Evaluating integrated assessment models with stylized facts - an exercise with ReMIND

Fifth Annual Meeting of the Integrated Assessment Modeling Consortium

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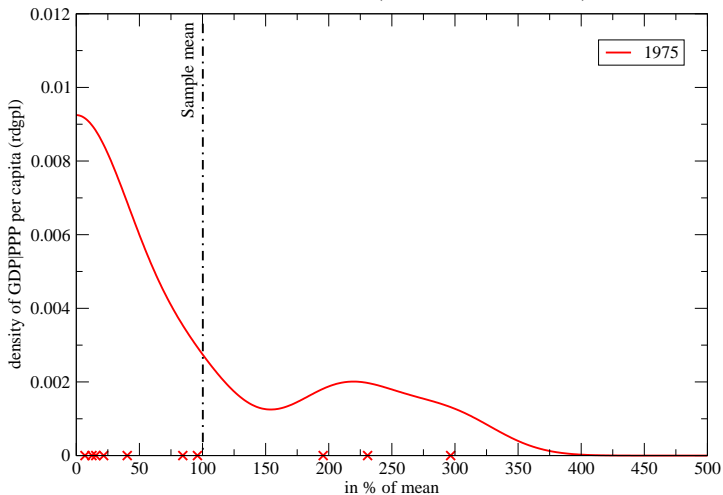11. November 2012

Content

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)

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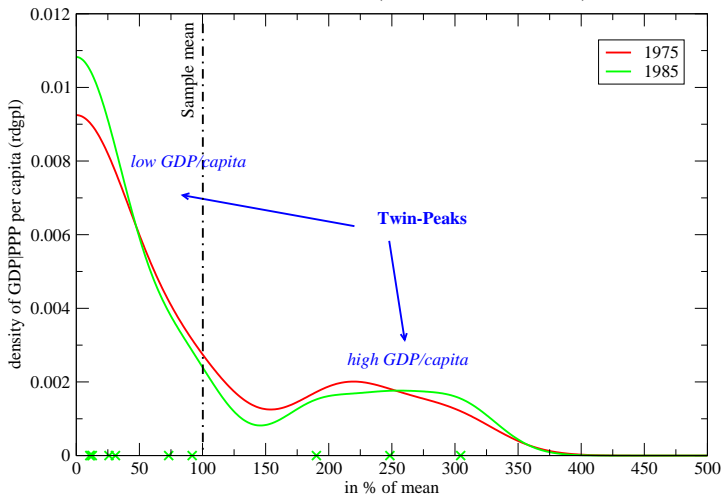Source of data: PWT 7.0 (189 countries and territories)

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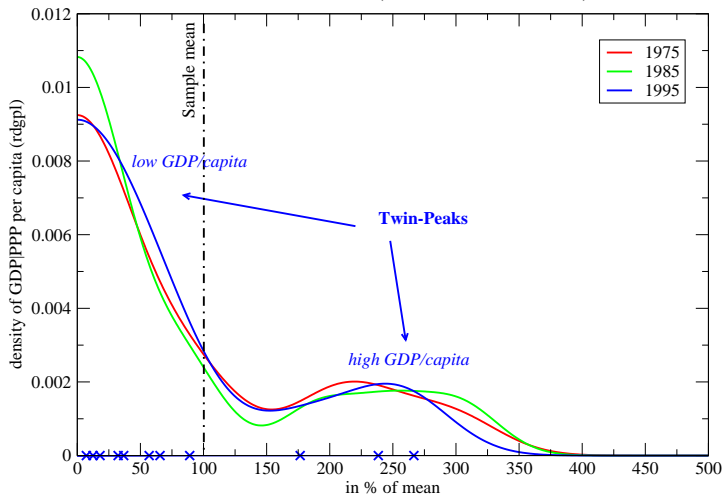Source of data: PWT 7.0 (189 countries and territories)

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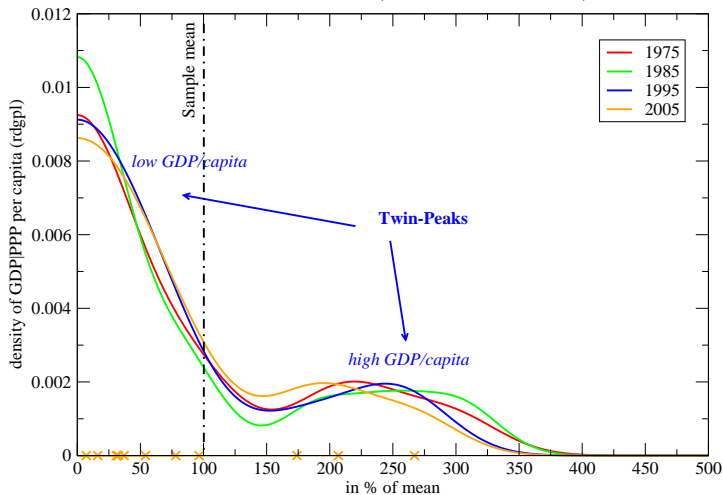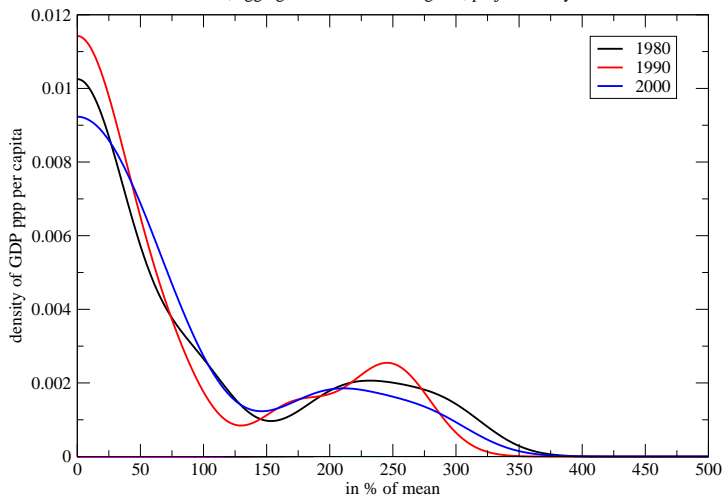Source of data: PWT 7.0 (189 countries and territories)

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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

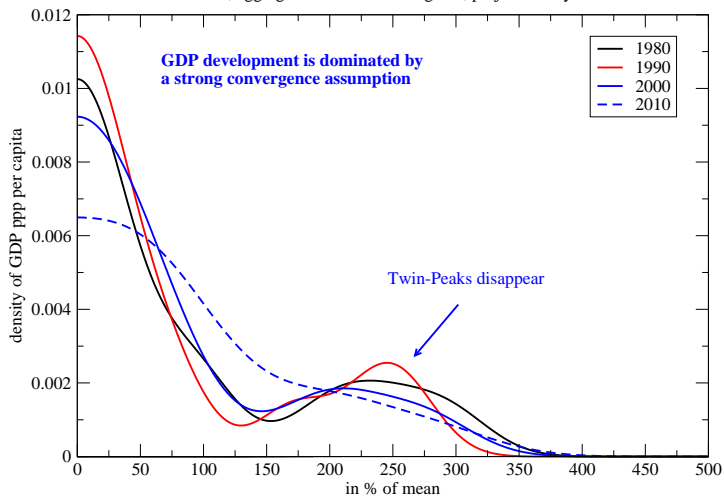based on PWT 7.0, aggregated to REMIND regions, projections by REMIND BAU

Testing stylized facts: Economic development

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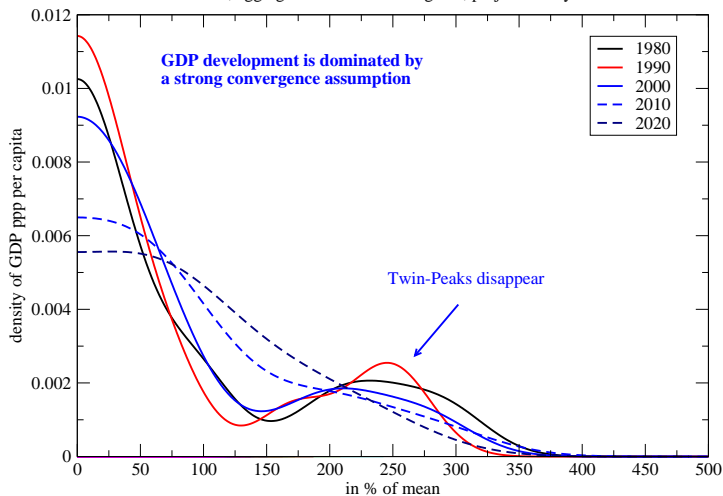based on PWT 7.0, aggregated to REMIND regions, projections by REMIND BAU

GDP development is dominated by
a strong convergence assumption

Twin-Peaks disappear

——	1980
——	1990
——	2000
– –	2010

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

Legend:
- 1980
- 1990
- 2000
- 2010
- 2020

y-axis: density of GDP ppp per capita

x-axis: in % of mean

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

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Twin-Peaks disappear

Legend:
- 1980
- 1990
- 2000
- 2010
- 2020
- 2030

y-axis: density of GDP ppp per capita
x-axis: in % of mean

Testing stylized facts: Economic development

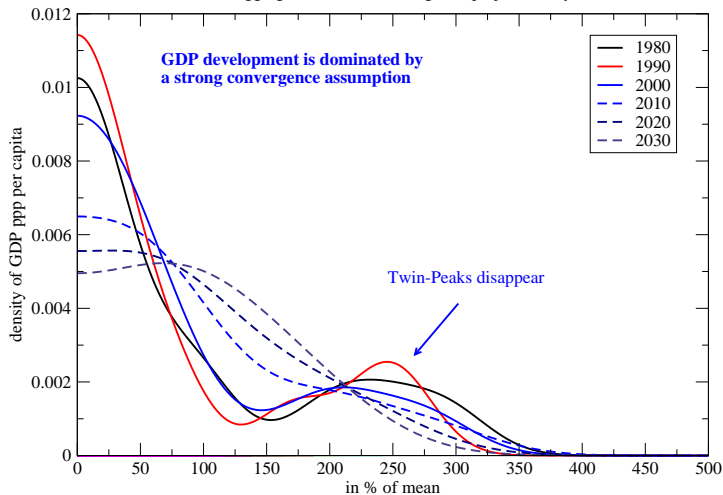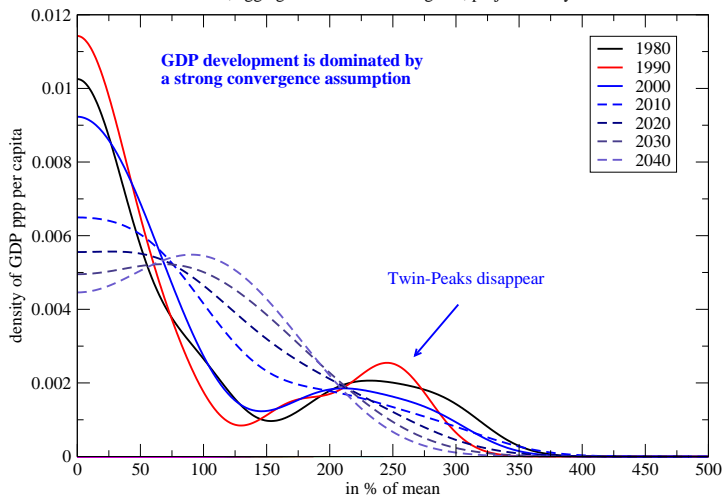Historic GDP development vs. projected GDP scenario

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- 2050

density of GDP ppp per capita

in % of mean

Testing stylized facts: Economic development

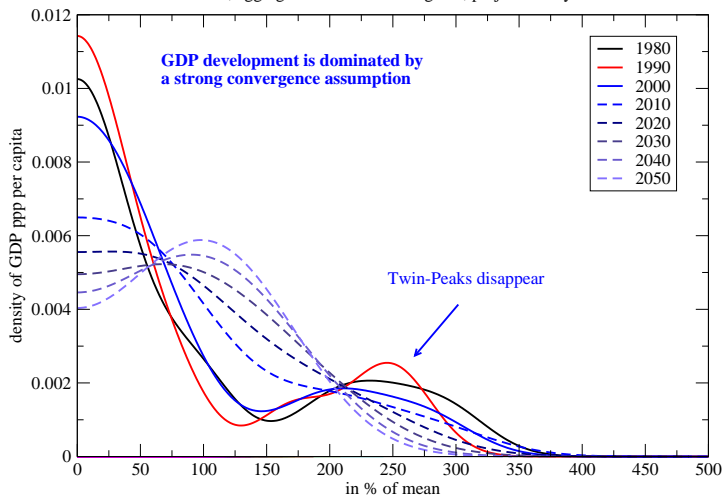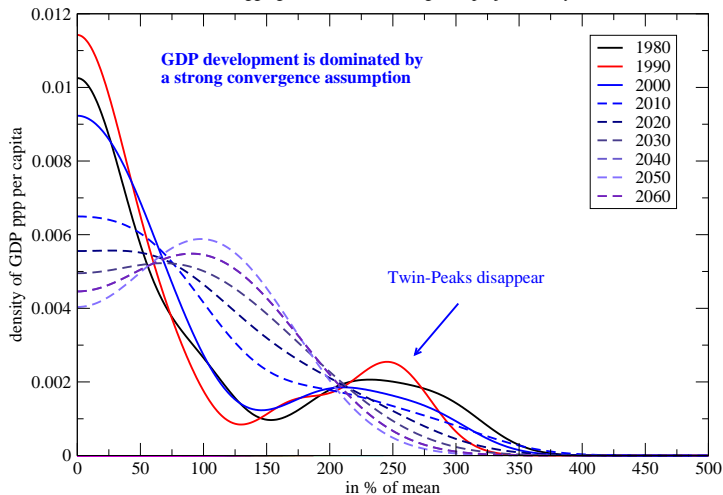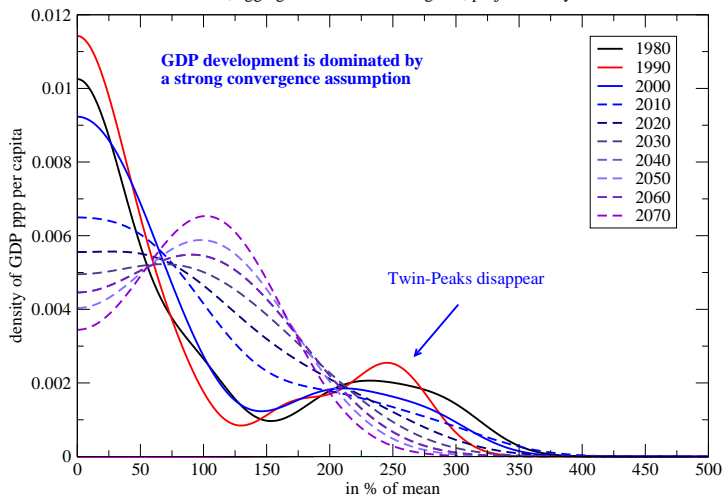Historic GDP development vs. projected GDP scenario

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Legend:
- 1980
- 1990
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- 2010
- 2020
- 2030
- 2040
- 2050
- 2060
- 2070

y-axis: density of GDP ppp per capita

x-axis: in % of mean

Testing stylized facts: Economic development

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Twin-Peaks disappear

Legend:
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080

y-axis: density of GDP ppp per capita (0, 0.002, 0.004, 0.006, 0.008, 0.01, 0.012)
x-axis: in % of mean (0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500)

Testing stylized facts: Economic development

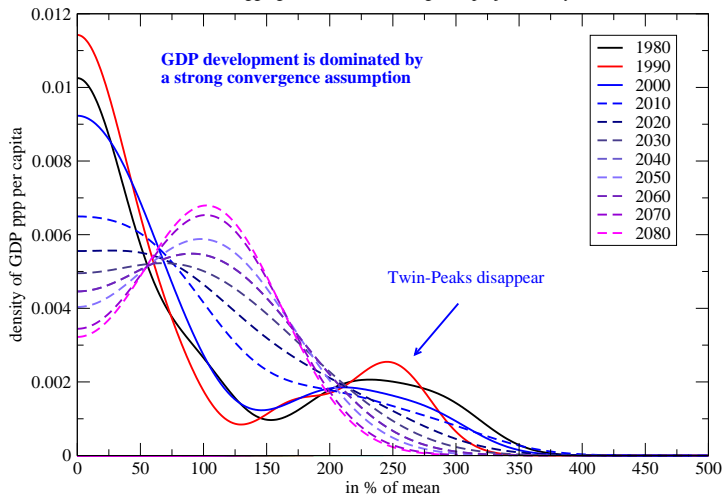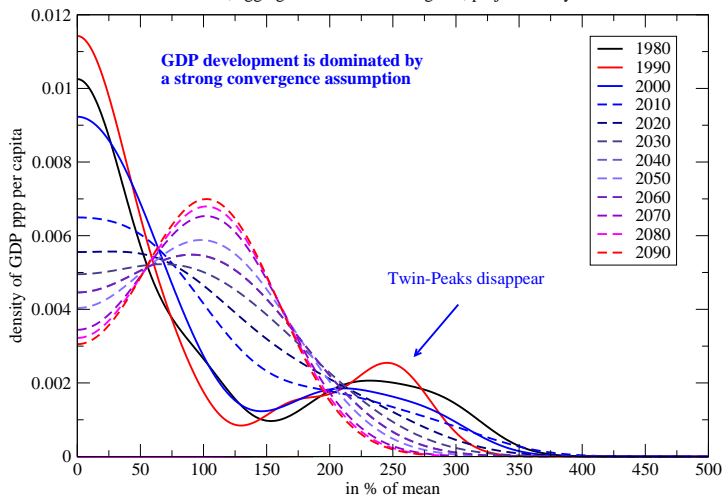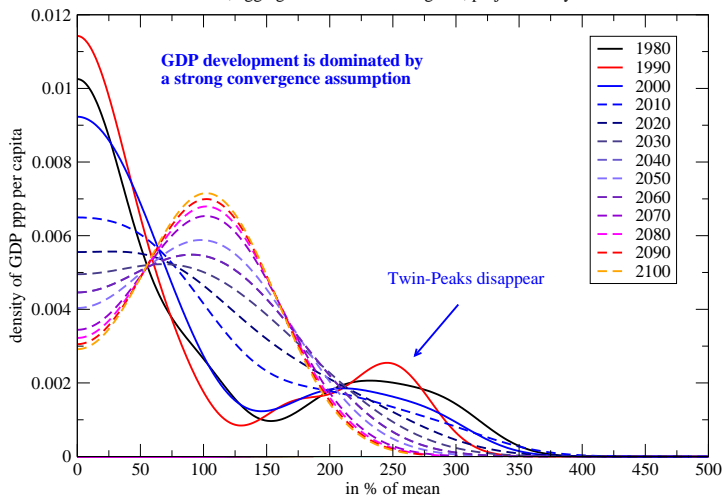Historic GDP development vs. projected GDP scenario

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Legend:
- 1980
- 1990
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- 2010
- 2020
- 2030
- 2040
- 2050
- 2060
- 2070
- 2080
- 2090
- 2100

y-axis: density of GDP ppp per capita

x-axis: in % of mean

Testing stylized facts:
Development of primary energy demand (intensity)

PE/GDP ppp (1980-2100)

Yearly trend in Primary Energy Intensity
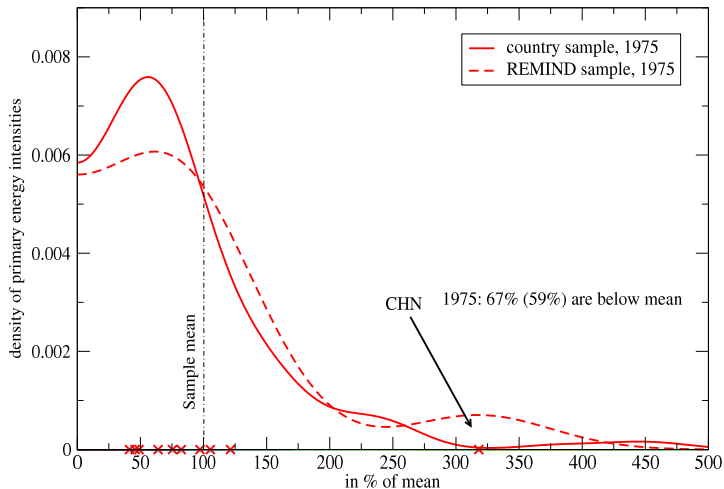
History vs. Projection
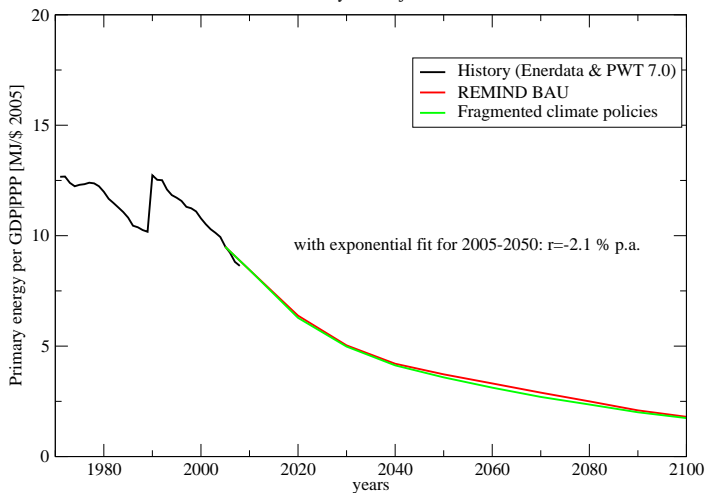
Evaluating Energy Development:
Dynamics in history

Testing stylized facts: Development of Energy Intensity

Historic evolution of Primary Energy Intensities

country sample vs. sample with REMIND regional aggregation

Testing stylized facts: Development of Energy Intensity

Historic evolution of Primary Energy Intensities
country sample vs. sample with REMIND regional aggregation
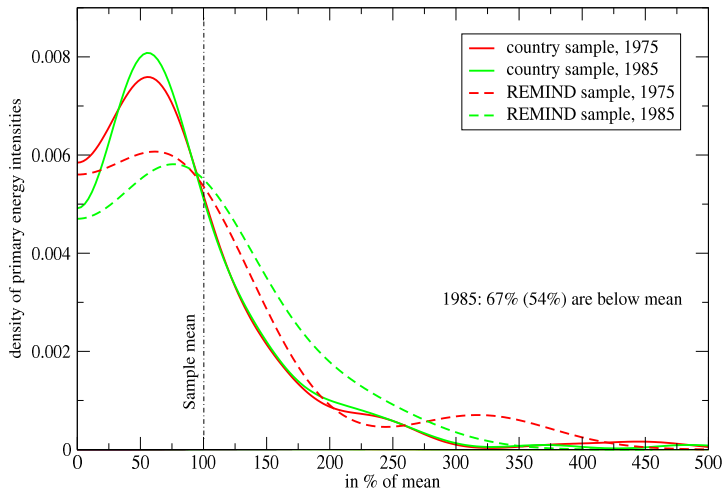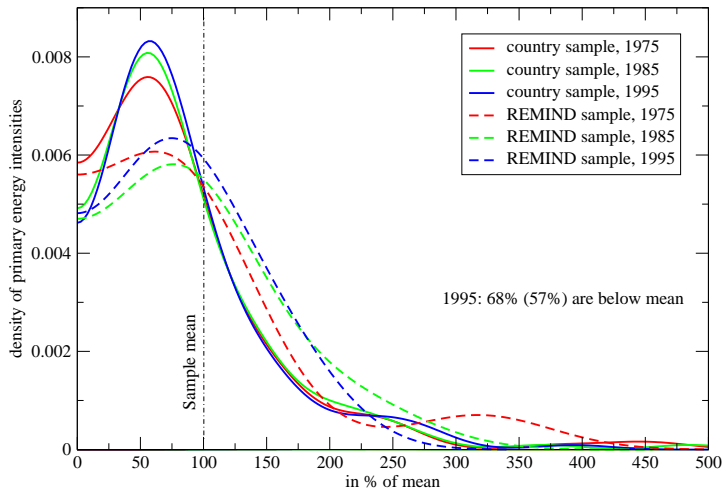
Legend:
- country sample, 1975
- country sample, 1985
- REMIND sample, 1975
- REMIND sample, 1985

1985: 67% (54%) are below mean

Sample mean

y-axis: density of primary energy intensities
x-axis: in % of 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

Legend:
- country sample, 1975
- country sample, 1985
- country sample, 1995
- REMIND sample, 1975
- REMIND sample, 1985
- REMIND sample, 1995

y-axis: density of primary energy intensities

x-axis: in % of mean

Sample mean

1995: 68% (57%) are below mean

Source of data: Enerdata, PWT 7.0

Testing stylized facts: Development of Energy Intensity

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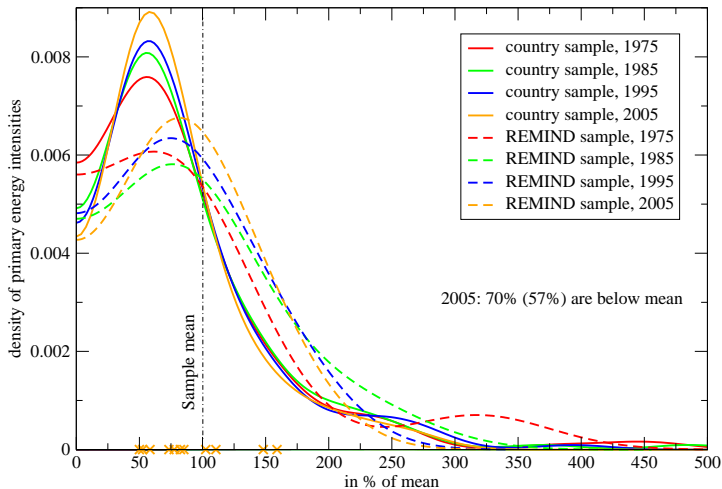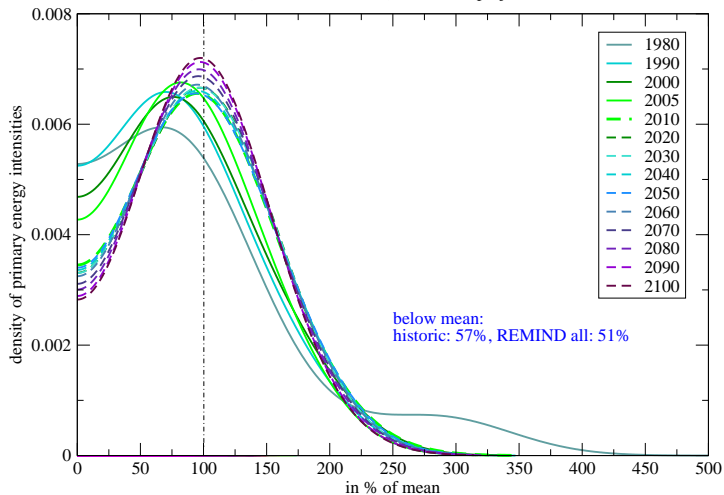country sample vs. sample with REMIND regional aggregation

Source of data: Enerdata, PWT 7.0

Evaluating Energy Development:
Continuation of history by REMIND

PE/GDP ppp (1980-2100)

Development of Primary Energy Intensity

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

below mean:
historic: 57%, REMIND all: 51%

Legend: 1980, 1990, 2000, 2005, 2010, 2020, 2030, 2040, 2050, 2060, 2070, 2080, 2090, 2100

y-axis: density of primary energy intensities
x-axis: in % of mean

Evaluating Development of Energy Demand:
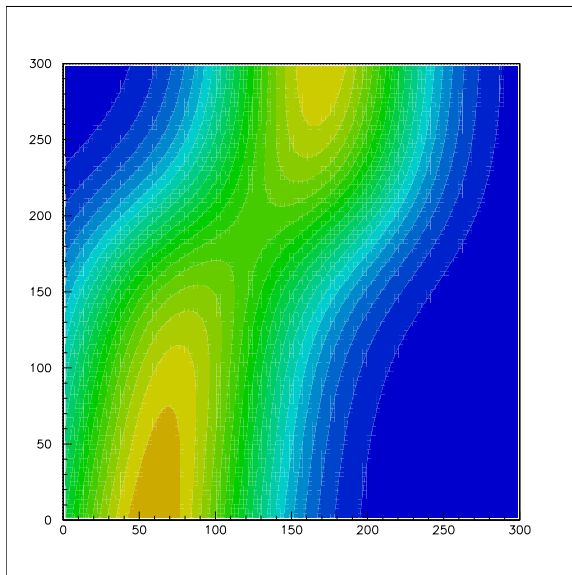Characteristics of intradistributional mobility

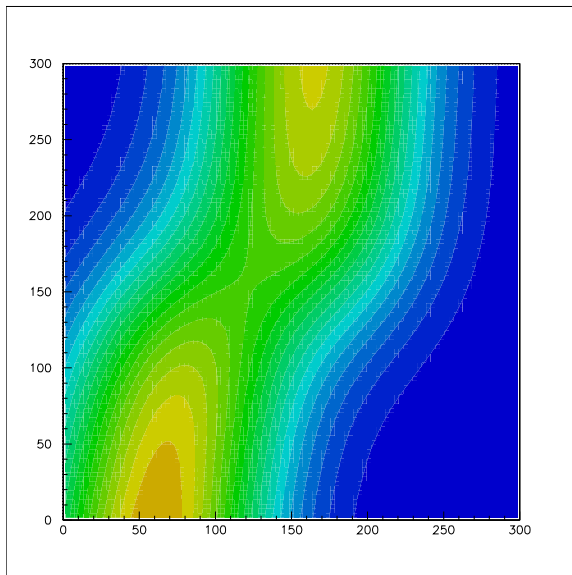# PE/GDP ppp (1975-1980) – cross-country sample
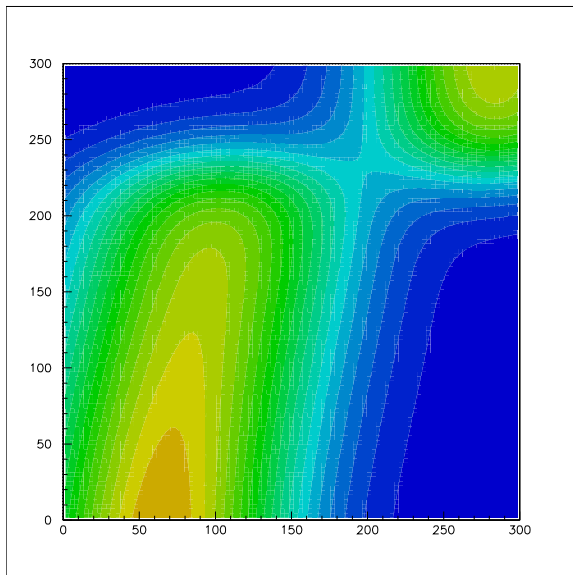
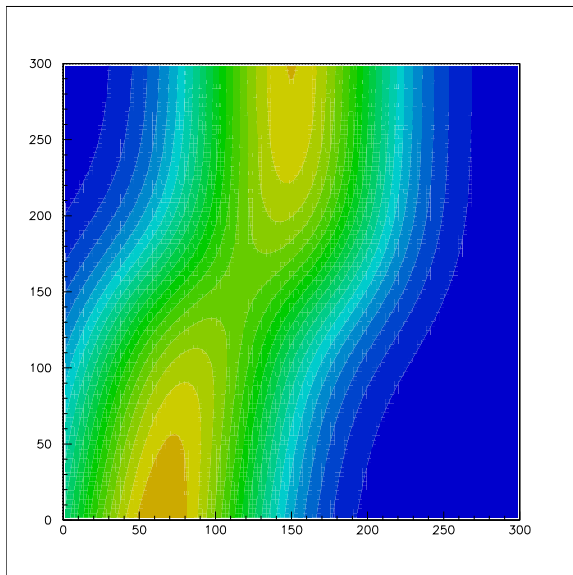# PE/GDP ppp (1980-1985) - cross-country sample
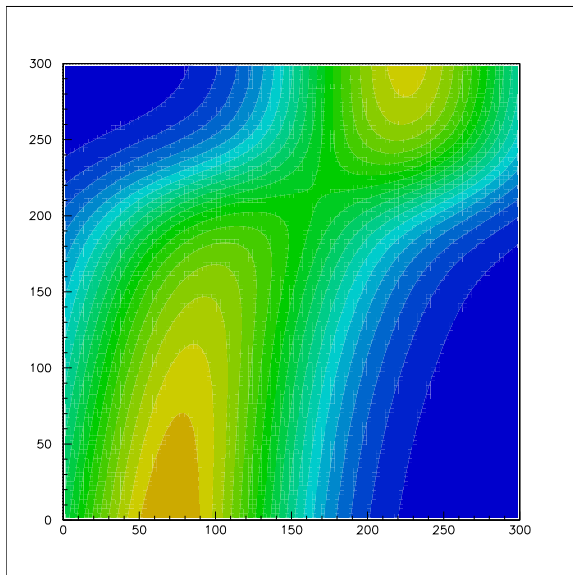
PE/GDP ppp (1985-1990) - cross-country sample

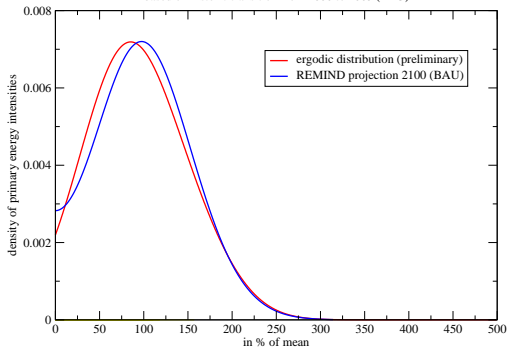# PE/GDP ppp (1995-2000) - cross-country sample
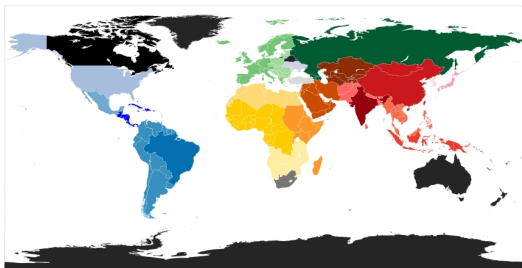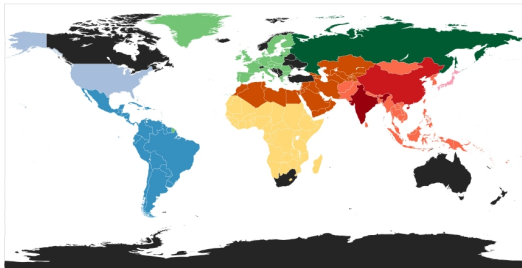
PE/GDP ppp (2000-2005) - cross-country sample

Evaluating Development of Energy Demand:
Ergodic distribution
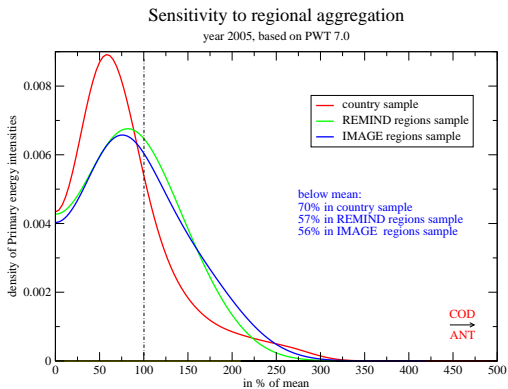
Ergodic distribution for Intensity of Primary Energy
based on historic transition from 2000 to 2005 (PAU)

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

Summary and keywords for discussion

- Summary
  - studying data with regression falls short, better to use distribution dynamics
  - <u>Evaluation of GDP:</u> historically observed multi-modality disappears, strong dominance of convergence assumption $\Rightarrow$ development of divergence scenarios useful to study sensitivity
  - <u>Evaluation of PE/GDP:</u> 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 transperancy

Thank you for you attention and comments!

This presentation has benefited from open source software:
LaTeX, xmgrace, libre office, pawX11, perl, fortran, linux/ubuntu.

Back-up: Method

Probability distribution $f(x)$ is estimated as

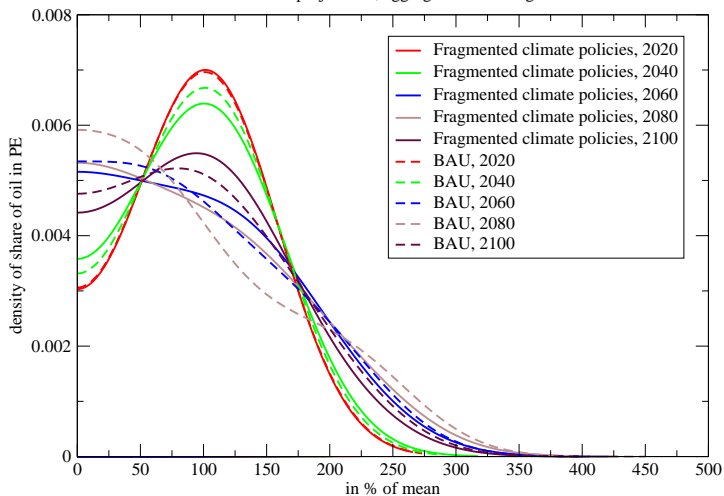$$f(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

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

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 oil share in PE

Distribution of share of Oil in Primary Energy

REMIND projections, aggregation to 11 regions

Proposal: list of stylized facts for IAMs

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

Proposal: list of stylized facts for IAMs

Process	Sub-process	Representation of process in IAM
Social & cultural change	Individual behavior	
	Social choice	
Institutional change	Rules, regulations, law	
	Policies, government	
Sudden events	Luck	
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