Modelling the diffusion and effect of behavior changing feedback devices

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The German "Energiewende" - Development of an Integrative and Transformative Research Design in the Case of the Energy Transition of the Ruhr Area and North Rhine-Westphalia (funded by BMBF)

- Goals of project: To provides a conceptual and methodical framework by which the “Energiewende” can be analysed and scientifically accompanied in an integrative way.

- Methods:
  - Integrative system analysis (energy and resource use) (WI)
  - Qualitative analysis of change agents (KWI)
  - Concrete real-world experiments („living labs“) (WI)
  - Developing strategies for the diffusion of successful approaches (WI)
  - Agent-based modelling (WI)

- Non-scientific Partners:
  - Federal State North Rhine-Westphalia
  - InnovationCity GmbH Bottrop
  - Cities of Dortmund and Oberhausen
Context of presented model

The „Energiewende“

Energy use (EU)

Residential buildings

Heating

30%

57%
Context of presented model

Behavior changing feedback devices
Purpose of model

Assess contribution to energy savings

Effect =

\[
\text{effect within household} \times \text{number of adopters} + \text{effect on behavioral norms}
\]
Conceptual model
Co-Diffusion of Devices and Behaviour

Behavior Diffusion

Device Effect

Technology Diffusion

HH A

Heating Behavior

Device Adoption

Slide 6
Model description

Overall approach

- Conceptual study to test relevance of ideas (effect of co-diffusion?)

- Agent-based modeling (Netlogo)
  - Interactions between households drive co-diffusion
  - Capture networks (socio-spatial effects), heterogeneity, bounded rationality

- Use two existing models:
  - Technology diffusion: Schwartz & Ernst 2009
  - Behavior diffusion: Anderson et al. 2014

- Device effect:
  - Asymptotic change of behavior towards incentivized target

- Network:
  - Empirical information on ego-networks of heating behavior
  - Higher probability for links: spatially close, similar agents
Model description

Sub-models

- Technology diffusion
  - Lead: adopt device
  - Maj: adopt device \((p=0.5)\), imitate \((p=0.5)\)
  - Hed: imitate majority of peers
  - \(p_{\text{decision}} = 0.004\)

- Behavior diffusion

\[
\beta_{i,t} = \beta_{i,t-1} + s_i \cdot \left( \frac{\sum_{j=1}^{N} w_{ij} \cdot \beta_{j,t-1}}{\sum_{j=1}^{N} w_{ij}} - \beta_{i,t-1} \right)
\]

- Device effect

\[
\beta_t = \beta_{t-1} + (\beta^*_\infty - \beta_{t-1}) \cdot \Delta \beta
\]
Results

Simulation results

- Simulated case: heating behavior
  - Initial heating behavior $\beta_{i,t=0} = 21.1 \, ^\circ\text{C}$
  - Incentivized behavior $\beta^*_{\infty} = 18 \, ^\circ\text{C}$
- Simulation time: 1990 – 2020
- Time step: 1 month
- 3000 Households

Behavior diffusion decreases heterogeneity within lifestyles... and between lifestyles
Model results

Mechanism

- Co-diffusion of devices and behavior amplifies the effect of behavior changing feedback devices because:

  1. Behavior diffusion $\rightarrow$ convergence of behavior
  2. Device adopters’ change is slowed down $\rightarrow$ stronger and prolongend effect of devices
  3. This additional effect is re-distributed to non-adopters
Survey on heating behavior change

‘Pattern oriented modeling’ with empirical data

Trial testing the effect of devices in Living Labs

Adapt empirical-based choice model to specific feedback device(s)

Agents

Social Data

Social Network

Policy Support

Scenarios for device introduction

Indicators
(C02 mitigation, resource balance)
Discussion
Relation to transitions thinking and modeling

- “Simple” case:
  - “Only” behavioral change / diffusion
  - Only demand side
  - No regime structure

- Captured core aspects of transitions thinking and modeling:
  - endogenous dynamics
  - co-evolution / co-diffusion
  - networks, heterogeneity, bounded rationality

- “Amplification of behavioral change” - effect may also prevail in other settings where technology induces change in behavior

- Addition to toolbox for mechanistic understanding of transitions
References

2. Anderson et al. (2014): Impact of Social Network Type and Structure on Modeling Normative Energy Use Behavior Interventions
Thank you for your attention!

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