investment risk can result in a severe investment cycle under emission trading.
  • Carbon taxation leads to lower electricity prices than emission trading.

• Both instruments create pain today.
• Affordable and competitive low-CO₂ electricity generation options must become available on a large scale.
Conclusions

• Example shows that making an energy transition simulation model is possible.

• Agent-based model seems to fit the objective, allowing for emergent properties and intuitive/natural conceptualization of actors, interaction and technology.

• Explication is a necessity.

• Comparison of the two policies is not easy, there are methodological issues.

• Agent-based models provide understanding and insight in the system and provide hints for intervention.
Key references


Thanks for your attention