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Interdisciplinarity: Its Bibliometric Evaluation and Its Influence in Research Outputs

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Agenda

1. Measuring & MappingInterdisciplinarity
   - Integration, Specialization & Diffusion Scores
   - Science overlay maps (locating research activity)
   - Research networking maps
2. Research Assessment applications
3. Effects of Interdisciplinarity
   - Parsing out effects of Variety, Balance & Disparity on scientific impact
   - National vs. International research – degree of interdisciplinarity
   - Programmatic comparison: Innovation Studies units vs. Business/Management schools
   - Disciplinarity & Journal ranks

#1: Papers Citing Level #2 Papers – Citing Paper Overlay Maps [Knowledge Diffusion]

- Diffusion scores
- Science Citing Overlay Maps
- Relative engagement by ISI Subject Categories

Tracking multi-generational research knowledge transfer with

- **Interdisciplinarity metrics**
- **Science overlay mapping**

#2: Main Level (e.g., research outputs of a target program) – publication overlay maps

- "Specialization" scores (Diversity of areas of publication)
- Science overlay maps (Location of publications among ISI Subject Categories)

- Integration scores (Average diversity of areas of citation)
- Science citation maps
- Bibliographic coupling

#3: Papers cited by #2

- Coherence measures (do #3 papers draw upon distinct topics?)
- ["Bibliographic Coupling" measures available – e.g., % shared references]

#4: Papers cited by #3

Interdisciplinary Research Metrics

- National Academies Keck Futures Initiative (15-year program) to boost interdisciplinary research in the US
- Measure interdisciplinarity for program evaluation
- For a body of research
  - Extract papers' cited references
  - Associate cited journals to Web of Science (WOS) Subject Categories (SCs)
  - Matrix of SC by SC interrelationships
  - For given paper set, calculate
    - "Integration" – breadth of SCs drawn upon
    - "Specialization" – concentration of publication activity
    - "Diffusion" – diversity of SCs citing the research

Heuristics of diversity

(Stirling, 1998; 2007)
(Rafols and Meyer, 2010)

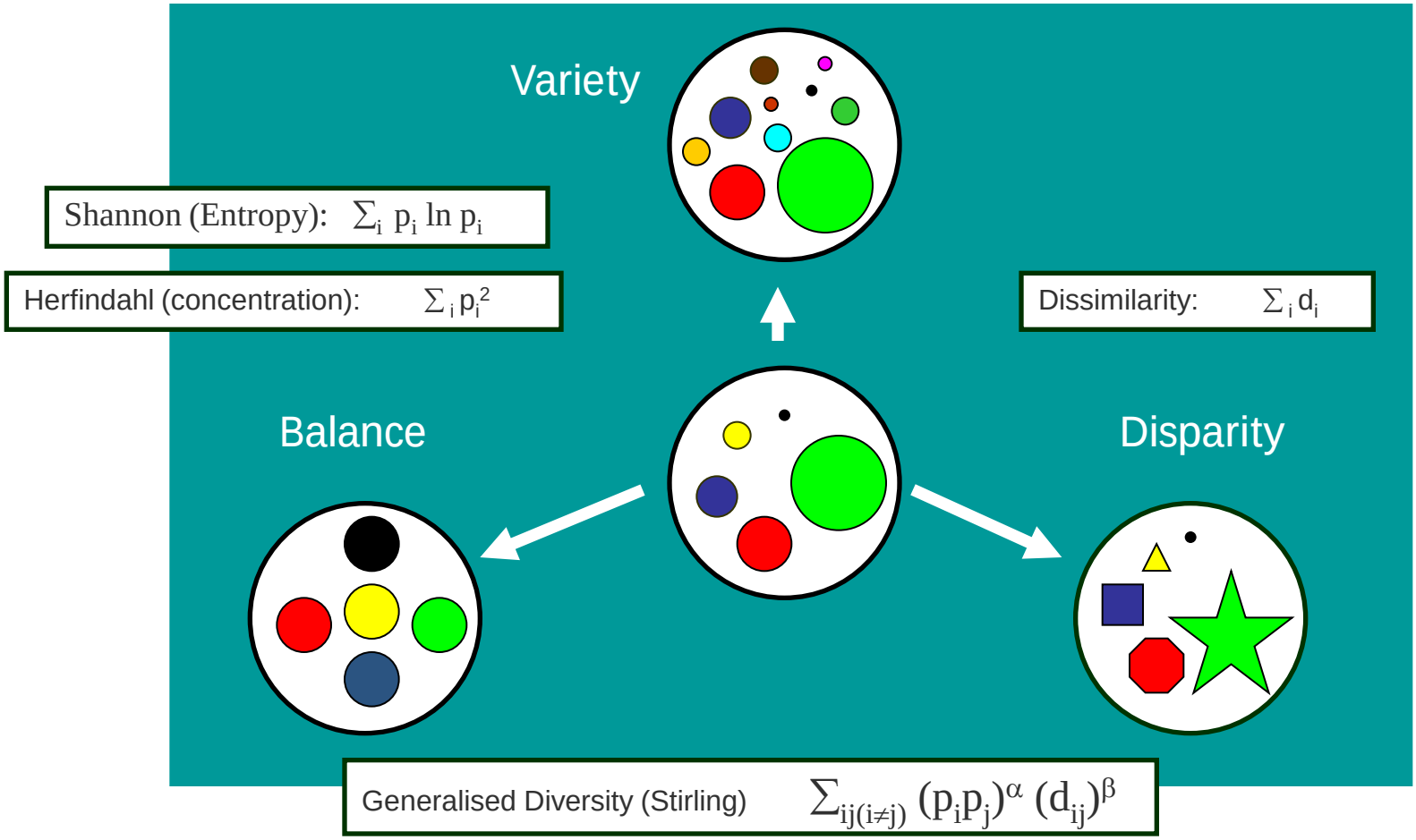
Diversity:

'attribute of a system whose elements may be apportioned into categories'

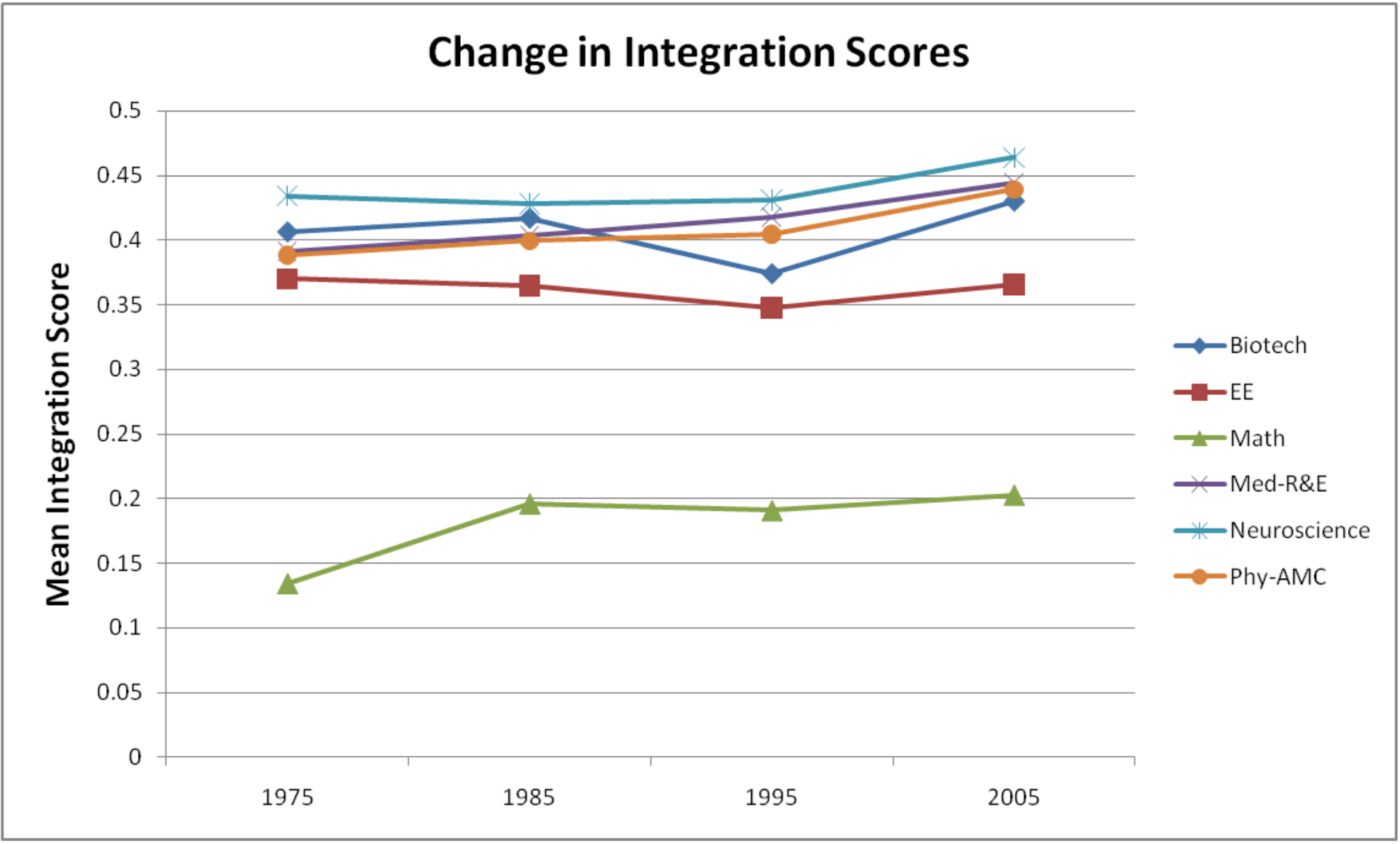
Characteristics:

Variety: Number of distinctive categories
Balance: Evenness of the distribution
Disparity: Degree to which the categories are different.

[** Shannon & Herfindahl do not include Disparity]



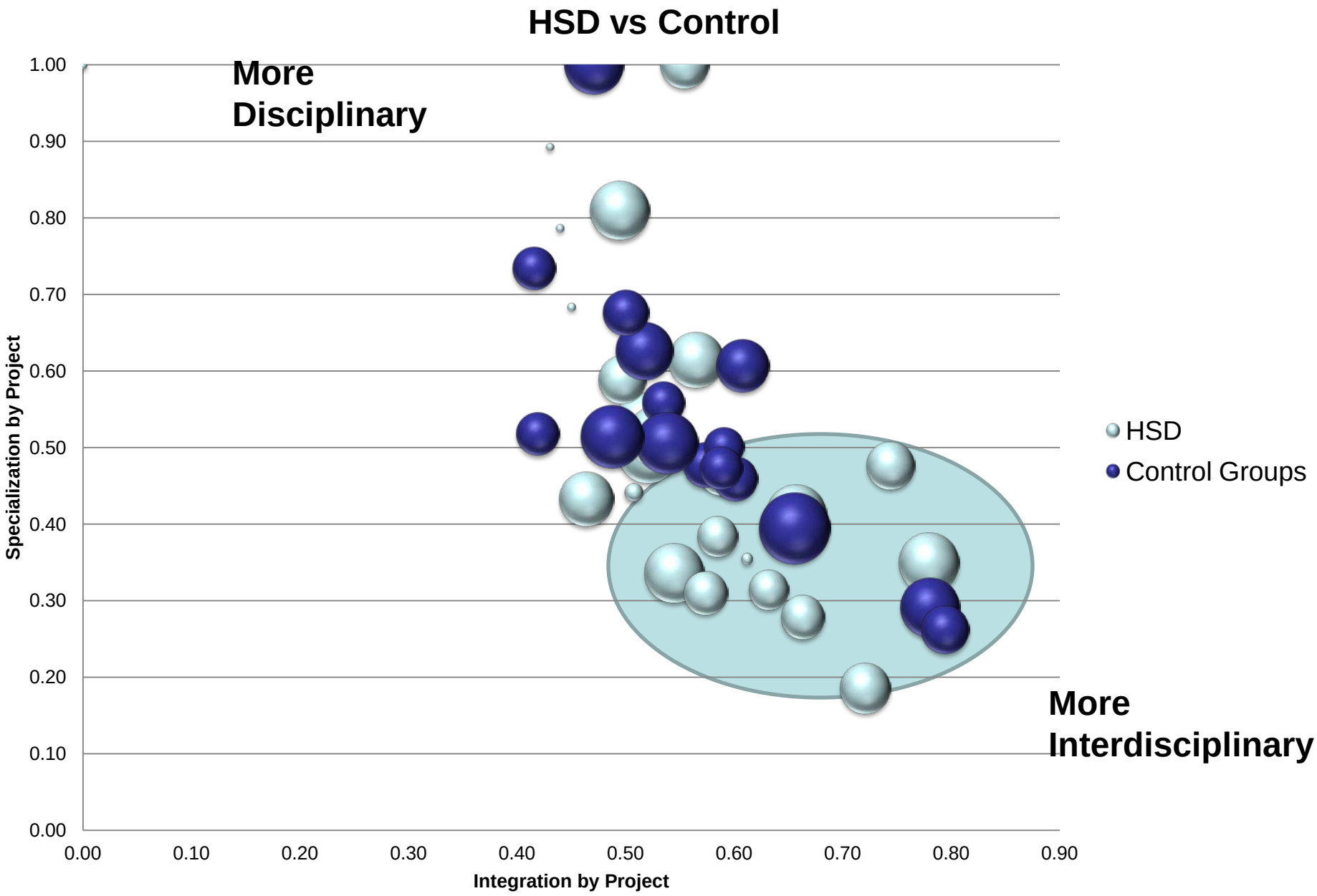
Benchmarking Integration Scores



Porter and Rafols (2009)

NSF Research Assessments

- RCN (Research Coordination Networks) Program
  - Can we see researcher network enrichment, Before to After?
- HSD (Human & Social Dynamics) and CMG (helping SRI) (Collaborations in Math & Geosciences) Programs
  - How interdisciplinary (compared to ~similar projects)?
- REESE (Research & Evaluation on Education in Science & Engineering) Program
  - How is Cognitive Science engaging with STEM education, over time?
- iUtah (EPSCOR)
  - Research engagement & networking -- Before vs. After

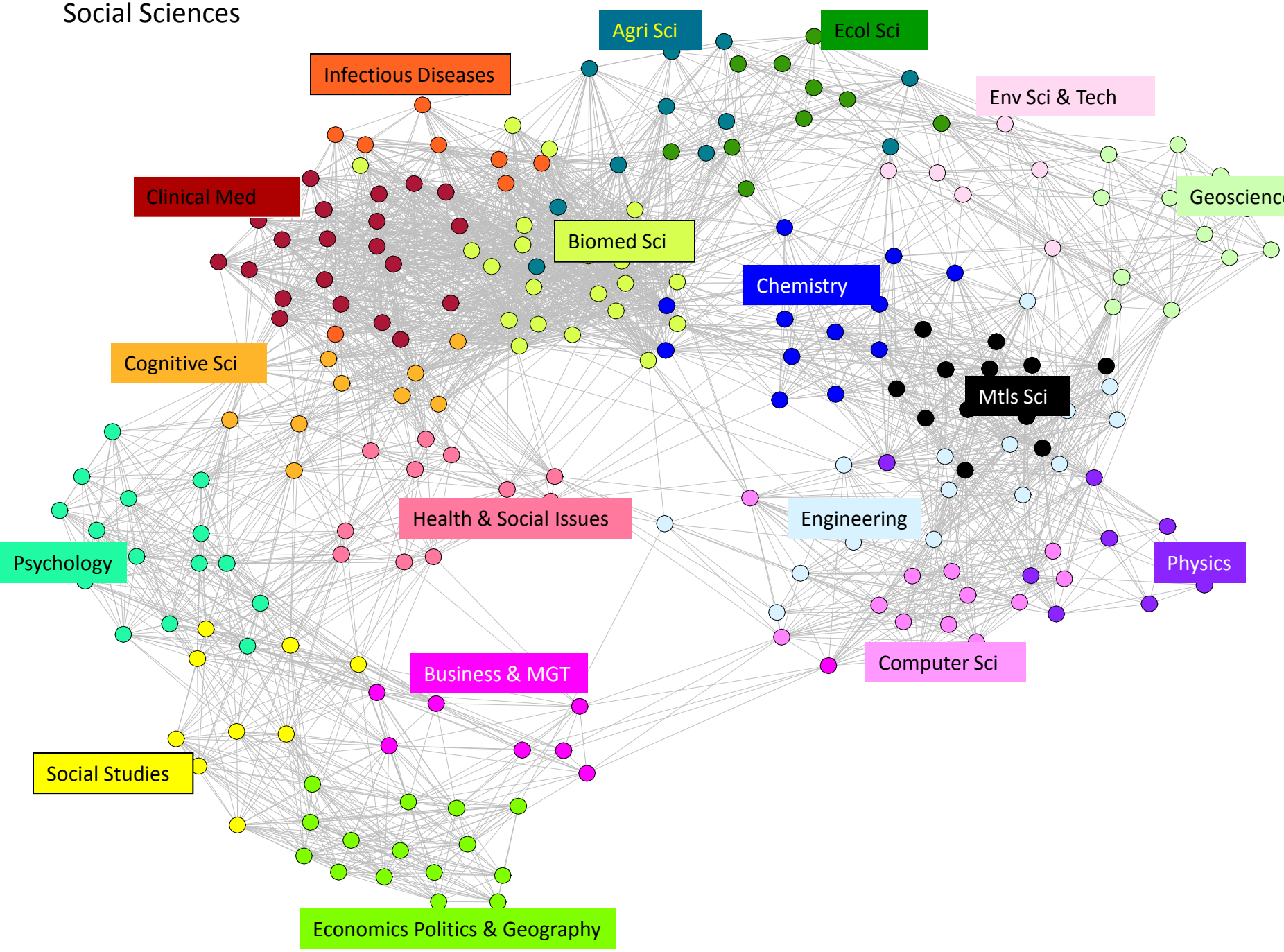

HSD vs Control
More Disciplinary
More Interdisciplinary
HSD
Control Groups
Specialization by Project
Integration by Project
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90

Dual, Complementary Mapping

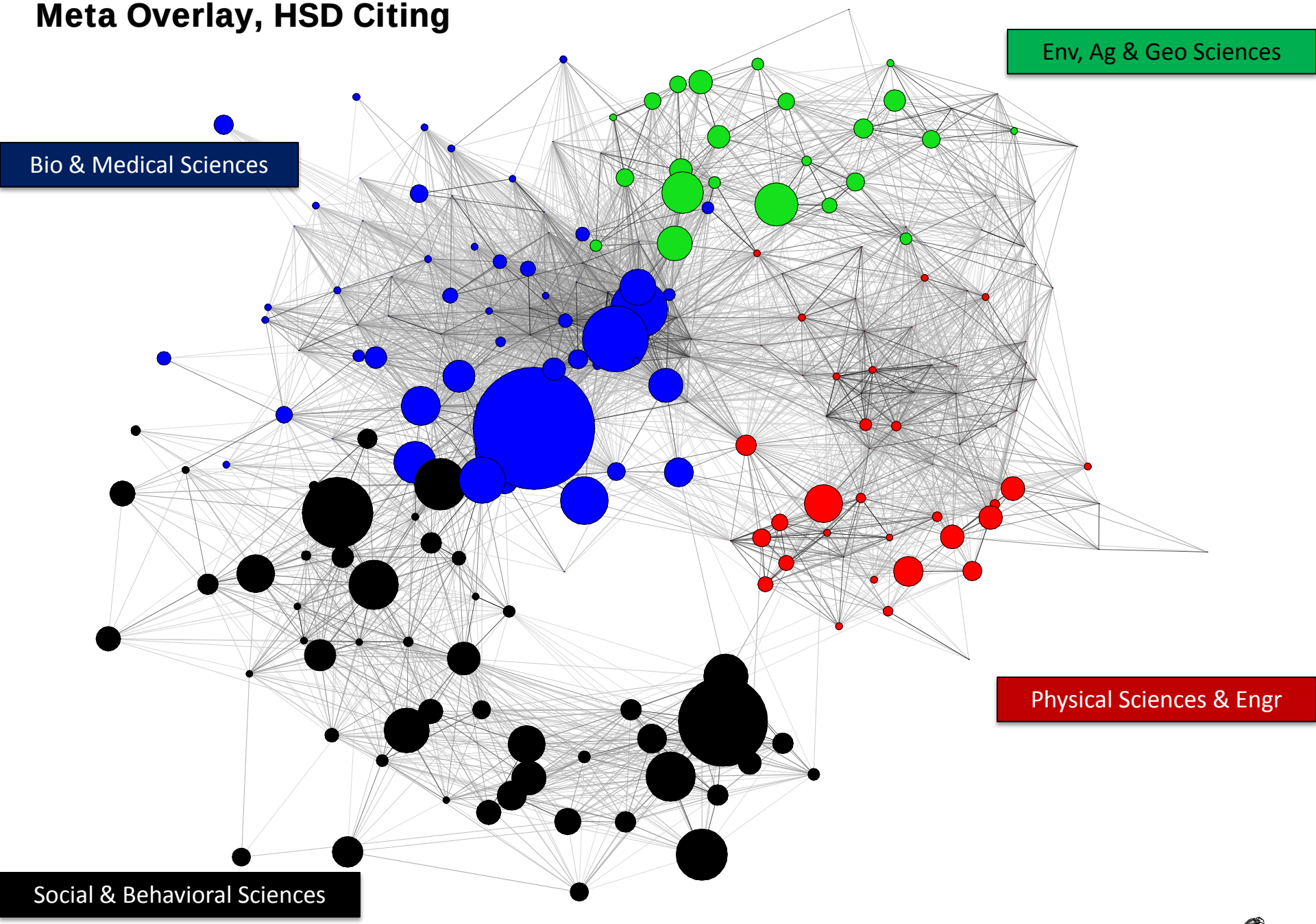
1) “Global” -- Science Overlay Maps: Show Diversity

2) “Local” – Research Network Maps: Show coherence

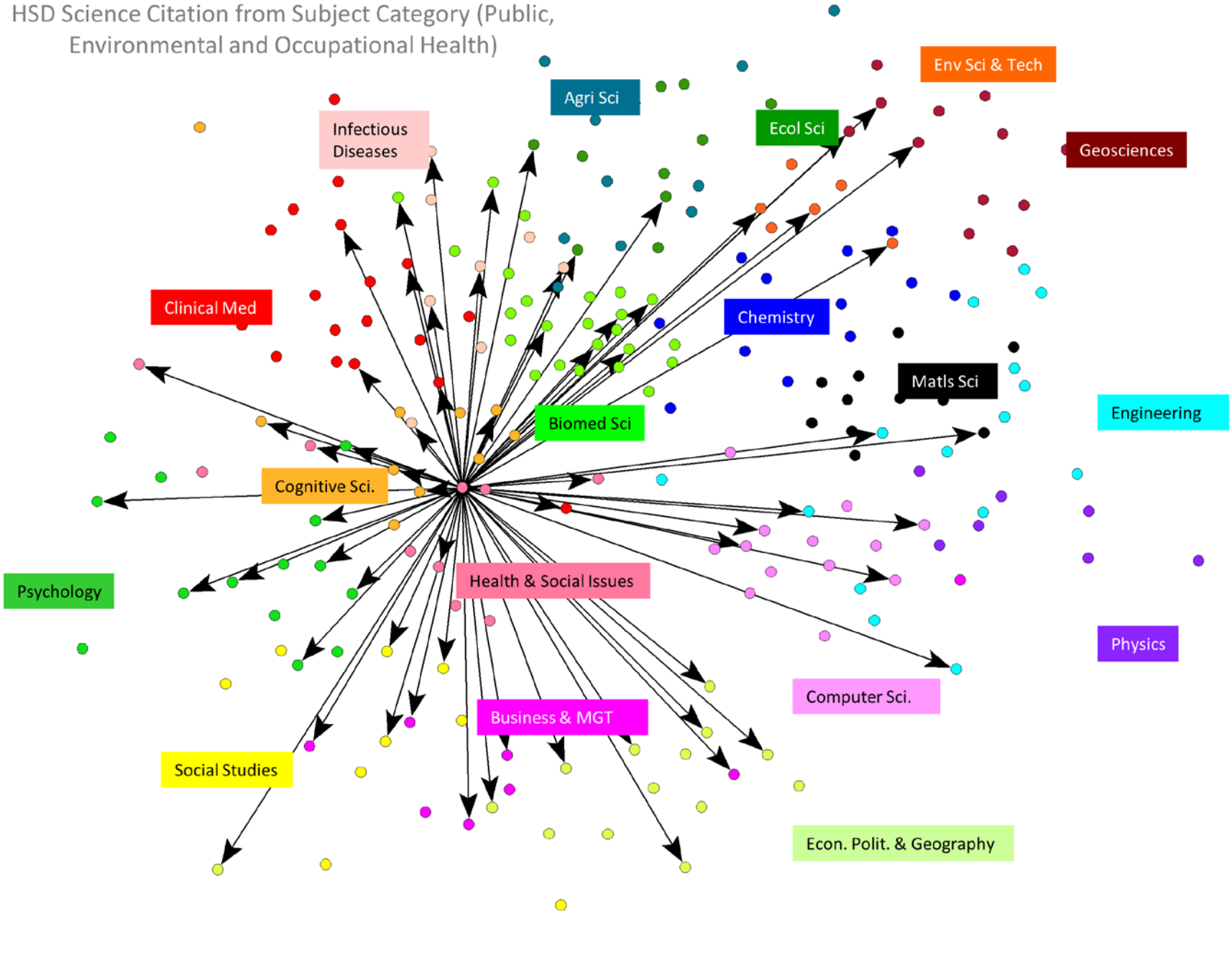
221 SC Base Map – Sciences + Social Sciences

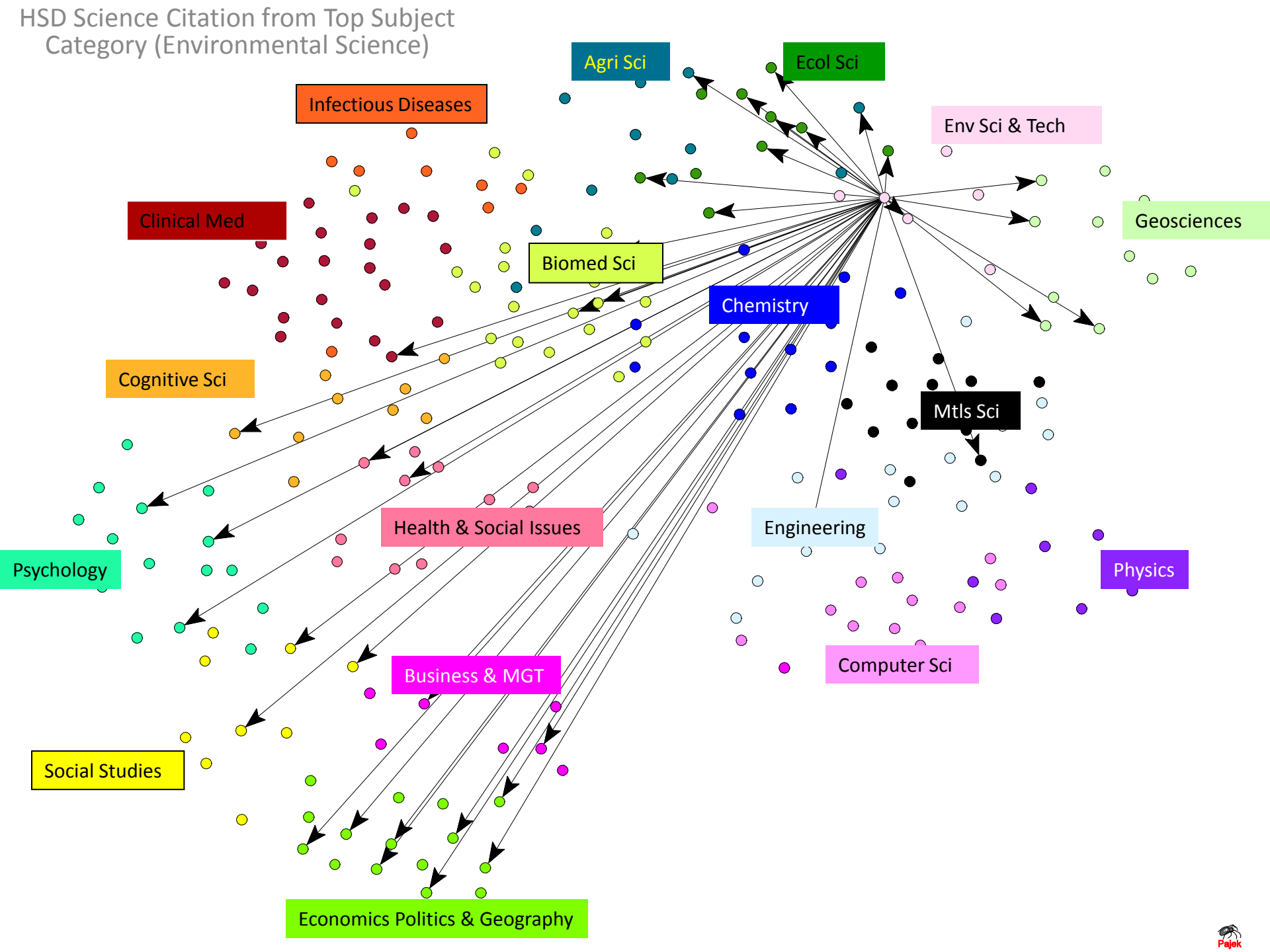


Meta Overlay, HSD Citing



Pajek


HSD Science Citation from Subject Category (Public, Environmental and Occupational Health)
Env Sci & Tech
Agri Sci
Infectious Diseases
Ecol Sci
Geosciences
Clinical Med
Chemistry
Matls Sci
Engineering
Biomed Sci
Cognitive Sci.
Psychology
Health & Social Issues
Physics
Computer Sci.
Business & MGT
Social Studies
Econ. Polit. & Geography
Pajek


HSD Science Citation from Top Subject Category (Environmental Science)
Agri Sci
Ecol Sci
Infectious Diseases
Env Sci & Tech
Clinical Med
Geosciences
Biomed Sci
Chemistry
Cognitive Sci
Mtls Sci
Health & Social Issues
Engineering
Psychology
Physics
Business & MGT
Computer Sci
Social Studies
Economics Politics & Geography
Pajek

[To identify research communities using a body of research knowledge]

68 Highly **Citing** Authors, based on shared NSF ROLE/REESE PIs & co-PIs being cited

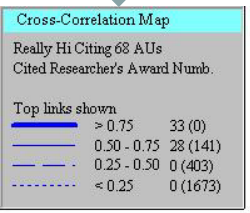
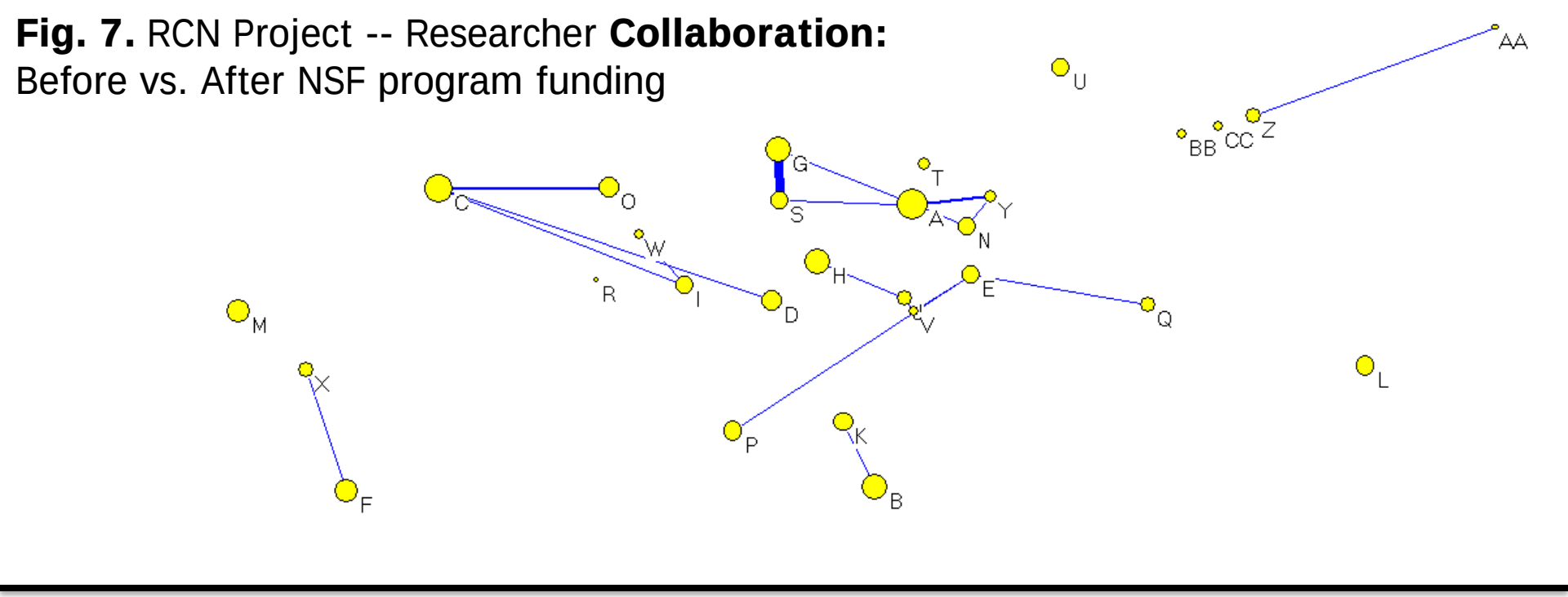
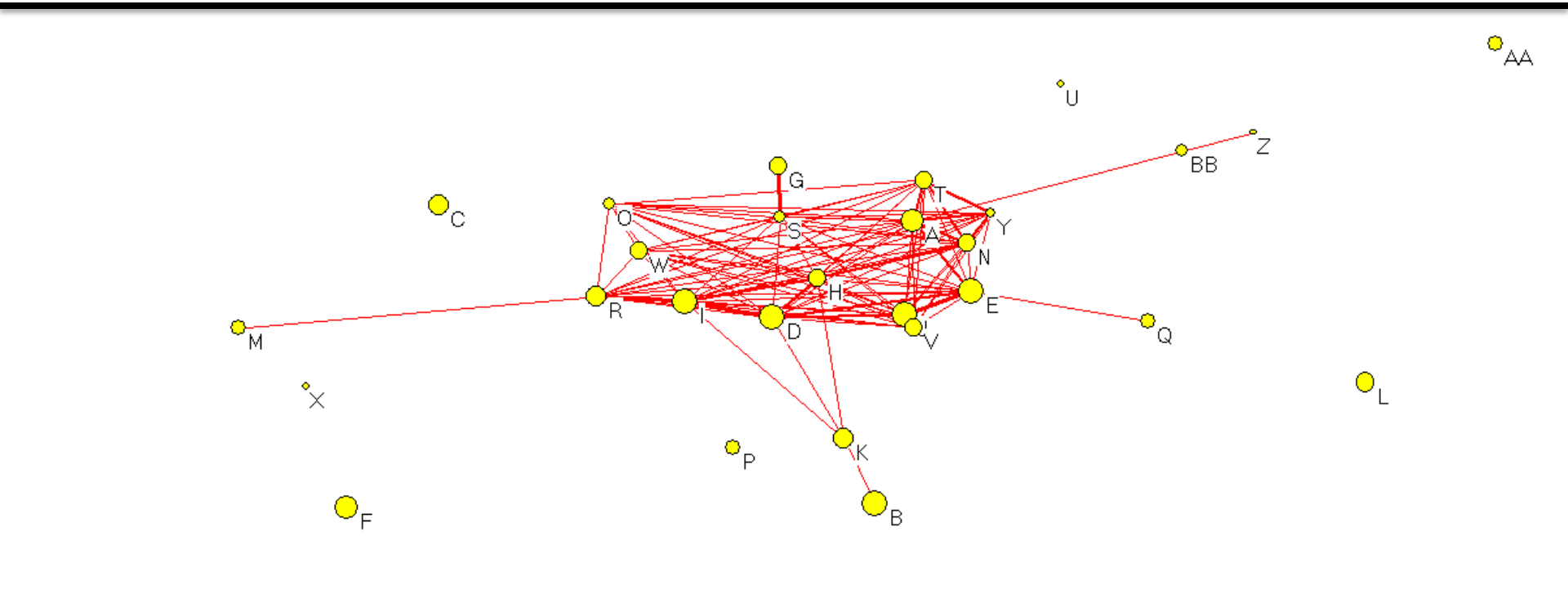
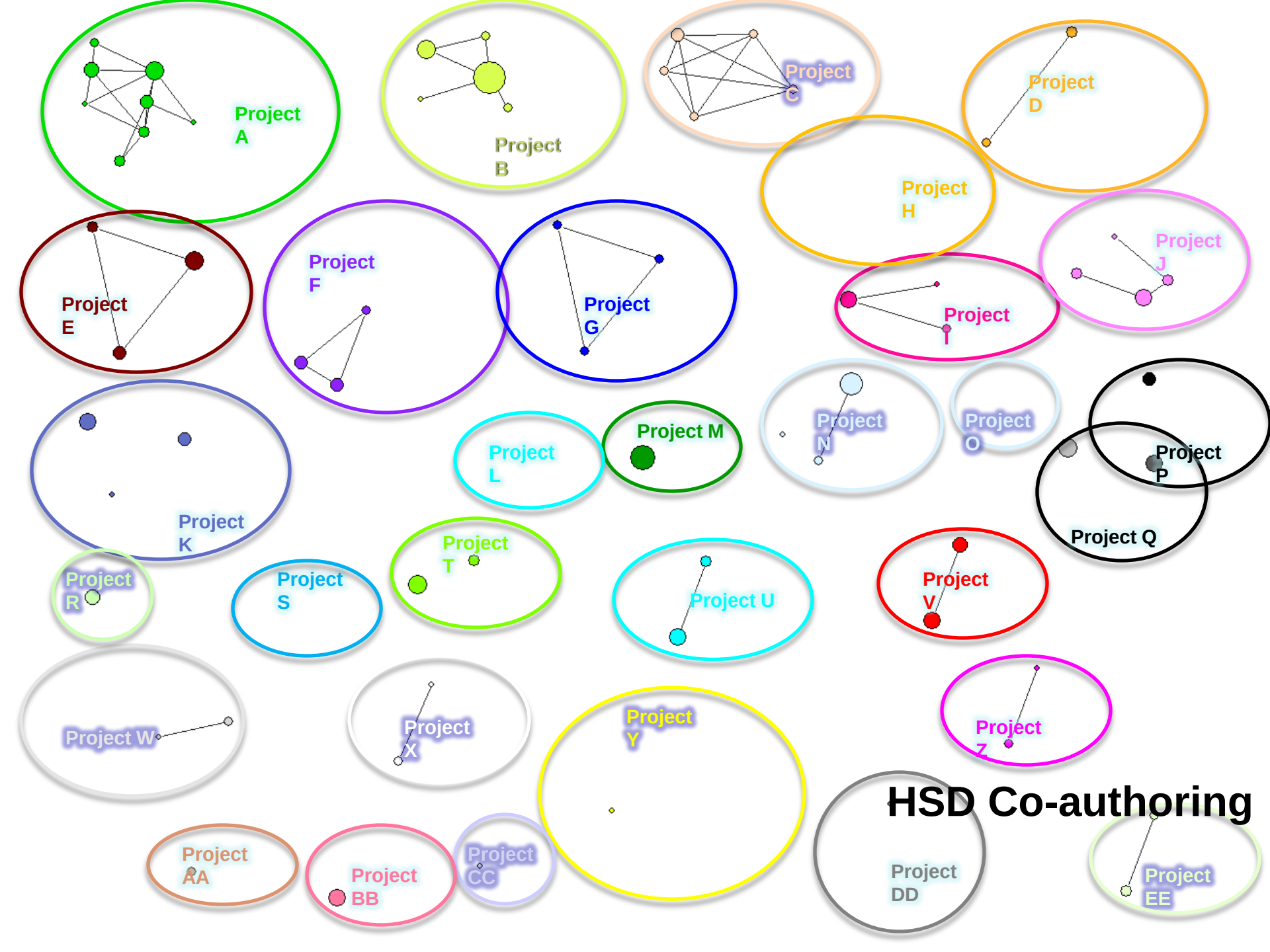


Fig. 7. RCN Project -- Researcher **Collaboration:** Before vs. After NSF program funding






Project A
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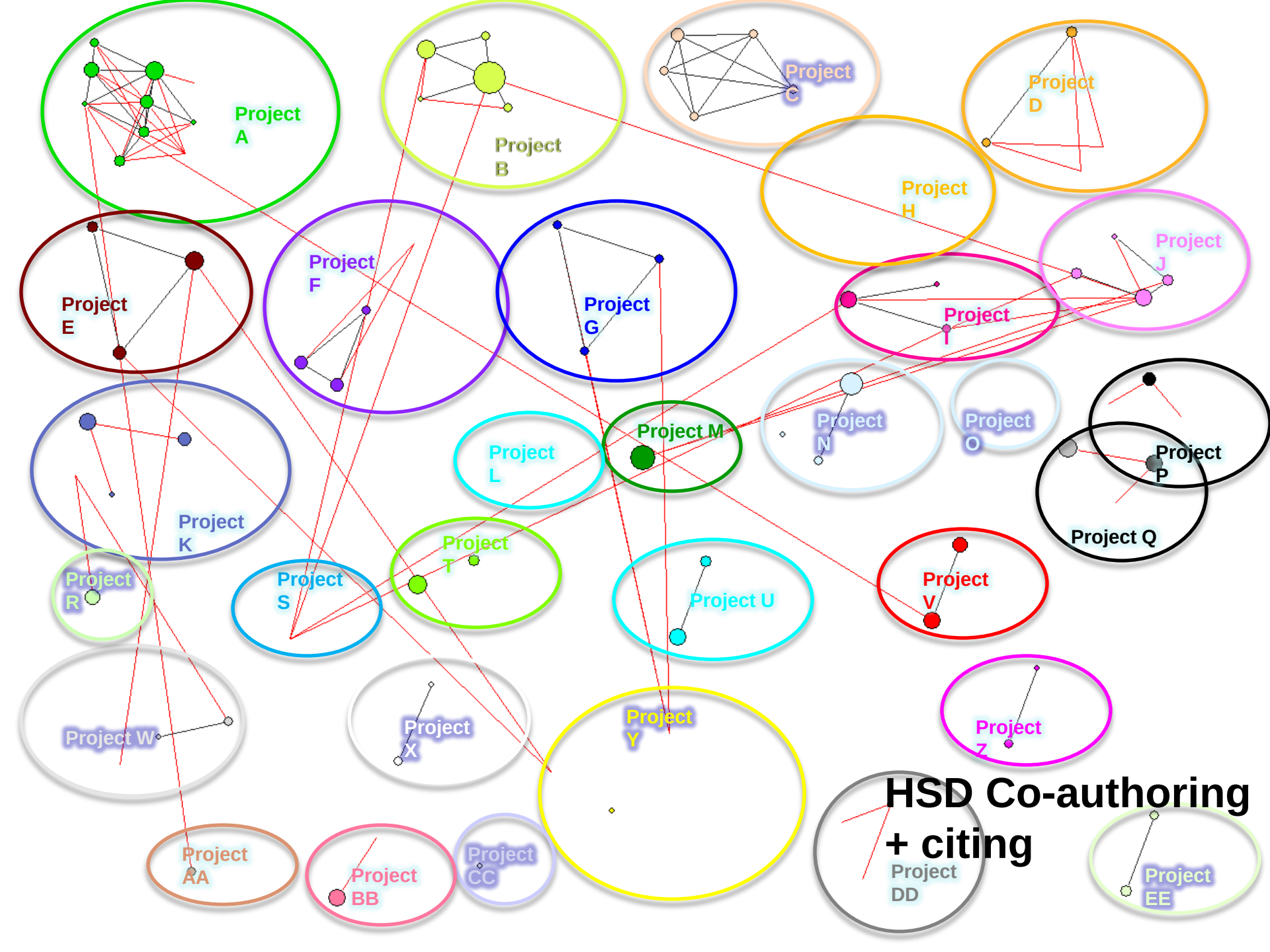
HSD Co-authoring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Project DD
Project EE
HSD Co-authoring
+ citing

Parsing out effects of Variety, Balance & Disparity on scientific impact (Yegros-Yegros et al.)

Articles and Proceedings of given WoS Subject Categories (2005)
(providing 5-year window for citations –data harvested in 2011)

Subject Categories	Pubs	Refs	Mean±SD	% Linked
Physics, Atom. Mol. Chem.	13,387	435,101	32.5±17.8	81.25%
Cell Biology	16,761	701,832	41.9±17.1	93.32%
Elect. &Electronic Eng.	22,223	447,660	20.1±12.1	55.23%
Food Science &Tech	10,037	284,069	28.3±14.3	74.41%
Total	62,408	1,868,662	29.9±17.5	78.51%

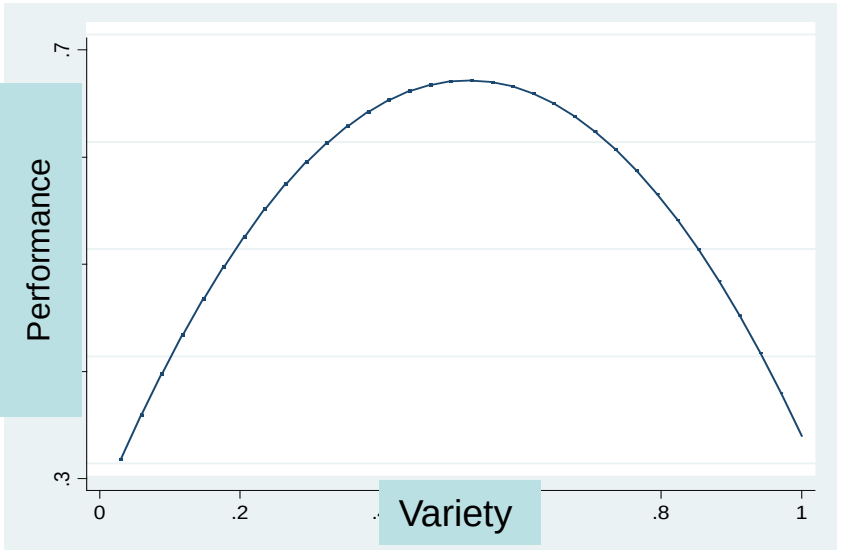
Summary

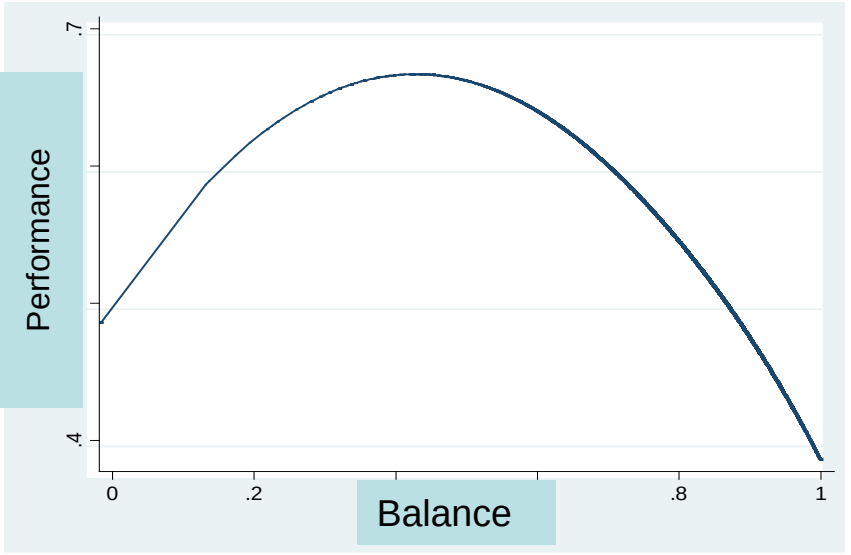
- Linear analysis: Variety favors scientific impact. Balance and cognitive distance have negative effects on *Log (Times Cited)*.
- Quadratic analysis: Performance shows an inverted U-shape dependence
    - *on Variety, Balance and Disparity*
    - with maximum at mid-level variety, low balance & low disparity (tentative)

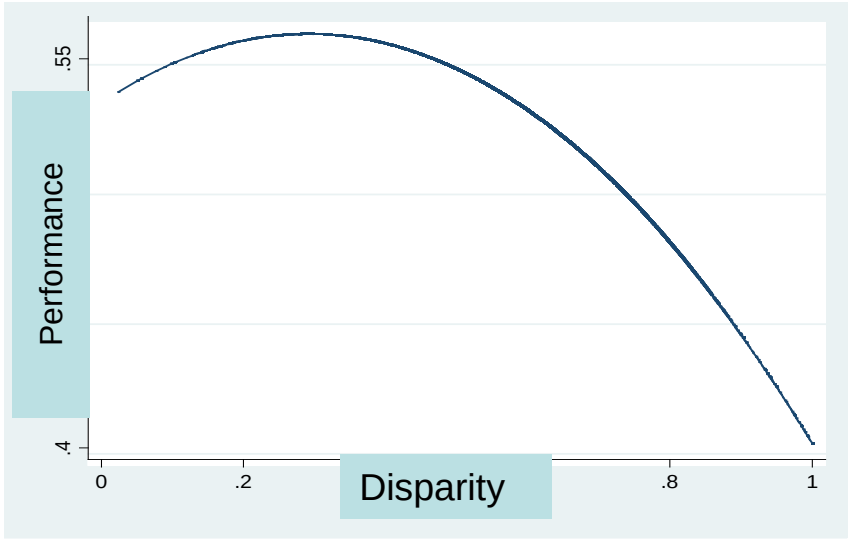
Limitations

- Use of problematic predefined categories (ISI SCI) over small number of references per paper
    - Measures very noisy. Other units of analysis (e.g. thematic clustering?)
- 22% of references not classified into Subject Categories.

Inverted U dependence of cites/paper on diversity







Inverted U dependence for

- Variety, Balance, Disparity

But

– max performance at **High Variety**

--max performance at **Low Balance**

--max performance at **Low Disparity**

(Relative to the distributions)

Research related to local topics vs.– non-local degree of interdisciplinarity – Chavarro et al.

- Sample of 14,000 publications from the Web of Science from authors affiliated to a **Colombian** institution since 1990.
- Logistic regression (4 models) of Integration score on

local topics or not, by discipline

Results: relationship between IDR and local focus

Approach	Interdisciplinarity Variable	Odds of local focus
Composite diversity measure	Integration Score	+1.7 times
Various aspects of diversity Positive relationship	Disparity	+3.0 times
	Balance	+2.9 times
Negative relationship	Variety	-0.087 times

Key finding:

- Research on local issues is more interdisciplinary than other kind of research
- Disparity and Balance increase local issues

Innovation Studies units vs. Business & Management schools – Rafols et al.

UK Innovation Studies (IS; broadly defined):

- Many IS Units embedded in Business & Management Schools (BMS)
- BMS have established criteria of excellence (ABS journal ranks)

Questions:

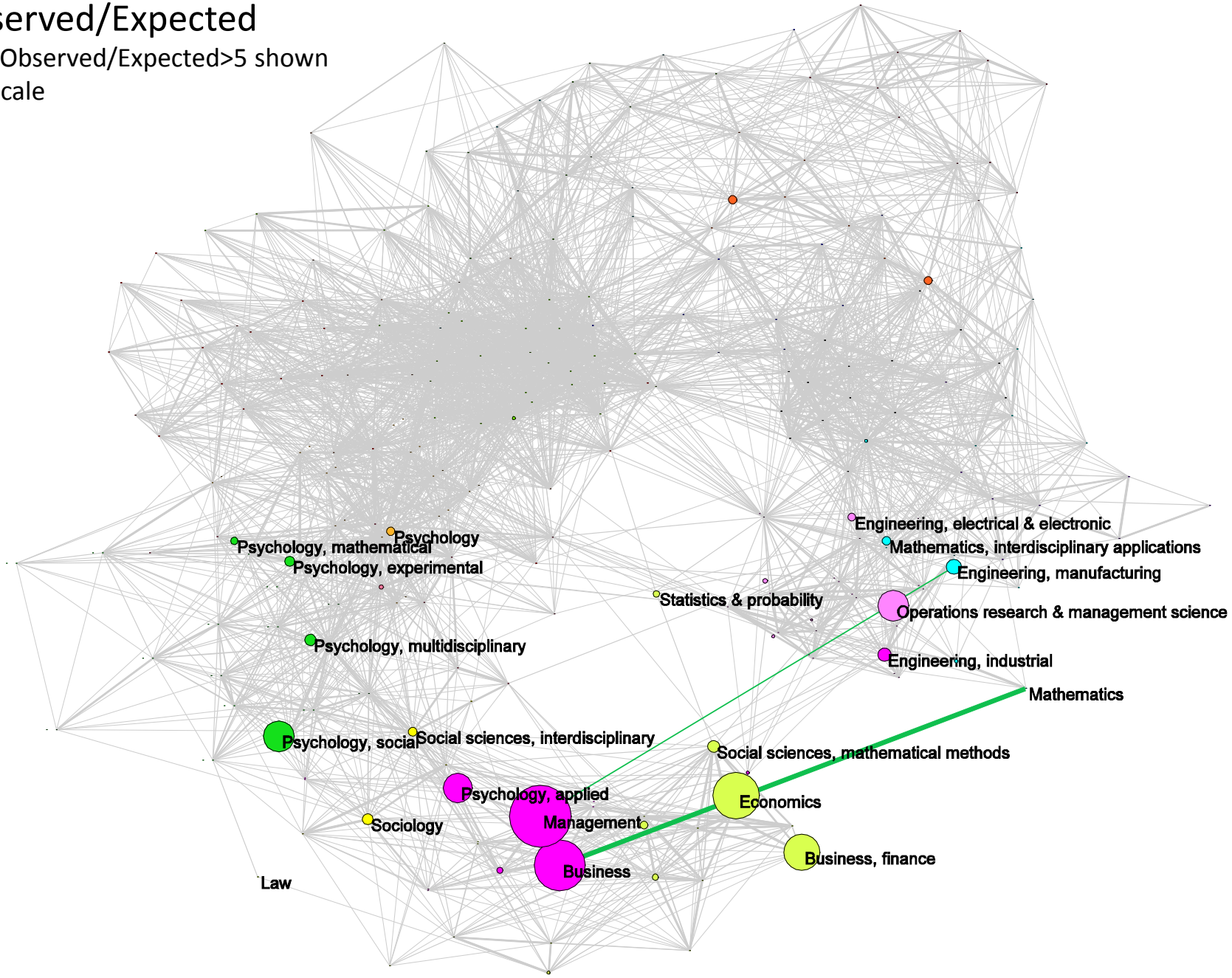
1. Are IS Units more interdisciplinary than BMS –as expected?
2. How does the research of IS vs BMS compare on conventional excellence measures?

Methods:

- Get publications from 3 BMS and 3 IS Units for 2006-2010.
- Compare degree of interdisciplinarity and excellence of publications using bibliometric analyses.

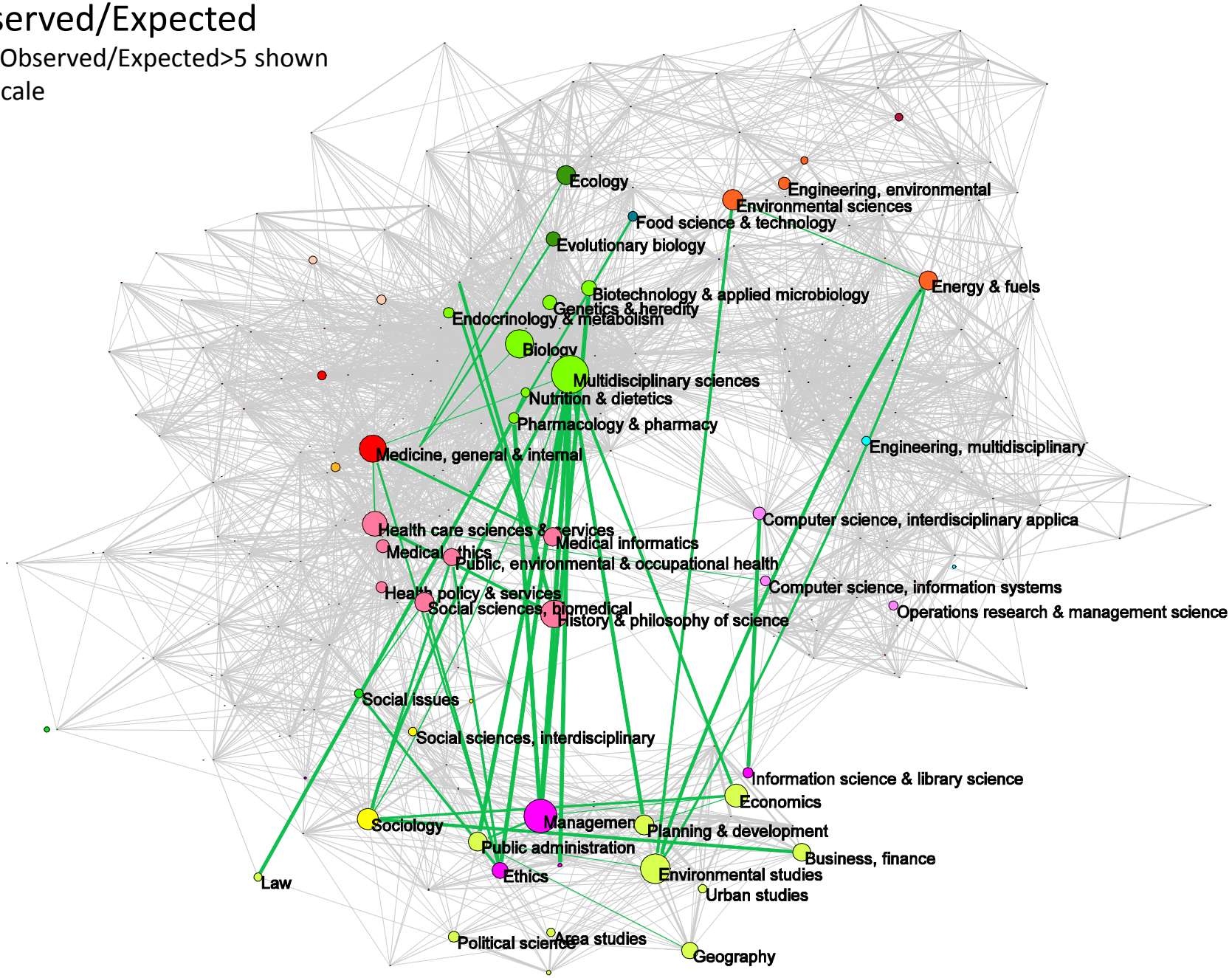
London Business School
Observed/Expected

Only Observed/Expected>5 shown
Log-scale



ISSTI Edinburgh
Observed/Expected

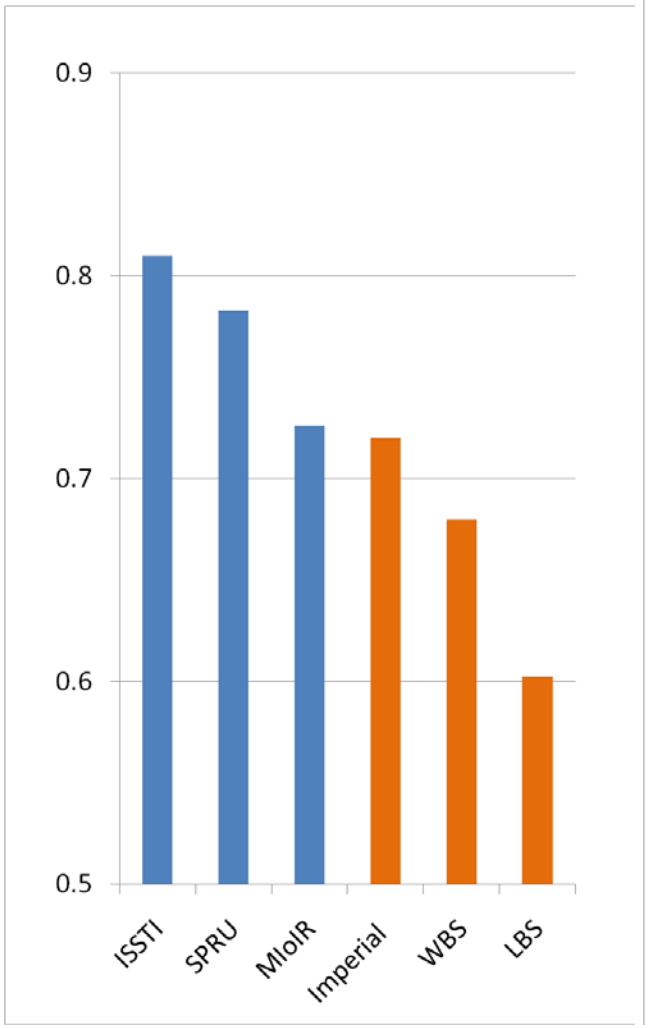
Only Observed/Expected>5 shown
Log-scale



Summary: IS units are more interdisciplinary than BMS

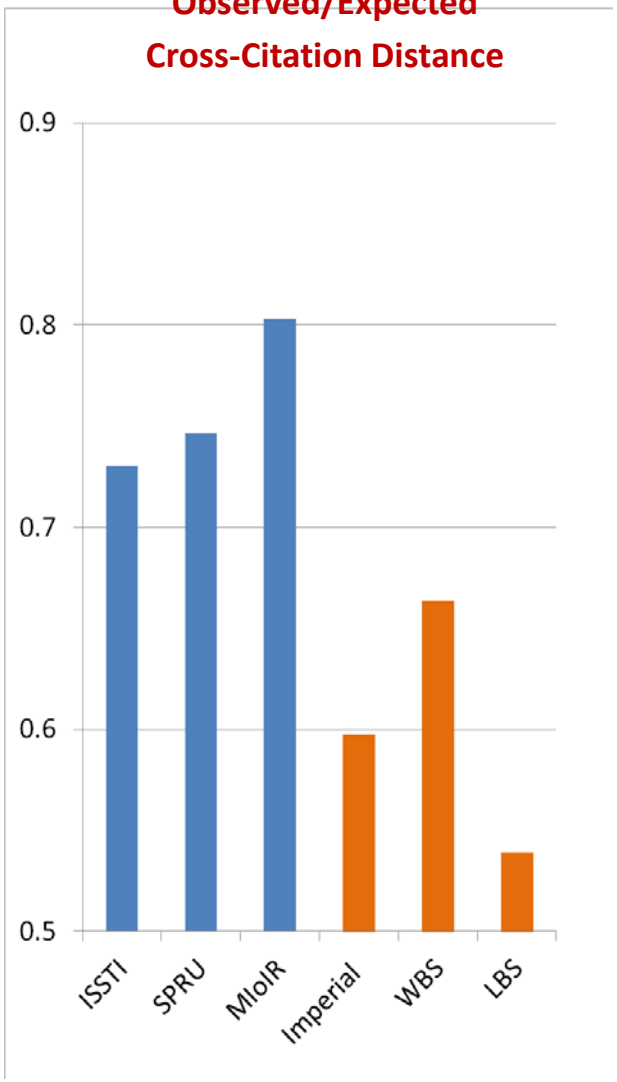
More Diverse

Rao-Stirling Diversity



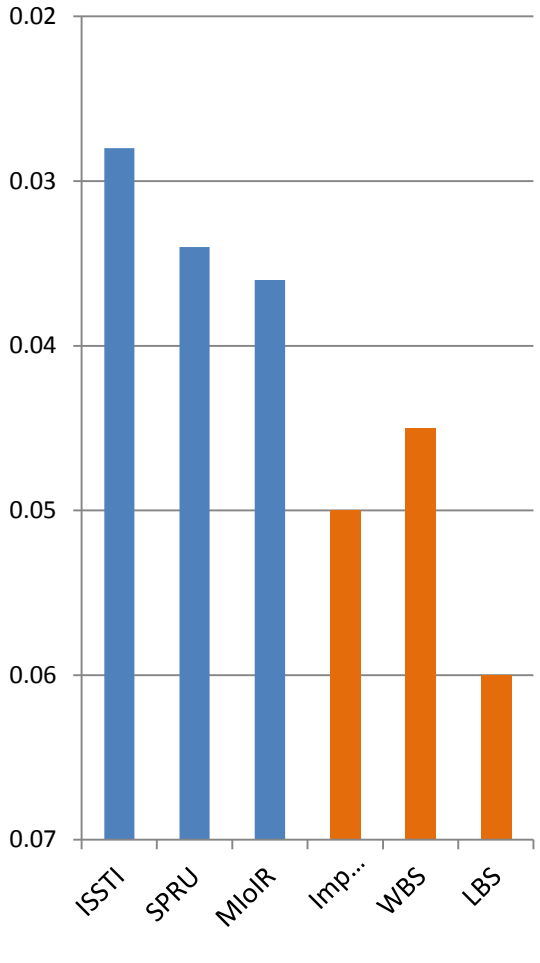
More Coherent

Observed/Expected Cross-Citation Distance

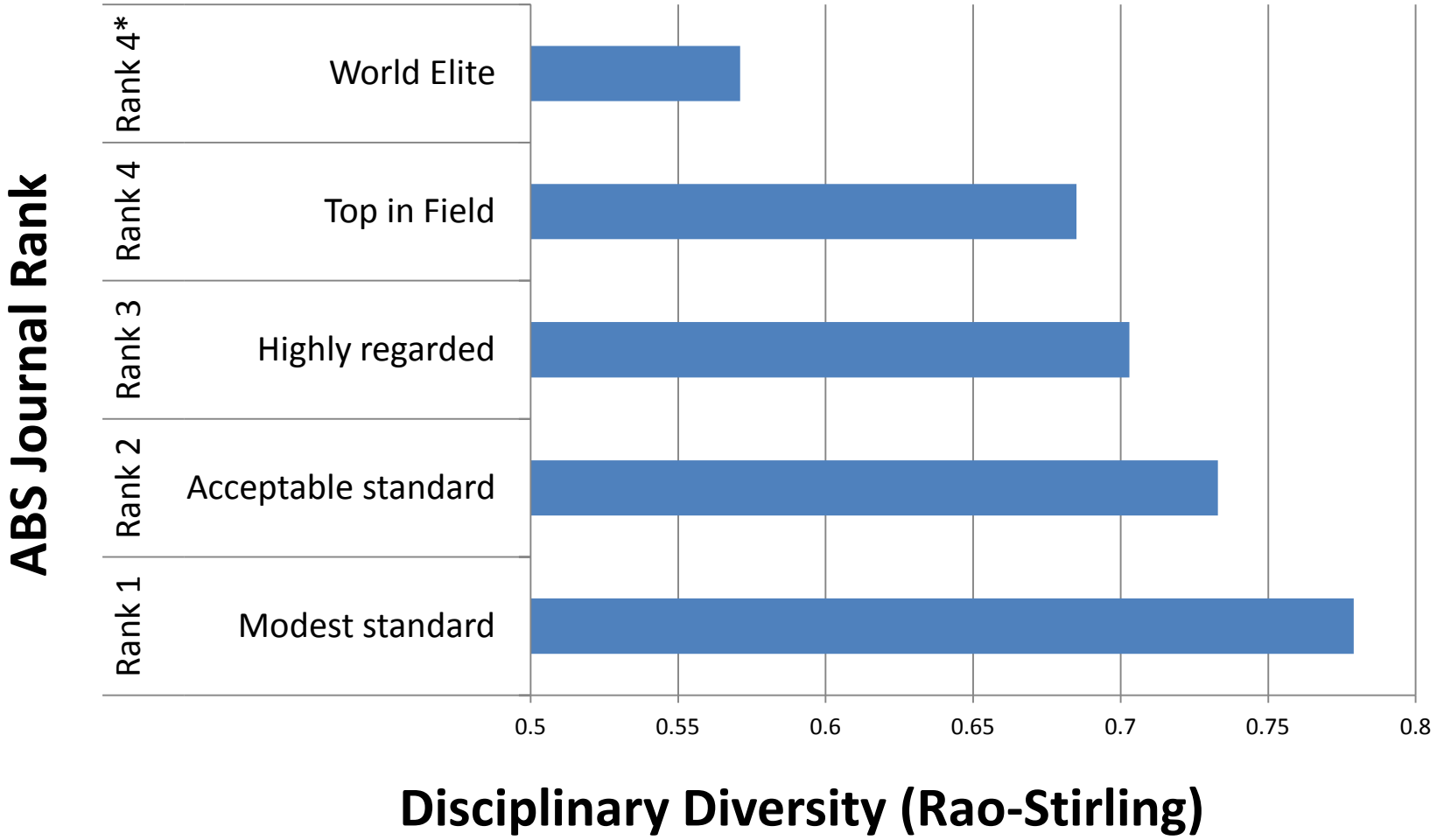


More Interstitial

Average Similarity



Disciplinary diversity of ABS Journal Ranks



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Interdisciplinarity Impacts

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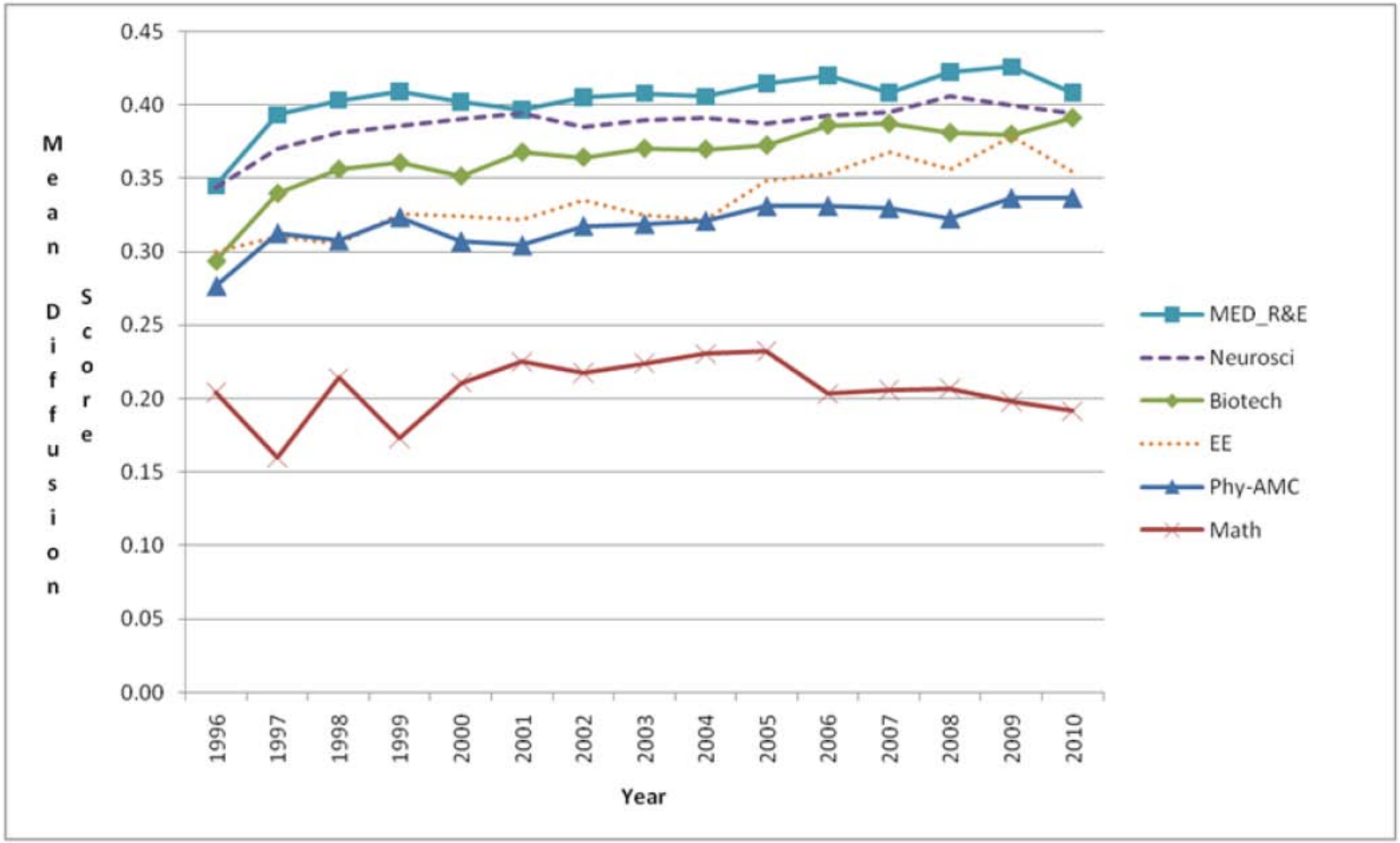
Resources

- **Science Overlay maps**: //www.leydesdorff.net/overlaytoolkit
- **Ongoing Research on Interdisciplinarity:** //idr.gatech.edu/test/ & www.interdisciplinaryscience.net
- Global Tech Mining Conference, in conjunction with the Atlanta Conference on Science & Innovation Policy, Sep. 24-28, 2013
- The text mining software used: www.theVantagePoint.com

Outtakes

Mean Annual Diffusion Scores for 6 Subject Categories



For most of the **1995 benchmarks,** Diffusion scores increase steadily with time. Mathematics is an outlier.

Quasi-Experimental Designs

- From publications
  - Mainly compare: Before vs. After
  - Special focus: Papers deriving from NSF support
- From citations
  - By researcher publications, or proposals
  - To researcher publications
- For Target & Comparison Group researchers
- Networks based on
  - Social links [e.g., co-authoring]
  - Intellectual links [e.g., cross-citing or bibliographic coupling on SCs, topics, or whatever]

Integration Score

$$I = 1 - \left[\frac{\left[\sum \left(f_i \times f_j \times COS\left(SC_i - SC_j \right) \right) \right]}{\sum \left(f_i \times f_j \right)} \right]$$

Porter et al. (2007)

where $i = row$; $j = column$; $f = frequency$

"cos (SCi – SCj)" measures the association between two SCs, based on a national co-citation sample from Web of Science. It reflects the relative tendency of two particular SCs to be co-cited.

****equivalently,**

$$I = 1 - \sum_{i,j} p_i p_j s_{ij}$$

Rafols and Meyer (2009)

where p_i is the proportion of references citing the SC i in a given paper. The summation is taken over the cells of the SC x SC matrix. s_{ij} is the cosine measure of similarity between SCs i and j

[This measure is basically 1 – Stirling D.]

Multiple Mapping Approaches

- Science overlay mapping
  - Working on patent overlay maps
  - Working on biomedical overlay maps (MEDLINE)
- Geo-maps
- Research Network Mapping [Social Network Analyses]
  - Co-authoring; co-citation; co-term; etc.
  - Bibliographic coupling

Science Overlay Mapping

- Rafols & Leydesdorff (with Meyer, Porter)
- Based on Web of Science (WoS)
  - Subject Categories (SCs; recast as Web of Science Categories – WCs – with WoS v. 5, late 2011)
  - Can do for Science (Science Citation Index) ~175 SCs, or
  - Science + Social Science (include Social Science Citation Index) ~224 SCs
- Base map
  - Nodes (SCs) and background links -- derive from an SC-by-SC cosine similarity matrix from a year of journal cross-citation data (recently, 2010)
  - Labels reflect groupings of SCs
- Overlays – a given body of research activity (e.g., a set of publications indexed in WoS)

Macro- and Meta-Disciplines

1. SC relatedness based on one year's data – WOS Journal X Journal **cross-citation** matrix
2. Loet Leydesdorff transforms to SC X SC matrix
   - Devise our interdisciplinarity metrics based on these
3. **Macro-Disciplines** come from Ismael Rafols' factor analyses:
   - 175 SC science base map (14 factors)
   - **224 SC science + social science base map (19 factors = Macro-Disciplines)**
4. **Meta-Disciplines** – we can further group to 4 or 6 overarching categories

Co-citation Map of the most cited authors by the 307 **nano social science** papers [Use Auto-corr on hi cited Authors]

Web of Science ("WOS")

- Indexes publications from ~12,000 leading journals
- Recently >1.5 million papers per year
- Includes several databases
  - **Science Citation Index Expanded (SCI)**
  - **Social Sciences Citation Index (SSCI)**
  - Arts & Humanities Citation Index (A&HCI)
  - Conference Proceedings
- Provides field-structured abstract records
  - Classify journals into **Subject Categories ("SCs") –** presently, 224 for SCI + SSCI
  - Provide Cited References for each paper – we apply thesauri to associate to **Cited SCs**
  - Separately search for Citing records for each paper to discern **Citing SCs**

Sample WOS Abstract Record (excerpted)

AU Oliver-Hoyo, M
Gerber, RW
TI From the research bench to the teaching laboratory: Gold nanoparticle layering
SO JOURNAL OF CHEMICAL EDUCATION
DT Article
C1 N Carolina State Univ, Dept Chem, Raleigh, NC 27695 USA.
AB ...
CR BENTLEY AK, 2005, J CHEM EDUC, V82, P765
BOLSTAD DB, 2002, J CHEM EDUC, V79, P1101
HALE PS, 2005, J CHEM EDUC, V82, P775, ...
NR 16
TC 1
PY 2007
VL 84
IS 7
BP 1174
EP 1176
SC Chemistry, Multidisciplinary; Education, Scientific Disciplines

Use thesauri to associate "J Chem Educ" with its SCs

HSD vs Citing SC changes