Research Topics as a Measure

Mapping and modeling the content of science

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ESLS - Project Colloquia

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BEHAVE

Introduction

Research topics (RTs) as a measure, beyond simple mapping

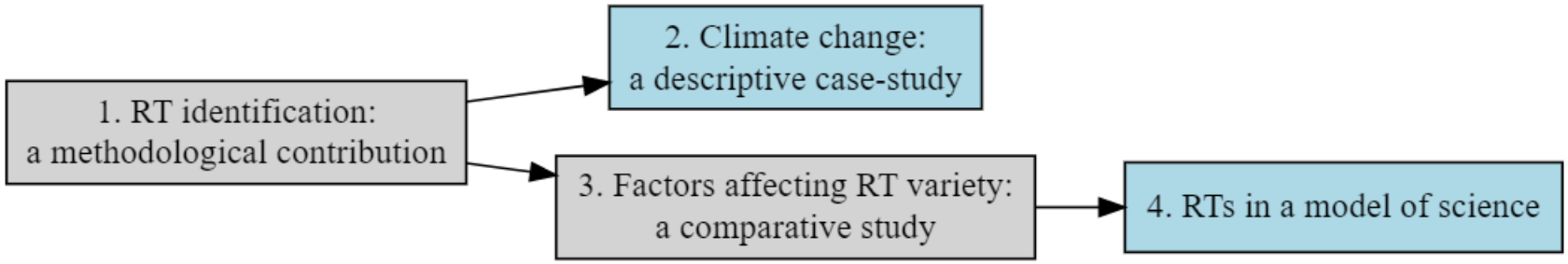
- Interesting *per se* as a phenomenon (what we do, how many different things we do, etc)
- As "control" for science studies (e.g. researchers mobility, etc)

Talking about conceptual dimensions often hinders intuition: *spatial metaphor*

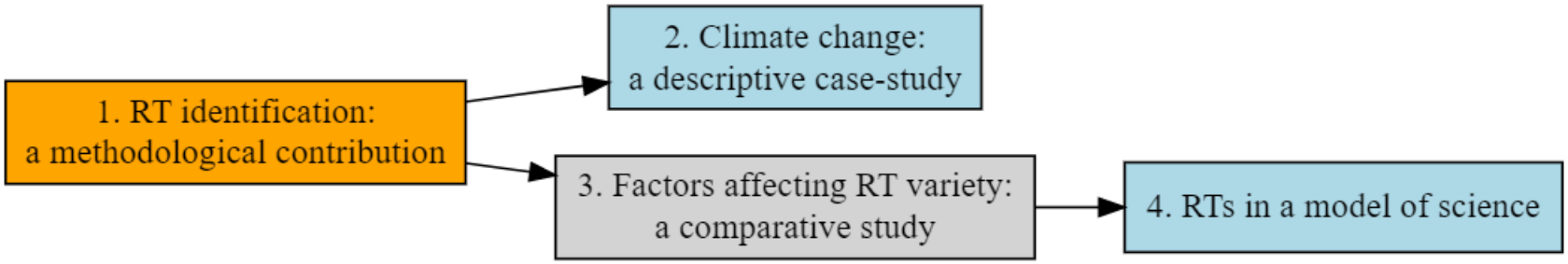
What *exactly* is an RT?

- Terminology and level of abstraction
- "Around 100 core scientists" (Kuhn 1970, Price 1986)
- Informal operationalisation

Roadmap


1. RT identification:
a methodological contribution
2. Climate change:
a descriptive case-study
3. Factors affecting RT variety:
a comparative study
4. RTs in a model of science

Roadmap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1 RT identification: a methodological contribution

Established approaches:

- Scientometrics: citational analysis (Garfield 1955, Kessler 1963, Small 1973)
- Early textual analysis: keywords co-occurrence (Callon et al. 1983)
- Topic modeling: LDA (Blei et al. 2003)

New developments:

- Vector space embedding (Mikolov et al. 2013)
- Language models (Reimers & Gurevych 2019, etc)

Usage of the new approaches in science studies is still limited...

1 RT identification: a methodological contribution

- COST data (10 calls, around 4k documents)
- Not a "ground truth" but still measure of overlap with human classification
- Benchmarking of textual classification algorithms
- Comparison of short/full texts
- Proposal of a specific combination of techniques

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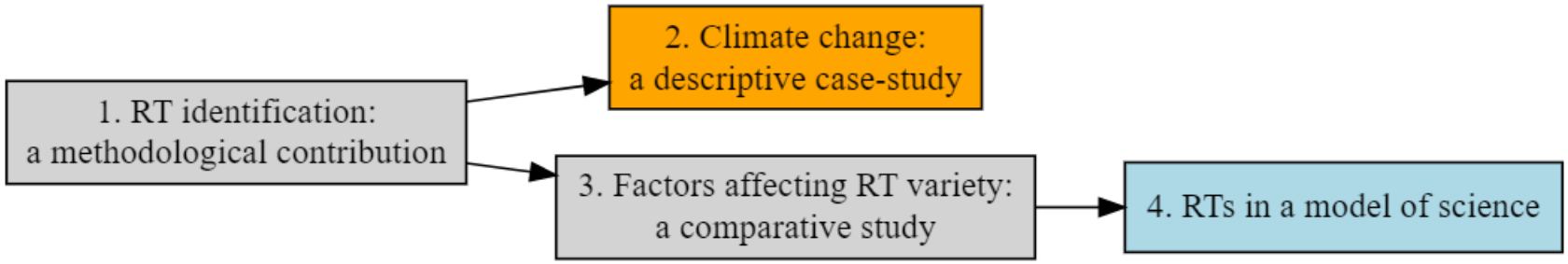
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2 Climate change: a descriptive case-study

Testing in an unsupervised setting (and common use-case): map a research area

Common limitations (e.g. Fu & Waltmann 2022):

- *Absolute* scientific production of only the *top countries*
- Analysis of the *5-10 main* topical trends (coarse grained)

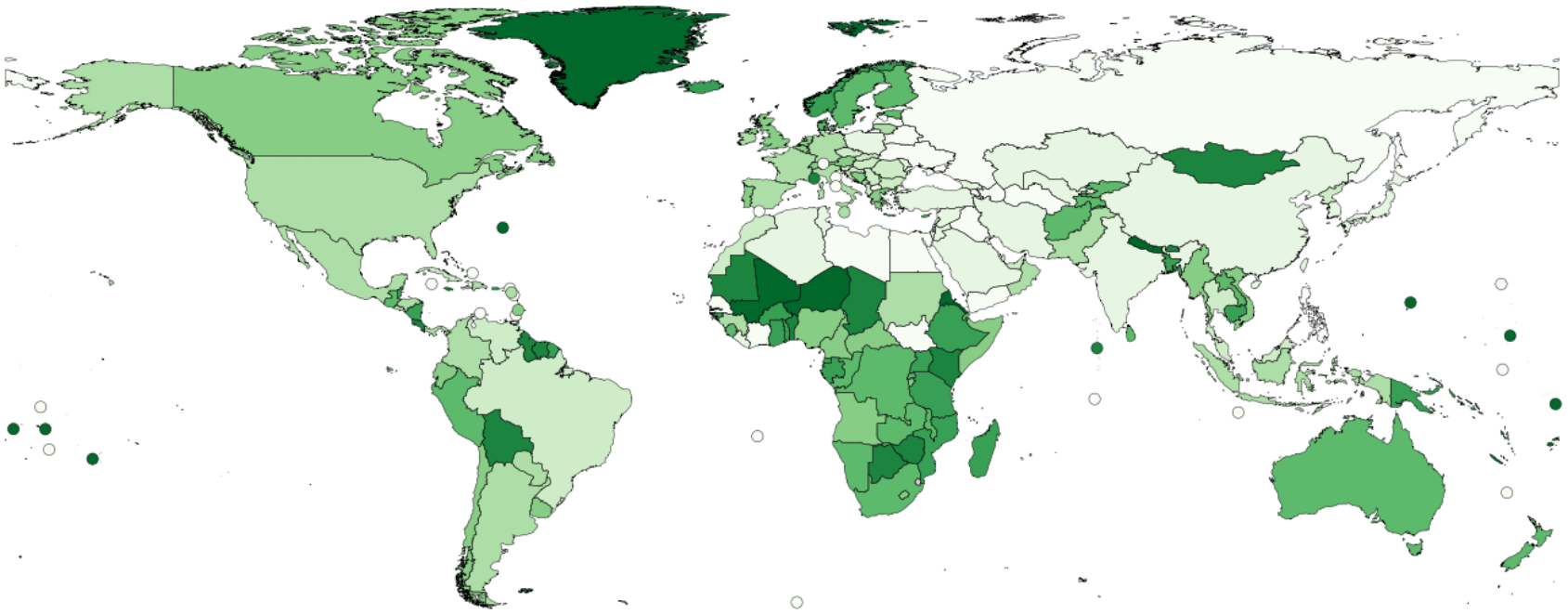
Case study: climate change research

- Public relevance
- Recent growth in size (0-1%)
- Variety of disciplines and RTs

Data:

- Scopus term search
- Time span 1990-2020
- 200k+ documents

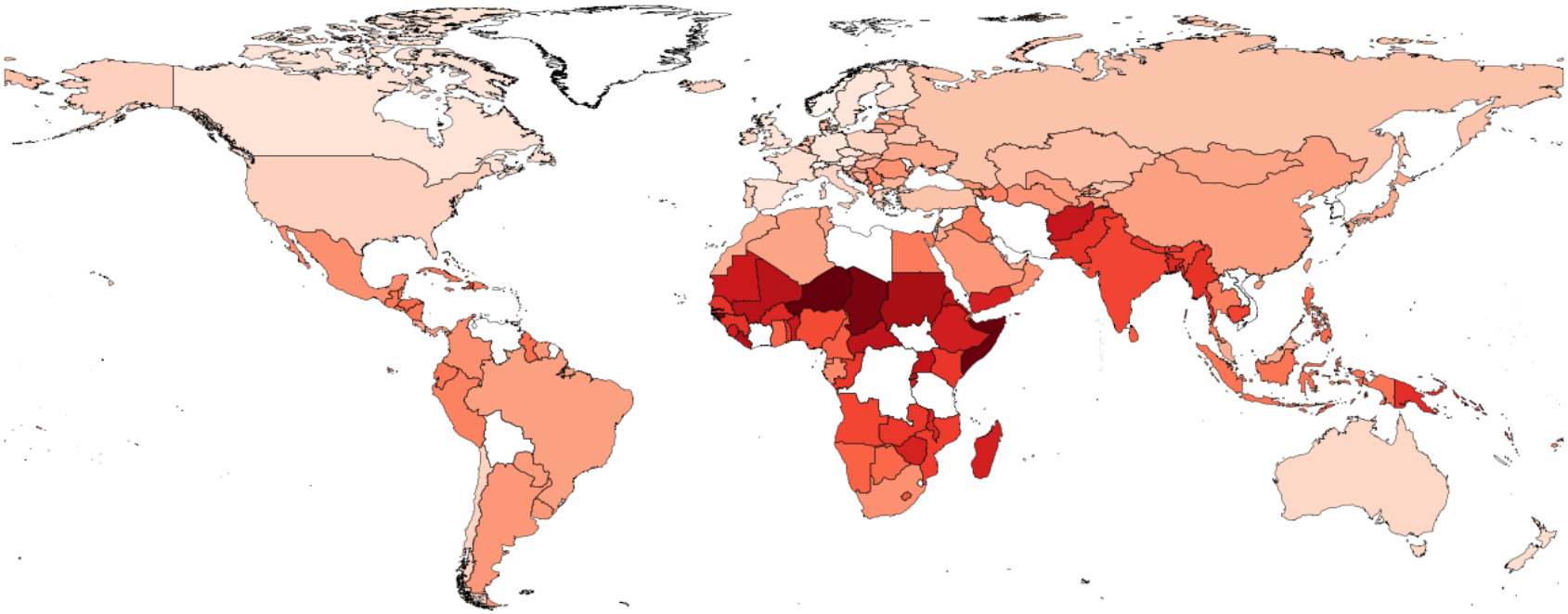
2 Climate change: a descriptive case-study



2016-2020 % of climate change research over country total publications

(darker color = higher value, max around 10%)

2 Climate change: a descriptive case-study



ND-GAIN index of vulnerability to
negative consequences of climate change

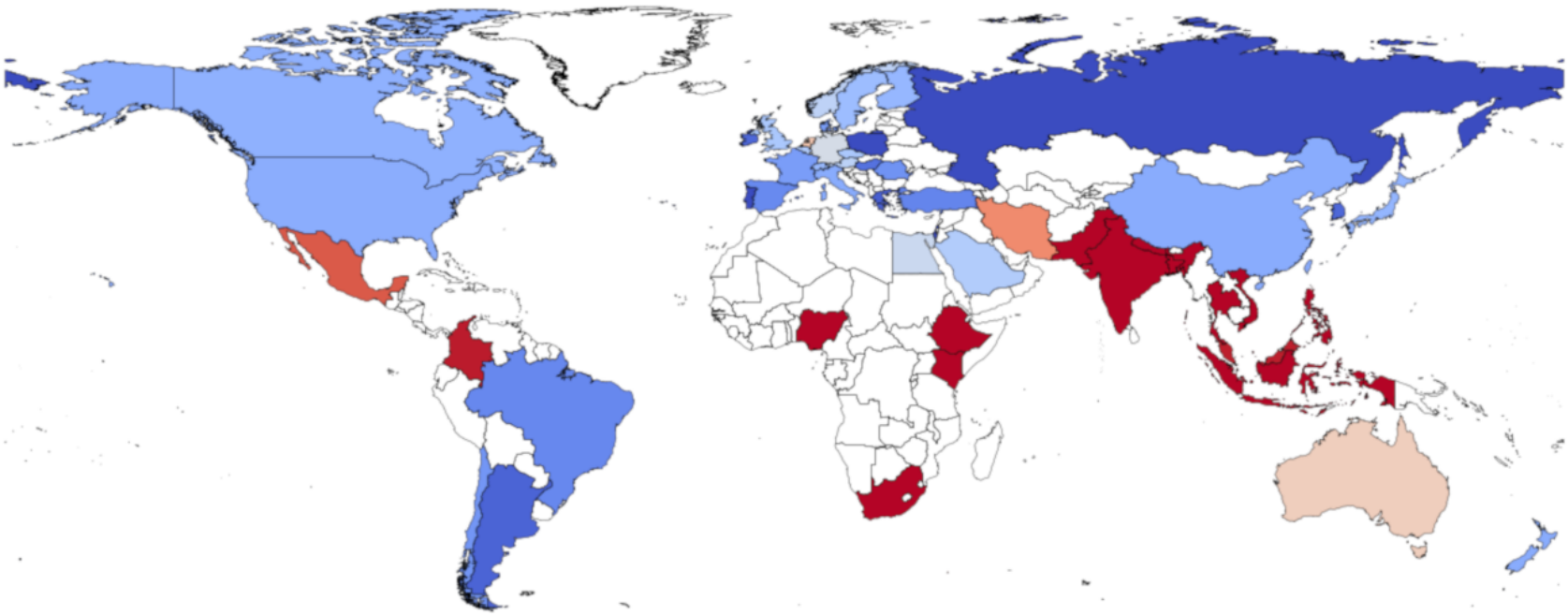
2 Climate change: a descriptive case-study

Analysis with our proposed method 800+ RTs

- Fine grained level of detail (possibly useful for practitioners, ESHS2022)
- Resolution level can be obtained bottom-up afterwards

- From absolute to relative distributions in the space
- Developing countries not only research climate change, they also have a higher representation of topics specific to them

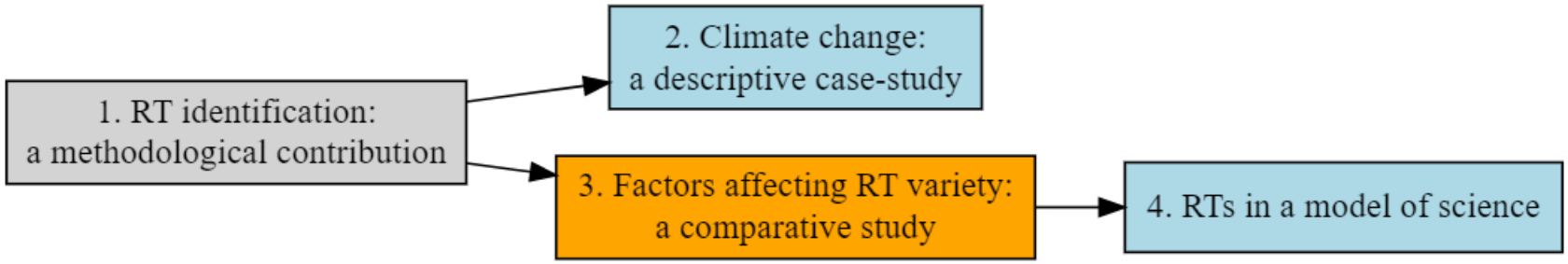
2 Climate change: a descriptive case-study



Topic 787, size 2074

Households in rural areas and small farmers, climate change consequences

Roadmap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3 Factors affecting RT variety: a comparative study

What factors influence the individual variety of research topics?
i.e. factors shaping *research agendas* (Horta & Santos 2020)

Exploration vs exploitation

March (1991), Kuhn (1977) *"The Essential Tension"*

Shifting topics and methods is *costly*, their choice implies *path dependence* (lock-in mechanism)

Factors vary (also) with: protected space, mutual dependence, task uncertainty (Whitley 2000)

3 Factors affecting RT variety: a comparative study

Scopus data, focus on textual data

Cross country comparison

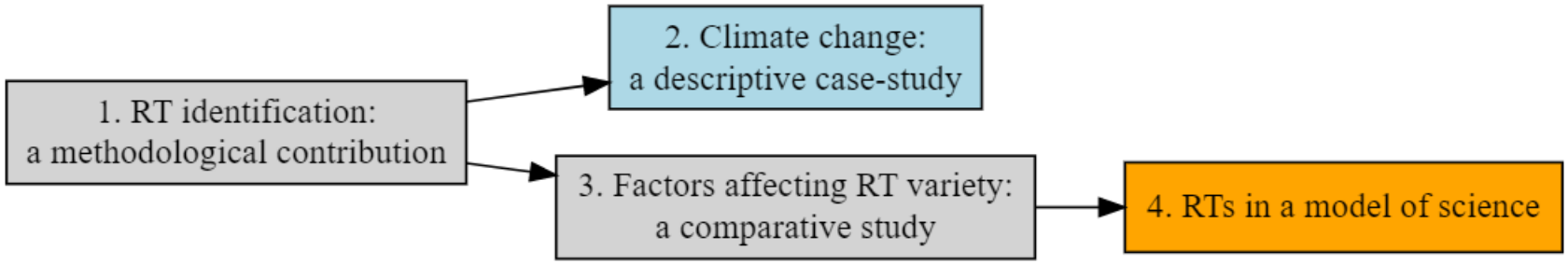
- Italy, Norway, Germany, United Kingdom
- Different career path, funding level, implementation of evaluation policies

Cross discipline comparison

- Sociology, StatMec and Nonlinearity, Molecular Biology
- Different across dimensions of Whitley's typology

Data collection is ongoing

Roadmap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4 RTs in a model of science

We draw on existing ABM literature on peer-review: Thurner & Hanel (2011), Squazzoni & Gandelli (2012, 2013), Bianchi & Squazzoni (2022)

Limit

Intrinsic quality of manuscripts as proportional (albeit in a noisy way) to the resources the author can access

Our proposal

Resources are an enabling factor, but the final quality of a contribution depends on the specific combination of TDM (theory, data, methods etc)

How to model this complexity?

Spatial representation of an *epistemic landscape*: Weisberg & Muldoon (2009), Alexander et al. (2015), Sobkowicz (2017), Avin (2019)

4 RTs in a model of science

Building blocks: Agents (authors & reviewers), Landscape, Journals, Resources

Algorithm 1 Main loop of the model

while $t \leq T$ **do**
- Compute fitness (scientific significance) of TDM
- Set manuscript quality $q_m = min\{fitness, resources\}$
- Determine journal for submissions
- Match author-reviewers
- Set evaluated quality $q_e \approx f(q_m, distance_J, distance_R, status)$
- Publish top-p papers per journal, according to q_e ranking
- Update (limited) resources according to publications
- Update NK-potential fitness (priority rule)
- Move authors (local search)

end while

4 RTs in a model of science

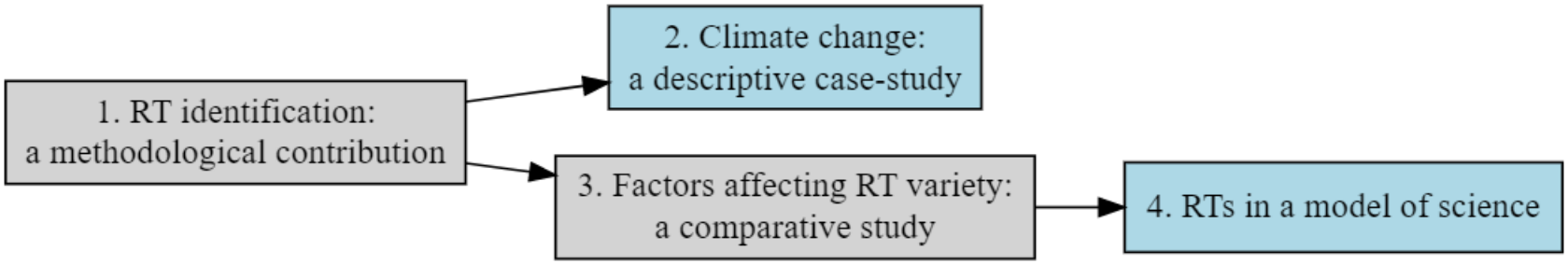
(The model was revisited after SSC2022 conference)

We are now running preliminary simulations

Main insights:

- The evolution of the field matters
- Relative scarcity/abundance of resources seems to have big impact on the role of other mechanisms

Plans for the future: calibration on empirical data from the previous contribution (!)



Thanks for the attention

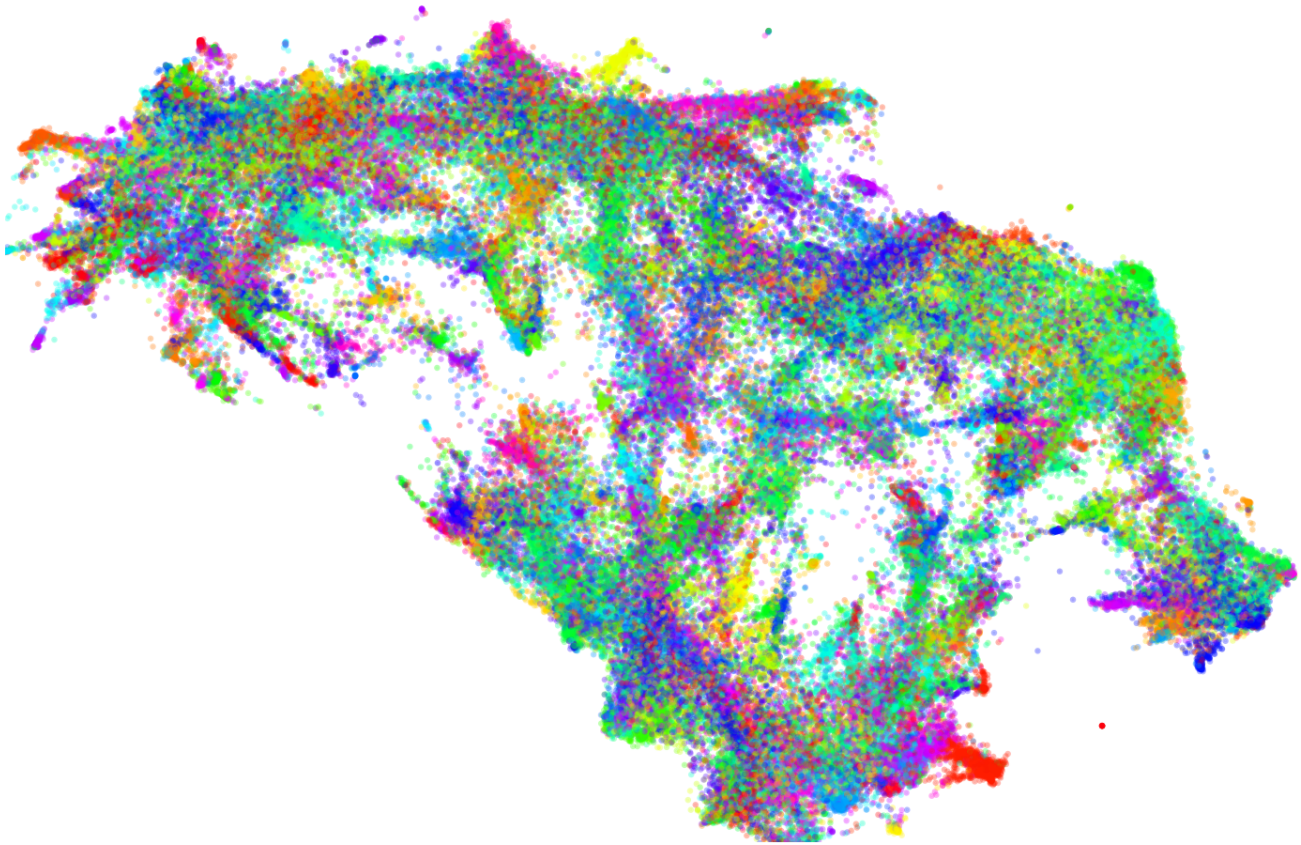
Appendix

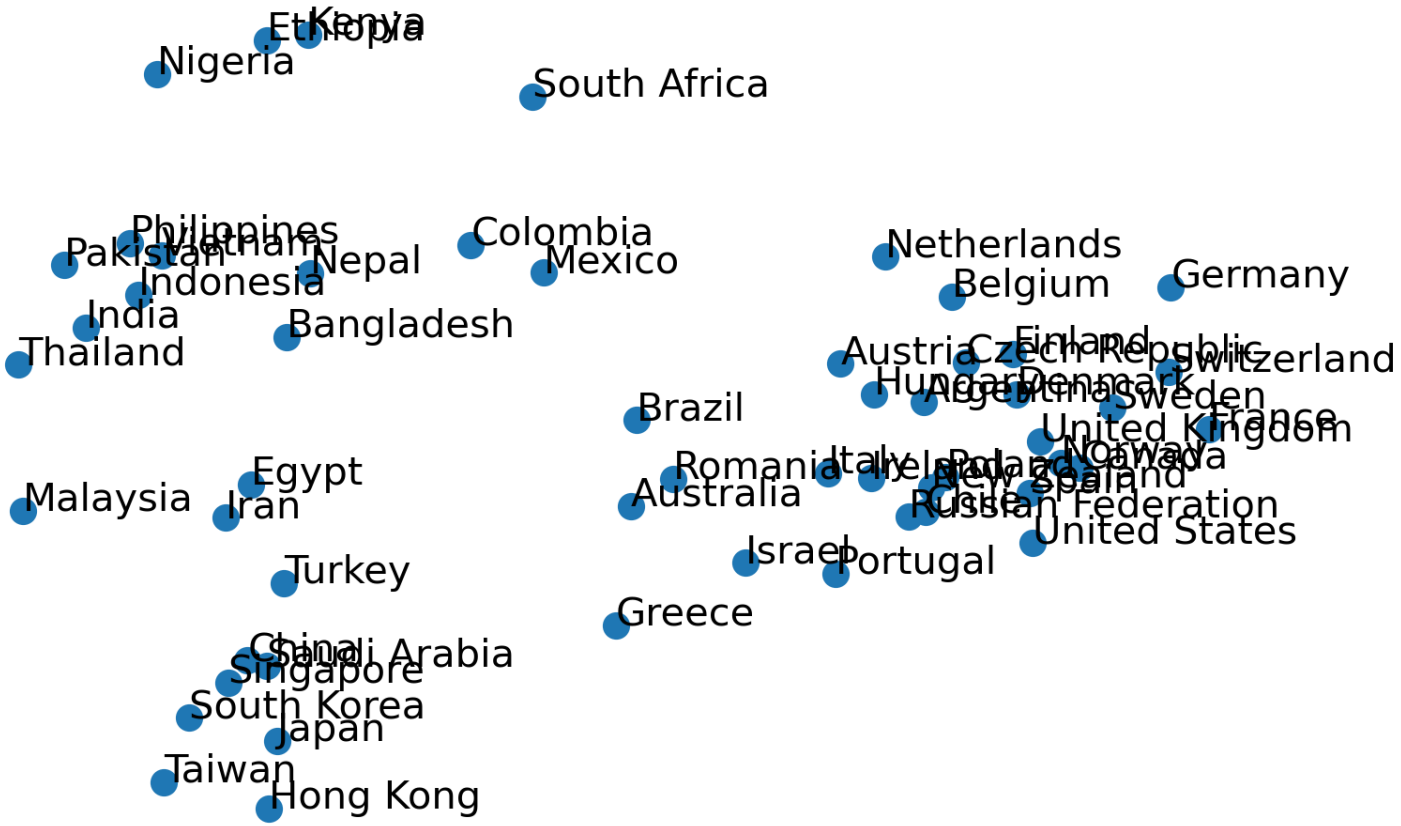
RT identification: our pipeline

- Document embedding (Reimers & Gurevych 2019)
- Repeated (20 iterations) application of dimensionality reduction (UMAP, McInnes & Healy 2018) and density-based clustering (HDBSCAN, Campello et al. 2013)
- Creation of a co-occurrence matrix of the documents (i.e. how many times doc A and B are labeled in the same cluster)
- Application of a threshold on the matrix in order to link only the documents always appearing together and identification of the connected components. These are the "core" part of the clusters
- The labeling is extended to the unlabeled documents via the following procedure:
  - pick a random unlabeled document with at least a link as strong as 1/2 the maximum (i.e. 10)
  - assign the label via a voting weighted by the links strenght
- The remaining unlabeled are those that where considered noise 50% or more of the times, these are assigned to the cluster with the closest centroid in the embedding space
- All the documents are color-coded in order to provide information on the quality of the clustering

Color-coding of the documents:

- Green: part of the core of a cluster, always labeled
- Yellow: labeled at least 50% of the times
- Orange: labeled less than 50% of the times
- Red: always considered noise

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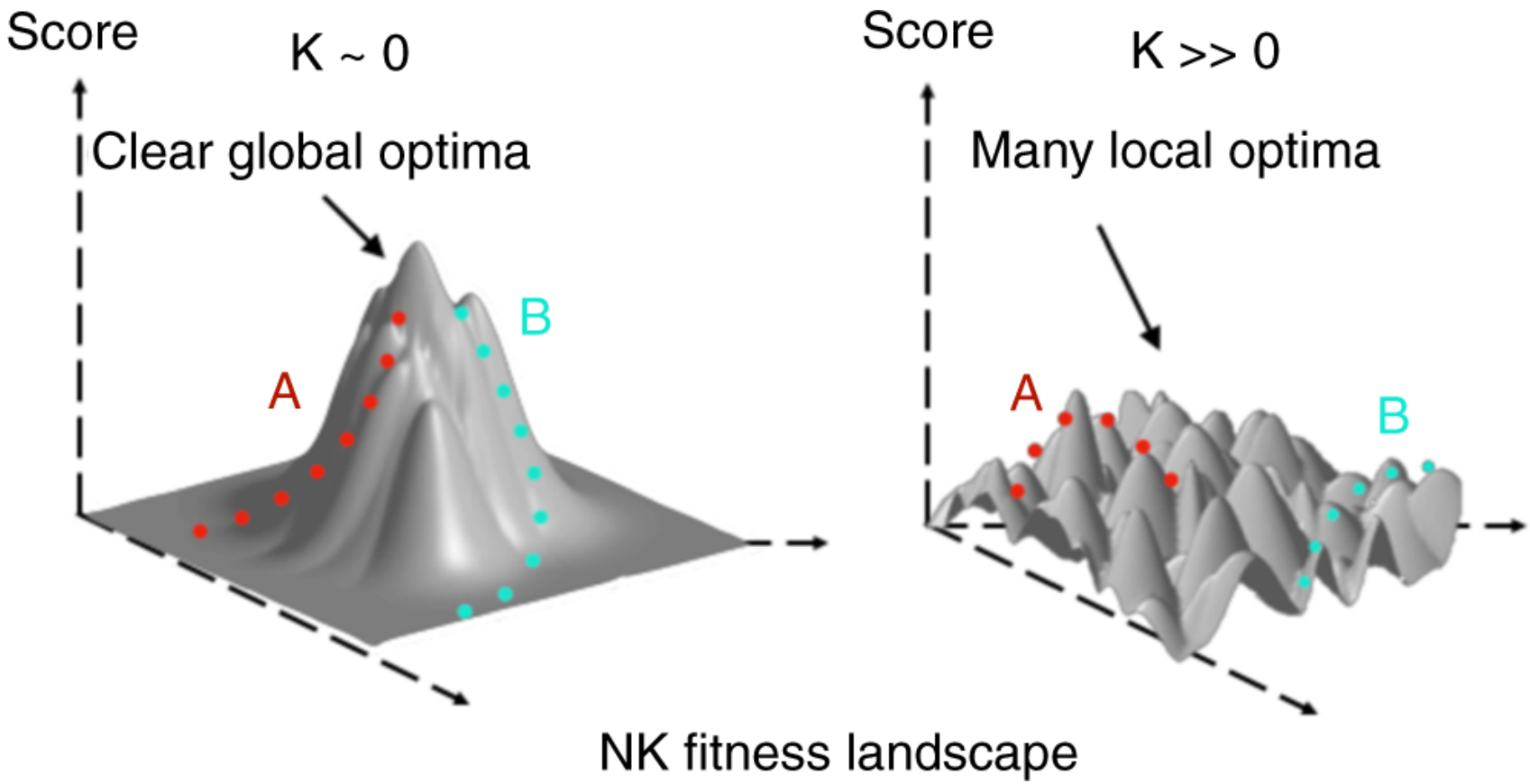
Score
K ~ 0
Clear global optima
A
B
Score
K >> 0
Many local optima
A
B
NK fitness landscape