Leveraging HERD Data to Understand Institutions' Competitive Edge, Growth Potential, and Strategic Collaborations

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Content

About The Data

Data Source: The Higher Education Research Data (HERD) Survey, conducted by the National Center for Science and Engineering Statistics (NCSES)

The survey Includes RD expenditure for ten broad scientific fields that delve into 43 sub-detailed research fields within these categories by year.

It covers 1139 Public and Private Higher Education institutions in the United States from 1973 to 2022.

Dollar amounts are in Thousands $

Accurate data, Updated regularly and widely accessible (Public)

Research & Development Expenditure

Dollars Higher Education Institutes secure from federal and non-federal sources that are used to advance research at the institutions.

Priorities

What areas an institution considers important for investment and growth. It can indicate the institution's strategic direction and its commitment to innovation.

Capabilities

Shed light on an institution's research capabilities and expertise. It can show the institution's ability to conduct cutting-edge research and develop new products or services.

Competitiveness

An indicator of an institution's competitiveness by specific research fields.

Opportunities

Identify areas for growth and possible collaborations and institutional partnerships

Economic Impact

This leads to developing new products or services that can be commercialized, generating revenue and creating jobs. Additionally, R&D expenditure can help institutions to improve their efficiency and productivity.

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Key Terms

- REVEALED COMPARATIVE ADVANTAGE
- RELATEDNESS (PROXIMITY)
- RELATEDNESS DENSITY
- INSTITUTION COMPLEXITY INDEX
- FIELD COMPLEXITY INDEX

Revealed Comparative Advantage

- To determine if an institution specializes in a scientific field, the scale of research it conducts in that field should have a high Revealed Comparative Advantage (RCA) compared to other fields within and nationwide.

- **Scientific Field Revealed Comparative Advantage:**

$$RCA_{if} = \frac{\dfrac{E_{fi}}{\sum E_{Fi}}}{\dfrac{\sum E_{fN}}{\sum E_{FN}}} >= 1$$

E_{fi} : *The RD Expenditure of a scientific field **f** from an institution **i***

$\sum E_{Fi}$: *Total RD Expenditure of all scientific fields **F** from the institution **i***

$\sum E_{fN}$: *The RD Expenditure of a scientific field **f** from all institutions in the Nation **N***

$\sum E_{FN}$: *Total export value of all scientific fields **F** from all institutions in the Nation **N***

[1] Balassa, B.: Trade liberalization and “revealed” comparative advantage 1. The manchester school 33(2), 99–123 (1965)

Specialization Matrix

Institution Name	**Scientific Field 1**	**Scientific Field 2**	**Scientific Field 3**	**Scientific Field ….**
Institution A	1	1	0	
Institution B	0	1	1	
Institution C	1	0	1	
Institution D	0	0	0	
Institution …				

Proximity Matrix

Based on the probability that Institution ***i*** spends on scientific field ***f1*** competitively given it spends on scientific field ***f2*** competitively and vise versa

$$\rho_{i,j,t} = min\{P(x_{i,t}|x_{j,t}), P(x_{j,t}|x_{i,t})\} \quad (2)$$

$$X_{i,c,t} = \begin{Bmatrix} 1 \; if \; RCA_{i,c,t} >= 1 \\ 0 \quad Otherwise \end{Bmatrix} \quad (3)$$

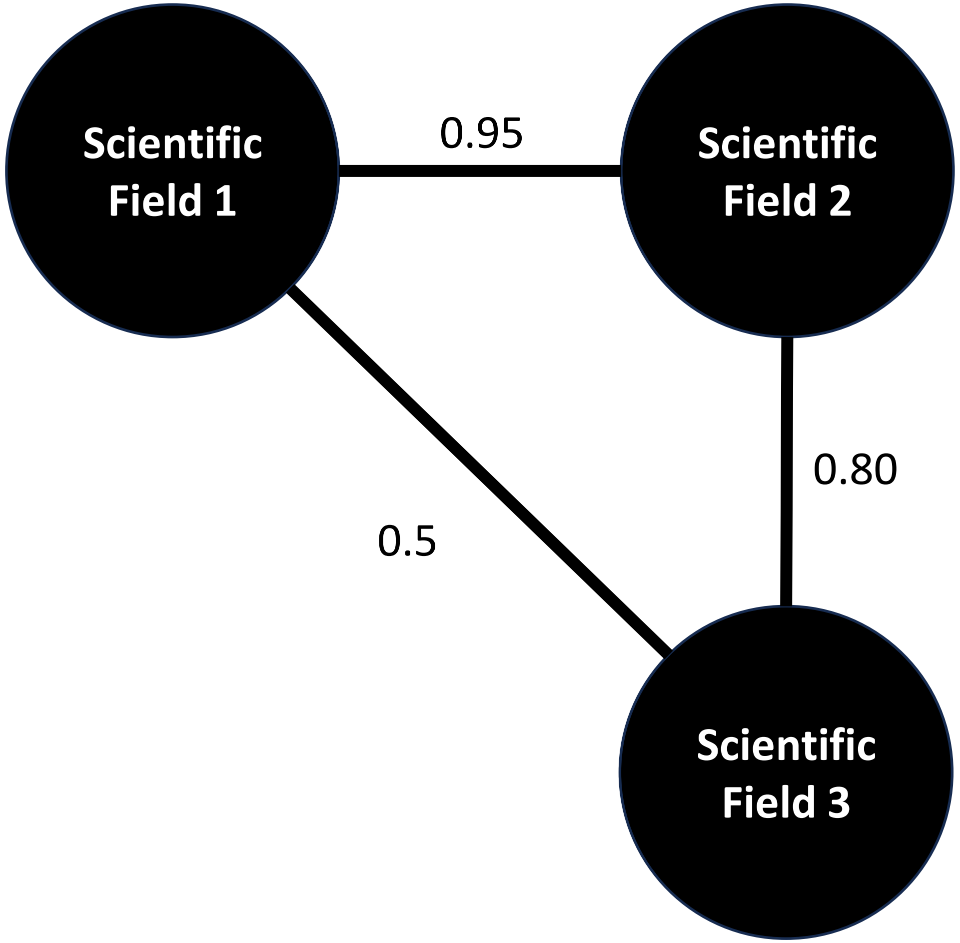
(Distance between products) is calculated by finding the minimum pairwise ρ of the pairs of the conditional probability from E.q.(2).

Proximity Matrix - Specialization Matrix

Institution Name	Scientific Field 1	Scientific Field 2	Scientific Field 3	Scientific Field ….
Institution A	1	1	0	
Institution B	0	1	1	
Institution C	1	1	1	
Institution D	0	1	0	
Institution …				

Proximity Matrix >>> Network

	Scientific Field 1	Scientific Field 2	Scientific Field 3
Scientific Field 1		0.95	0.5
Scientific Field 2	0.95		0.80
Scientific Field 3	0.5	0.80	



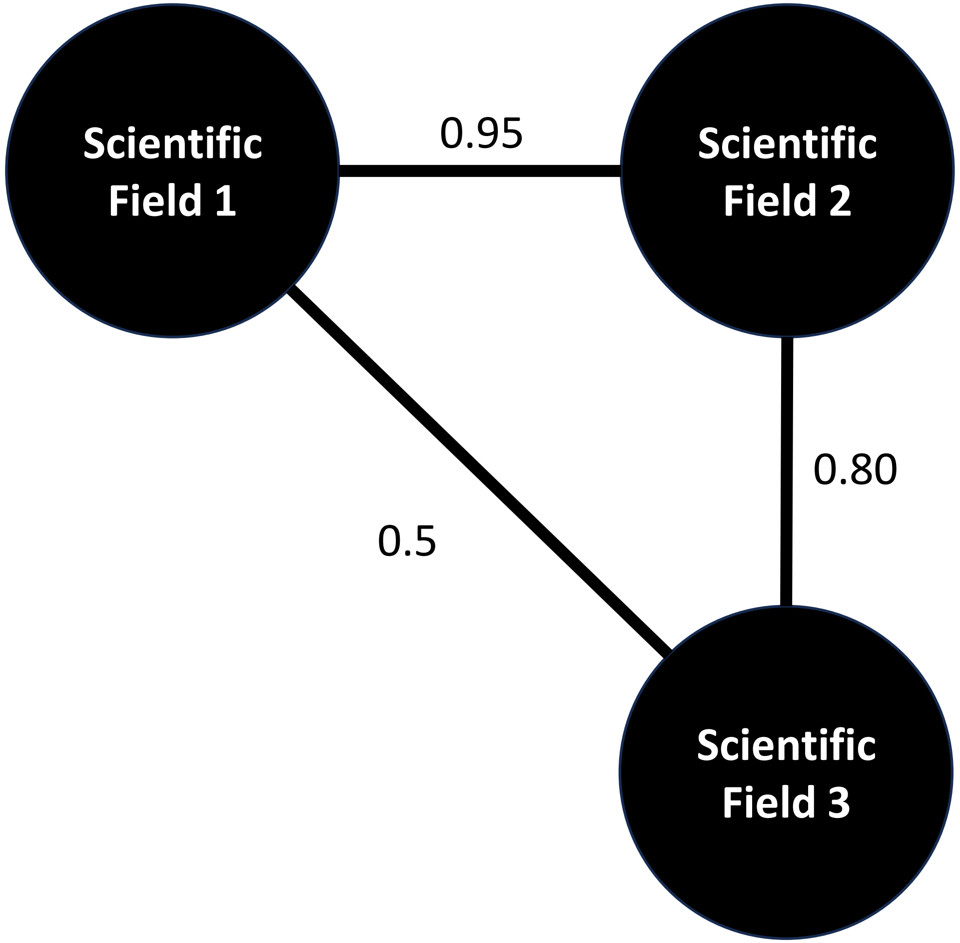
Relatedness Density – A Measure of Growth Potential

- The ratio between

the sum of relatedness a field has with all other fields in an institution with RCA>=1

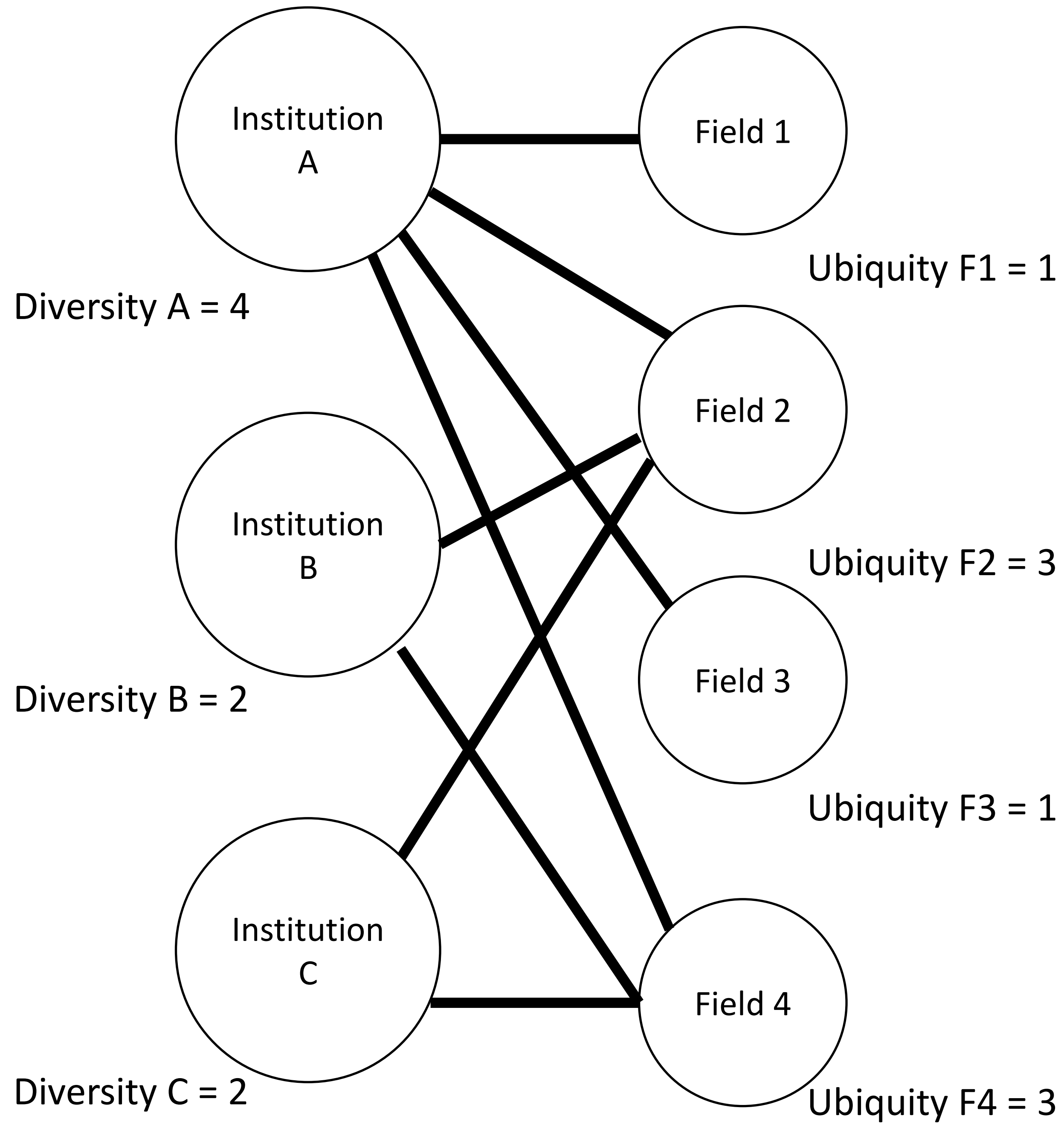
and

the sum of relatedness that a field has with all other fields in all institutions with RCA>=1



Diversity: Number of fields spends competitively on (RCA>=1).

A higher diversity indicates a more diversified research portfolio.



Ubiquity: Number of institution that spends on the field competitively (RCA>=1).

A higher ubiquity indicates that the research is commonly found in many different institutions.

Hausmann, R., Hidalgo, C. A., Bustos, S., Co
Simoes, A. (2014). *The atlas of economic com*
Mapping paths to prosperity. Mit Press.

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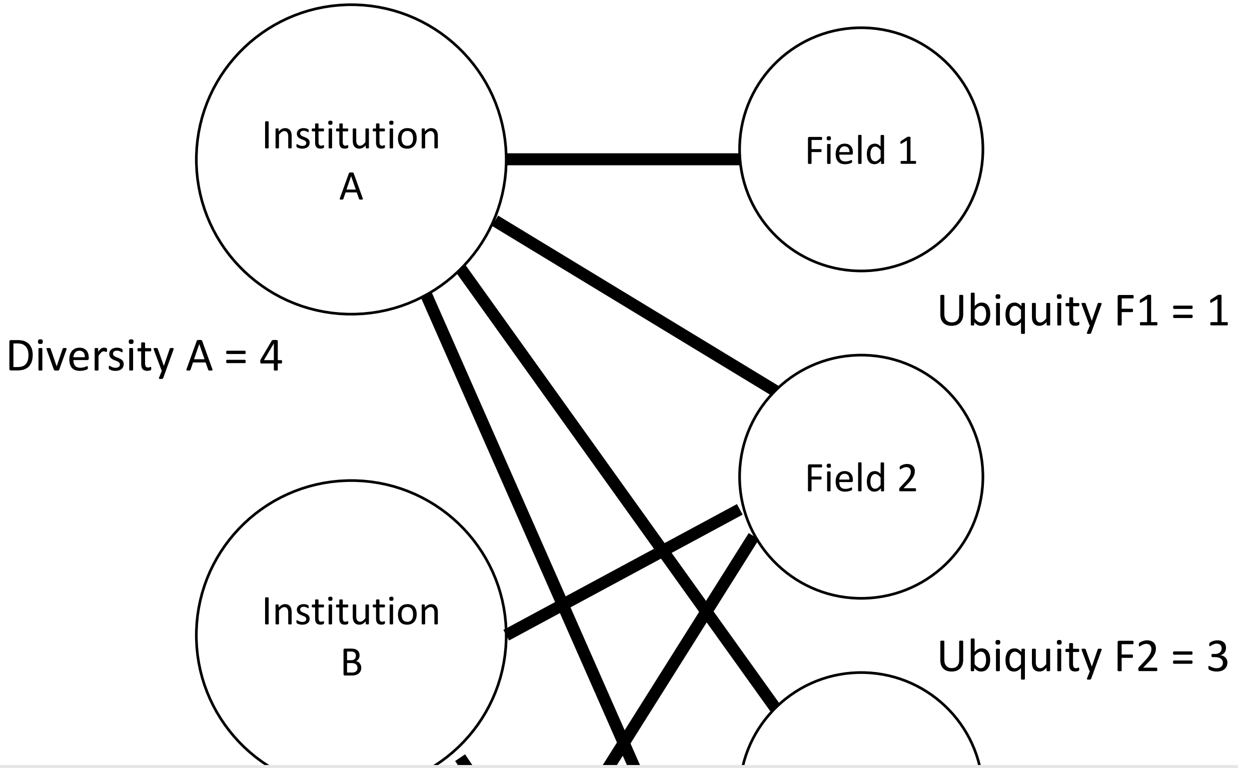


Ubiquity: Number of institution that spends on the field competitively (RCA>=1).

A field with higher ubiquity indicates that the research is commonly found in many different institutions.

Based on Diversity and Ubiquity >>>>>>>>> **Field Complexity Index**

- Measures the complexity of a product based on the knowledge and skills required to produce it and how unique is that fields among institutions.
- Calculated by considering the following factors:
  - Diversity of Institutions that spend competitively on the field.
  - The ubiquity of the product (how many Institutions have it).

A higher FCI indicates that the field requires more specialized knowledge and skills to produce

Institution Complexity Index (CI)

- Measures an institution's research complexity based on the diversity and sophistication of its research activity.

- Higher ECI indicates that an institution conducts a wider range of complex research, which is associated with higher levels of economic development.

Calculation of ECI:

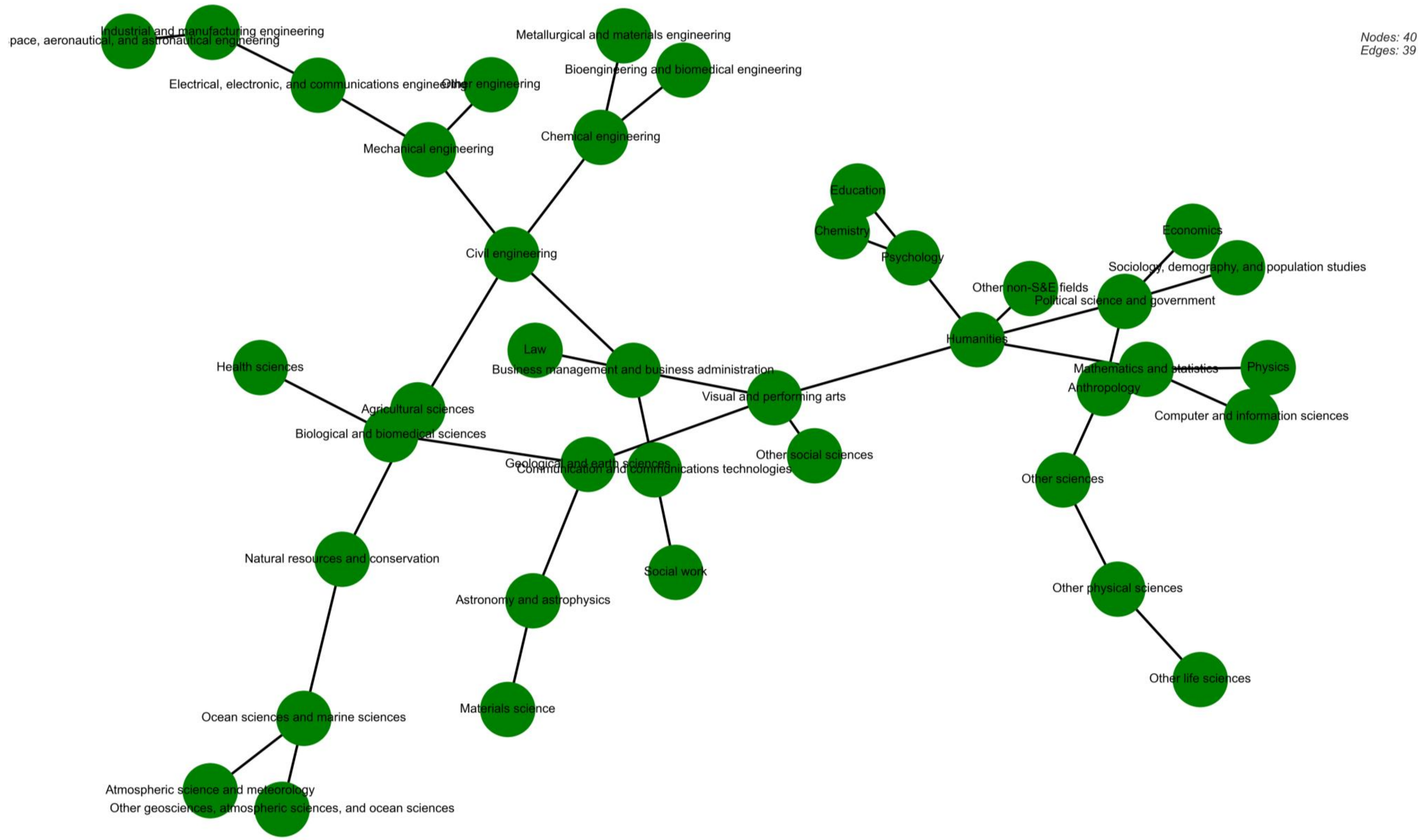
- Diversity: Calculated by measuring the number of different products a country exports. (A country with a higher diversity of exports has a higher ECI.)
- Ubiquity: Calculated by measuring the number of countries that export a particular product. (A product that is exported by many countries has higher ubiquity but lower complexity)

- A country that exports products with higher ubiquity has a higher ECI.

Complexity:

- Obtaining the diversity and Ubiquity of the research fields with high revealed comparative advantage.
- Consider the **FCI of the products a country exports**.
- A country that exports products with a higher FCI has a higher ECI.

Scientific Fields Network - 2022



Fields Breakdown: 2022

Fields Complexity Index: 2022

Aerospace, aeronautical and, astronautical engineering are the fields with the highest complexity, while health sciences the fields with the lowest complexity Index.

- A fields with high complexity index refer to a fields that needs a large amount of knowledge, capabilities, and advanced technology to produce.
- Fields with high complexity indexes are associated with higher levels of economic development and income and are often produced by institutions with diverse capabilities.
- Fields with Low complexity indexes are fields that require specialized knowledge and expertise that doesn't need to be diverse.

Detailed_Field	
Aerospace, aeronautical, and astronautical engineering	0.99
Industrial and manufacturing engineering	0.85
Electrical, electronic, and communications engineering	0.85
Mechanical engineering	0.81
Other engineering	0.73
Civil engineering	0.69
Chemical engineering	0.66
Metallurgical and materials engineering	0.62
Atmospheric science and meteorology	0.58
Agricultural sciences	0.58
Mathematics and statistics	0.55
Computer and information sciences	0.54
Economics	0.53
Natural resources and conservation	0.52
Visual and performing arts	0.52
Physics	0.52
Political science and government	0.50
Ocean sciences and marine sciences	0.49
Geological and earth sciences	0.48
Humanities	0.48
Other physical sciences	0.46
Communication and communications technologies	0.46
Business management and business administration	0.45
Other sciences	0.45
Other social sciences	0.44
Anthropology	0.42
Other non-S&E fields	0.42
Astronomy and astrophysics	0.41
Education	0.39
Materials science	0.39
Chemistry	0.37
Other geosciences, atmospheric sciences, and ocean sciences	0.37
Sociology, demography, and population studies	0.37
Bioengineering and biomedical engineering	0.34
Law	0.26
Psychology	0.25
Social work	0.20
Other life sciences	-1.23
Biological and biomedical sciences	-1.64
Health sciences	-4.52

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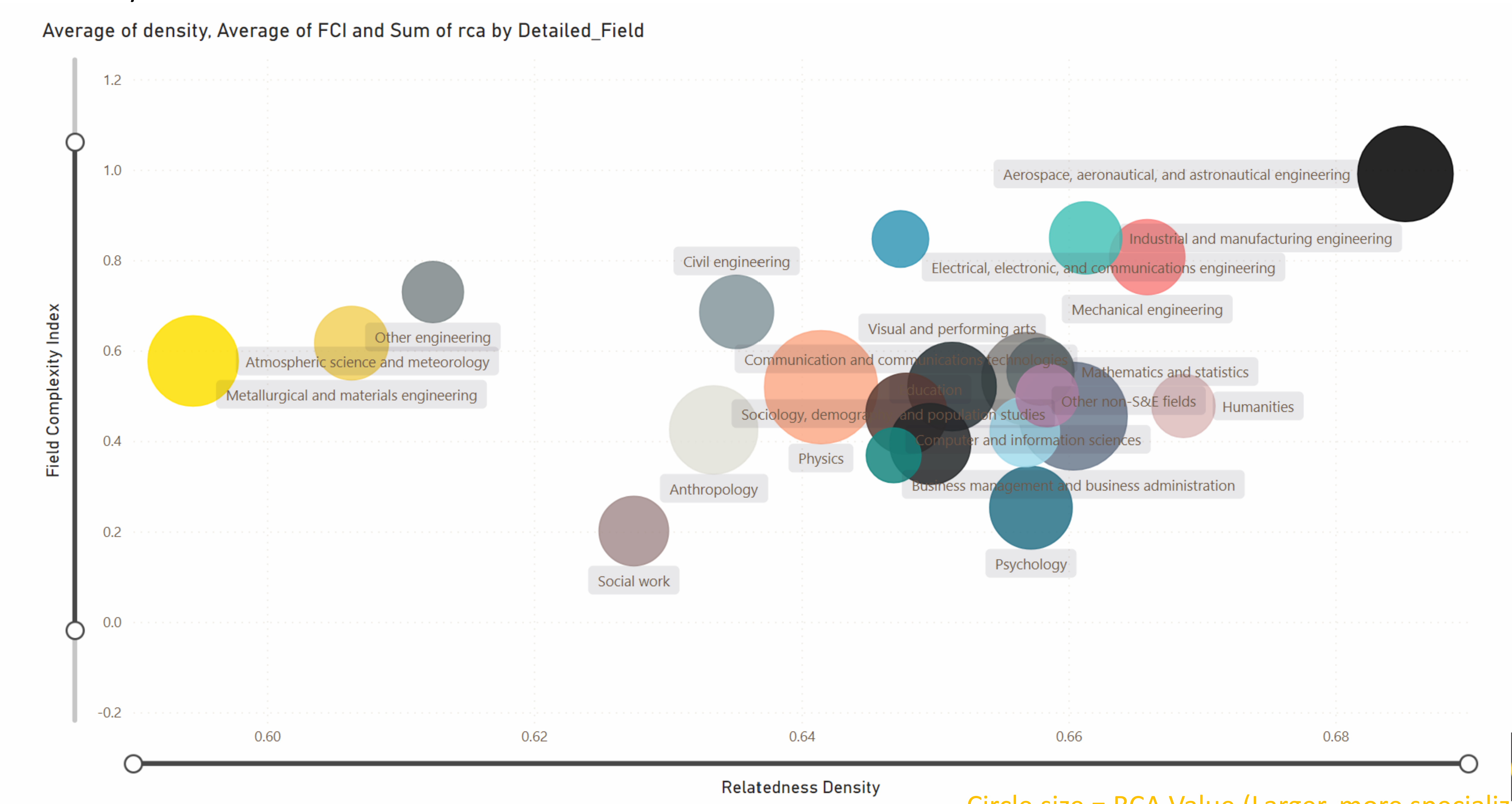
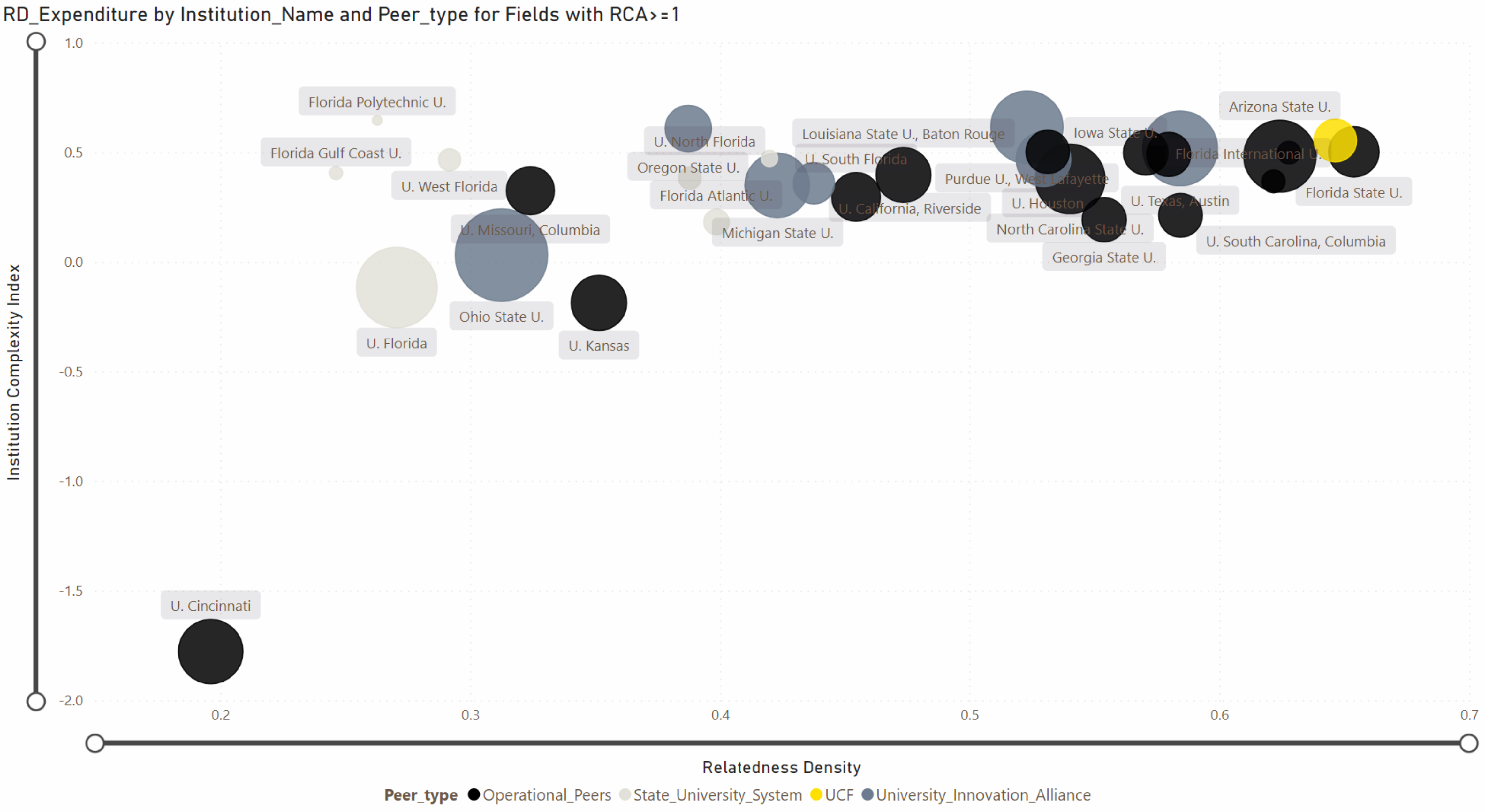
University of Central Florida – 2022 – Fields with RCA>=1



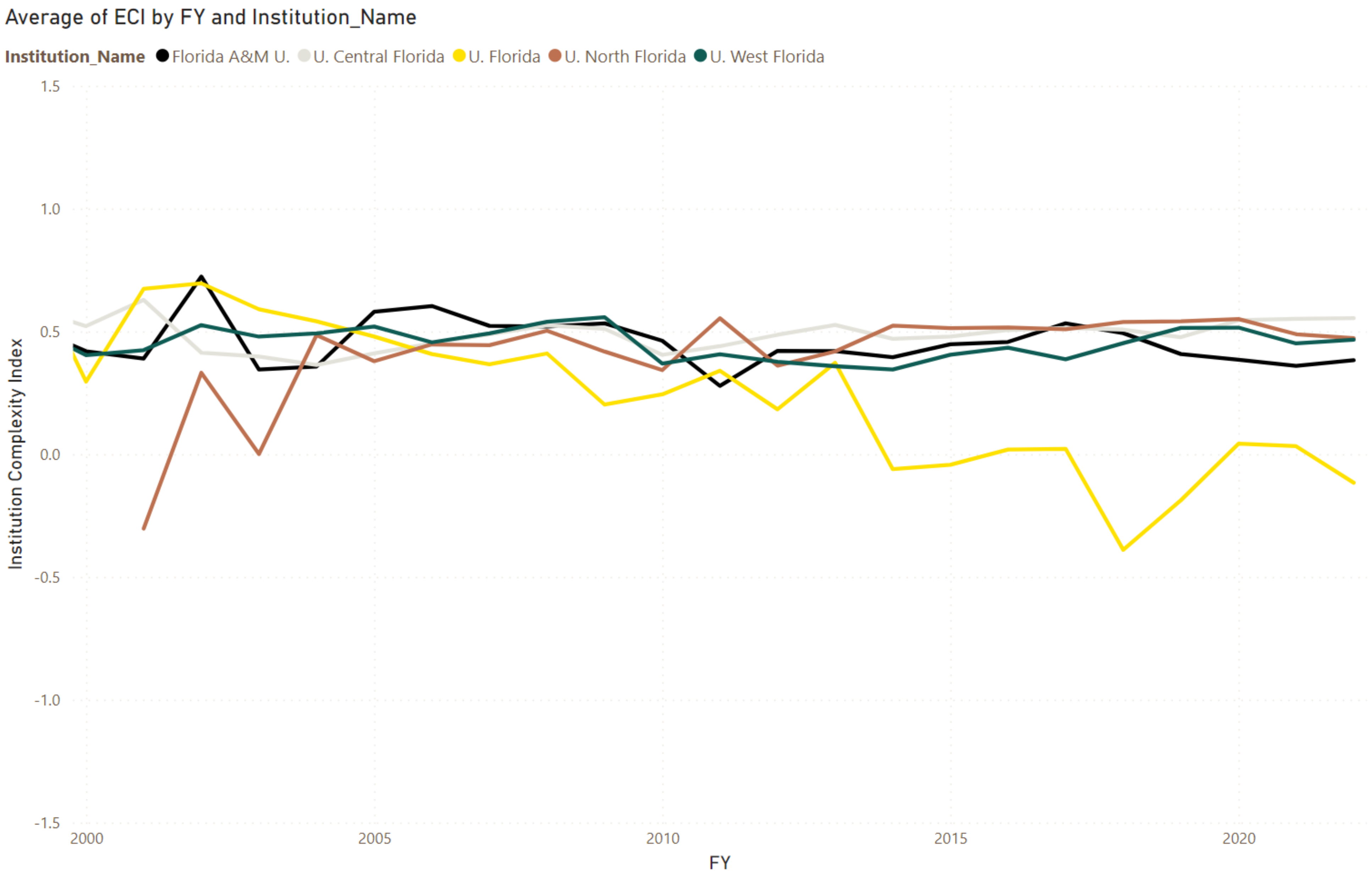
Circle size = RCA Value (Larger, more specialized)

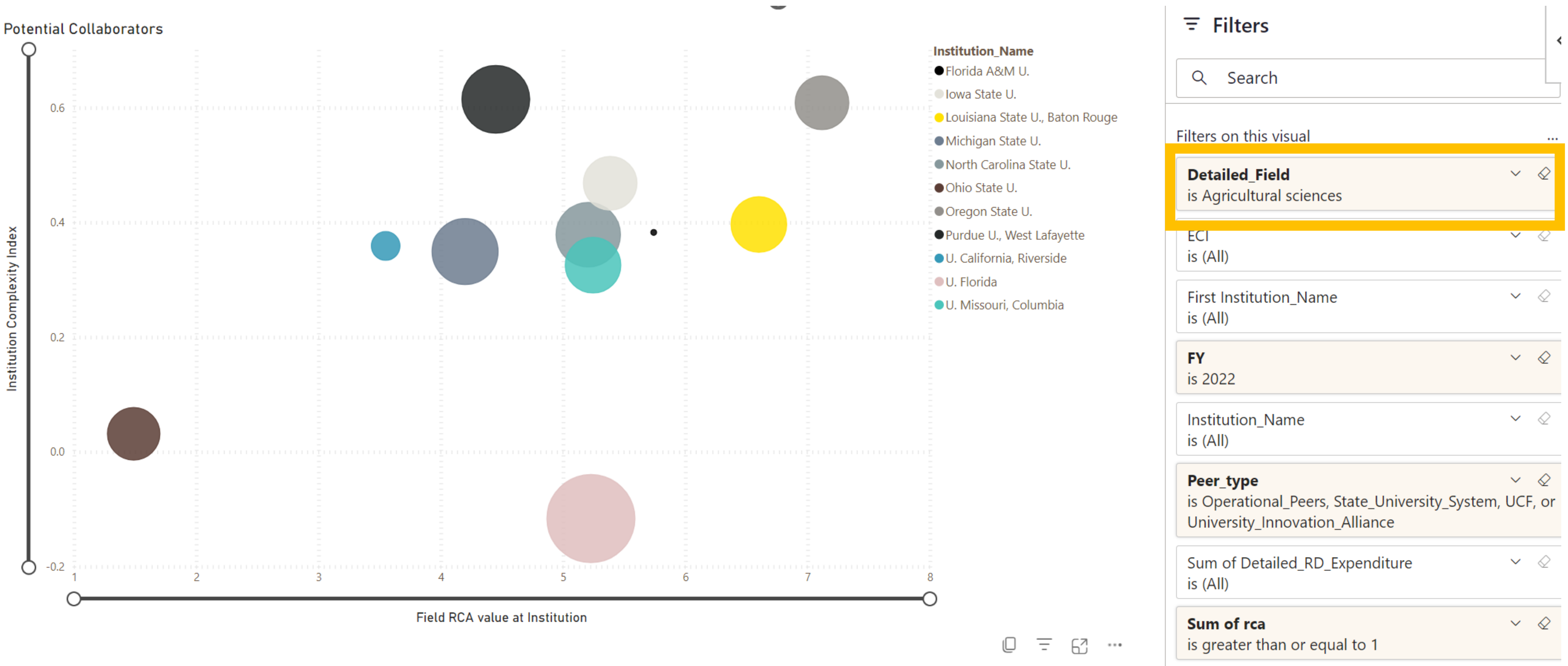
University of Central Florida Peers – 2022 – Fields with RCA>=1



Circle size = R&D Expenditure

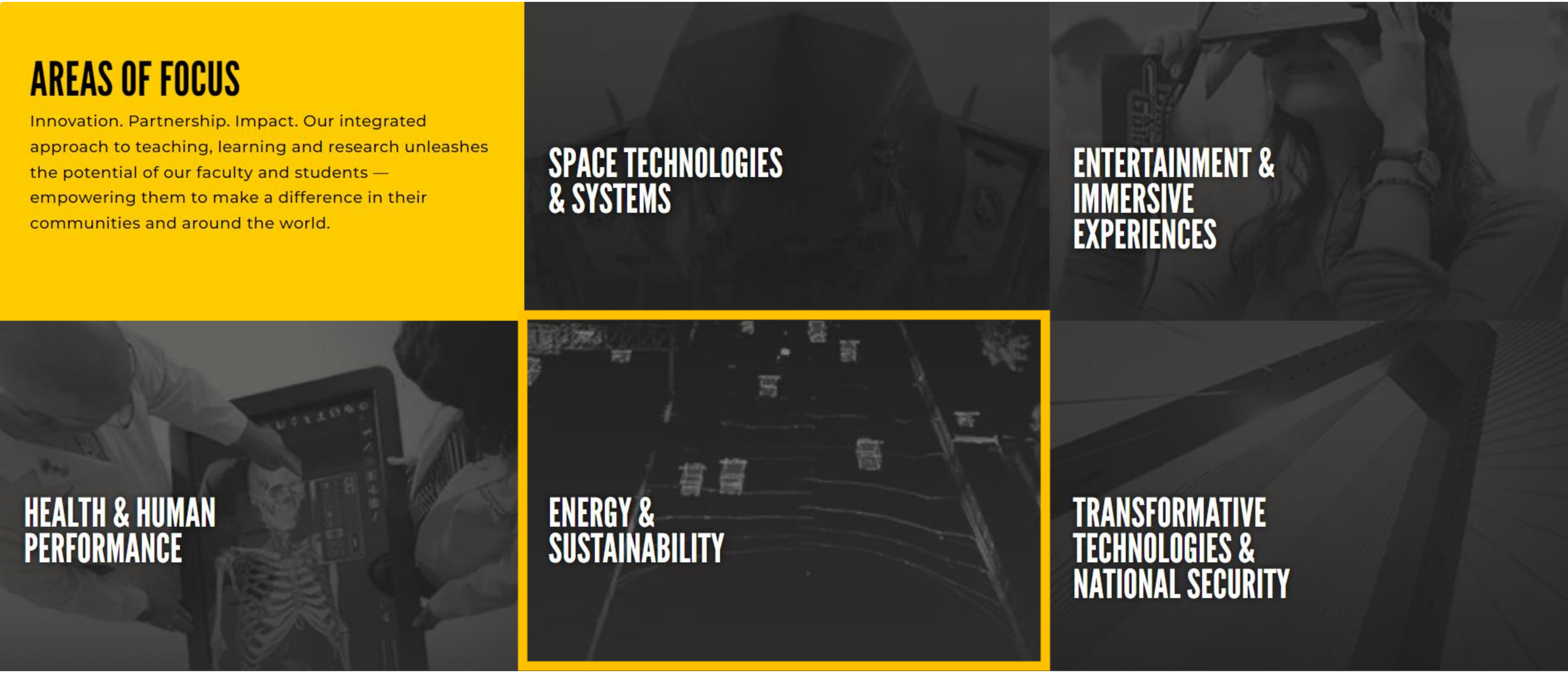
Selected Institutions Complexity Index 2000 - 2022





Circle size = R&D Expenditure

UCF - Areas of Research Focus



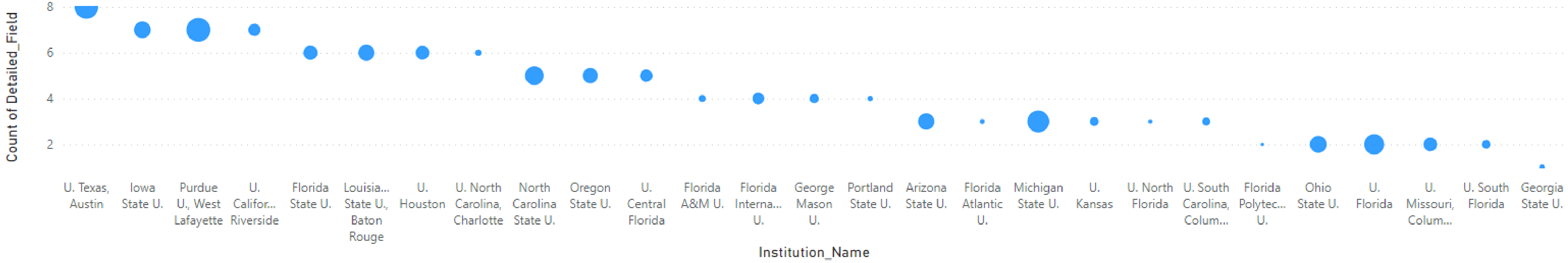
https://www.ucf.edu/unleashing-potential/

NSF Detailed fields that are related to ENERGY AND SUSTAINABILITY:

1. **Aerospace, Aeronautical, and Astronautical Engineering:** Research in efficient propulsion systems, lightweight materials, and sustainable aviation technologies.
2. **Agricultural Sciences:** Sustainable agriculture practices, bioenergy production from crops, and research on the environmental impact of agricultural activities.
3. **Bioengineering and Biomedical Engineering:** Development of sustainable and energy-efficient medical technologies.
4. **Chemical Engineering:** Research on chemical processes for energy production, including sustainable fuel and chemical production.
5. **Civil Engineering:** Infrastructure development with a focus on sustainable and resilient designs, including energy-efficient buildings and transportation systems.
6. **Electrical, Electronic, and Communications Engineering:** Development of smart grids, renewable energy systems, and efficient electronic devices.
7. **Environmental Science and Meteorology:** Study of climate change, environmental impact assessments, and sustainable resource management.
8. **Geological and Earth Sciences:** Exploration of sustainable energy sources, geological sequestration of carbon, and understanding Earth's resources for sustainable practices.
9. **Materials Science:** Research on sustainable materials and technologies for energy applications.
10. **Mechanical Engineering:** Development of energy-efficient machinery, renewable energy technologies, and sustainable manufacturing processes.
11. **Ocean Sciences and Marine Sciences:** Exploration of ocean energy resources and research on the impact of climate change on marine ecosystems.
12. **Physics:** Fundamental research on energy-related phenomena and technologies.
13. **Natural Resources and Conservation:** Sustainable management of natural resources, conservation efforts, and ecosystem services related to energy.

Institution_Name	Count of Detailed_Field	Sum of Detailed_RD_Expenditure
U. Texas, Austin	8	$361,425
Iowa State U.	7	$165,668
Purdue U., West Lafayette	7	$374,852
U. California, Riverside	7	$74,693
Florida State U.	6	$108,712
Louisiana State U., Baton Rouge	6	$150,680
U. Houston	6	$101,259
U. North Carolina, Charlotte	6	$12,103
North Carolina State U.	5	$213,249
Oregon State U.	5	$132,516
U. Central Florida	5	$77,638
Florida A&M U.	4	$16,002
Florida International U.	4	$66,828
George Mason U.	4	$34,828
Portland State U.	4	$7,499
Arizona State U.	3	$155,968
Florida Atlantic U.	3	$5,299
Michigan State U.	3	$308,141
U. Kansas	3	$31,680
U. North Florida	3	$2,790

Count of Detailed_Field and Sum of Detailed_RD_Expenditure by Institution_Name



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Institution_Name	Count of Detailed_Field	Sum of Detailed_RD_Expenditure	
U. Texas, Austin	6	$275,995	Chemical Engineering Material Science
Florida State U.	5	$102,249	Material Science
U. Houston	5	$92,092	Chemical Engineering
Iowa State U.	4	$47,955	Chemical Engineering
Purdue U., West Lafayette	4	$177,109	Chemical Engineering
U. California, Riverside	4	$33,671	Chemical Engineering
U. North Carolina, Charlotte	4	$8,332	Chemical Engineering
Florida International U.	3	$51,268	Chemical Engineering
Louisiana State U., Baton Rouge	3	$38,758	Chemical Engineering
North Carolina State U.	3	$71,596	Chemical Engineering
U. Central Florida	3	$54,796	
Florida A&M U.	2	$2,971	
Total	**67**	**$1,375,403**	

- UCF has advanced capabilities in physics.
- UCF has to collaborate with an institution to strengthen Material Science and chemical engineering related capabilities.

Total_FY_RD_Expendit	Institution_Name	Chemical engineering	Chemistry	Electrical, electronic, and communications engineering	Materials science	Mechanical engineering	Physics	Number of Competitive Fields
$ 1,363,388	Ohio State U.	0.789	0.451	0.679	0.495	2.932	0.683	1
$ 1,085,834	U. Florida	0.454	0.972	0.985		0.704	0.502	0
$ 845,896	U. Texas, Austin	4.887	1.135	2.692	13.998	3.924	1.007	6
$ 797,224	Arizona State U.	0.860	0.591	1.878		0.618	0.694	1
$ 759,229	Michigan State U.	1.383	0.948	0.657		0.717	8.087	2
$ 754,627	Purdue U., West Lafayette	2.902	1.886	2.329		3.730	0.919	4
$ 615,070	U. Cincinnati	0.528	0.529	0.516		0.868	0.193	0
$ 583,203	North Carolina State U.	5.402	0.994	1.133		1.023	0.696	3
$ 432,310	U. Missouri, Columbia	0.221	0.643	0.474	0.174	0.428	0.271	0
$ 405,267	U. Kansas	1.614	1.328	0.232		0.261	0.331	2
$ 405,166	U. South Florida	0.632	0.673	0.579		0.557	0.373	0
$ 393,184	Iowa State U.	1.888	1.671	0.869		1.095	1.502	4
$ 355,986	Florida State U.	0.367	2.669	1.409	3.527	2.628	4.161	5
$ 344,556	Louisiana State U., Baton Rouge	2.234	1.680	0.435		0.971	1.850	3
$ 297,934	Oregon State U.	0.682	0.391	1.411	0.834	1.093	0.351	2
$ 281,665	Florida International U.		4.681	1.352		1.541	0.577	3
$ 240,126	U. Houston	5.154	9.614	1.325		1.490	1.378	5
$ 230,068	George Mason U.		0.242	2.582	2.099	0.267	0.107	2
$ 229,162	U. South Carolina, Columbia	2.998	0.180	0.715		2.459	0.417	2
$ 221,488	U. Central Florida		0.997	1.225		2.335	5.672	3
$ 215,908	Georgia State U.		1.839				0.715	1
$ 199,135	U. California, Riverside	2.984	2.446	1.283		0.984	1.348	4
$ 61,748	Florida Atlantic U.	2.212	1.211	0.011			0.332	2
$ 50,636	Florida A&M U.	1.880	0.013	0.357		0.831	1.367	2
$ 43,126	U. North Carolina, Charlotte		1.422	1.408		3.131	1.706	4
$ 41,483	Portland State U.		2.393	1.424		0.817	0.220	2
$ 38,870	U. West Florida		0.173			0.013		0
$ 18,394	U. North Florida		1.708	0.292		4.035	0.895	2
$ 9,896	Florida Gulf Coast U.		0.961					0
$ 1,725	Florida Polytechnic U.		0.107	8.683		5.189		2

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How Can this be Utilized:

- ❑ Internal Perspective:

- Identify institution-strong Research fields. (RCA>=1)
- Identify institution level of specialization (**value** of RCA when RCA>=1)
- Identify institution-weak Research fields. (RCA<1)
- Identify Institutions' fields with higher potential for growth based on relatedness to existing specializations (relatedness density).
- Identify Institutions' fields with a larger economic growth impact. (Based on the Field complexity index).
- Benchmark Institution diversity of research specialization with other institutions (Institution Complexity Index).
- Benchmark Institution specialization performance in specific research fields with other institutions (RCA).

- ❑ External Perspective: (Institutional Parterships)

- Finding Institutional peers with complementing strengths in the research field weak at our institution.

Questions

Thank You