
Temporal Meaning of Patents

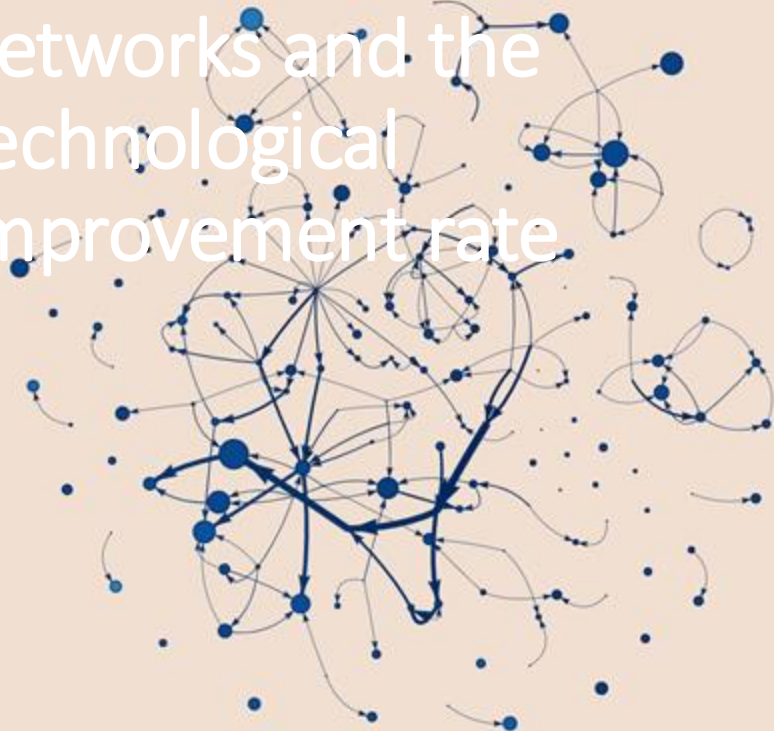
David Dekker, Haris Matsantonis,
George Tzougas, George Streftaris,
Dimitris Christopoluos

March 2025



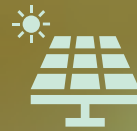
Patent Citation ['Y02E60']

Patent citation
networks and the
technological
improvement rate



Example

Solar



Nuclear



Wind



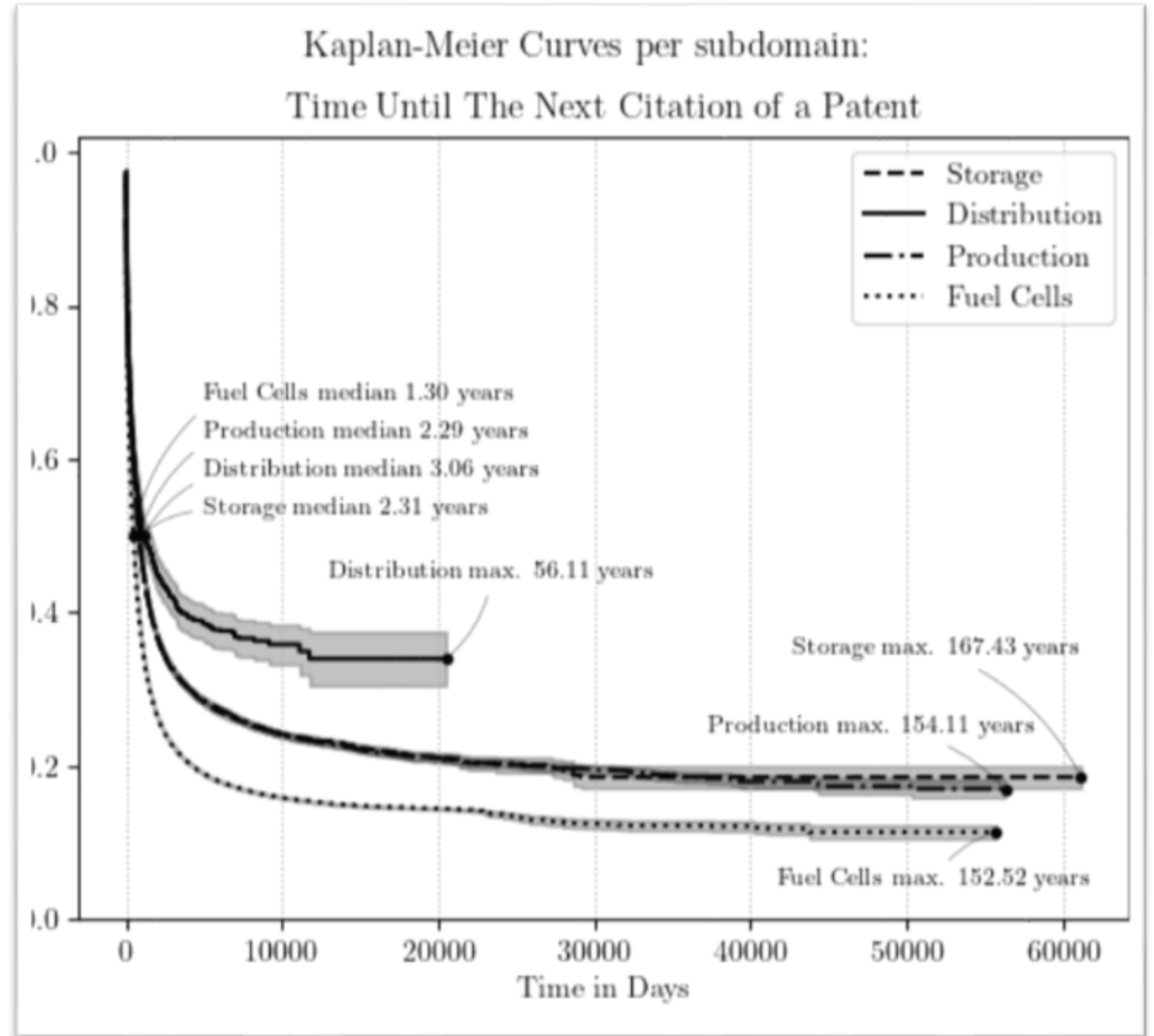
Water



(e.g., Benson and Magee 2015)

Technological Improvement Rate and Future Cost Curves

- Faster subsequential inventions lead to faster efficiency improvements.

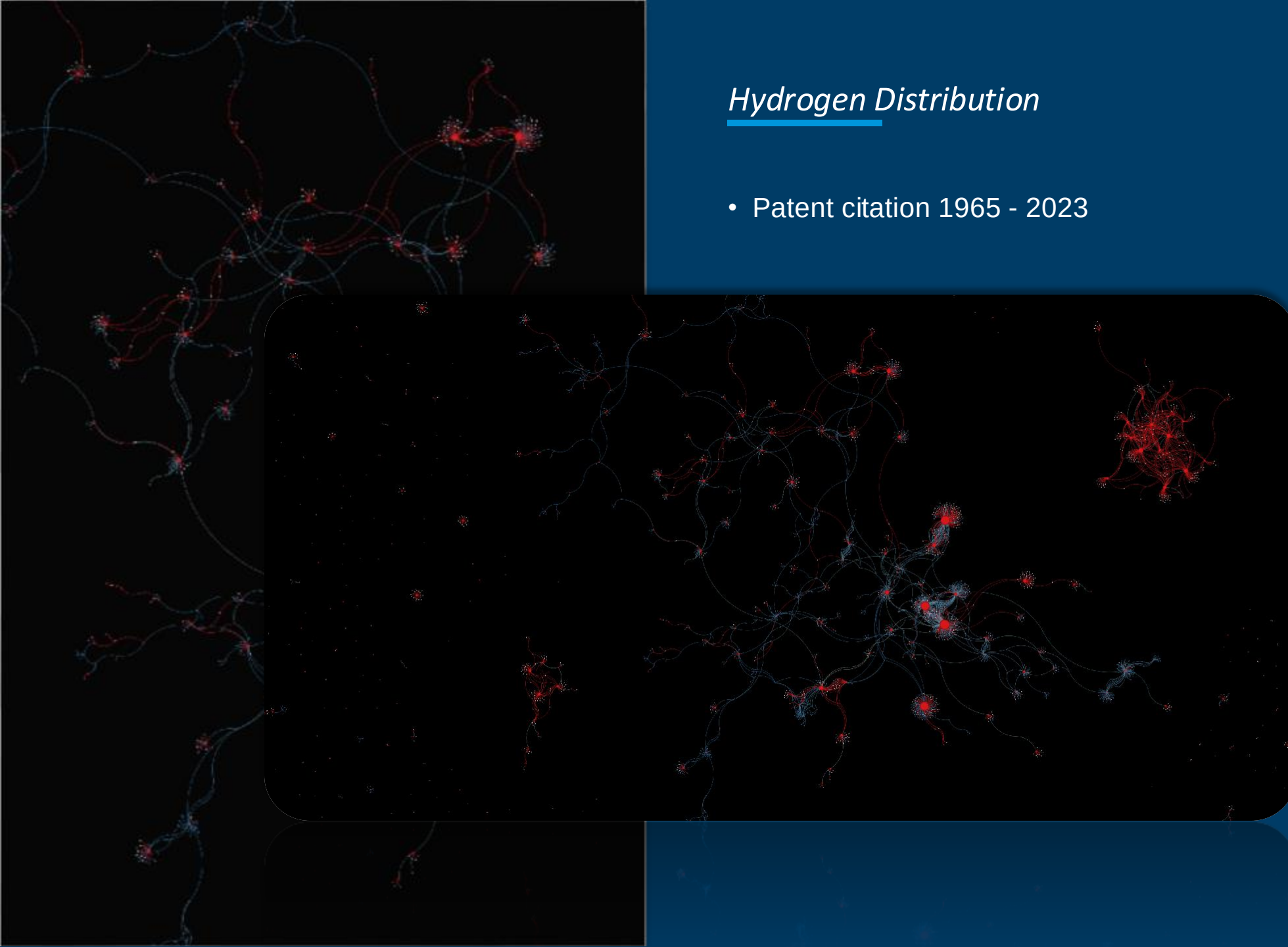


Kaplan-Meier curves for hydrogen technology domains.



Hydrogen Distribution

- Patent citation 1965 - 2023





Clustering meanings instead of finding meaning of clusters

Data Preprocessing

- Multilingual patent dataset is filtered to include **only English CO2-related patents** with sufficient text length.
- Textual features are derived using TF-IDF and PCA, **and categorical data** is one-hot encoded.

Poisson Variational Autoencoder

- Transforms features into count-based data to align with a **Poisson likelihood model**, suitable for discrete data analysis.
- Latent representations of patents are learned using PVAE, enabling the extraction of thematic clusters in patent data.

Dynamic Temporal Clustering:

- A 5-year rolling window approach is used to capture **temporal shifts** and the evolution of patent clusters.
- **K-means clustering** is applied on latent representations with **silhouette score** used to assess cluster quality.

Cluster Evolution Analysis:

- **Silhouette scores** track cluster consistency over time, identifying stable clusters and outliers.
- Transition matrices show how patents shift between clusters, providing insights into emerging and consolidating CO2 technologies.

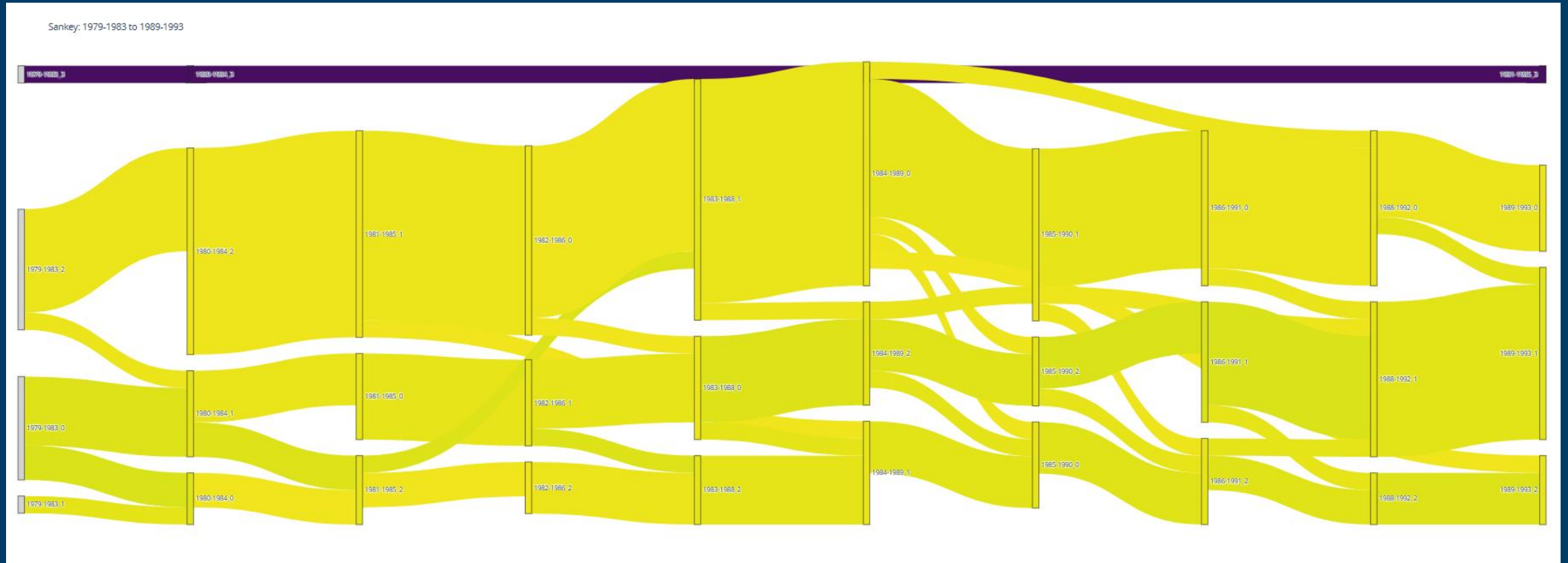


Categorical data: CPC classifications, patents belong to multiple groups

167 C01B32/50 Chemistry metallurgy Carbon dioxide	109 F25J2200/02 Mechanical Engineering lighting heating weapons blasting in a single pressure main column	89 F25J2200/70 Mechanical Engineering lighting heating weapons blasting Refluxing the column with a	91 F25J2200/74 Mechanical Engineering lighting heating weapons blasting Refluxing the column with at	86 F25J2215/04 Mechanical Engineering lighting heating weapons blasting Recovery of liquid products
116 F25J2215/80 Mechanical Engineering lighting heating weapons blasting Carbon dioxide	174 F25J2220/82 Mechanical Engineering lighting heating weapons blasting Separating low boiling, i.e. more	98 F25J2230/30 Mechanical Engineering lighting heating weapons blasting Compression of the feed stream	96 F25J2245/02 Mechanical Engineering lighting heating weapons blasting Recycle of a stream in general, e.g. a	123 F25J2270/90 Mechanical Engineering lighting heating weapons blasting External refrigeration, e.g.
189 F25J3/0266 Mechanical Engineering lighting heating weapons blasting separation of carbon dioxide	139 F25J3/08 Mechanical Engineering lighting heating weapons blasting Separating gaseous impurities	301 Y02C20/40 General Tagging of New Technological Developments general Tagging of Cross-Sectional Technologies	172 Y02P20/151 General Tagging of New Technological Developments general Tagging of Cross-Sectional Technologies	448 Y10S62/928 General Tagging of New Technological Developments general Tagging of Cross-Sectional Technologies
>427				0

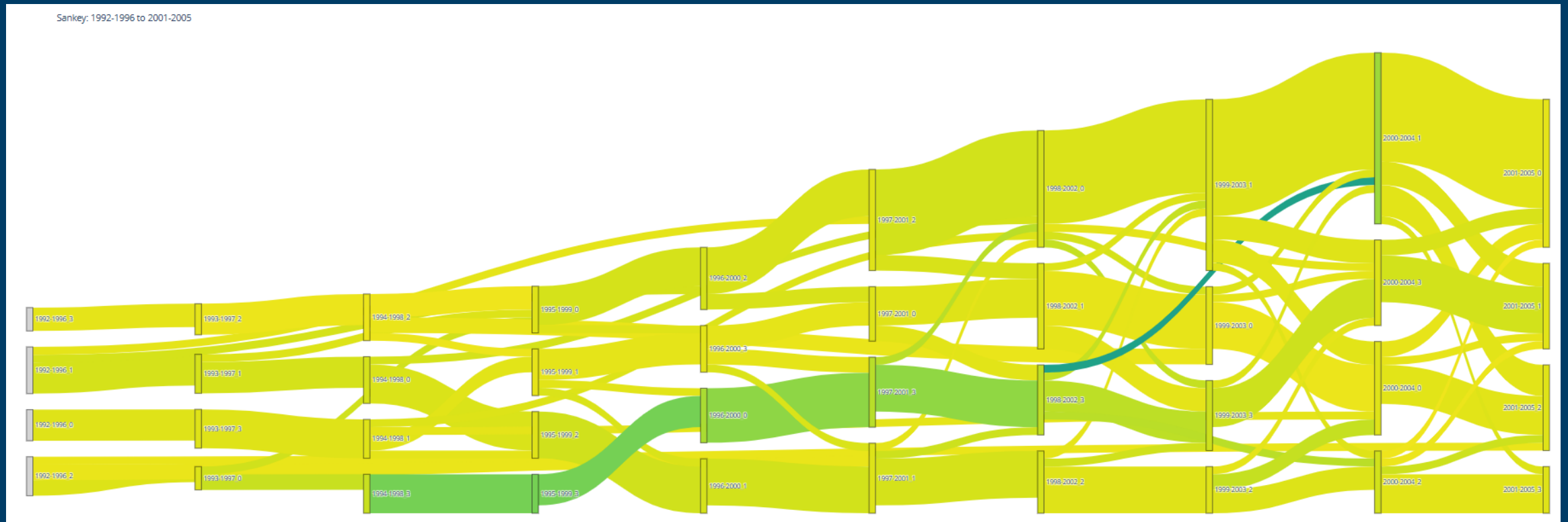


Sankey 10 years of 5 year-rolling clusters (1979- 1983) – (1989-1993)

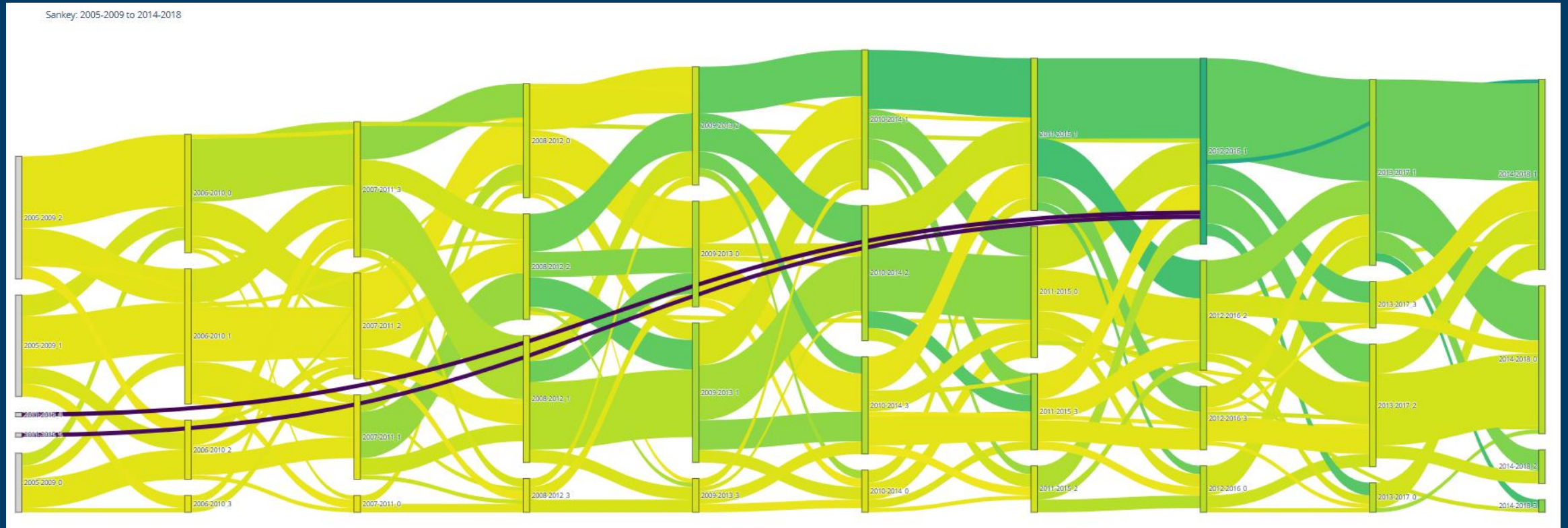




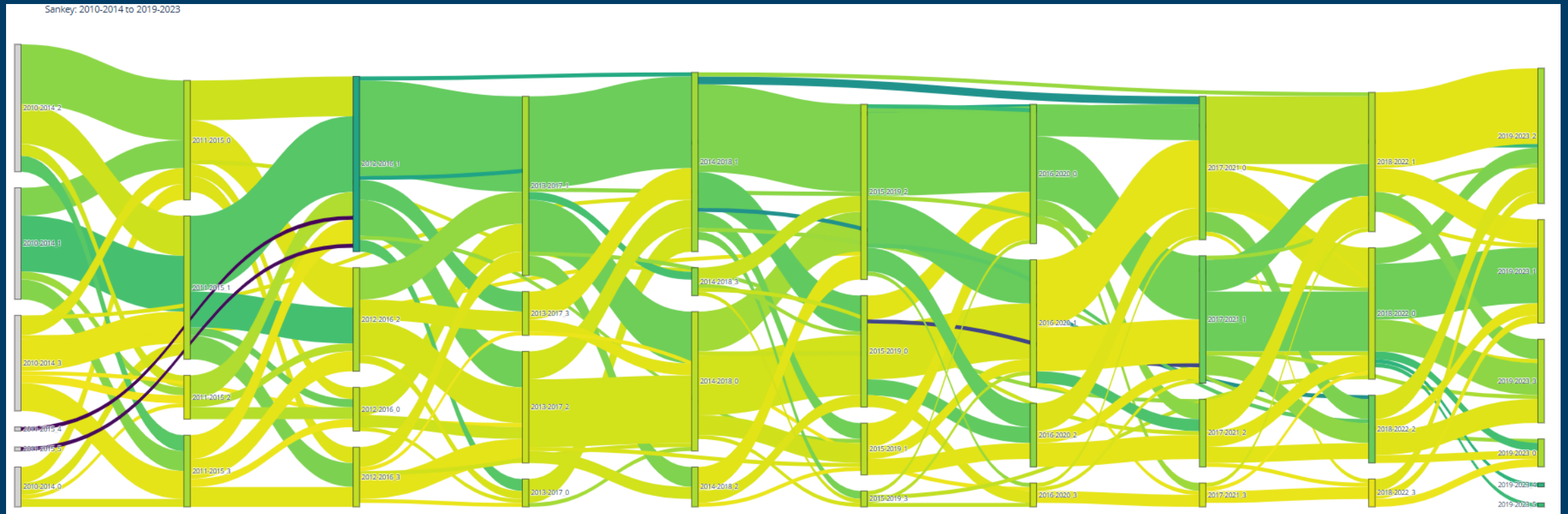
Sankey 10 years of 5 year-rolling clusters (1992- 1996) – (2001-2005)



Sankey 10 years of 5 year-rolling clusters (2005-2009) – (2014-2018)



Sankey 10 years of 5 year-rolling clusters (2010-2014) – (2019-2023)





Conclusion & Discussion

Conclusion

- Fixed classification doesn't warrant temporal consistent meaning
- Change in silhouette scores indicate increased ambiguity, and co-occur with instability
- Increases in invention create more ambiguity

Discussion

- Methodological refinements and extension to larger multilingual data
- What does this imply for the **rate of knowledge production** on lower levels of aggregation?
- Capturing **the meaning of 'changes in meaning'** will help communicate the direction of innovation and can inform policy makers and other stake holders (investors) alike.

d.dekker@hw.ac.uk

Thank
you.