Hands-on Bioeconomy Measurement Workshop ICABR 2024

- Bioeconomy Indicators and Dynamics

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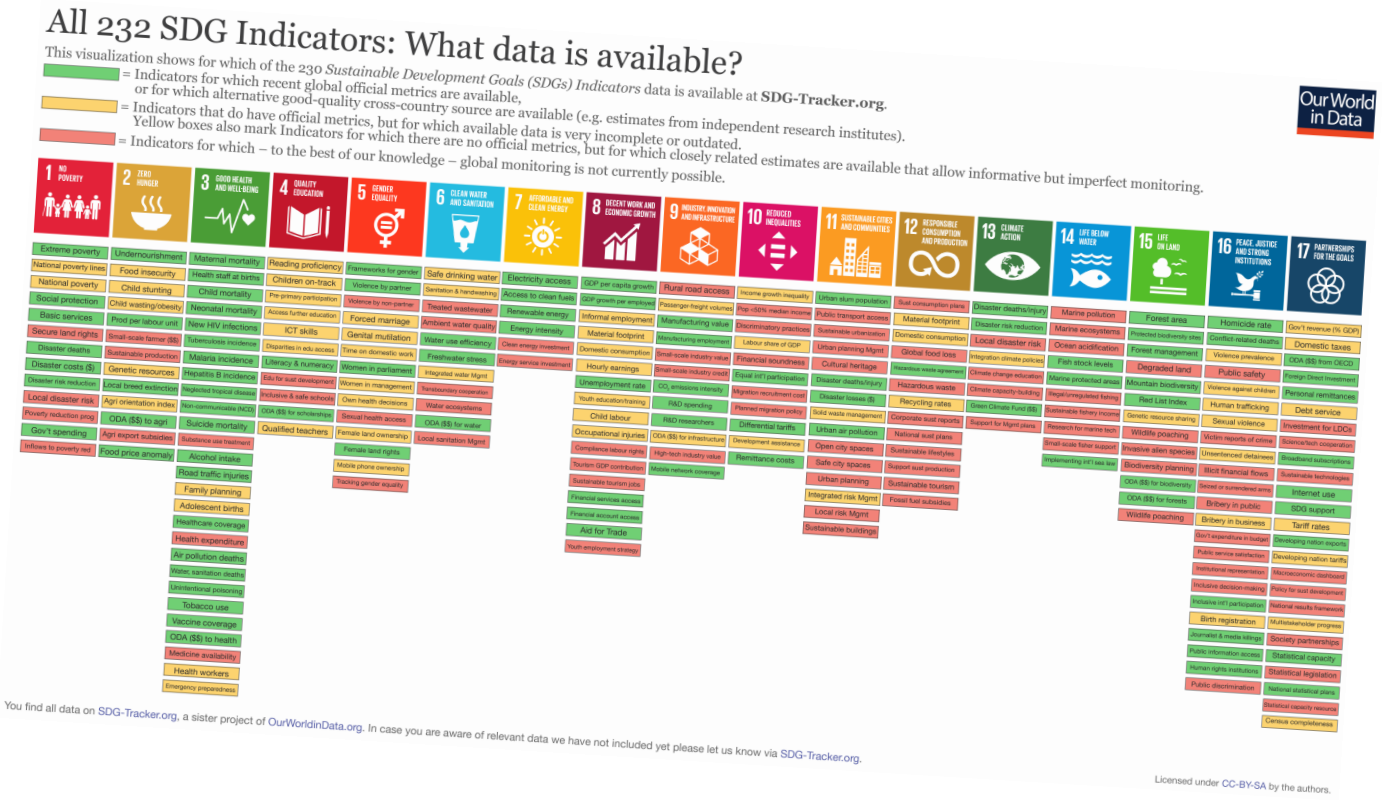
Learning Objectives

- Evaluate the progress of the bioeconomy using many indicators
- Analyze the dynamics with Markov transition matrices

Indicator Frameworks

- Governments and NGOs widely use indicator frameworks to track progress towards crucial societal objectives
  + Europe 2020 Strategy: 27 indicators
  + EU SDGs: 100 indicators
  + UN SDGs: 232 indicators
  + World Bank World Development: 1600 indicators



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Indicator Frameworks – The pitfalls

Risk of overuse, non-use, and misuse of these indicators

Simplifies the intricate complexity of the bioeconomy (and any other systems)

No indicator or set of indicators can perfectly capture different aspects of reality

A compromise regarding what can be quantified, the type of data collected, and its quality

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Objective of the indicator framework

- *Find patterns in the evolution of the EU circular bioeconomy*

  + Any number of indicators

  + Markov transition matrices

- *Compare the evolution in selected EU Member States*

  + France, Germany, The Netherlands, Poland, Italy, Spain, Portugal, Slovakia, Latvia

  + *Between 2006 and 2016*

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Data

- Time-series data from Eurostat’s ‘indicator set to measure the progress towards the SDGs’ and ‘monitoring framework on the circular economy’
- 41 ‘bioeconomy-related’ and circular-economy indicators
- Checked the indicators for consistency in their interpretation

Data - List of (some of) the indicators

Code	Description	Desired Direction
cei_cie010	Value added at factor costs (Mio Euro)	+
cei_cie010	Value added at factor costs (% of GDP)	+
cei_cie010	Gross investment in tangible goods (Mio Euro)	+
cei_cie010	Gross investment in tangible goods (% of GDP)	+
cei_cie010	Persons employed (umber)	+
cei_cie010	Persons employed (% of total employment)	+
cei_wm030	Recycling of biowaste (kg per capita)	+
sdg_02_20	Agricultural factor income per annual work unit	+
sdg_02_30	Government support to agricultural research and development (Mio Euro)	+
sdg_02_30	Government support to agricultural research and development (Euro per inhabitant)	+
sdg_02_40	Area under organic farming - % of utilised agricultural area (UAA)	+
sdg_02_50	Gross nutrient balance on agricultural land by nutrient (nitrogen)	0
sdg_02_50	Gross nutrient balance on agricultural land by nutrient (phosphorus)	0
sdg_02_60	Ammonia emissions from agriculture (tonne)	-
sdg_02_60	Ammonia emissions from agriculture (kg/ha)	-

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Methodology - Normalization

- Indicators must be normalized to enable comparison because they have different units and dimensions. Different methods have been used for that:

An indicators value is linearly interpolated until 2030. The difference between the latest and the first observation is divided by the difference in years and then multiplied by the difference between 2030 and the latest observation and added to the value of the latest observation.

Source: Eurostat (2019)

This method is sensitive to outliers in the time-series data because only two observations are included in its calculation.

Subtract the minimum value across all countries from the indicator value and divide the difference by the range of values across all countries

Source: Lafortune et al. (2018)

Relates to the indicator values in all included countries but means little for the development of a single country independently

The latest value of an indicator is subtracted from the target value and is divided by the standard deviation across all countries

Source: OECD (2019)

The resulting score is related to all included countries, and importantly, target values for each indicator are necessary.

- We analyzed EU MSs independently and targets were not available for a significant number of indicators

=> We used z-scores as method to normalize the indicators.

Methodology – Z-scores

- To normalize indicators and remove units and magnitudes

z_{it}: z-score of indicator i in year t

x_{it}: value

$\bar{x}_i$: temporal mean

s: temporal standard deviation

$$z_{it} = \frac{x_{it} - \bar{x}_i}{s_i}$$

- To rank the normalized indicators according to the ‘speed’ of their development over time, we calculated the slope parameter of a linear regression of a z-score of indicator i on time

$\hat{\beta}_i$: least-squares estimate for the slope

t: *time*

z_i: *z-score of indicator i*

$$\beta_i = \frac{Cov[t, z_i]}{Var[t]}$$

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Exercise 1 – Z-scores

- We will calculate z-scores for different kind of indicators
- You can find the exercise in the file indicator_framework exercise 1.xlsx

Methodology – Markov transition matrices

- Development of the intra-distribution of indicators over time.
- Quah (1993) was the first in the cross-country growth and income literature to investigate patterns in income distributions using Markov transition matrices.
- Zaghini (2005) examined the intra-distribution dynamics of the Lafay index of 208 sectors. The variation of the relative ranking of sectors by the Lafay index over time depicts these intra-distribution dynamics.
- We allocate indicators to four equal segments according to their z-score.

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Methodology – Markov transition matrices

- To build a Markov chain, we need a transition matrix and an initial distribution
- Assuming a finite set $S = \{1, \ldots, m\}$ of states, a real number p_{ij} must be assigned to each pair $(i, j) \in S^2$ of states, ensuring that the properties

$$p_{ij} \geq 0 \quad \forall (i, j) \in S^2 \qquad \& \qquad \sum_{j \in S} p_{ij} = 1 \quad \forall i \in S$$

- are satisfied.

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Methodology – Markov transition matrices

- The transition matrix **P** can be defined as follows:

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mm} \end{pmatrix}$$

- where the value of each cell is a transition probability, that is, the probability that an indicator from segment i moves to segment j in the next year.

- We calculated the transition probabilities for each period by counting the number of transitions between intervals of the relative change of indicator levels.

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Methodology – Metrics of mobility

- To compare the extent of indicator movement between segments

$$M_1 = \frac{n - \mathrm{tr}(\mathrm{P})}{n-1}$$

n: number of rows and columns of a transition matrix *P*

tr(P): trace of P

det(P): determinant of *P*

$$M_2 = 1 - \left|\det(\mathrm{P})\right|$$

- M1 relates to the trace of the transition matrix and measures the ratio between diagonal and off-diagonal transition probabilities.
- M2 uses the determinant of the transition matrix and measures all changes in the matrix.

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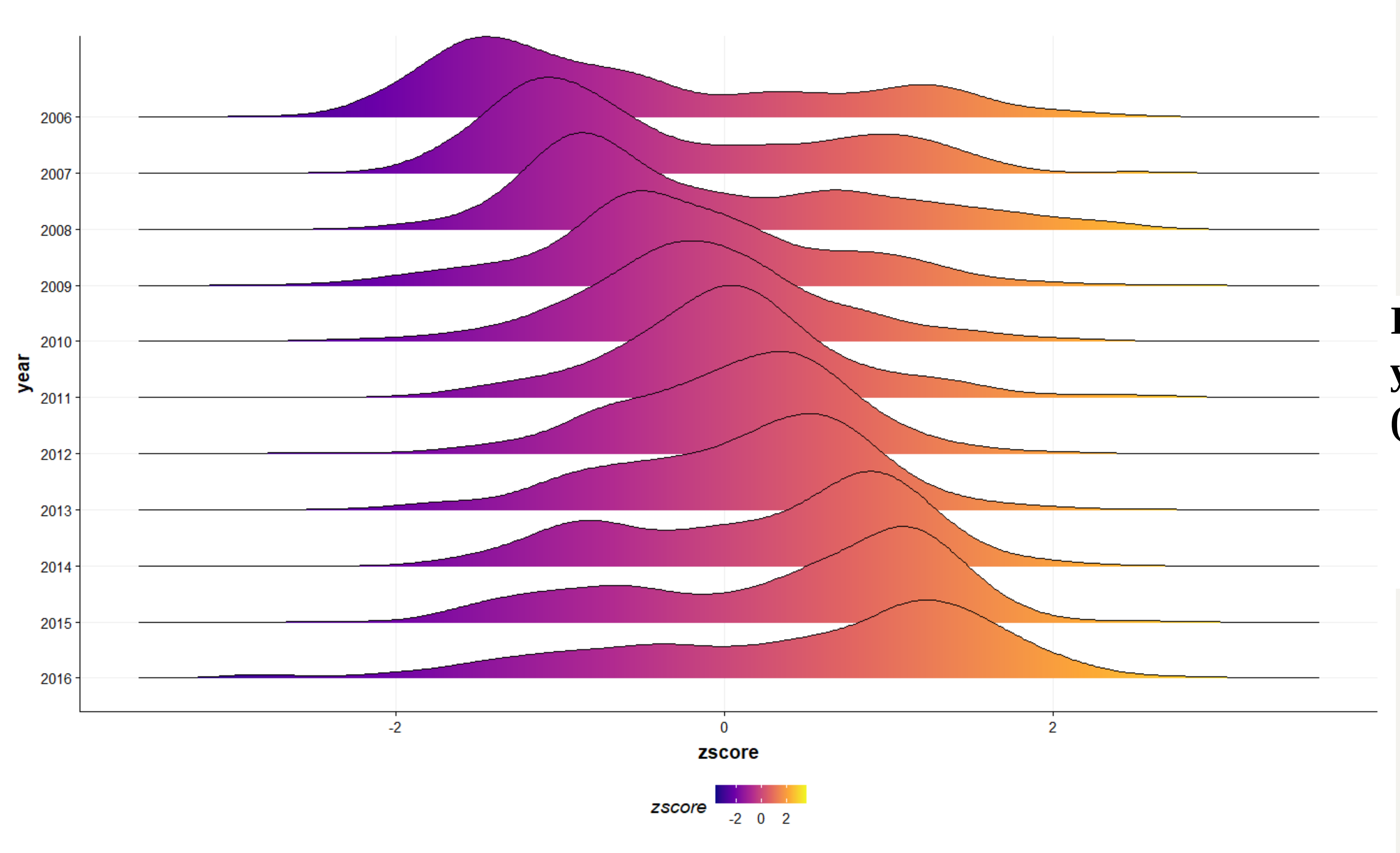
Exercise 2

- We will create box-plots for a large number of z-scores, construct Markov transition matrices, and calculate metrics of mobility.

- You can find the exercise in the file indicator_framework exercise 2.xlsx

Results - External shape of circular bioeconomy indicators



Indicator distribution by year for all countries (Kernel density estimates).

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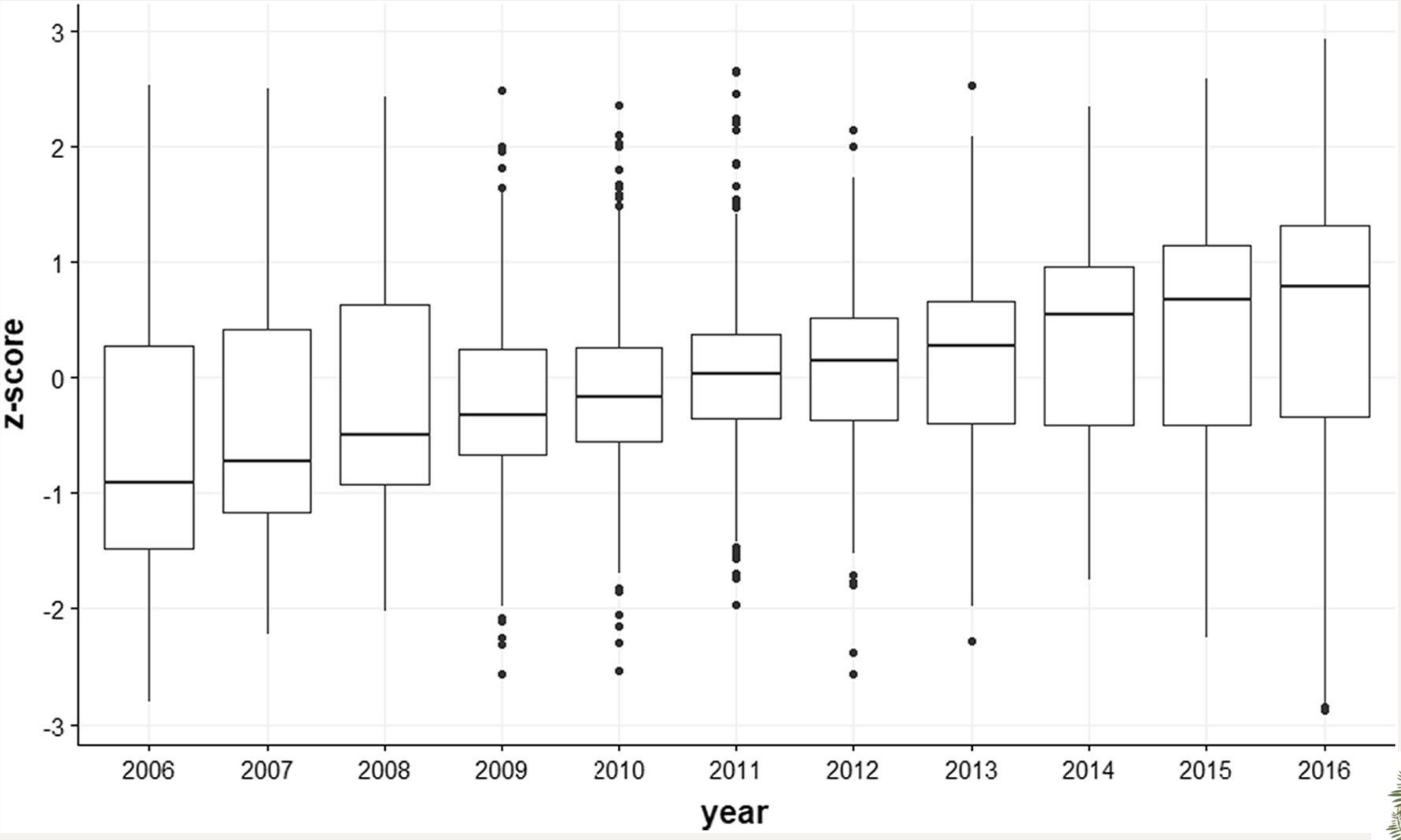
Results - Descriptive statistics from the indicator distribution

	EU-10										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mean	-0.622	-0.430	-0.122	-0.155	-0.122	0.052	0.081	0.138	0.310	0.405	0.466
Median	-0.954	-0.758	-0.476	-0.248	-0.164	0.029	0.175	0.286	0.555	0.706	0.733
St. dev.	1.113	0.953	1.005	0.842	0.735	0.716	0.677	0.761	0.858	0.941	1.134
Range	5.339	4.972	4.359	5.044	4.885	4.621	4.554	4.800	4.096	4.832	5.747

Results - Development from 2006 to 2016 as box plots



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Results - Highest and lowest z-score slope estimates

Most progressing indicators	β	Most regressing indicators	β
Germany			
Share of renewable energy in gross final energy consumption – electricity	0.300	Patent applications to the European Patent Office (total number)	-0.291
Share of renewable energy in gross final energy consumption – all sectors	0.299	Patent applications to the European Patent Office (number per million inhabitants)	-0.288
Employment rate	0.294	Ammonia emissions from agriculture (kg per hectare)	-0.288
Recycling of biowaste	0.293	Ammonia emissions from agriculture (tonnes)	-0.278
R&D personnel – business enterprise sector	0.292	Private investments, jobs, and gross value added related to circular economy sectors – value added at factor cost – % of GDP	-0.172
Finland			
Area under organic farming	0.298	Employment in knowledge-intensive services	-0.295
Recycling rate of municipal waste	0.296	Circular material use rate	-0.294
Share of renewable energy in gross final energy consumption – heating and cooling	0.295	R&D personnel – government sector	-0.277
Share of renewable energy in gross final energy consumption – all sectors	0.292	R&D personnel – higher education sector	-0.272
Employment in high- and medium-high technology manufacturing	0.292	Gross domestic expenditure on R&D – higher education sector	-0.234

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Results - Highest and lowest z-score slope estimates

Most progressing indicators	β	Most regressing indicators	β
Slovakia			
Tertiary educational attainment	0.297	Private investments, jobs, and gross value added related to circular economy sectors – gross investment in tangible goods – % of GDP	-0.229
Energy productivity	0.295	Adult participation in learning	-0.223
Share of renewable energy in gross final energy consumption – electricity	0.292	Gross nutrient balance on agricultural land – phosphorous	-0.206
Greenhouse gas emissions (index 1990 = 100)	0.290	Private investments, jobs, and gross value added related to circular economy sectors – gross investment in tangible goods – million euros	-0.194
Share of renewable energy in gross final energy consumption – all sectors	0.289	Employment rate of recent graduates	-0.091
Latvia			
Private investments, jobs, and gross value added related to circular economy sectors – % of total employment [V16111]	0.299	Ammonia emissions from agriculture (tonnes)	-0.286
Surface of marine sites designated under NATURA 2000	0.298	Ammonia emissions from agriculture (kg per hectare)	-0.266
Tertiary educational attainment	0.293	Private investments, jobs, and gross value added related to circular economy sectors – value added at factor cost – % of GDP	-0.264
Share of renewable energy in gross final energy consumption – electricity	0.288	Private investments, jobs, and gross value added related to circular economy sectors – ross investment in tangible goods – % of GDP	-0.252
Circular material use rate	0.282	Gross nutrient balance on agricultural land – nitrogen	-0.245

Results – Circular bioeconomy intra-distribution dynamics

- The development of the intra-distribution of indicators over time using Markov transition matrices

- Short-term: Average of one-year transition matrices from 2007 to 2016

- Long-term: Ten-year transition matrices based on the transition from 2006 to 2016

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Results – Circular bioeconomy intra-distribution dynamics

- Each value in a matrix gives the probability that an indicator moves from a segment, which corresponds to a quartile of the z-scores across all indicators for one year, in period t to another segment in period t+1

- For example, cell p_{11} gives the probability that an indicator is among the ten or eleven indicators with the lowest z-scores in the first period and among the ten or eleven indicators with the lowest z-scores in the second period.

- The matrices present a transition of each indicator's z-score relative to each other.

- The diagonal values depict how dynamic a circular bioeconomy is in a country. If the diagonal values are higher than the non-diagonal values, more indicators stay in their respective z-score segment from one year to the next.

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mm} \end{pmatrix}$$

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Results – Short-term and long-term transition matrices

One-year transition matrix					Ten-year transition matrix				
Germany									
	S_1	S_2	S_3	S_4		S_1	S_2	S_3	S_4
S_1	.50	.26	.13	.11	S1	.00	.40	.40	.20
S_2	.17	.26	.39	.18	S2	.00	.30	.30	.40
S_3	.17	.34	.25	.24	S3	.10	.10	.30	.50
S_4	.14	.12	.21	.53	S4	.82	.18	.00	.00
Ergodic	.241	.241	.244	.273	Ergodic	.244	.243	.244	.268
Portugal									
	S_1	S_2	S_3	S_4		S_1	S_2	S_3	S_4
S_1	.53	.30	.13	.04	S1	.10	.20	.50	.20
S_2	.30	.38	.19	.13	S2	.10	.20	.20	.50
S_3	.09	.19	.48	.25	S3	.30	.10	.20	.40
S_4	.06	.10	.19	.65	S4	.45	.45	.09	.00
Ergodic	.233	.234	.246	.288	Ergodic	.244	.244	.244	.268

Results – Mobility Metrics

For both metrics, a higher value suggests a higher indicator mobility between segments, while zero indicates no mobility at all.

The metrics indicate if the indicators grow or decline in a homogenous manner, showing how dynamic a circular bioeconomy is in a country

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Results – Mobility Metrics

Short-term mobility in two periods						
Country	One-year 2007–2011		One-year 2012–2016		Change in Mobility	
	M_1	M_2	M_1	M_2	ΔM_1	ΔM_2
Germany	0.83	0.96	0.81	0.98	-0.02	0.02
Finland	0.83	0.98	0.65	0.97	-0.18	0.00
The Netherlands	0.80	0.95	0.63	0.97	-0.18	0.02
France	0.77	0.97	0.73	0.98	-0.04	0.01
Poland	0.68	0.98	0.75	0.99	0.07	0.01
Slovakia	0.78	0.98	0.81	0.99	0.03	0.01
Italy	0.73	0.98	0.73	0.98	0.00	-0.01
Spain	0.69	0.94	0.67	0.96	-0.02	0.02
Portugal	0.72	0.94	0.59	0.96	-0.12	0.02
Latvia	0.80	0.98	0.67	0.92	-0.13	-0.07

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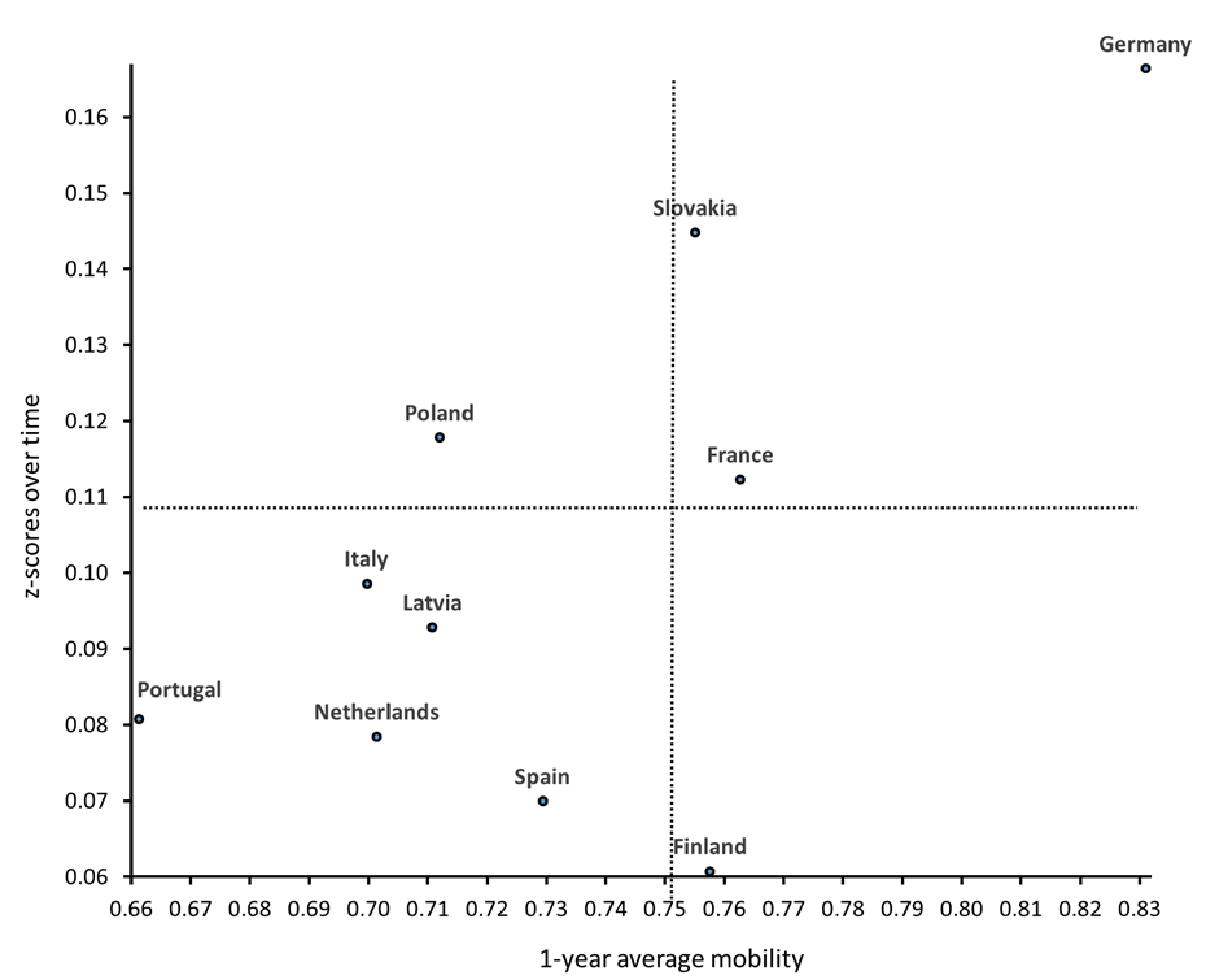
Results – 1-year mobility and z-scores over time



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Discussion

- Evolutions of the EU-10 circular bioeconomies were generally progressive considering all indicators, but not homogeneous

- E.g. in Germany: indicators sharply differed in their developments, and their relative rankings strongly varied in consecutive years

- Indicator movement between segments (mobility)
  - + Higher in the long-term than in the short-term
  - + Short-term mobility higher in the second half

- Policy recommendation: *consider all indicators!*

Discussion

- Cross-country comparison: Slovakia, Poland, and Latvia developed quickly in comparison to the rest of the EU-10

- Contrary to D'Adamo (2020), but we look at progress: a catch-up effect?

- Finland, Spain, The Netherlands, and Portugal improved the slowest, even though they have dedicated bioeconomy strategies

- Perhaps the impacts of these policy strategies are limited and more concrete policy actions are needed

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