Evaluating integrated assessment models with stylized facts - an exercise with ReMIND
Fifth Annual Meeting of the Integrated Assessment Modeling Consortium

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Content

Stylized facts
   Short introduction and methodological notes

Convergence of growth
   Historical development
   Continuation of history in REMIND

Convergence of energy demand
   Development of trend
   Dynamics in history
   How does REMIND continue the history?
      Intradistributional mobility
      Ergodic distribution
      Sensitivity to regional mapping

Summary and keywords for discussion
Introduction and methodological notes

- **Stylized facts**, Kaldor 1957: confronting models with observed patterns and trends omitting small details

- **Acceptance of stylized facts?!**
  See e.g. debate on income convergence and critics by Quah 1993 and others: ... *the widely used initial level regression shed no light on convergence* [i.e. cross-section dispersion diminishes over time] ⇒ ignorance of multi-modality, regression to mean, Galton’s Fallacy, need to learn about distribution dynamics

- **Method:**
  1. search historic data for candidates of stylized facts (SF),
  2. test how SF shows up when aggregating to native model regions
  3. judge plausibility of how IAMs continue the history
Testing stylized facts:
Economic development
Testing stylized facts: Economic development

Distribution of regional GDP around moving world mean

Source of data: PWT 7.0 (189 countries and territories)

Sample mean

Sample mean

data are aggregated to 11 REMIND regions:
AFR, CHN, EUR, IND, JPN, LAM, MEA, OAS, ROW, RUS, USA.
Note: no GDP of SU before 1990 and other FS countries.
Testing stylized facts: Economic development

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Twin-Peaks

high GDP/capita

low GDP/capita

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Twin-Peaks

high GDP/capita

low GDP/capita

Sample mean

density of GDP/PPP per capita (rdpgpl)

in % of mean

0 50 100 150 200 250 300 350 400 450 500

0 0.002 0.004 0.006 0.008 0.01 0.012

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Evaluating Economic Development:
Continuation of history by REMIND’s default GDP scenario
Testing stylized facts: Economic development

Historic GDP development vs. projected GDP scenario
based on PWT 7.0, aggregated to REMIND regions, projections by REMIND BAU
Testing stylized facts: Economic development

Historic GDP development vs. projected GDP scenario
based on PWT 7.0, aggregated to REMIND regions, projections by REMIND BAU

GDP development is dominated by a strong convergence assumption

Twin-Peaks disappear
Testing stylized facts: Economic development

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Density of GDP PPP per capita

in % of mean
Testing stylized facts: Economic development

Historic GDP development vs. projected GDP scenario
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GDP development is dominated by a strong convergence assumption

Twin-Peaks disappear
Testing stylized facts:
Development of primary energy demand (intensity)
Yearly trend in Primary Energy Intensity

History vs. Projection

with exponential fit for 2005-2050: \( r = -2.1 \% \text{ p.a.} \)
Evaluating Energy Development:
Dynamics in history
Testing stylized facts: Development of Energy Intensity

Historic evolution of Primary Energy Intensities
country sample vs. sample with REMIND regional aggregation

Source of data: Enerdata, PWT 7.0
Testing stylized facts: Development of Energy Intensity

Historic evolution of Primary Energy Intensities

country sample vs. sample with REMIND regional aggregation

1985: 67% (54%) are below mean

Source of data: Enerdata, PWT 7.0
Testing stylized facts: Development of Energy Intensity

Historic evolution of Primary Energy Intensities
country sample vs. sample with REMIND regional aggregation

Source of data: Enerdata, PWT 7.0

1995: 68% (57%) are below mean
Testing stylized facts: Development of Energy Intensity

Historic evolution of Primary Energy Intensities

country sample vs. sample with REMIND regional aggregation

Source of data: Enerdata, PWT 7.0

2005: 70% (57%) are below mean
Evaluating Energy Development:
Continuation of history by REMIND
Development of Primary Energy Intensity

Historic data (Enerdata, PWT 7.0), REMIND projections from 2010

below mean: historic: 57%, REMIND all: 51%
Evaluating Development of Energy Demand:
Characteristics of intradistributional mobility
PE/GDP ppp (1975-1980) - cross-country sample
PE/GDP ppp (1980-1985) - cross-country sample
PE/GDP ppp (1985-1990) - cross-country sample
PE/GDP ppp (1995-2000) - cross-country sample
PE/GDP ppp (2000-2005) - cross-country sample
Evaluating Development of Energy Demand:
Ergodic distribution
Ergodic distribution for Intensity of Primary Energy
based on historic transition from 2000 to 2005 (PAU)
Sensitivity to mapping: REMIND (11), IMAGE (26)
Sensitivity to mapping: REMIND (11), IMAGE (26)

Sensitivity to regional aggregation
year 2005, based on PWT 7.0

below mean:
70% in country sample
57% in REMIND regions sample
56% in IMAGE regions sample

country sample
REMIND regions sample
IMAGE regions sample

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ant
Summary and keywords for discussion

▶ Summary

▶ studying data with regression falls short, better to use distribution dynamics
▶ Evaluation of GDP: historically observed multi-modality disappears, strong dominance of convergence assumption ⇒ development of divergence scenarios useful to study sensitivity
▶ Evaluation of PE/GDP: distribution of PE/GDP appears relatively stable over decades (high persistence, some mobility towards mean), mean decreasing by 2.1 % p.a. (2010-2050), regional aggregation resembles country pattern, projections by REMIND continue observed historical distribution dynamics

▶ Keywords for Discussion

▶ Developing a list of stylized facts relevant for IAMs
▶ Setting a standard for evaluation and transparency
Thank you for your attention and comments!

This presentation has benefited from open source software: \textsc{LaTeX}, \textsc{xmgrace}, \textsc{libre office}, \textsc{pawX11}, \textsc{perl}, \textsc{fortran}, \textsc{linux/ubuntu}. 
Probability distribution $f(x)$ is estimated as

$$f(x) = \frac{1}{nh} \sum_{i=1}^{n} K \left( \frac{x - x_i}{h} \right)$$

$$K(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right),$$

with $h$ bandwidth, $n$ number of observations, and $K(x)$ Kernel function. Here: Gaussian Kernel, choice of $h$ as in Silverman 1986, p. 44.
Distribution of share of Oil in Primary Energy

REMIND projections, aggregation to 11 regions

- Fragmented climate policies, 2020
- Fragmented climate policies, 2040
- Fragmented climate policies, 2060
- Fragmented climate policies, 2080
- Fragmented climate policies, 2100
- BAU, 2020
- BAU, 2040
- BAU, 2060
- BAU, 2080
- BAU, 2100

Distribution of oil share in PE
## Proposal: list of stylized facts for IAMs

<table>
<thead>
<tr>
<th>Process</th>
<th>Sub-process</th>
<th>Example of stylized trends &amp; patterns</th>
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</thead>
<tbody>
<tr>
<td>Social &amp; cultural change</td>
<td>Individual behavior</td>
<td>Trend towards more bureaucracy.</td>
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<td>Social choice</td>
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<tr>
<td>Institutional change</td>
<td>Rules, regulations, law</td>
<td>Trend towards democratization.</td>
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<td>Policies, government</td>
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<tr>
<td>Sudden events</td>
<td>Luck</td>
<td>Major nuclear GAU every 25 years.</td>
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<td>Catastrophes</td>
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<td>Geographic change</td>
<td>Resources and reserves</td>
<td>&quot;Peak oil&quot; not for gas (@ Hefner)</td>
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<td>Land-use patterns</td>
<td>Decreasing soil quality.</td>
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<tr>
<td>Climate change</td>
<td>Regional &amp; global patterns</td>
<td>Accelerated anthropogenic climate change.</td>
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<tr>
<td>Economic development</td>
<td>Growth</td>
<td>@ Kaldor, Dosi, Romer &amp; Jones, Acemoglu</td>
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<td>Demographic change</td>
<td>Aging of societies, stagnation in OECD.</td>
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<td>Structural change</td>
<td>Accelerated urbanization. Role of services.</td>
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<tr>
<td>Energy transition</td>
<td>Change in quantities</td>
<td>@ Smil, Grubler</td>
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<td>Change in structure</td>
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<td>Technological change</td>
<td>Creation of knowledge</td>
<td>Knowledge basis and break-through correl.</td>
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<td>Diffusion of knowledge</td>
<td>S-shaped diffusion.</td>
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