

Structural biases in university rankings: a complex network approach to bridge the gap



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University rankings: handle with care



Positive feedback between ranking outcomes and funding



- **Academic conformism** (*reactivity to rankings*)
- **Consolidation** of existing **gaps** (*Matthew effect*), often between universities in wealthier and poorer contexts

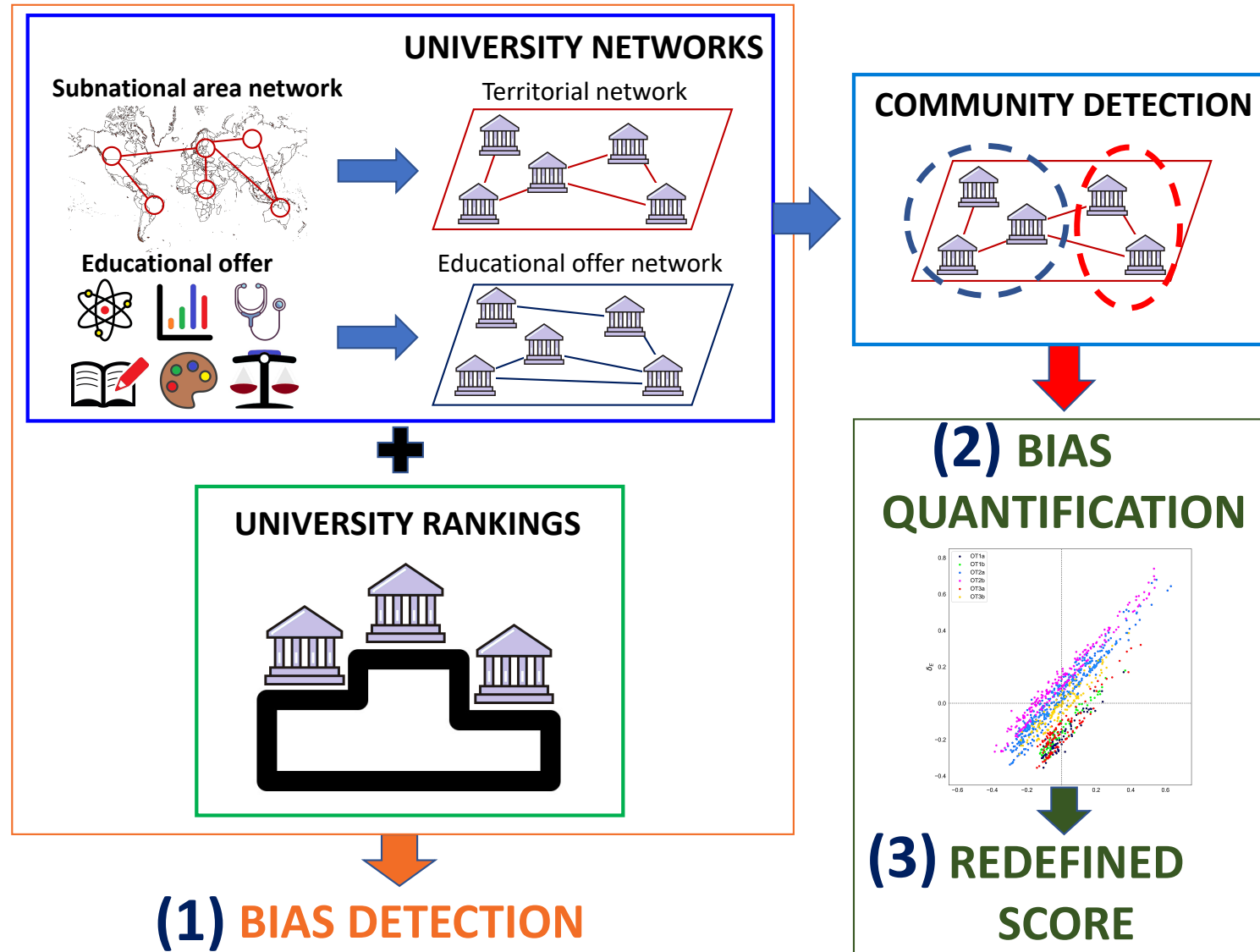
Our research goal

Measuring and removing structural biases that inhomogeneously affect the ranking outcomes of universities from diversified territorial and educational contexts

Three-step process



- 1. Detecting biases** determined by either the territorial conditions or the educational offer
- 2. Quantifying** the **effect of biases** on the performance of each university
- 3. Defining a fairer ranking** in which the detected biases are mitigated

Workflow: a first glance



Case studies: global and national scale

Two academic ecosystems

INTERNATIONAL	ITALIAN
<p>Universities from OECD countries, rated in the 2021 Times Higher Education (THE) ranking</p>  <p>→ An overall score + 5 sectorial dimensions: <i>teaching, research, citations, industry income, international outlook</i></p>	<p>Italian universities, surveyed through the 2019/2020 Centro Studi Investimenti Sociali (CENSIS) rankings</p>  <p>→ An overall score + 6 sectorial dimensions: <i>services, scholarships, structures, communication & digital services, international outlook, employability</i></p>

A complex network approach to debiasing

Following our previous study for the analysis of international rankings involving United Nation Member States...

scientific reports

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An equity-oriented rethink
of global rankings with complex
networks mapping development

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Scientific Reports **10**, 18046 (2020)

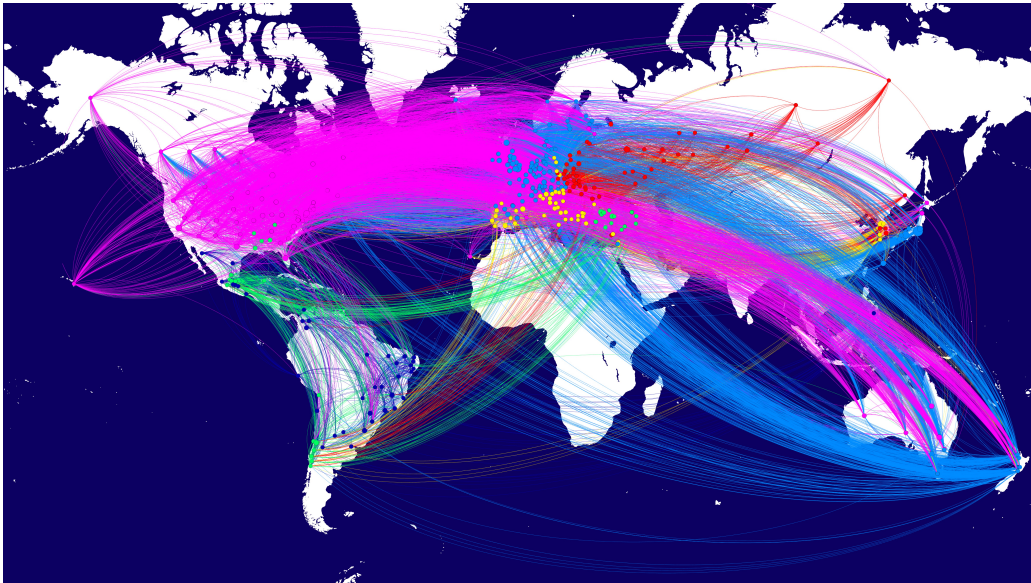
...we model both the international and the Italian academic systems as a pair of
complex networks

TERRITORIAL NETWORK

EDUCATIONAL OFFER NETWORK

Territorial network

Edges between universities are weighted by the statistically significant ($p < 10^{-2}$) **Pearson correlation between development indicators** of the regions in which they are based (**subnational resolution**)



Educational offer network

		SUBJECTS				
		s_1	s_2	...	...	...
UNIVERSITIES	u_1	0	1	...	...	...

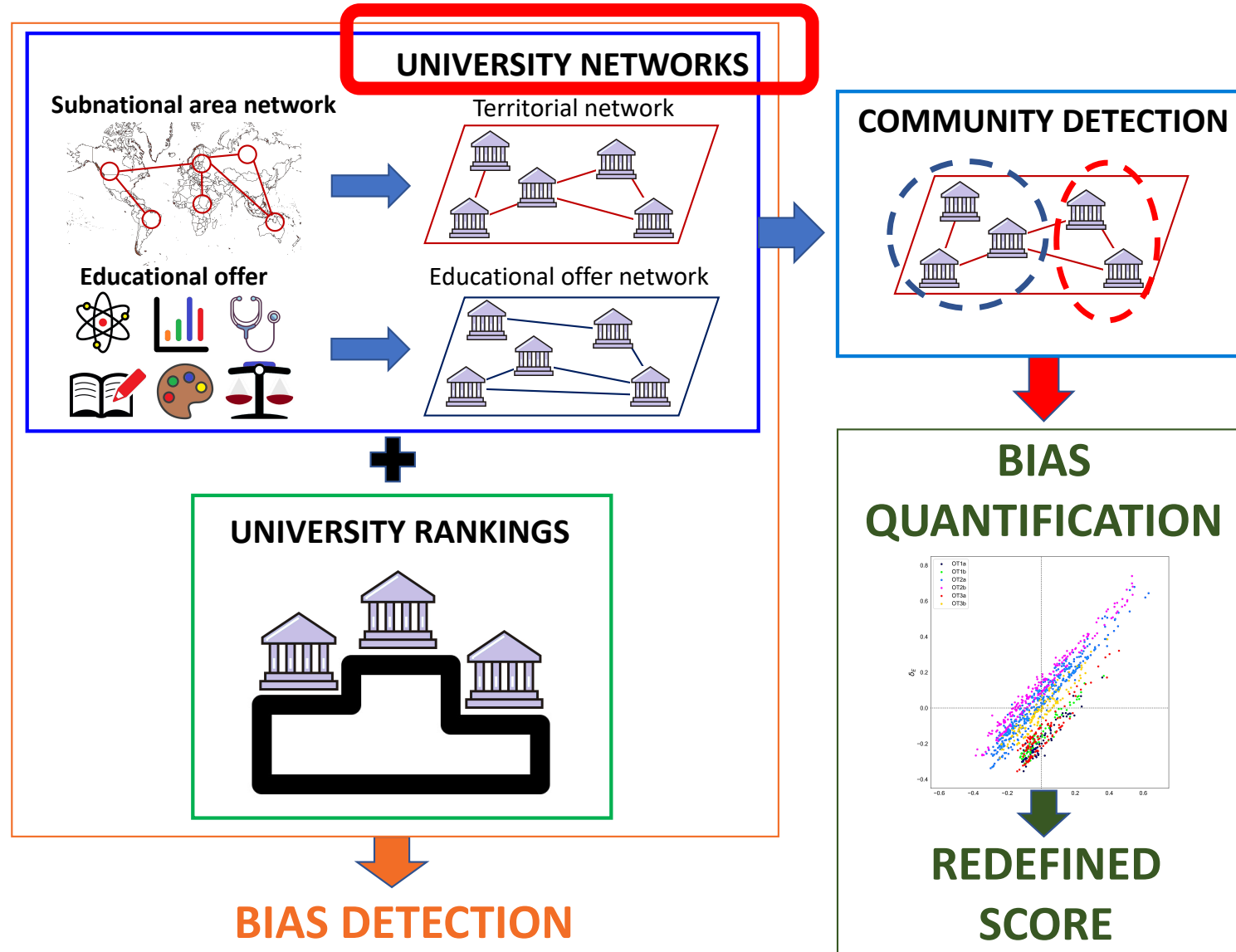
	u	1	0	...	...	...
	v	0	1	...	...	...

The edge between two given universities u and v is weighted according to the **overlap between** their **educational offers** Γ_u and Γ_v , quantified by the Dice index

$$D_{uv} = \frac{2|\Gamma_u \cap \Gamma_v|}{|\Gamma_u| + |\Gamma_v|}$$

$|S|$ denotes the cardinality of the set S .

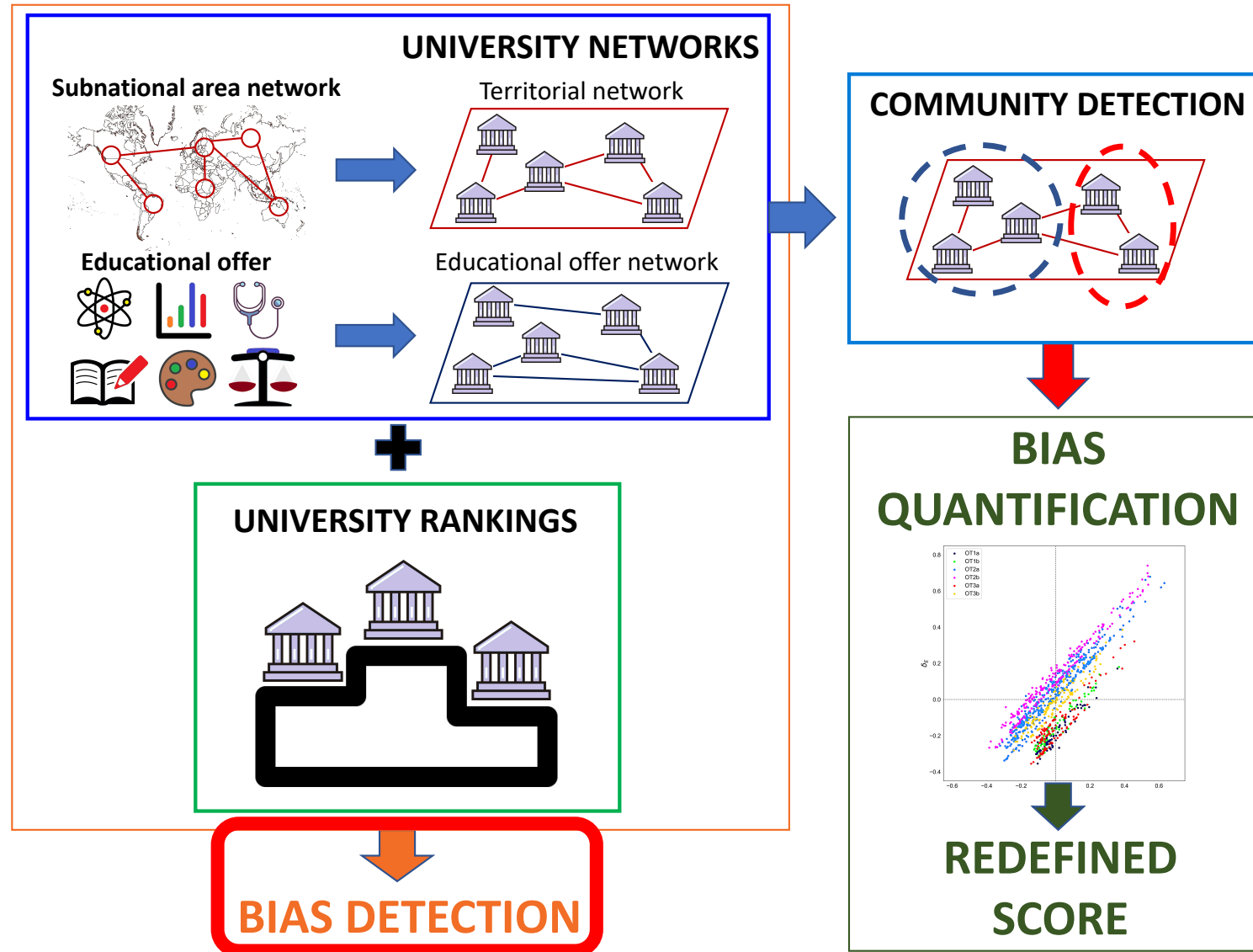
Workflow



University networks

INTERNATIONAL	ITALIAN
<p data-bbox="155 496 690 548">Territorial network</p> <ul data-bbox="155 576 1200 953" style="list-style-type: none"><li data-bbox="155 576 1200 868">○ 1088 universities (nodes) distributed in 343 TL2 regions, characterized through 97 socio-economic indicators<li data-bbox="155 896 614 953">○ 351186 edges <p data-bbox="155 1053 894 1105">Educational offer network</p> <ul data-bbox="155 1133 1174 1348" style="list-style-type: none"><li data-bbox="155 1133 1174 1276">○ 1088 universities (nodes), providing 30 educational offer categories<li data-bbox="155 1290 614 1348">○ 539305 edges	<p data-bbox="1365 496 1900 548">Territorial network</p> <ul data-bbox="1365 576 2410 953" style="list-style-type: none"><li data-bbox="1365 576 2410 868">○ 92 universities (nodes) distributed in 53 Italian provinces, characterized through 121 socio-economic indicators<li data-bbox="1365 896 1760 953">○ 2396 edges <p data-bbox="1365 1053 2104 1105">Educational offer network</p> <ul data-bbox="1365 1133 2333 1348" style="list-style-type: none"><li data-bbox="1365 1133 2333 1276">○ 92 universities (nodes), providing 152 educational offer categories<li data-bbox="1365 1290 1760 1348">○ 2007 edges

Workflow



Bias detection through assortativity

The **assortativity** r_w quantifies the **tendency** of a (weighted) network **to connect nodes with similar values** of a continuous **attribute** x

$$r_w = \frac{\sum_{ij} \left(w_{ij} - \frac{s_i s_j}{W} \right) x_i x_j}{\sum_{ij} \left(s_i \delta_{ij} - \frac{s_i s_j}{W} \right) x_i x_j}$$

[w_{ij} weight of link (i, j) , $s_i = \sum_j w_{ij}$ strength of node i , $W = \sum_{ij} w_{ij}$]

Bias detection through assortativity

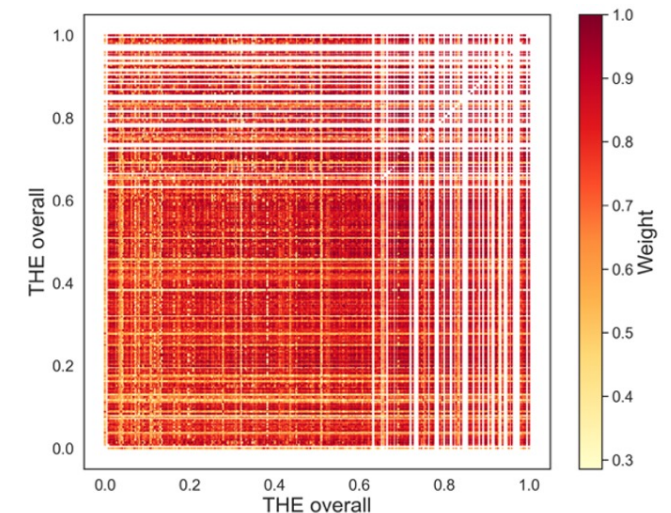
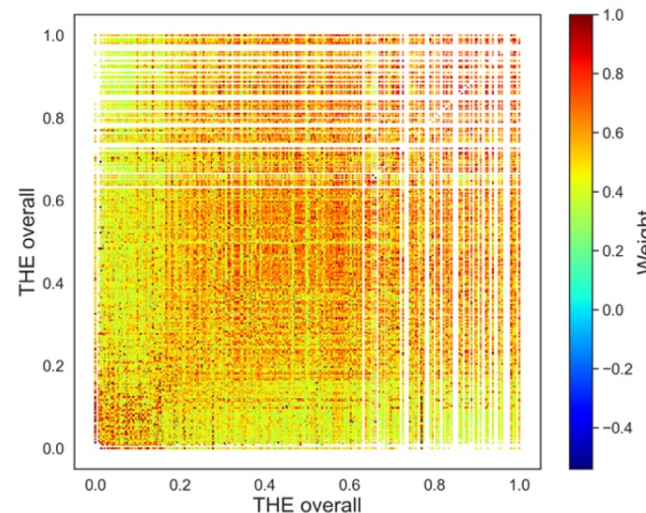
The **assortativity** r_w is equivalent to the **weighted Pearson correlation** between two **vectors** of length $2m$ (with m the number of edges), whose **entries** coincide with the attributes x_i **and** x_j of two nodes connected by an edge of weight w_{ij}
→ We can associate a **standard error** and a **p-value** to r_w

In our case, the attribute x corresponds to each (overall and sectorial) ranked index

Scatter plots of link weights as a function of the *THE overall* indexes of connected nodes

Left → territorial network

Right → educational offer network



Assortativity of university networks

International case

	Territorial network	Educational offer network
THE overall score	0.109 ± 0.001 ($p < 10^{-9}$)	0.003 ± 0.001 ($p < 0.007$)
THE teaching	0.043 ± 0.001 ($p < 10^{-9}$)	0.002 ± 0.001 ($p = 0.044$)
THE research	0.059 ± 0.001 ($p < 10^{-9}$)	0.002 ± 0.001 ($p = 0.015$)
THE citations	0.143 ± 0.001 ($p < 10^{-9}$)	0.004 ± 0.001 ($p = 10^{-4}$)
THE industrial income	0.015 ± 0.001 ($p < 10^{-9}$)	0.003 ± 0.001 ($p = 0.003$)
THE international outlook	0.147 ± 0.001 ($p < 10^{-9}$)	0.002 ± 0.001 ($p = 0.038$)

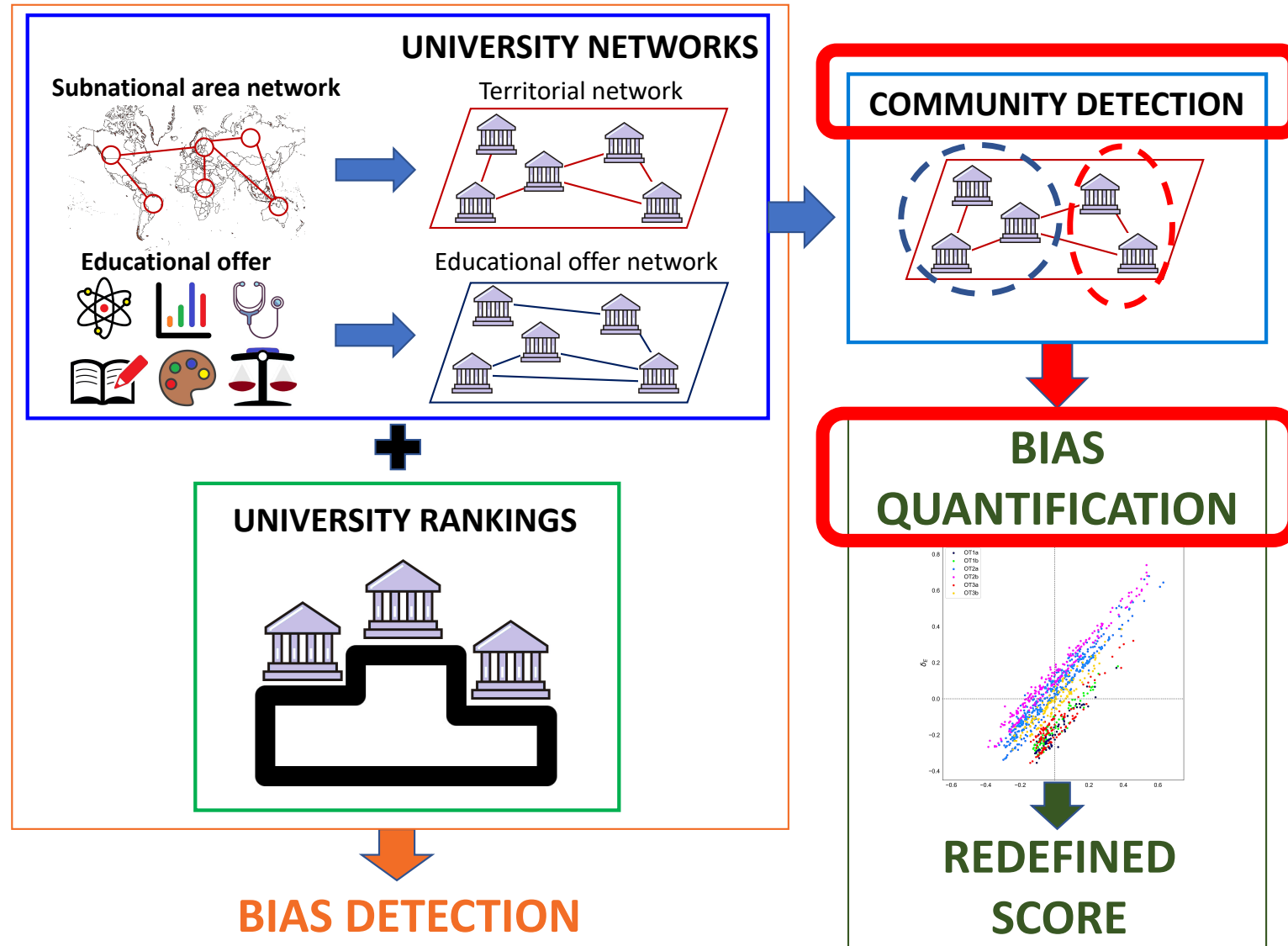
Italian case

	Territorial network	Educational offer network
CENSIS overall score	0.289 ± 0.018 ($p < 10^{-9}$)	-0.019 ± 0.017 ($p = 0.275$)
CENSIS services	0.027 ± 0.019 ($p = 0.161$)	-0.002 ± 0.017 ($p = 0.954$)
CENSIS scholarships	-0.017 ± 0.019 ($p = 0.388$)	-0.010 ± 0.017 ($p = 0.541$)
CENSIS structures	0.077 ± 0.019 ($p = 6 \cdot 10^{-5}$)	-0.020 ± 0.017 ($p = 0.243$)
CENSIS communication and digital services	0.122 ± 0.019 ($p < 10^{-9}$)	-0.012 ± 0.017 ($p = 0.475$)
CENSIS international outlook	0.288 ± 0.018 ($p < 10^{-9}$)	0.007 ± 0.017 ($p = 0.667$)
CENSIS employability	0.436 ± 0.022 ($p < 10^{-9}$)	-0.003 ± 0.019 ($p = 0.865$)

Territorial networks are assortative ($p < 10^{-2}$) with respect to most of the indexes

Such a striking effect is **not observed in educational offer networks**

Workflow



Network communities and debiasing parameters

Community detection in the territorial (T) and educational offer (E) networks provides a **reference frame for a fair evaluation** of academic performance in rankings.

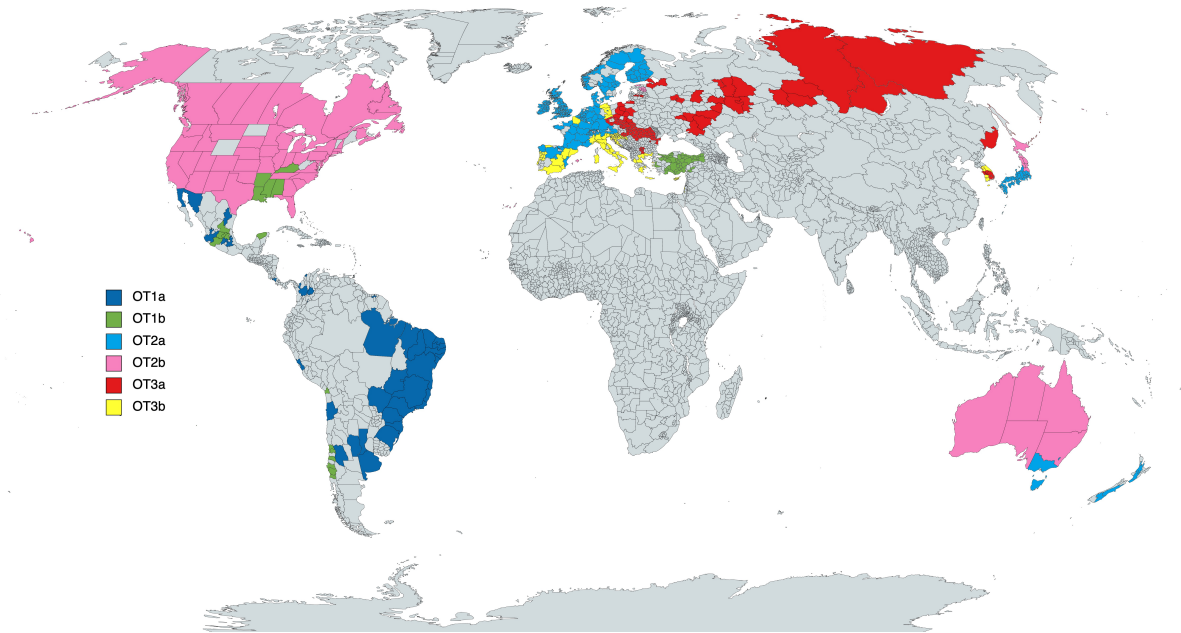
For a given ranked index I , we associate to each university u two **debiasing parameters**

$$\delta_T(u) = I(u) - \frac{\sum_{v \in C_T} w_{uv}^T I(v)}{\sum_{v \in C_T} w_{uv}^T}, \quad \delta_E(u) = I(u) - \frac{\sum_{v \in C_E} w_{uv}^E I(v)}{\sum_{v \in C_E} w_{uv}^E}$$

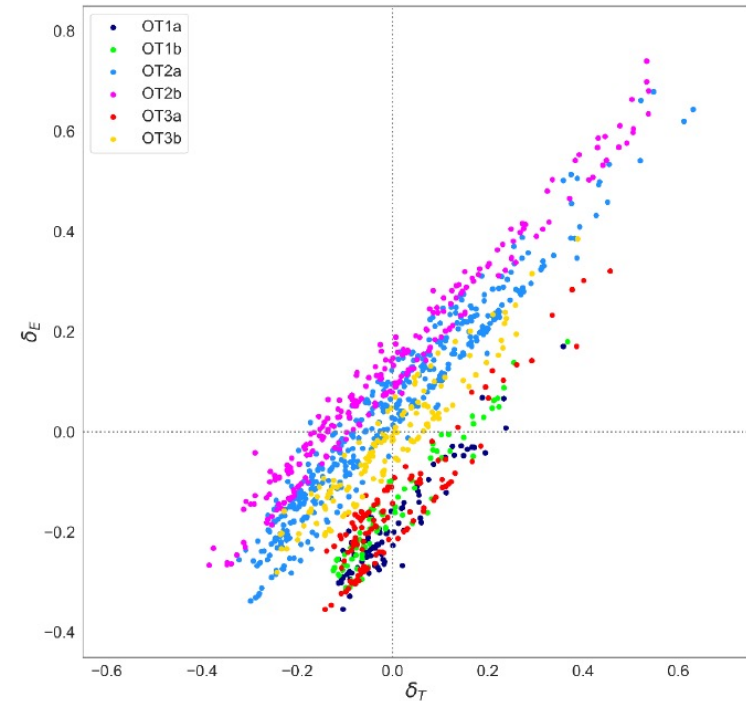
which **refer the performance of an institution to the rest of its own community** (C_T for the territorial network, C_E for the educational offer network)

Territorial bias quantification

OECD territorial communities



Debiasing parameter distribution (*THE* overall ranking)



The **stratification** observed in the scatter plot indicates a **systematic advantage** of universities based in wealthier territories

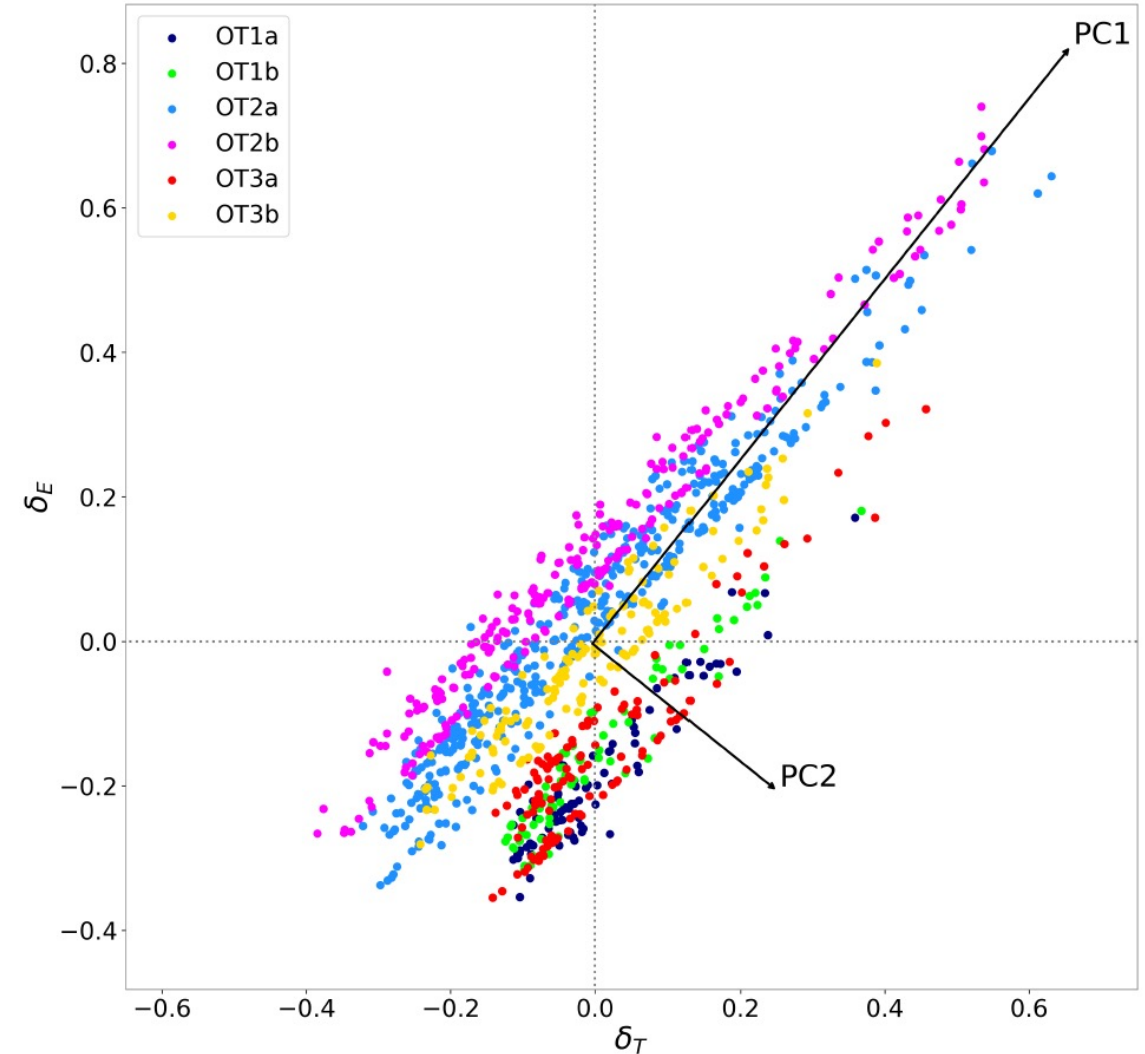
No similar effect is observed for educational offer community membership

A fairer rating from principal components

The **principal components** of the debiasing parameter distributions provide a key to **define a fairer ranking**

- **PC1** represents a **redefined ranking**, in which territorial influence is mitigated
- **PC2** quantifies the **territorial dragging** effect → **incorporates bias**

THE overall case: the territorial network is much **less assortative with respect to PC1** (0.054) than to the original ranking (0.109)



Emerging merit and success confirmations

From THE overall to its **debiased redefinition PC1**

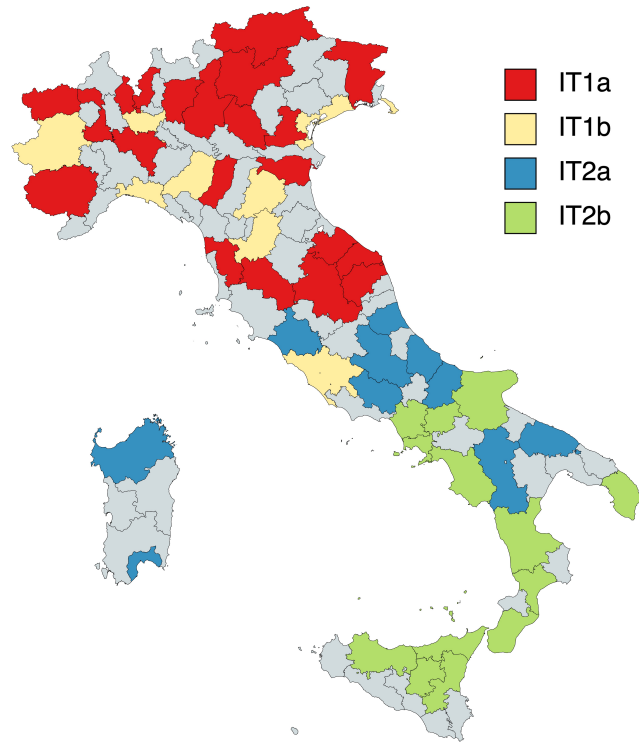
- **Small changes on top** of the list: the merit of outstanding universities is not due to a territorial bias
- The **largest placement improvements** are achieved by **universities operating in less advantaged contexts** (eastern Europe and center-south America)

University	Subregion	Country	PC1
California Institute of Technology	California	United States	0.916 (+3)
University of Oxford	South East England	United Kingdom	0.902 (-1)
Massachusetts Institute of Technology	Massachusetts	United States	0.884 (+2)
Imperial College London	Greater London	United Kingdom	0.877 (+7)
Stanford University	California	United States	0.873 (-3)
University of Cambridge	East of England	United Kingdom	0.871 (0)
ETH Zurich	Zurich	Switzerland	0.847 (+7)
Princeton University	New Jersey	United States	0.837 (+1)
Harvard University	Massachusetts	United States	0.837 (-6)
University of California, Berkeley	California	United States	0.793 (-3)

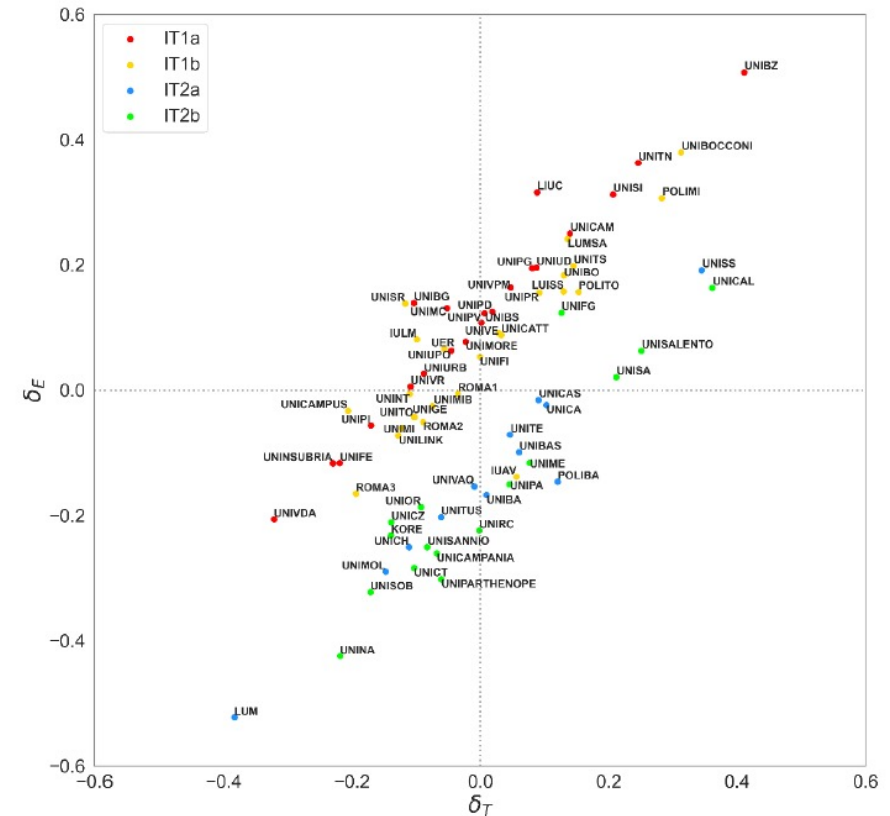
Full PC1 ranking (1088 universities) available at Scientific Reports **12**, 4995 (2022)

The Italian case: a gapped distribution

Italian territorial communities



Debiasing parameter distribution (*CENSIS* overall ranking)

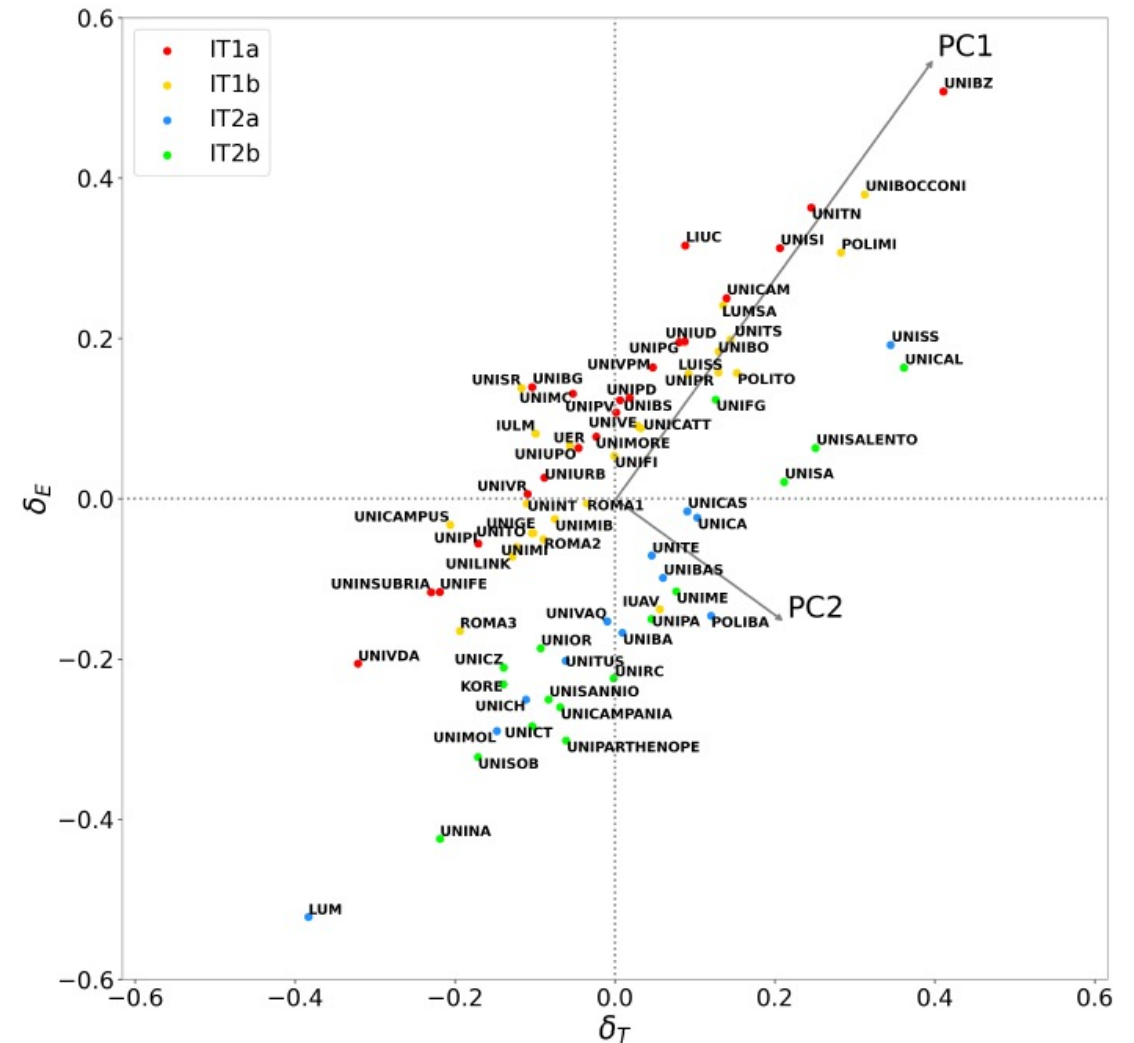


In the Italian case study, the debiasing parameter scatter plots referred to many ranked indexes exhibit a **gap**, reflecting the North-South polarization of the country

Debiasing Italian rankings

In the ***CENSIS overall*** case, **assortativity** of the territorial network with respect to PC1 (0.113) is **strongly mitigated** with respect to the value obtained with the original ranking (0.450)

The **gap between the North and South** clusters, measured along the PC2 direction, is **numerically relevant**: 2.8 times the average standard deviation of PC2 within each cluster



Debiasing Italian rankings

A pair of universities from disadvantaged territorial communities reach the top 10 positions in the **redefined CENSIS overall ranking**

University	Province of main seat	PC1
Free University of Bolzano	Bolzano	0.652 (0)
“Luigi Bocconi” University of Milano	Milano	0.491 (+1)
University of Trento	Trento	0.438 (−1)
Milano Politecnico	Milano	0.414 (0)
University of Siena	Siena	0.374 (0)
University of Sassari	Sassari	0.358 (+5)
University of Calabria	Cosenza	0.345 (+7)
“Carlo Cattaneo University – LIUC	Varese	0.308 (+4)
University of Camerino	Macerata	0.285 (−3)
“Maria SS. Assunta” Free University – LUMSA	Roma	0.275 (+5)

The largest placement improvement with respect to the original ranking involve in a predominant way universities from the south of the country

Conclusions and outlook

We have achieved two relevant results: 1) **measuring the impact of territory** on the scores of universities in rankings, 2) **decoupling this bias** from the definition of performance, thus developing a fairer rating system.

We refer the performance of a university to a **multifaceted and high-dimensional representation** of its context, determined by a large number of socio-economic indicators

Universities achieving the largest position **improvements** in PC1 with respect to the original overall rankings belong to comparatively **disadvantaged territorial communities**

A complementary research question: how much the advantageous features of a territory are influenced by the **presence of outstanding universities**

Thank you for your attention!

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