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# Quantifying the research preferences of top research universities: why they make a difference?

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## Abstract

Research universities are institutions with a strong vocation and advocacy towards research. They are in the top of the world university rankings because of their excellence in research. This paper analyzes research universities focusing on their research preferences. We have selected the top twelve universities of THE World University Rankings 2019 and Scopus and SciVal as source of data with a five-year publication window. In order to analyze university preferences, we have applied a statistitical technique called cosine similarity. Besides, cluster analysis through VOSviewer showed and classified the terms most used by universities. The results have revealed that research universities have a strong commitment in specific areas. Finally, we have analyzed the scientific production in collaboration between all them and their preferences to cooperate.

## Introduction

World leading universities devote to research as a central part of their mission. These institutions focus on the discovery of new scientific knowledge and future researchers training (Mohrman, Ma & Baker, 2008). Research universities make the difference with teaching universities giving more emphasis to research instead of teaching. In fact, pursuing publishing is not something that defines teaching universities. Research universities also commit to teaching as a social role of universities, but their nature is rather shaped by a research infrastructure (Taylor, 2006).

According to League of European Research Universities (LERU) the research universities are the ultimate source of innovation in the economy, society and culture. They train people to think with skepticism, creativity, and high-level capability that society demands (LERU, 2019).

The United States developed the concept of research universities. The Carnegie Classifications defines them as institutions that offer baccalaureate and doctorate programs (Carnegie Foundation, 2001). Taylor (2006) stayed that the key characteristics of leading research universities are: a) Presence of pure and applied research. b) Delivery of research-led teaching. c) Breadth of academic disciplines. d) High proportion of postgraduate research programs. e) High levels of external income. f) An international perspective.

All over the world, countries have recognized that research universities are key to the knowledge economy of the 21st century (Clark, 2004; Etzkowitz & Leydesdorff, 2000). Power & Dusdal (2017a) examined three leading countries in organizational development and scientific innovation (Germany, France and the United Kingdom). They found that global investments or the number of researchers do not influence in countries' productivity. Their findings explained that the institutionalization of research university support high productivity.

Specially, United Kingdom has a group of leading research universities that has attracted the best talent worldwide (Powell & Dusdal 2017b). Research universities are a fundamental element in the connection between research and teaching by giving freedom to teach and to study, autonomy and commitment to science as well as the hosting of future researchers.

During the twentieth century, United States (US) foster a small nucleus of productive "super research universities". This expansion was product of the increase of massive tertiary education in this nation (Fernandez & Baker, 2017). US research universities are research centers increasing the knowledge in all scientific disciplines. They are contributing to the general economy of the country and also to local and regional economies. The US university system is one of the best in the world including the number of Nobel Laureates awarded to their faculty members. Some countries have tried to imitate the model of the US university system, but with limited success. The reason is that most university systems are controlled by governments (Atkinson & Blanpied, 2008).

The Times Higher Education (THE) World University Rankings defines different criteria to include universities, three of which meet the concept of research universities: i: Enough publications – An institution must publish more than 1,000 papers over the previous 5 years, and more than 150 publications in any single year. ii. Thresholds are also applied per subject for the subject rankings. iii: Subject breadth – An institution must not be focused on a single narrow subject area.

Research questions addressed in this work are: What is peculiar about the scientific production of research universities? Is there any research preference in their publications? Do research preferences have any resemblance among them? What are the most used terms in the production of these universities? The most prolific authors, are they national or international? Are these universities collaborating with each other or are they competing among themselves? Which are the preferences to collaborate?

**Data and method**

We first concentrate on those research universities that state prestigious university brands. We have used the Times Higher Education (THE) Ranking World University rankings 2019 to sort the top twelve institutions. We have used Elsevier's Scopus to extract publications because it is one of the world's most comprehensive bibliometric databases and is employed by THE to calculate rankings. We also retrieved the number of publications of the top universities for each research subject in those years. These information was included in Elsevier's SciVal to apply indicators and in the VOSviewer program to create clusters and maps.

Scientific collaboration is a quality that defines leading world-class institutions since they cannot excel in isolation, as they are purpose-built for cooperation. For this reason, we have also analyzed collaboration among them.

The research universities chosen for the study are as a follows: University of Oxford, University of Cambridge, Stanford University, Massachusetts Institute of Technology, California Institute of Technology, Harvard University, Princeton University, Yale University, Imperial College London, University of Chicago, ETH Zurich, and Johns Hopkins University.

We downloaded 668,204 publications from Scopus which is all the scientific production from the universities in the period of time 2014-2018. The data for each institution was processed using the data management software program, SPSS. Data were retrieved in december 2018.

*Similarity measurement among top universities*

Two institutions are similar in research preference if their cosine similarity is close. This study compared the research preference using cosine similarity rather than Euclidean distance. Cosine similarity refers to cosine of the angle between two vectors. Generally, the angle between two vectors is used as a measure of divergence between the vectors. Cosine is used as the numeric similarity (where cosine has the property that it is 1.0 for identical vectors and 0.0 for orthogonal vectors) (Singhal, 2001; Zhigang, Gege, & Haiyan, 2017; Lin, Hu, & Hou, 2018)

The cosine similarity of two vectors A and B using a dot product and size as

$$\mathbf{A} \cdot \mathbf{B} = \|\mathbf{A}\| \, \|\mathbf{B}\| \cos\theta$$

Cosine similarity

$$\text{similarity} = \cos(\theta) = \frac{\mathbf{A} \cdot \mathbf{B}}{\|\mathbf{A}\|\|\mathbf{B}\|} = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^2} \sqrt{\sum_{i=1}^{n} B_i^2}},$$

University performance in Times Higher Education (THE) are grouped into five areas: teaching (the learning environment) (30%); research (volume, income and reputation) (30%); citations (research influence) (30%); international outlook (staff, students and research) (7.5%); and industry income (knowledge transfer) (2.5%).

We selected the metrics: research and citations. They meet 60% of the score and they have a strong influence in the character of a research university.

- Research (volume, income, and reputation) – 30%: the most prominent indicator in this category looks at a university's reputation for research excellence among its peers, based on the responses to our annual Academic Reputation Survey. Therefore: Reputation survey: 18%, Research income: 6% and Research productivity from Scopus: 6%.
- Citations (research influence) – 30%: it examines the research influence by capturing the average number of times a university's published work is cited by scholars globally. The data include more than 25,000 academic journals indexed by Elsevier's Scopus database.

The indicators used in this study (SciVal, 2019)

- Scholarly output which is the total number of publications of an entity.
- % International collaboration indicates the extent to which an entity's publications have international co-authorship.
- Citation count is the total number of citations received by an entity. This is a complement to scholarly output.
- Publications in Top 10 Journal Percentiles, which indicates the extent to which an entity's publications are present in the most-cited journals.
- Outputs in Top Citation Percentiles, which indicates the extent to which an entity's publications are present in the most-cited percentiles.
- Field-Weighted Citation Impact (FWCI) indicates how the number of citations received by an entity's publications compares with the average number of citations received by all other similar publications.

## Results

In the following table we can observe the position of the top twelve institutions in THE. We also have applied the bibliometric indicators to scientific production.

**Table 1. Indicators applied to top 12 research universities**

| Research universities | Countries | Overall | Research (volume, income and reputation) | Citations (research influence) | Scholarly Output | Collaboration (%) | Citation Count | Publications in Top 10 Journal Percentiles (%) | Outputs in Top 10 citation percentile (%) | Field- Weighted Citation Impact (FWCI) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Times Higher Education World University | | | Scopus- SCIval (2014 - 2018) | | | | | |
| University of Oxford | United Kingdom | 96 | 99.5 | 99.1 | 68,034 | 58.7 | 855,705 | 48.7 | 27.0 | 2.3 |
| University of Cambridge | United Kingdom | 94.8 | 98.8 | 97.1 | 56,726 | 59.3 | 699,059 | 49.5 | 27.9 | 2.1 |
| Stanford University | United States | 94.7 | 96.8 | 99.9 | 67,662 | 41.0 | 966,946 | 51.6 | 29.5 | 2.6 |
| Massachusetts Institute of Technology | United States | 94.2 | 92.7 | 99.9 | 44,840 | 48.9 | 660,727 | 55.0 | 30.7 | 2.4 |
| California Institute of Technology | United States | 94.1 | 97.2 | 99.2 | 22,250 | 52.0 | 327,666 | 47.1 | 33.6 | 2.2 |
| Harvard University | United States | 93.6 | 98.4 | 99.6 | 148,972 | 43.6 | 2,005,555 | 49.4 | 29.1 | 2.3 |
| Princeton University | United States | 92.3 | 93.6 | 99.4 | 22,417 | 46.2 | 288,466 | 50.4 | 28.6 | 2.4 |
| Yale University | United States | 91.3 | 93.5 | 97.8 | 44,497 | 38.4 | 537,206 | 49.2 | 27.3 | 2.1 |
| Imperial College London | United Kingdom | 90.3 | 87.7 | 97.8 | 57,576 | 60.3 | 684,087 | 49.2 | 27.1 | 2.2 |
| University of Chicago | United States | 90.2 | 90.1 | 99 | 30,787 | 35.8 | 407,384 | 47.8 | 27.0 | 2.2 |
| ETH Zurich | Switzerland | 89.3 | 91.4 | 93.8 | 38,806 | 65.3 | 445,479 | 53.1 | 28.1 | 2.0 |
| Johns Hopkins University | United States | 89 | 90.5 | 98.5 | 65,637 | 39.4 | 797,610 | 44.8 | 26.3 | 2.2 |

We can observe that the two best research universities in the world are from the United Kingdom. They are the corners of the ‘golden triangle’. Golden triangle universities have some of the largest UK university financial endowments. Followed by these are the universities of the United States where most of them are private. Currently, there are more than 250 of these institutions in the United States. In table 2 we can observe the total amount of publication and the percentage with the total of each disciplines. The average of international collaboration is 49%. Percentage of publications in the top 10 journal percentiles is 49.65 and the percentage of outputs in top 10 citation percentiles is 48%.

*Research preferences at Top Research Universities*

**Table 2. Research preferences in the Top Twelve Research Universities**

| | University of Oxford | | University of Cambridge | | Stanford University | | Massachusetts Institute of Technology | | California Institute of Technology | | Harvard university | | Princeton University | | Yale University | | Imperial College London | | University of Chicago | | ETH Zurich | | Johns Hopkins University | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| Agricultural and Biological Sciences | 4,501 | 4.65 | 3,725 | 4.29 | 2,997 | 2.93 | 1,317 | 1.92 | 1,070 | 2.66 | 2,670 | 5.31 | 1,246 | 3.39 | 2,149 | 3.76 | 2,518 | 3.60 | 1,376 | 2.92 | 2,786 | 4.75 | 2,155 | 2.73 |
| Arts and Humanities | 4,357 | 4.50 | 3,807 | 4.38 | 1,848 | 1.81 | 616 | 0.90 | 128 | 0.32 | 2,567 | 5.11 | 1,640 | 4.47 | 2,035 | 3.56 | 242 | 0.35 | 1,867 | 3.96 | 392 | 0.67 | 1,220 | 1.55 |
| Biochemistry, Genetics and Molecular Biology | 10,495 | 10.85 | 9,644 | 11.10 | 10,828 | 10.59 | 5,431 | 7.93 | 1,764 | 4.38 | 5,052 | 10.05 | 1,982 | 5.40 | 6,911 | 12.10 | 6,775 | 9.68 | 5,448 | 11.57 | 4,362 | 7.43 | 9,434 | 11.95 |
| Business, Management and Accounting | 966 | 1.00 | 1,039 | 1.20 | 903 | 0.88 | 576 | 0.84 | 51 | 0.13 | 804 | 1.60 | 315 | 0.86 | 370 | 0.65 | 328 | 0.47 | 507 | 1.08 | 511 | 0.87 | 321 | 0.41 |
| Chemical Engineering | 1,588 | 1.64 | 1,978 | 2.28 | 2,061 | 2.02 | 2,600 | 3.79 | 883 | 2.19 | 1,088 | 2.16 | 975 | 2.66 | 821 | 1.44 | 2,156 | 3.08 | 599 | 1.27 | 2,032 | 3.46 | 872 | 1.10 |
| Chemistry | 3,740 | 3.87 | 4,087 | 4.70 | 3,533 | 3.45 | 4,191 | 6.12 | 1,991 | 4.95 | 1,991 | 3.96 | 1,836 | 5.00 | 1,810 | 3.17 | 3,581 | 5.12 | 1,746 | 3.71 | 4,304 | 7.33 | 1,738 | 2.20 |
| Computer Science | 4,457 | 4.61 | 3,589 | 4.13 | 5,983 | 5.85 | 5,292 | 7.72 | 2,381 | 5.92 | 1,984 | 3.95 | 2,869 | 7.82 | 1,340 | 2.35 | 4,709 | 6.73 | 1,290 | 2.74 | 5,321 | 9.06 | 2,582 | 3.27 |
| Decision Sciences | 492 | 0.51 | 521 | 0.60 | 611 | 0.60 | 591 | 0.86 | 85 | 0.21 | 383 | 0.76 | 284 | 0.77 | 217 | 0.38 | 405 | 0.58 | 347 | 0.74 | 439 | 0.75 | 262 | 0.33 |
| Dentistry | 39 | 0.04 | 17 | 0.02 | 74 | 0.07 | 14 | 0.02 | 0 | 0.00 | 68 | 0.14 | 3 | 0.01 | 44 | 0.08 | 13 | 0.02 | 52 | 0.11 | 2 | 0.00 | 70 | 0.09 |
| Earth and Planetary Sciences | 3,325 | 3.44 | 3,949 | 4.54 | 3,324 | 3.25 | 3,128 | 4.57 | 8,485 | 21.09 | 1,721 | 3.42 | 2,801 | 7.63 | 1,792 | 3.14 | 2,136 | 3.05 | 1,505 | 3.19 | 4,154 | 7.08 | 3,061 | 3.88 |
| Economics, Econometrics and Finance | 1,388 | 1.43 | 1,076 | 1.24 | 1,182 | 1.16 | 598 | 0.87 | 144 | 0.36 | 1,323 | 2.63 | 721 | 1.96 | 762 | 1.33 | 289 | 0.41 | 1,042 | 2.21 | 697 | 1.19 | 435 | 0.55 |
| Energy | 885 | 0.91 | 1,145 | 1.32 | 1,410 | 1.38 | 1,942 | 2.83 | 557 | 1.38 | 385 | 0.77 | 573 | 1.56 | 314 | 0.55 | 1,721 | 2.46 | 173 | 0.37 | 1,391 | 2.37 | 316 | 0.40 |
| Engineering | 4,476 | 4.63 | 6,136 | 7.06 | 6,790 | 6.64 | 9,936 | 14.50 | 4,718 | 11.73 | 2,960 | 5.89 | 3,020 | 8.23 | 1,794 | 3.14 | 7,663 | 10.95 | 1,090 | 2.31 | 6,663 | 11.35 | 3,621 | 4.59 |
| Environmental Science | 2,639 | 2.73 | 2,251 | 2.59 | 2,226 | 2.18 | 1,682 | 2.45 | 1,156 | 2.87 | 1,428 | 2.84 | 1,168 | 3.18 | 1,361 | 2.38 | 2,310 | 3.30 | 501 | 1.06 | 3,046 | 5.19 | 1,177 | 1.49 |
| Health Professions | 488 | 0.50 | 365 | 0.42 | 794 | 0.78 | 159 | 0.23 | 18 | 0.04 | 164 | 0.33 | 47 | 0.13 | 370 | 0.65 | 385 | 0.55 | 232 | 0.49 | 195 | 0.33 | 757 | 0.96 |
| Immunology and Microbiology | 2,966 | 3.07 | 1,813 | 2.09 | 2,320 | 2.27 | 1,089 | 1.59 | 341 | 0.85 | 991 | 1.97 | 467 | 1.27 | 1,469 | 2.57 | 2,116 | 3.02 | 1,141 | 2.42 | 864 | 1.47 | 2,386 | 3.02 |
| Materials Science | 3,225 | 3.33 | 4,391 | 5.05 | 4,284 | 4.19 | 6,110 | 8.92 | 2,580 | 6.41 | 2,294 | 4.56 | 2,025 | 5.52 | 1,318 | 2.31 | 4,108 | 5.87 | 1,256 | 2.67 | 4,194 | 7.14 | 1,936 | 2.45 |
| Mathematics | 3,859 | 3.99 | 2,830 | 3.26 | 3,418 | 3.34 | 3,383 | 4.94 | 1,760 | 4.37 | 1,802 | 3.58 | 2,510 | 6.84 | 1,219 | 2.13 | 3,158 | 4.51 | 1,567 | 3.33 | 3,424 | 5.83 | 1,671 | 2.12 |
| Medicine | 18,501 | 19.12 | 11,516 | 13.25 | 25,201 | 24.64 | 3,335 | 4.87 | 601 | 1.49 | 5,754 | 11.44 | 1,125 | 3.06 | 15,511 | 27.16 | 13,965 | 19.95 | 12,631 | 26.81 | 2,601 | 4.43 | 27,493 | 34.83 |
| Multidisciplinary | 1,892 | 1.96 | 1,715 | 1.97 | 2,267 | 2.22 | 1,868 | 2.73 | 921 | 2.29 | 1,595 | 3.17 | 877 | 2.39 | 1,150 | 2.01 | 1,001 | 1.43 | 932 | 1.98 | 882 | 1.50 | 1,085 | 1.37 |
| Neuroscience | 3,437 | 3.55 | 2,847 | 3.28 | 3,520 | 3.44 | 1,331 | 1.94 | 440 | 1.09 | 1,550 | 3.08 | 640 | 1.74 | 2,804 | 4.91 | 1,375 | 1.96 | 1,351 | 2.87 | 915 | 1.56 | 3,808 | 4.82 |
| Nursing | 906 | 0.94 | 630 | 0.72 | 819 | 0.80 | 42 | 0.06 | 6 | 0.01 | 268 | 0.53 | 30 | 0.08 | 799 | 1.40 | 553 | 0.79 | 624 | 1.32 | 154 | 0.26 | 1,489 | 1.89 |
| Pharmacology, Toxicology and Pharmaceutics | 1,106 | 1.14 | 899 | 1.03 | 974 | 0.95 | 509 | 0.74 | 107 | 0.27 | 350 | 0.70 | 73 | 0.20 | 1,106 | 1.94 | 877 | 1.25 | 648 | 1.38 | 485 | 0.83 | 1,507 | 1.91 |
| Physics and Astronomy | 7,427 | 7.68 | 9,277 | 10.67 | 8,231 | 8.05 | 10,617 | 15.50 | 9,683 | 24.07 | 4,903 | 9.75 | 6,525 | 17.78 | 4,064 | 7.12 | 6,188 | 8.84 | 4,280 | 9.09 | 6,967 | 11.87 | 5,437 | 6.89 |
| Psychology | 2,108 | 2.18 | 1,544 | 1.78 | 2,166 | 2.12 | 387 | 0.56 | 89 | 0.22 | 1,661 | 3.30 | 493 | 1.34 | 2,369 | 4.15 | 388 | 0.55 | 1,477 | 3.14 | 377 | 0.64 | 1,486 | 1.88 |
| Social Sciences | 7,311 | 7.56 | 5,799 | 6.67 | 4,422 | 4.32 | 1,705 | 2.49 | 270 | 0.67 | 4,488 | 8.93 | 2,440 | 6.65 | 3,151 | 5.52 | 948 | 1.35 | 3,421 | 7.26 | 1,461 | 2.49 | 2,516 | 3.19 |
| Veterinary | 170 | 0.18 | 328 | 0.38 | 79 | 0.08 | 65 | 0.09 | 6 | 0.01 | 39 | 0.08 | 22 | 0.06 | 55 | 0.10 | 99 | 0.14 | 2 | 0.00 | 85 | 0.14 | 100 | 0.13 |

The colour green means acceptable values and the red colour might be a room for improvement. Most of research universities have a strong production in Medicine followed by Biochemistry, Genetics and Molecular Biology. However University of Princeton, California Institute of Technology and ETH Zurich have more production in Physics and Astronomy. We must bear in mind that scientific disciplines have different patterns of publication and some disciplines attract more economic funding than others. Both circumstances could affect to scientific production.

Table 3 shows the resulting adjacency matrix, which represents the level of similarity between two pairs of institutions.

**Table 3. Adjacency matrix of top research universities' cosine similarity in research areas**

| | University of Oxford | University of Cambridge | Stanford University | Massachusetts Institute of Technology | California Institute of Technology | Harvard University | Princeton University | Yale University | Imperial College London | University of Chicago | ETH Zurich | Johns Hopkins University |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| University of Oxford | 1 | | | | | | | | | | | |
| University of Cambridge | 0.835 | 1 | | | | | | | | | | |
| Stanford University | 0.847 | 0.754 | 1 | | | | | | | | | |
| Massachusetts Institute of Technology | 0.799 | 0.826 | 0.747 | 1 | | | | | | | | |
| California Institute of Technology | 0.870 | 0.772 | 0.790 | 0.806 | 1 | | | | | | | |
| Harvard University | 0.810 | 0.785 | 0.790 | 0.824 | 0.808 | 1 | | | | | | |
| Princeton University | 0.793 | 0.866 | 0.793 | 0.855 | 0.782 | 0.746 | 1 | | | | | |
| Yale University | 0.864 | 0.895 | 0.828 | 0.709 | 0.833 | 0.780 | 0.847 | 1 | | | | |
| Imperial College London | 0.784 | 0.797 | 0.772 | 0.713 | 0.844 | 0.755 | 0.812 | 0.840 | 1 | | | |
| University of Chicago | 0.851 | 0.773 | 0.754 | 0.767 | 0.786 | 0.867 | 0.739 | 0.756 | 0.759 | 1 | | |
| ETH Zurich | 0.836 | 0.794 | 0.834 | 0.869 | 0.903 | 0.790 | 0.872 | 0.809 | 0.764 | 0.741 | 1 | |
| Johns Hopkins University | 0.848 | 0.804 | 0.854 | 0.766 | 0.848 | 0.863 | 0.740 | 0.800 | 0.839 | 0.842 | 0.806 | 1 |

Cosine similarity is 0.87 for University of Oxford and California Institute of Technology. This represents a strong similarity between them. However the University of Oxford and Imperial College London has a 0.784 similarity. It means University of Oxford is more like California Institute of Technology than Imperial College London in research preferences.

Next figure analyses the terms used in the scientific production of all universities together. We have chosen a map based on bibliographic data. We used fractional counting method to perform the map.

The minimum number of occurrences of a term is 100. Of 639,854 terms, 1,215 meet the threshold. For each of the 1,215 terms, we calculated a relevance score. Based on this score, the study showed the most relevant terms. The default choice is to select the 60% most relevant terms. Finally, we selected a total of 500 terms.

There are 6 clusters. Red color represents the Cluster 1- Physical sciences with 184 items. Green color represents the Cluster 2- Health sciences with 133 items. The blue color represents the Cluster 3- Social sciences with 85 items. The yellow color is Cluster 4- Life sciences with 79 items. Color pink Cluster 5 with 15 items. Finally the purple color is Cluster 6 with 2 items.

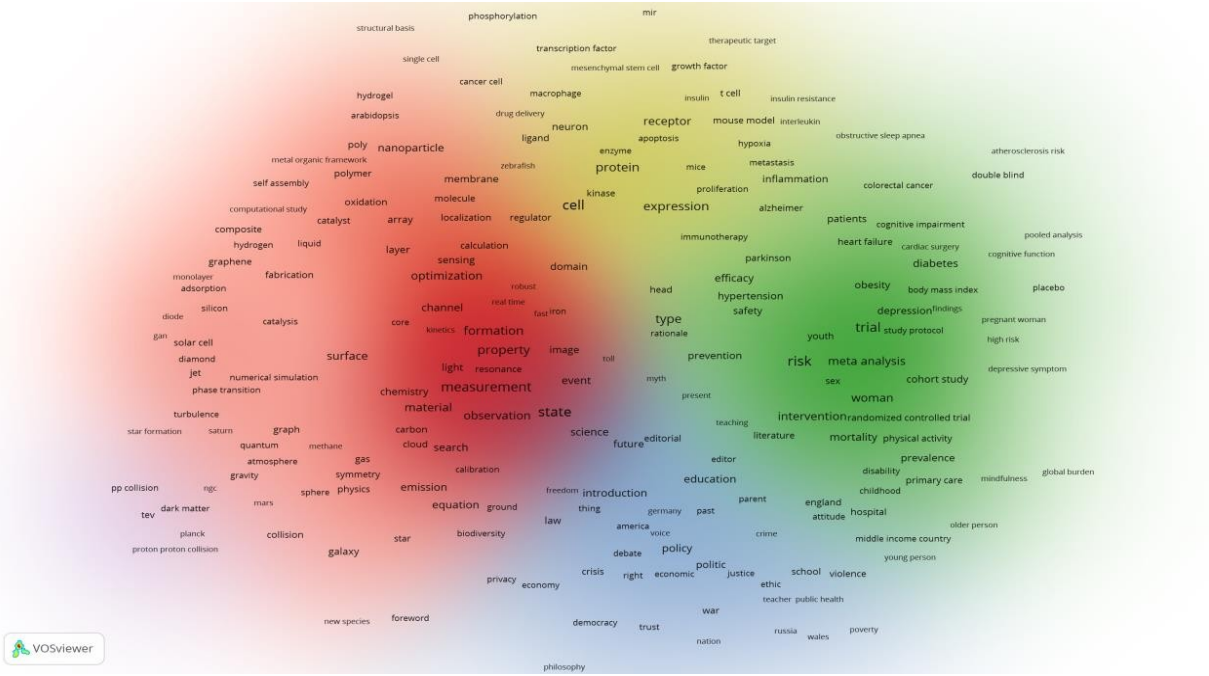


**Figure 1. Co-occurrence map based on text data**

Risk is the term most used in the production of universities 4,896 occurrences with a relevance of 0.81; Cell is used a number of 4,490 times with a relevance of 0.67; State is used a number of 4,197 with a relevance of 0.29; and Measurement with 3,967 occurrences and 0.82 relevance. Risk, cell, state and measurement could be the same four most common words in the publications of the universities ranked 13-200 in THE.

The next figure analyses the authors in the scientific production of all universities together. We have chosen a map based on bibliographic data for a co-authorship analysis. The fractional counting method was used for this analysis. We have ignored documents with a large number of authors only choosing 10 as the largest number of authors per document. Moreover we selected prolific authors with at least 50 documents and 200 citations. The number of citations of an author equals the total number of citations the documents of the author have received in Scopus.

Of the 450,562 authors, 1,783 meet the thresholds. For each of the 1,783 authors we calculated a total strength of the co-authorship links.

We have applied an author disambiguation process. We checked that the analyzed production belongs to each of the authors and there was no mixed production within the same name.

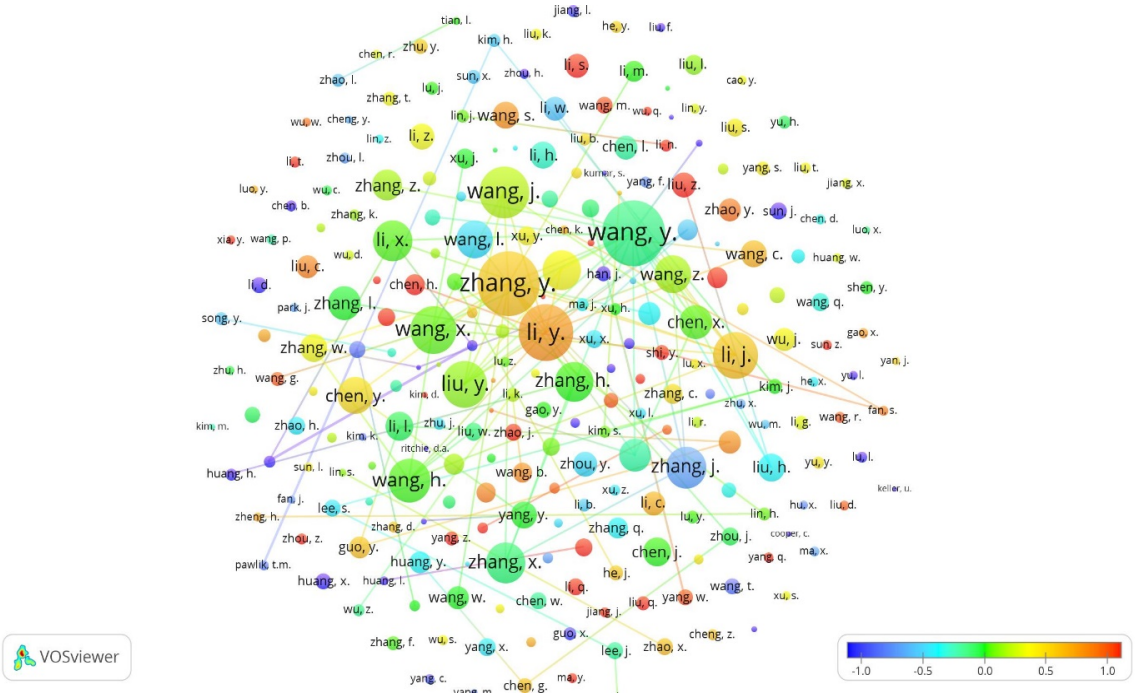


**Figure 2. Co-authorship map based on bibliographic data.**

There is a total of 16 clusters with 12,219 links and a total link strength of 18,099. We notice a larger amount of Asiatic names appearing the most in the documents of all these institutions.
Cluster 1 obtains the majority of items (38), followed by cluster 2 (28 items), cluster 3 (27 items), cluster 4 (27 items), cluster 5 (26 items), cluster 6 (19 items), cluster 7 (18 items), cluster 8 (17 items), cluster 9 (16 items), cluster 10 (14 items),cluster 11 (7 items), cluster 12 (3 items), cluster 13 (3 items), cluster 14 (2 items), cluster 15 (2 items), cluster 16 (2 items).
Wang, Y is the author with the largest number of documents and links. The second is Zhang, Y.

Are research universities outputs  favored by collaboration with these asiatic researchers? or, are they improving the scores of these institutions as a member of staff? These research questions emerged from the results and we will study in future works.

*Scientific collaboration among 12 top universities*

There are 28,348 documents published in cross-institutional collaboration among those research universities. They published together 13,908 documents in Open Access (articles published in "Gold" OA, including full OA journals, hybrids, open archive and promotional OA). Alternatively, they published 14,440 in other type of access including subscription or green OA.

The next map shows the terms used in the title and abstract of the 28,348 documents in collaboration. We chose binary counting method with a minimum of 20 occurrences. Of the 63,780 terms, 472 meet the threshold. 150 terms selected to appear in the map.

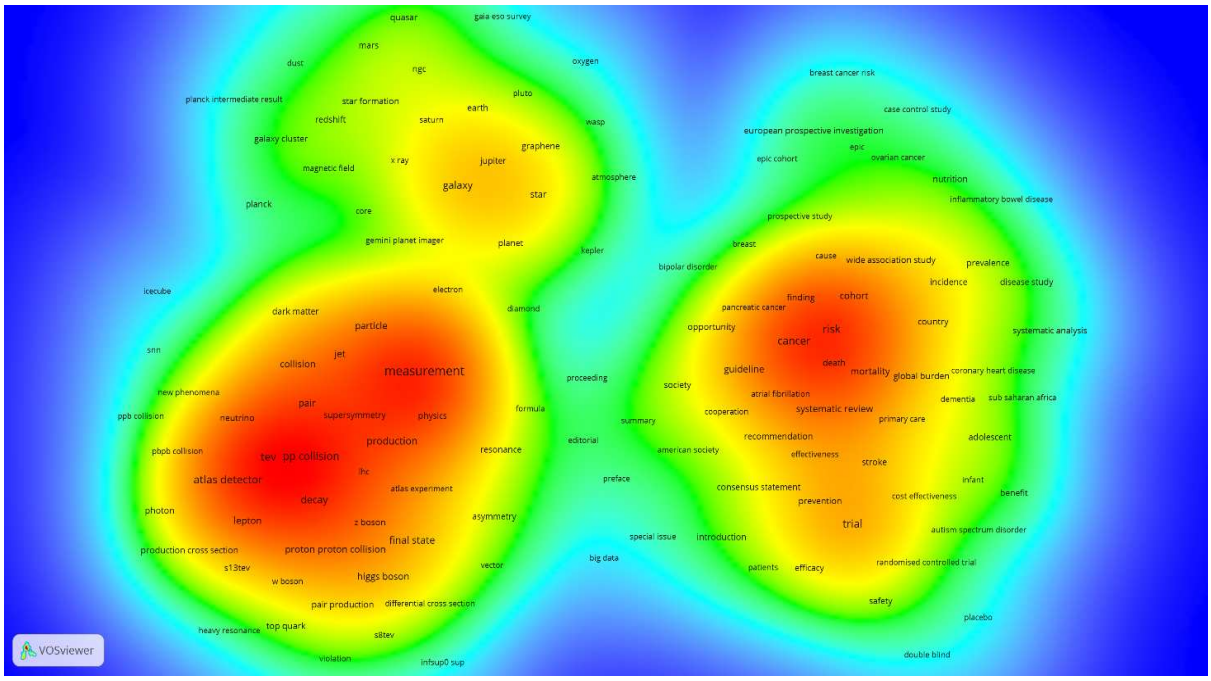


**Figure 3. Co-occurrence map based on collaboration production among research universities**

There are 7 clusters with 1,408 links and 11,228 link strength. Measurement is the term most repeated with 940 occurrences, a total number of 65 links. Follow by Risk with 542 occurrences and 52 links, Atlas detector with 445 and 45 links and Cancer with 433 occurrences and 45 links.

The fifteen institutions behind these collaborations: University of Oxford (8,071), University of Cambridge (7,300), Massachusetts Institute of Technology (6,963), Harvard University (6,227), Stanford University (6,003), Imperial College London (5,950), California Institute of Technology (4,624), Johns Hopkins University (3,985), University of Chicago (3,974), Princeton University (3,920), Yale University (3,911), ETH Zürich (3,273), CNRS- Centre National de la Recherche Scientifique (2,442), UCL (University College London) (2,435), University of California, Berkeley (2,174).

The funding sponsors that finance these publications: National Science Foundation (NSF) (2,437), National Institutes of Health (NIH) (2,012), U.S. Department of Energy (1,247), European Research Council (1,226), Wellcome Trust (1,097), National Aeronautics and Space Administration (1,071), Science and Technology Facilities Council (973), European Commission (870).

**Table 4. Indicators applied to scientific production in collaboration among Research Universities**

| | Scholarly Output | Citation Count | Citations per Publication | Field-Weighted Citation Impact | Collaboration (%) | Collaboration Impact (%) | Outputs in Top 10 citation percentile (%) | Publications in Top 10 Journal Percentiles (%) |
|---|---|---|---|---|---|---|---|---|
| Total | 28,348 | 760,023 | 27.4 | 3.82 | 69.8 | 30.8 | 45.4 | 61.3 |
| Agricultural and Biological Sciences | 1,782 | 37,670 | 21.1 | 2.91 | 74 | 18.7 | 41.1 | 85.4 |
| Arts and Humanities | 408 | 2,604 | 6.4 | 2.44 | 47.3 | 8.8 | 13.2 | 53.3 |
| Biochemistry, Genetics and Molecular Biology | 5,157 | 157,775 | 30.6 | 3.5 | 71.5 | 32.5 | 52.4 | 55.3 |
| Business, Management and Accounting | 235 | 2,907 | 12.4 | 3.29 | 54.5 | 13.2 | 28.5 | 55.7 |
| Chemical Engineering | 885 | 26,982 | 30.5 | 3.15 | 66.9 | 28.6 | 53.6 | 61.4 |
| Chemistry | 1,890 | 49,072 | 26 | 2.94 | 70.2 | 26.8 | 54.4 | 74.7 |
| Computer Science | 1,841 | 28,761 | 15.6 | 3.61 | 64 | 14.7 | 21.4 | 30.7 |
| Decision Sciences | 267 | 3,795 | 14.2 | 3.69 | 55.1 | 15.5 | 25.5 | 46 |
| Dentistry | 14 | 81 | 5.8 | 4.47 | 35.7 | 8.8 | 21.4 | 83.3 |
| Earth and Planetary Sciences | 4,313 | 103,229 | 23.9 | 2.79 | 83.5 | 26.1 | 51.5 | 35.1 |
| Economics, Econometrics and Finance | 559 | 7,519 | 13.5 | 3.34 | 43.8 | 11.3 | 33.5 | 60.8 |
| Energy | 417 | 10,291 | 24.7 | 3.35 | 71.9 | 27.1 | 48 | 58.6 |
| Engineering | 2,663 | 50,225 | 18.9 | 3.29 | 67 | 20.9 | 34.5 | 49.9 |
| Environmental Science | 1,149 | 30,597 | 26.6 | 3.87 | 75.9 | 23 | 50 | 77.5 |
| Health Professions | 147 | 2,666 | 18.1 | 3.19 | 54.4 | 24.9 | 37.4 | 54.2 |
| Immunology and Microbiology | 1,186 | 30,376 | 25.6 | 2.94 | 69.7 | 26.7 | 48.4 | 33.6 |
| Materials Science | 2,218 | 46,981 | 21.2 | 3.31 | 70.7 | 23.2 | 41.9 | 51.9 |
| Mathematics | 1,734 | 17,212 | 9.9 | 3.02 | 62.3 | 11.4 | 18.8 | 33.7 |
| Medicine | 6,929 | 205,172 | 29.6 | 5.17 | 64.6 | 35.9 | 45.8 | 59.3 |
| Multidisciplinary | 1,672 | 103,124 | 61.7 | 4.75 | 73 | 66.1 | 67.3 | 97.9 |
| Neuroscience | 1,454 | 33,846 | 23.3 | 2.97 | 64.7 | 26.5 | 49.6 | 40.6 |
| Nursing | 286 | 5,734 | 20 | 3.22 | 63.6 | 26 | 35.3 | 62.6 |
| Pharmacology, Toxicology and Pharmaceutics | 353 | 5,843 | 16.6 | 2.66 | 64.9 | 19.9 | 39.4 | 50.5 |
| Physics and Astronomy | 8,180 | 219,081 | 26.8 | 3.36 | 81.8 | 29.1 | 49.1 | 42.2 |
| Psychology | 608 | 8,530 | 14 | 2.87 | 50.2 | 16.4 | 34.4 | 52.6 |
| Social Sciences | 1,149 | 14,831 | 12.9 | 3.85 | 48.1 | 16.5 | 25.1 | 60.8 |
| Veterinary | 37 | 299 | 8.1 | 2.53 | 40.5 | 12.2 | 24.3 | 73.5 |

The scientific production received a total of 760,023 citations. A Field-Weighted Citation Impact of 3.82 and a 61.3% of publications in Top 10 Journal Percentiles. The highest score in citation per publication placed in the field of Biochemistry, Genetics and Molecular Biology (30.6), Chemical Engineering (30.5) and Medicine (29.6). The top Field-Weighted Citation Impact (FWCI) is in the field of Medicine (5.17). The highest percentages of international collaboration are in Earth and Planetary Sciences (83.5), Physics and Astronomy (81.8) and Environmental Science (75.9).

Apart of Multidisciplinary, the fields with highest international collaboration impact are Medicine, Biochemistry, Genetics and Molecular Biology and Physics and Astronomy. The outputs in Top 10 citation percentile are in Chemistry, Chemical Engineering and Biochemistry, Genetics and Molecular Biology. The publications in Top 10 Journal Percentiles are in the field of Agricultural and Biological Sciences, Dentistry and Environmental Science.

## Conclusions

The study analyzed research preferences of Top-12 research universities according to the last edition of THE ranking 2019. We have used the Scopus database to extract data and SciVal to apply indicators with a 5-year publication window.
The percentage of international collaboration is 49%. Percentage of publications in the top 10 journal percentiles is 49.65 and the percentage of outputs in top 10 citation percentiles is 48%. Research universities published in the area of Medicine. But others like MIT - Massachusetts Institute of Technology, California Institute of Technology, Princeton University focused their production on Physics and Astronomy.
Cosine revealed the similarity of universities with more analogous research preferences and others. For example California Institute of Technology and ETH Zurich or University of Cambridge with University of Princeton.
Cluster techniques classified outputs into Life Sciences, Physical Sciences, Social Sciences and Health Sciences. The majority of terms from research universities concentrate in the Physical Sciences cluster.
From the co-authorship map have extracted a great number of Asiatic names. This motivates us to investigate if they are responsible of raising scientific production and impact of these universities.

Research universities have 28,348 in common. They are collaborating the most in Physics and Astronomy, Medicine, and Biochemistry. University of Oxford is the most collaborator institution.

*Next steps and future works*

In future research, we will compare the research patterns of the lower ranked research universities with the Top-12. At the same time, we will analyze the scientific collaboration between the runners-up universities and top universities to know the benefits obtained from this diversity.

We motivate research universities to become more strategic, successful, and quality-oriented in their collaborations.

An emerging recommendation from this study is that governments and private companies such as Fortune 500 companies should do more research investment in universities since it is clear it becomes a profitable asset. The future in rankings will depend more on corporate policies for financing research. It is an imperative need to invest in universities and adopt measures to improve the quality of education and research to become a key player in the higher education sector in the world sphere.

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