MODELLING THE REBOUND EFFECT IN PANTA RHEI

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The Rebound Effect

Definition: “[…] some or all of the expected reductions in energy consumption as a result of energy efficiency improvements are offset by an increasing demand for energy services […]”

Barker et al. 2008: The Macroeconomic Rebound Effect and the UK Economy

Straight forward example:

⇒ 10 % increase in energy efficiency
⇒ 6 % decrease in energy consumption
⇒ 40 % rebound effect
ReCap project (https://www.macro-rebounds.org/english/)

- Reconsidering the Role of Energy and Resource Productivity for Economic Growth, and Developing Policy Options for Capping Macro-Level Rebound Effects
- Three year project funded by BMBF as part of FONA
- Partners: IÖW Berlin (lead), University of Göttingen

The problem: energy consumption is declining less than expected
- Have rebound effects been neglected?
- What are magnitude and drivers of rebounds?
- How to model and address them?
The problem

Target of the German Energy Concept: Reduction of the primary energy consumption by 20% until 2020

Source: Umweltbundesamt

* preliminary figures
** Targets of the Energy Concept and the German Sustainable Development Strategy: Reduction of the primary energy consumption by 20 % until 2020 and by 50 % until 2050 (base year 2008)

Source: German Federal Environment Agency on basis of the Working Group on Energy Balances (AGEB), Evaluation Tables on the Energy Balance for Germany 1990 to 2017, as of 07/2018; for 2016/2017 - AGEB: Primary energy consumption, as of 12/2018
Rebound definition in ReCap

- Only part of rebound effects considered in PANTA RHEI

**macro level**

- **economy-wide rebound effect**

**meso level**

- **macroeconomic rebound effects**
  - international
    - international trade and relocation
    - international energy markets
  - national
    - general market price of energy
    - macroeconomic multiplier
  - mesoeconomic rebound effects
    - single energy market
      - energy price in one energy market
    - intermediate goods and services
      - output
      - lower prices and higher sales
    - final goods and services
      - lower prices and higher sales
      - income
      - substitution

**micro level**

- **microeconomic rebound effects**
  - firms
    - direct
      - output
      - substitution
    - indirect
  - households
    - direct
      - output
      - substitution
    - indirect
Literature on modelling rebounds

- Broad range of macroeconomic models for various uses
  - Rebounds are just sometimes considered explicitly
  - Rebounds and policies are rarely modelled together
- Four models examining the macro-rebound screened in detail

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Publication of Choice</th>
<th>Size of the Rebound Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computable general equilibrium model</td>
<td>Allan et al. (2007)</td>
<td>55-62% short term 27-31% long term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Koesler et al. (2016)</td>
</tr>
<tr>
<td>Macroeconometric Model</td>
<td>Barker et al. (2008)</td>
<td>11% (Macro) + 15% (Micro) = 26%</td>
</tr>
</tbody>
</table>
PANTA RHEI:

- Macroeconometric energy and environmental national model (INFORUM type, similar to E3ME)
- Parameters econometrically derived from historical time series, no neoclassical general equilibrium
- Based on official statistics (SNA, time series of IOT)
- Bottom-up (63 sectors)
- Fully interdependent
- Energy balance systematic
- Open for expert information/input from bottom-up models
- **Net impacts** (direct, indirect, induced effects)

Comparison of models results for different scenarios: Energy efficiency increase or energy policy compared to Reference
1. Autonomous increase in energy efficiency in industry (or in transport or housing): +10% in manufacturing from 2021 on

- **Final Energy Demand (Variable eevb) decreases by 10% of its 2021 value from 2021 onwards in all sectors belonging to manufacturing via fix**

![Diagram]

- **Energy Demand in Industry i**
- **Production costs in Industry i**
- **Prices in Industry i**
- **Prices in Industries using i as input**

- **Production, Employment, Investment**
- **Demand**
2. Lower electricity prices due to lower demand:
exogenous assumption as the most expensive power plant in
Germany or neighbour countries sets the price
Wholesale price: -1 €Cent/kWh from 2021 onwards

► reduction of epstromhh[1] by 1 (procurement component of
electricity price for households) via fix

3. Higher private consumption due to higher income and lower
(energy) prices

► Creation of a variable representing the hypothetical real
income gain, used to calculate a higher cpvr (final
consumption of households in real terms)
4. **(Additional) Investment** in more energy-efficient production in industry (25 BN € in 2021 according to another study)
   
   - *irsr (equipment investment, various elements) and ibsr (building investment, by energy supply) are raised*

5. **Higher exports** due to lower production costs (export prices):
   price elasticity of exports 5 (instead of 1)
   
   - *exn (Exports) modified by multiples of the resulting delta from previous scenarios*
Schematic overview

- Total input
  - Consumption of priv. HH
  - Gov. Consumption
  - Gross fixed capital formation
  - Stock changes
  - Exports

- Final uses of products
  - Gross value added

- Output
  - Compensation of employees
  - Consumption of fixed capital
  - Net operating surplus

- Total supply
  - Intermediate consumption

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Rebound effects – first results

- Model based calculation of the rebound:

\[ 1 - \frac{\Delta eevb_{\text{scenario \ x}}}{\Delta eevb_{\text{initial \ fix}}} \]

![Graph showing difference in rebound level by scenario](image-url)
Summary and outlook

► Rebound effects due to autonomous increase in energy efficiency are low in PANTA RHEI
  ⇦ Parameters of behavioural equations are estimated econometrically (are they too low in the long term?)
  ⇦ Less optimistic about substitution possibilities (elasticities) than neoclassical CGE models
  ⇦ Macroeconomic/sectoral approach does not cover all rebounds (on micro level/international level)

► Model adjustment
  ⇦ Elasticities for industry from ex-post estimations (using very detailed cost structure data from German manufacturing)
  ⇦ Sensitivity analyses
Summary and outlook (2)

- Main research interest is in policies to reduce rebound effects (not in modelling rebounds)
- Implementing different policy sets in the model and compare macroeconomic effects
  - Current policy
  - Prices (taxes, caps, market-based instruments)
  - Regulation
  - Policy mixes and rebound-proof policies

- Develop/evaluate rebound-proof policies with stakeholders and also discuss model characteristics such as elasticities
Thank you for your attention.

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Literature

► Allan, Grant; Hanley, Nick; McGregor, Peter; Swales, Kim; Turner, Karen (2007a): The impact of an increased efficiency in the industrial use of energy: A computable general equilibrium analysis for the United Kingdom, in Energy Economics 29, 779-798.


► Koesler, Simon; Swales, Kim; Turner, Karen (2016): International spillover and rebound effects from an increased energy efficiency in Germany, in Energy Economics 54, 444-452.


## Model characteristics and results

<table>
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<tr>
<td><strong>Causal shock</strong></td>
<td>Rise in energy productivity by 20%</td>
<td>Rise in energy productivity by 5%</td>
<td>Various policy measures</td>
<td>Rise in energy productivity by 10% (depending on sc.)</td>
</tr>
<tr>
<td><strong>Production function</strong></td>
<td>Cobb-Douglas</td>
<td>Multi-level production functions (CES, sector specific)</td>
<td>No explicitly stated production funct.; diff. factor demand functions</td>
<td>KLEM (CES, sector/country specific)</td>
</tr>
<tr>
<td><strong>Elasticity of substitution</strong></td>
<td>1 (between labour, capital, and Energy)</td>
<td>0.3 (between energy and non-energy components)</td>
<td>0.8</td>
<td>Various; between 0.15 and 0.72</td>
</tr>
<tr>
<td><strong>Effect on GDP</strong></td>
<td>Short term: +1%-2% Long term: 14% higher</td>
<td>Short t.: +0.11% Long t. +0.17%</td>
<td>+1.26%</td>
<td>- Sc. 1: Germany: +0.13%; ROW: +0%</td>
</tr>
<tr>
<td><strong>Rebound effects</strong></td>
<td>Not quantified</td>
<td>Electricity production: 62% s. t., 27% l. t. - Remaining energy prod.: 55% s. t., 31% l. t.</td>
<td>- Macro rebound (by their definition): 11% - Direct rebound: 15% (exogenous) Total rebound: 26%</td>
<td>- 47% - 57%, depending on scope and scenario</td>
</tr>
</tbody>
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Conclusions from the literature review

- Similar comparisons of a scenario with autonomous increase in energy efficiency with a reference case throughout publications
  - Direct effect on the production function
  - Private households only indirectly affected
- An exception is Barker et al. modelling explicit policies
- Elasticities along the cause-impact chain are responsible for the size of the rebound effects (in particular SE of energy)
  - Need for discussion about the relationship between energy and capital (substitutes vs. complements)
- Although causal shocks (increase in energy efficiency) are largely the same, results differ significantly
- High(er) rebound effects in CGE models
How to model rebounds in PANTA RHEI?

[Diagram of economic and energy systems]

- Input-Output-Table, National Accounts
- Energy balance, satellite balance for renewable energy, energy prices

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Rebound effects – first results

- Model based calculation of the rebound:
  \[ \text{Delta(eevb(scenario))} / \text{delta(eevb(fix))} \]
Rebound effects – first results

Model based calculation of the rebound:

\[ 1 - \frac{\Delta eevb_{\text{scenario}}}{\Delta eevb_{\text{fix}}} \]

![Bar chart showing rebound effects from 2021 to 2030.](chart.png)