Economic Development and Innovation in Smaller Metros and Regions: A Global View

Daniel Calto

Director of Solution Services

Research Intelligence

Elsevier Inc.

University of Arkansas

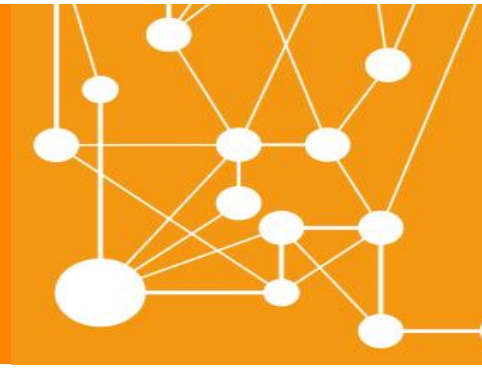
Fayetteville, AR

May 21, 2019

Agenda

- The Global R&D Landscape
- Innovation Models around the World
- Data Sources, Tools, and Technologies
- Topics of Prominence—Modelling Research
- Strategies and Tools for Smaller Universities and Metros
  - Tracking manufacturing capabilities
  - Analyzing and visualizing university collaborations
  - Strategies for smaller universities and metros

The Global R&D Landscape



ELSEVIER

Empowering Knowledge

Grand Challenges Are Multidisciplinary and Global

Climate Change

Energy

Aging Populations

Poverty Reduction

Cybersecurity

Food and Water Security

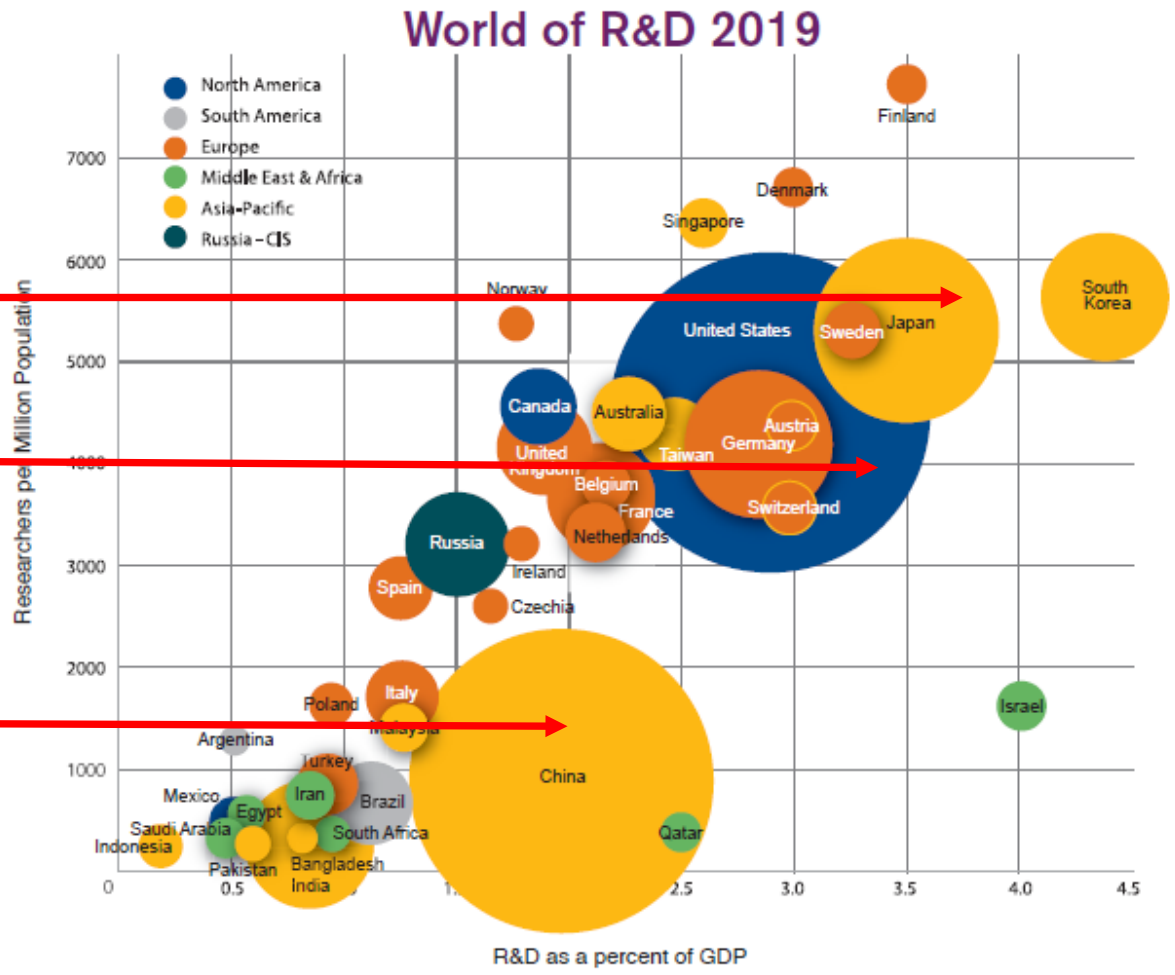
Environment

2018 Global R&D Expenditures (PPP USD)

Japan: 3.50%
GERD/GDP
$191.5B USD (PPP)

US: 2.74%
GERD/GDP
$565.8B USD (PPP)

China: 1.97%
GERD/GDP
$485.5B USD (PPP)



The size of the circles in this chart reflects the relative amount (compared to the U.S. as a baseline) of annual R&D investments by the indicated country. Regional groupings are indicated by the colors of the balls in the legend. The horizontal axis reflects R&D spending as a percent share of each country's GDP (gross domestic product). The vertical axis reflects on the number of researchers (including scientists and engineers) per million population for the respective countries.

- The world as a whole spent $2.172T in R&D in 2018
- In 2016 South Korea spent $90B, 4.3% of its GDP, on R&D.
- China's R&D vs. GDP, at 1.97%, has surpassed that of the EU as a whole (1.85%) and the UK (1.73%)
- No EU major EU economy except Germany (2.84%) is on track to spend the EU goal of 3.00% in 2020
- India's investments in R&D were the 5th-highest globally, surpassing South Korea's sending for the first time. In 2011 they were the 8th largest spender.
- US R&D spending in 2018 was up 5.2% over the prior year to $565B, while China's spending rose 9.1% to $485B

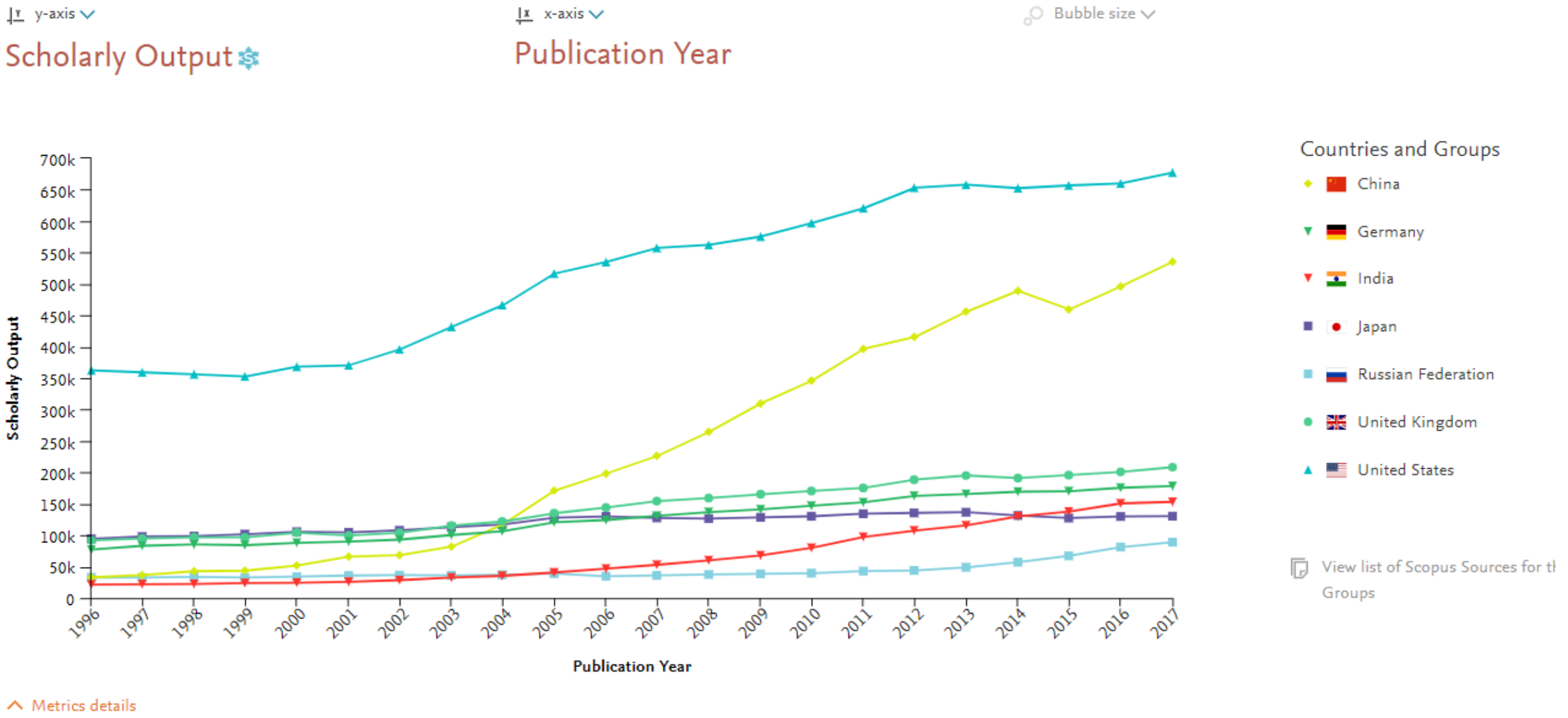
https://digital.rdmag.com/researchanddevelopment/2019_global_r_d_funding_forecast?pg=1#pg1

2019 Forecast GERD vs. GDP by Country (PPP $USD)

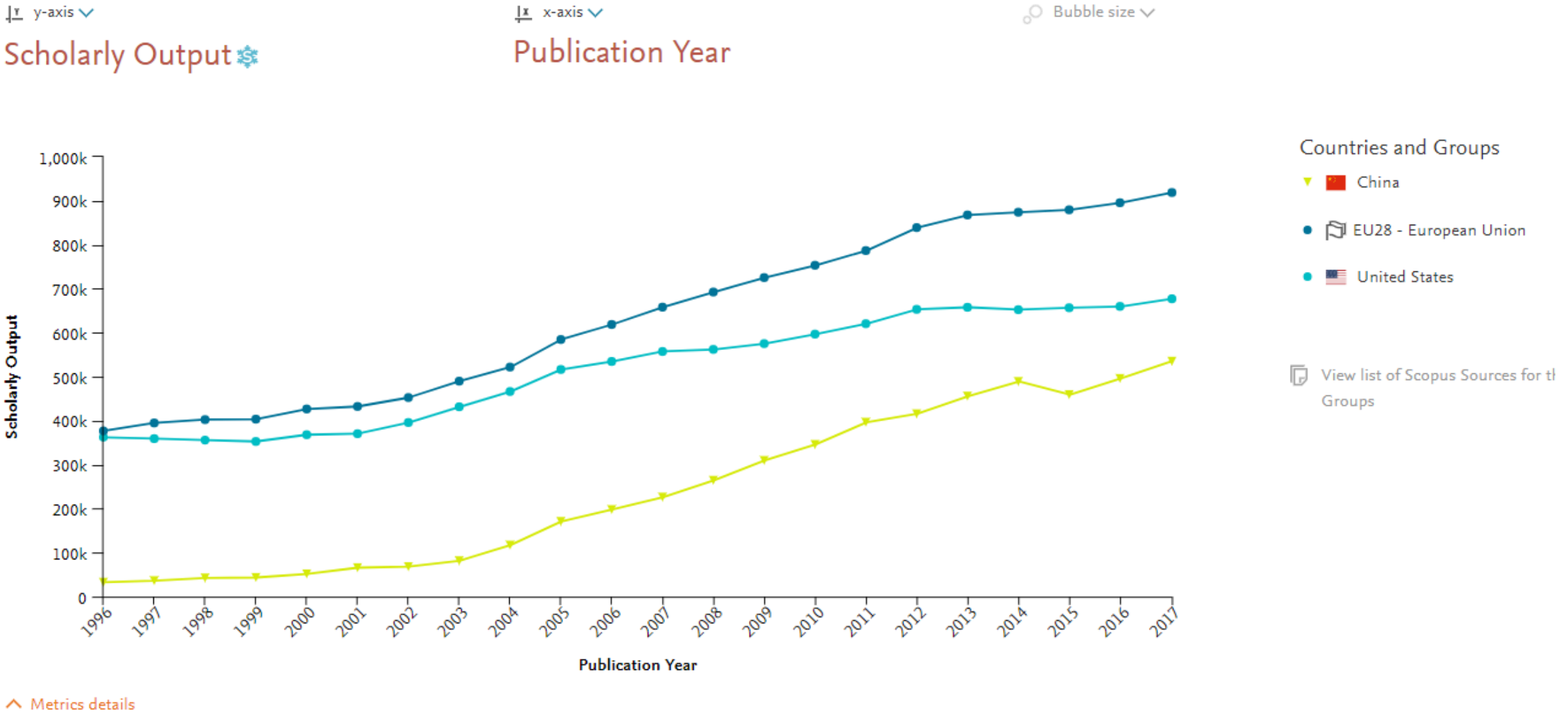
Forecast Gross Expenditures on R&D

		2017 Actual			2018 Estimated			2019 Forecast		
		GDP PPP Bil, USD	R&D as % GDP	GERD PPP Bil, USD	GDP PPP Bil, USD	R&D as % GDP	GERD PPP Bil, USD	GDP PPP Bil, USD	R&D as % GDP	GERD PPP Bil, USD
1	United States	19,360.0	2.83%	537.59	19,921.0	2.84%	565.76	20,458.9	2.84%	581.03
2	China	23,120.0	1.96%	444.82	24,646.0	1.97%	485.53	26,223.3	1.98%	519.22
3	Japan	5,405.0	3.50%	185.53	5,469.9	3.50%	191.45	5,519.1	3.50%	193.17
4	Germany	4,150.0	2.84%	114.84	4,253.8	2.84%	120.81	4,338.9	2.84%	123.22
5	India	9,447.0	0.84%	76.91	10,146.1	0.85%	86.24	10,937.5	0.86%	94.06
6	South Korea	2,027.0	4.30%	85.43	2,087.8	4.32%	90.19	2,148.4	4.35%	93.46
7	France	2,826.0	2.25%	62.13	2,885.4	2.25%	64.92	2,943.1	2.25%	66.22
8	Russia	4,000.0	1.52%	57.81	4,068.0	1.52%	61.83	4,129.0	1.50%	61.94
9	United Kingdom	2,880.0	1.73%	49.16	2,926.1	1.72%	50.33	2,970.0	1.73%	51.38
10	Brazil	3,219.0	1.18%	37.14	3,293.0	1.17%	38.53	3,375.3	1.16%	39.15
11	Canada	1,764.0	1.80%	30.85	1,801.0	1.80%	32.42	1,837.0	1.80%	33.07
12	Australia	1,235.0	2.34%	28.64	1,272.1	2.34%	29.77	1,311.5	2.35%	30.82
13	Taiwan	1,175.0	2.45%	28.20	1,197.3	2.45%	29.33	1,221.3	2.46%	30.04

US, China, UK, Germany, India, Japan, and Russia Output, 1996-2017



US, EU, and Chinese Paper Output, 1996-2017



US, EU, and Chinese Paper Output, Materials Science, 1996-2017

US, EU, and Chinese Paper Output, Medicine, 1996-2017

Innovation Models around the World

ELSEVIER

Empowering Knowledge

What is Innovation?

- https://www.youtube.com/watch?v=IyLgJWPdT_w
- https://www.youtube.com/watch?v=qWFf3Ks6CxE

Swatch Group—World's Largest Watch Company

Watch brands

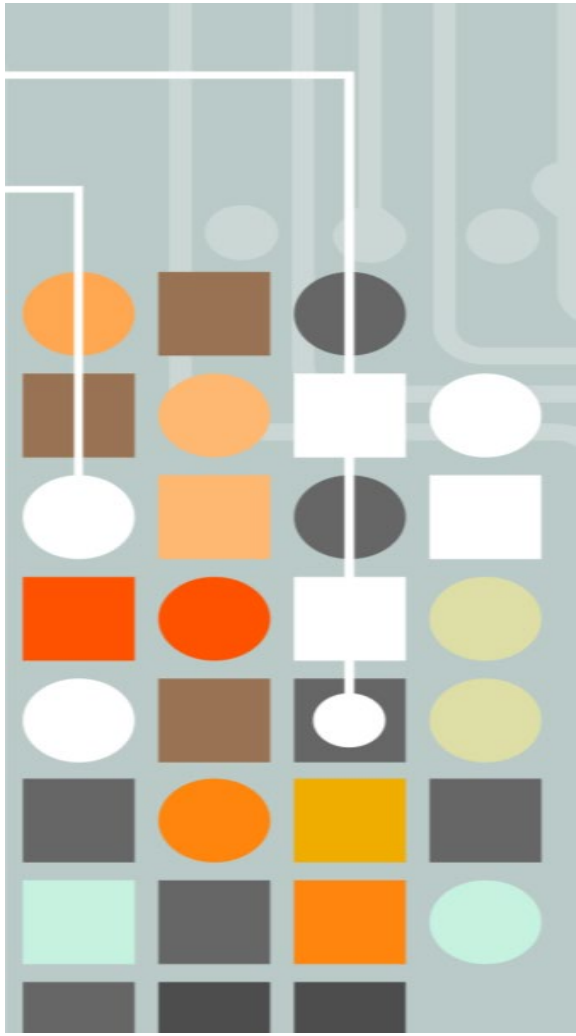
Basic range	Middle range	High range	Prestige & Luxury range
swatch	TISSOT	LONGINES	OMEGA
flik flak	Calvin Klein	RADO	Breguet
	BALMAIN	UNION	BLANCPAIN
	CERTINA		Glashütte
	MIDO		HARRY WINSTON
	HAMILTON		JAQUET DROZ
			LÉON HATOT

Primary Innovation Models

- **Venture-Capital based**: Silicon Valley, New York, Berlin, Beijing
- **University-driven**: MIT/Kendall Square, Tel Aviv, Cambridge (UK)
- **Regional innovation models**: United Kingdom, EU "smart specialization," RTP, Cornell
- **Large-Industry Innovation**: Honda, Apple, Airbus, Alibaba, Wipro
- **"Workshop" Innovation**: Shenzhen, Mittelstand, South India, Italian Fashion
- **Specialized Commercialization Institutes**: Frauenhofer, CSIRO, DARPA
- **Freestanding Research Institutes:** Max Planck, Salk, Scripps, Broad Institutes
- **Government Laboratories:** NIH, CNRS, CERN, Los Alamos, Chinese Academy of Sciences
- **Triple-Helix Models**: EU, South Korea, Japan, China
- **National Research Assessment Frameworks:** UK REF, Australian Research Council ERA

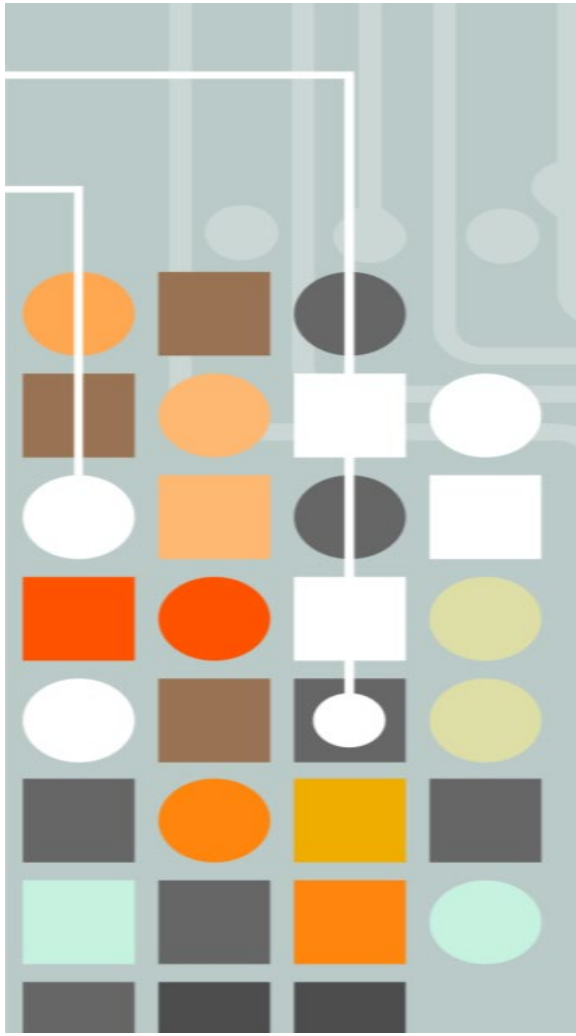
Model Parameters

- Time to Profitability
- Financing Model and Capital Requirements
- Complexity
- Geography
- Legal Landscape: Patent Law and Enforceability
- Culture
- Definition of Success

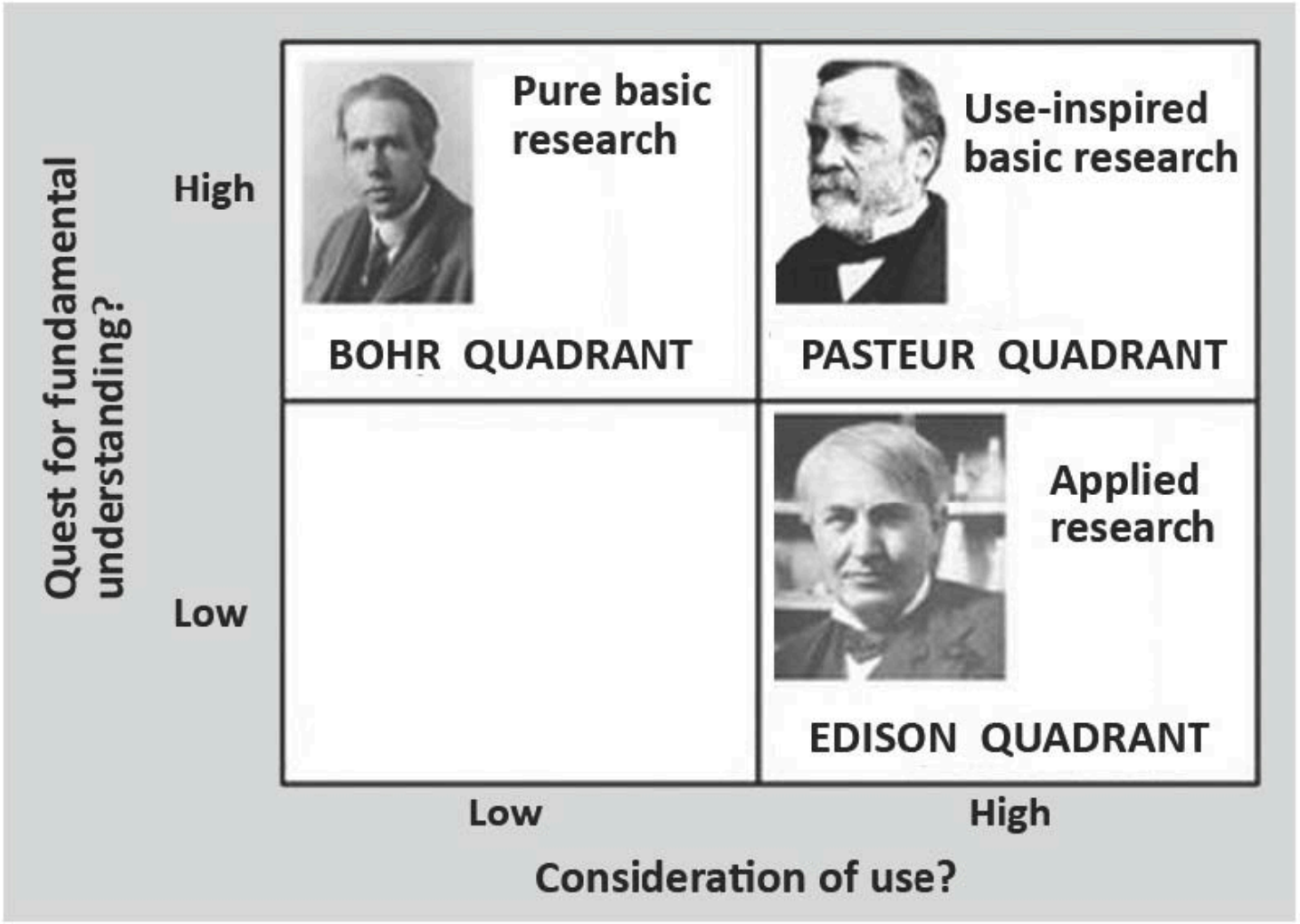


Model Parameters (cont.)

- Time to Profitability
- Financing Model and Capital Requirements
- Complexity
- Geography
- Legal Landscape: Patent Law and Enforceability
- Culture
- Definition of Success

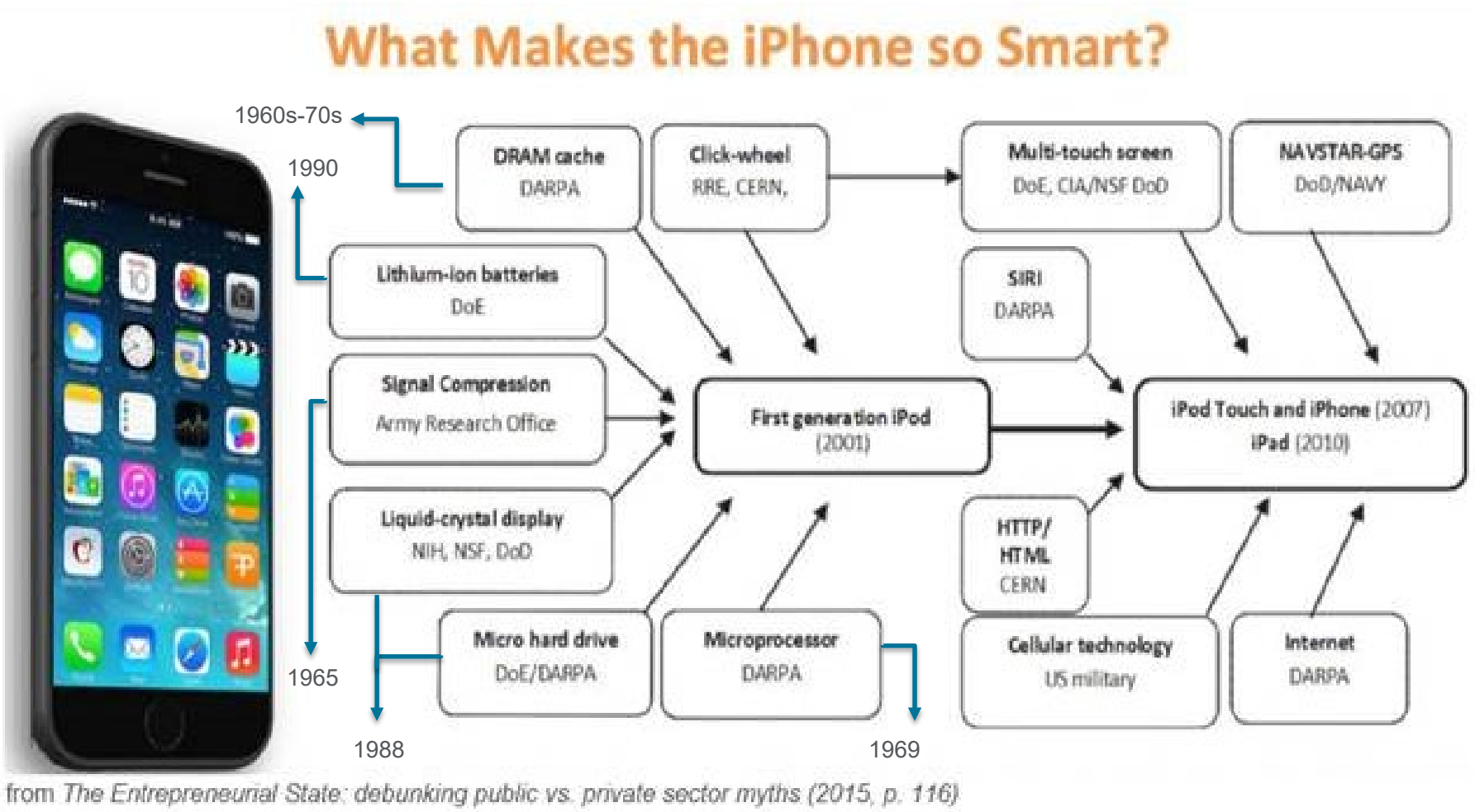


Pasteur's Quadrant—Basic and Applied Research



Stokes, D. E. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation* . Brookings Institution Press . Retrieved from http://www.amazon.com/Pasteurs-Quadrant-Science-Technological-Innovation/dp/0815781776

Impact of Basic Research on Innovation--Smartphones



from *The Entrepreneurial State: debunking public vs. private sector myths (2015, p. 116)*

Why Universities?

ScienceDirect

Journals & Books

Download PDF Share Export

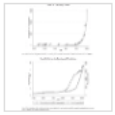
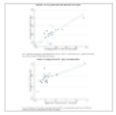
Search ScienceDirect Advanced

Outline

Highlights
Abstract
Keywords
JEL No
1. Data
2. Empirical framework
3. Results
4. Mechanisms
5. Conclusions
Acknowledgements
Appendix. Supplementary materials
References

Show full outline

Figures (2)

Tables (8)

Table 1
Table 2
Table 3
Table 4
Table 5

ELSEVIER

Economics of Education Review
Volume 68, February 2019, Pages 53-67

The economic impact of universities: Evidence from across the globe

Anna Valero [a], John Van Reenen [b]

[a] London School of Economics and Centre for Economic Performance, Houghton Street, London WC2A 2AE
[b] MIT Department of Economics, Centre for Economic Performance and NBER, 77 Massachusetts Ave, Cambridge, MA 02139, USA

Received 18 January 2018, Revised 6 September 2018, Accepted 7 September 2018, Available online 14 September 2018.

Check for updates

Show less

https://doi.org/10.1016/j.econedurev.2018.09.001

Get rights and content
Under a Creative Commons license
open access

Highlights

- Using international data on universities we study their impact on regional growth.
- Increases in universities are positively and robustly associated with higher growth.

Recommended articles

Living to fight another day: The ecological and ev...
Quaternary Science Reviews, 2018
Download PDF View details

A Minimal Turing Test
Journal of Experimental Social Psychology, Volume 79, ...
Download PDF View details

People are averse to machines making moral de...
Cognition, Volume 181, 2018, pp. 21-34
Download PDF View details

1 2 Next

Citing articles (1)

Article Metrics

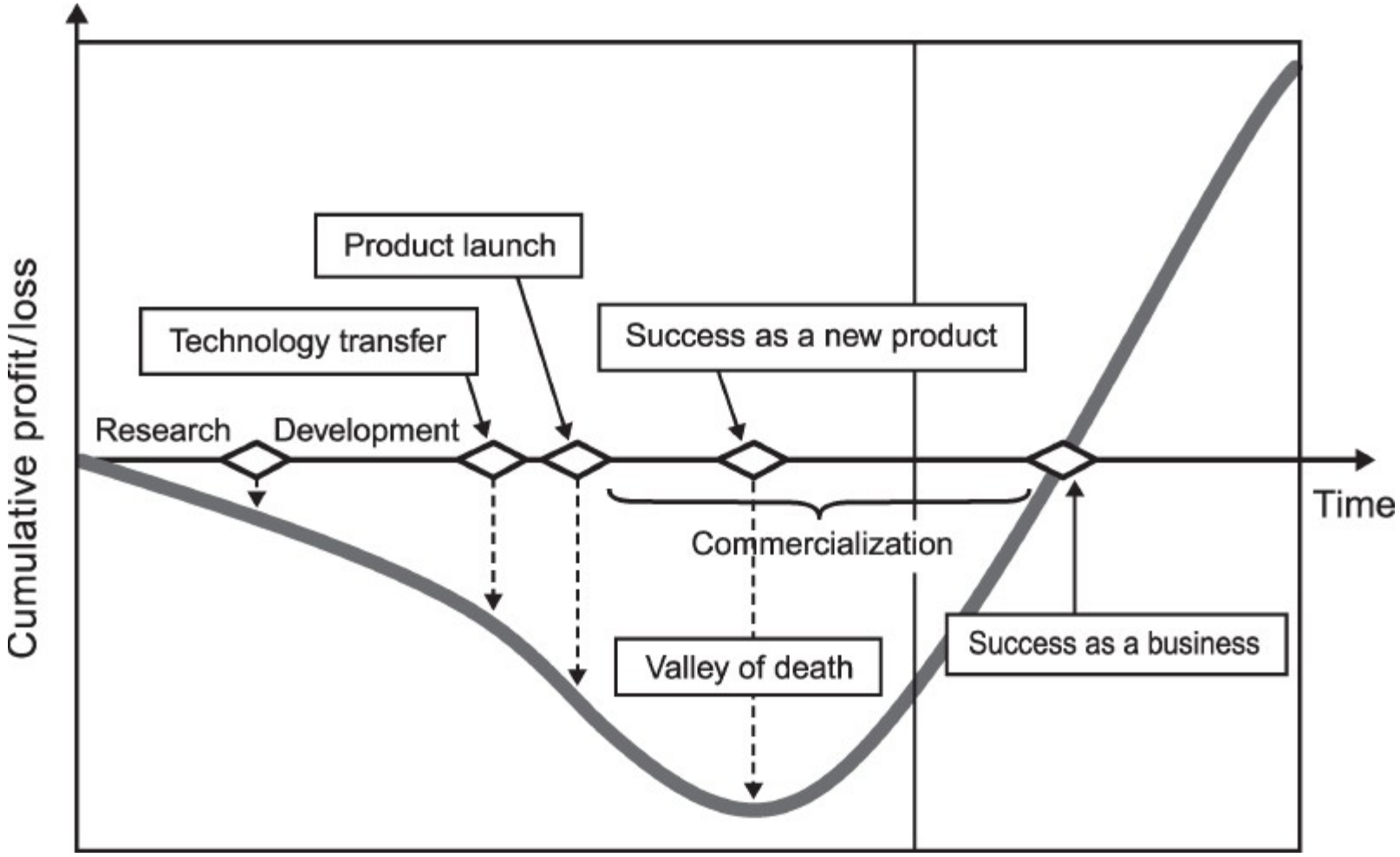
Citations
Citation Indexes: 1

Captures
Readers: 129

Mentions
Blog Mentions: 3

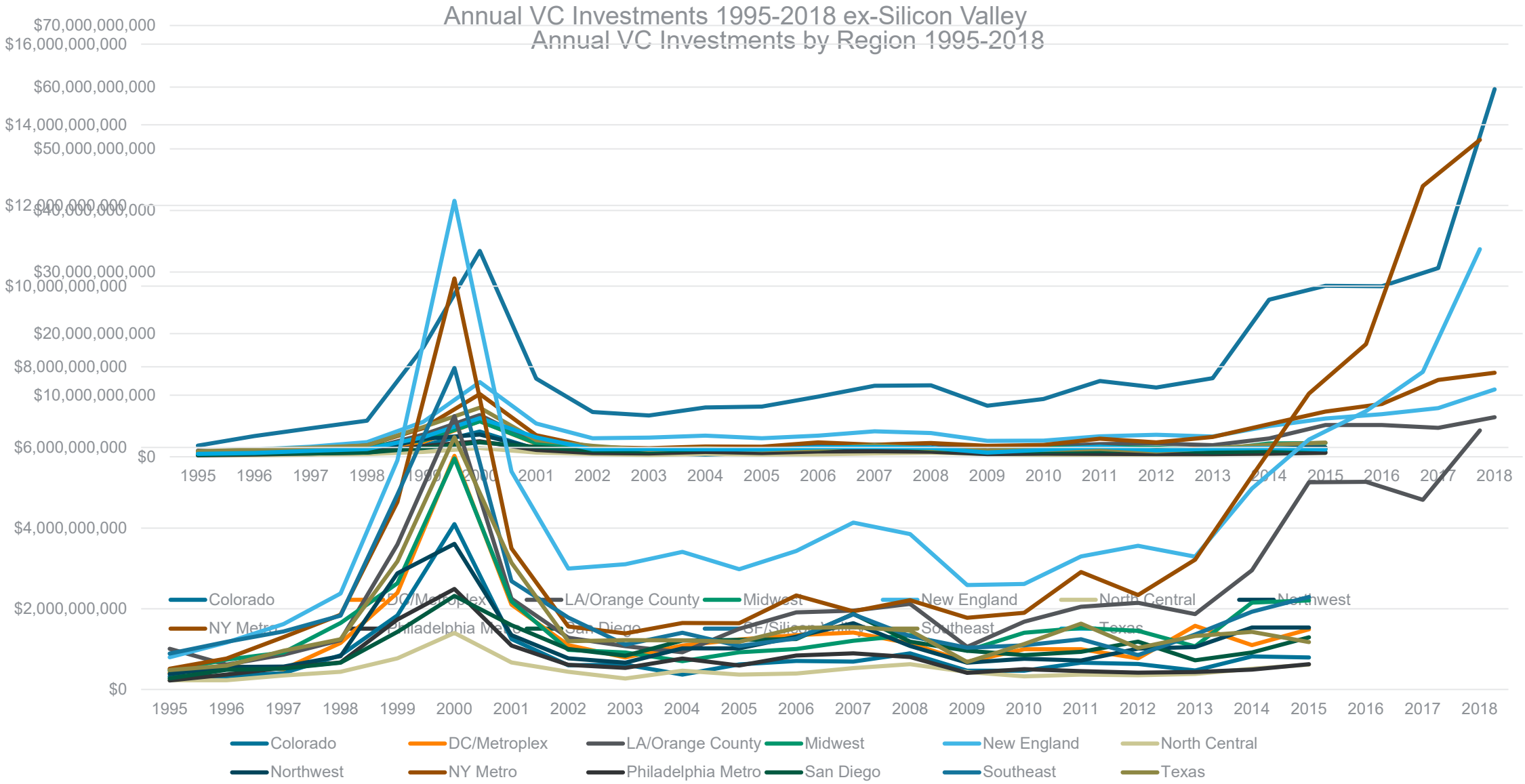
Social Media

The Valley of Death

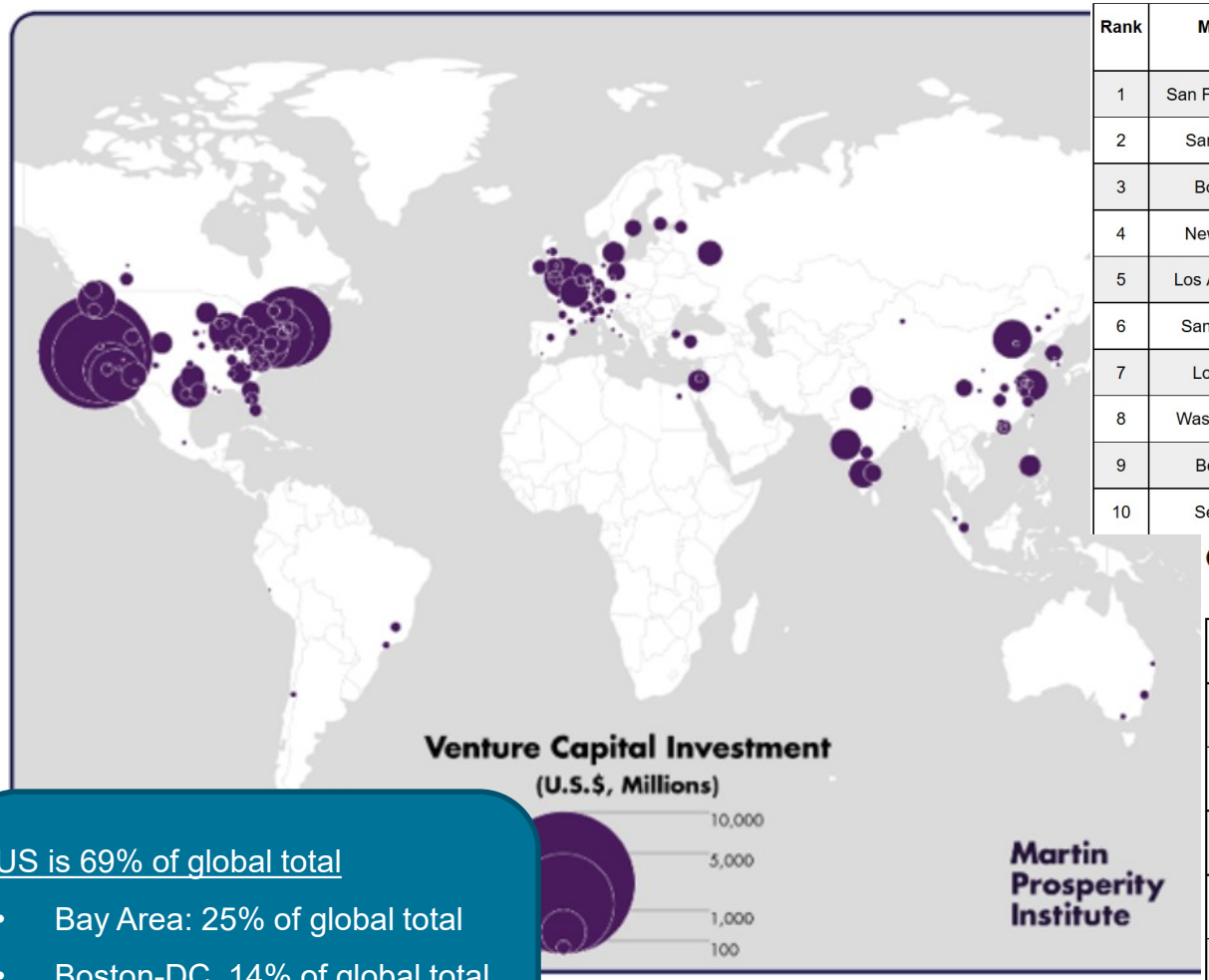


Source: altenergystocks.com (Osawa and Miyazaki, 2006)

Annual VC Investments by Region



The Global Geography of Venture Capital



US is 69% of global total

- Bay Area: 25% of global total
- Boston-DC 14% of global total

Asia 14.5%

Europe 13.5%

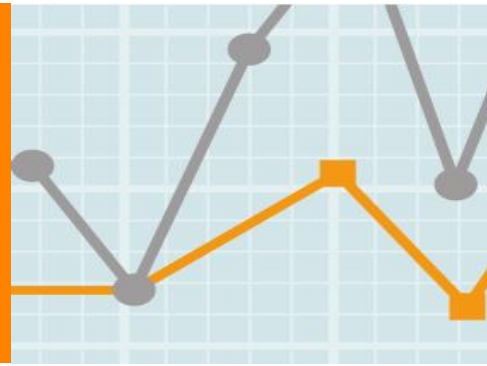
Venture-Capital Investment by City

Rank	Metro	Venture Capital Investment (millions)	Share of Global Venture Capital Investment
1	San Francisco	$6,471	15.4%
2	San Jose	$4,175	9.9%
3	Boston	$3,144	7.5%
4	New York	$2,106	5.0%
5	Los Angeles	$1,450	3.4%
6	San Diego	$1,410	3.3%
7	London	$842	2.0%
8	Washington	$835	2.0%
9	Beijing	$758	1.8%
10	Seattle	$727	1.7%

Cities Ranked by Economy

Metro	Global City Rank	Venture Capital Rank
New York	1	4
London	2	7
Tokyo	3	54
Hong Kong	4	107
Paris	5	16
Singapore	6	79
Los Angeles	7	5
Seoul	8	37

Measuring the Impacts of Innovation



ELSEVIER

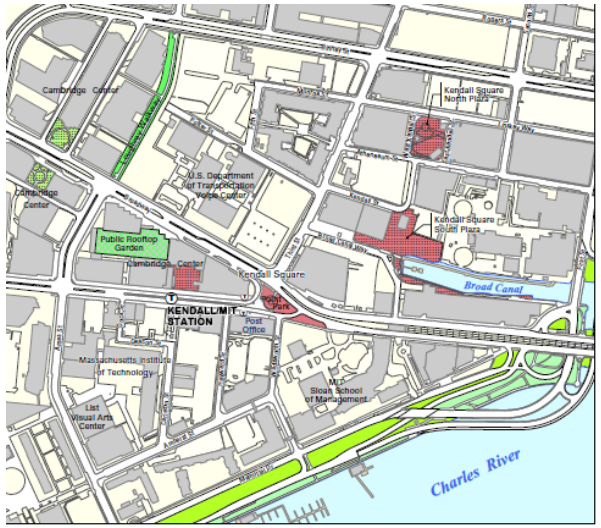
Empowering Knowledge

Measuring the Impact of Innovation

- Topics of Prominence
  - What are they and how do they work?
  - Strategic use to map areas of research strength
  - University/Industry collaboration opportunities
- Usage Data – Abstract Downloads by Originating Institution
- Patent-Cited Publications—Commercialization Footprints
- Institutional Media Mentions and other Metrics

University Impacts on Regional Economies are both Direct and Indirect

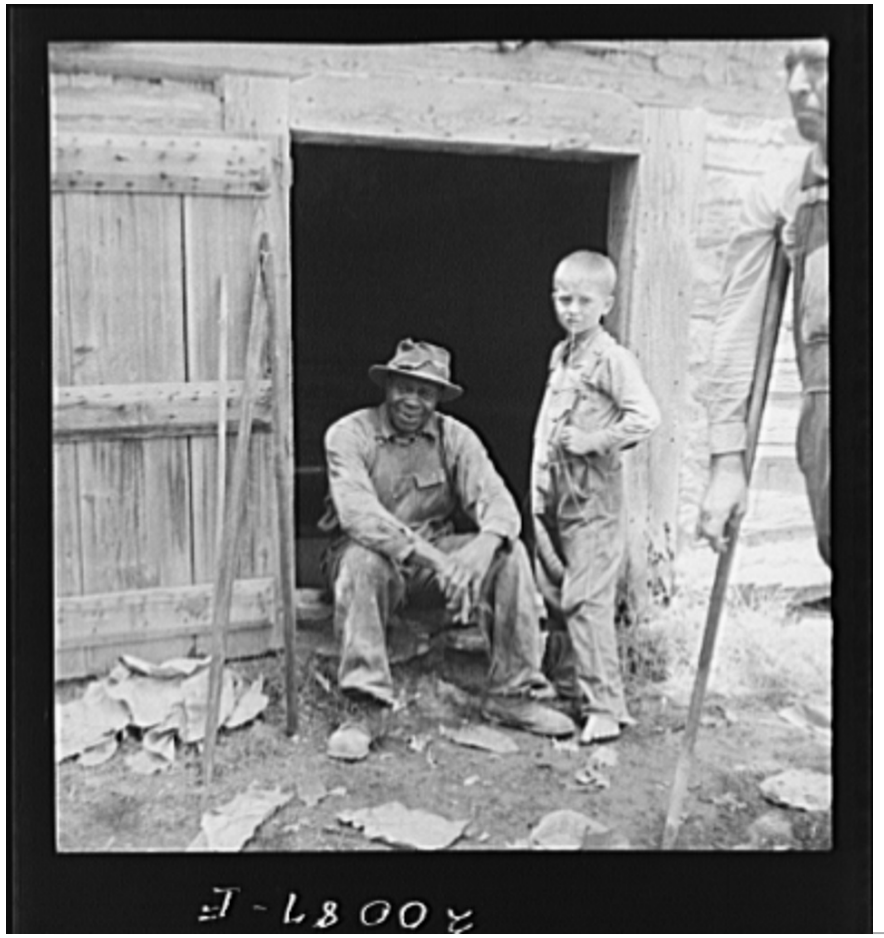
Massachusetts Institute of Technology



- MIT graduates have started over 25,800 currently active companies with annual global sales of $2T.
- If these companies formed an independent nation, the revenues would make that nation the 17th-largest in the world.
- 26% of revenues from all Massachusetts firms are derived from the 6,900 companies in the state founded by MIT graduates, generating an estimated 985,000 jobs. These firms generate $164B in annual sales.
- California has an additional 526,000 jobs from 4,100 MIT-alumni firms, followed by New York with 231,000 jobs.
- Over 30% of foreign MIT students found companies, more than half of which are located in the United States.
- MIT also has direct impacts both formally and informally on cluster formation in Greater Boston Area, including on formation and rapid growth of Kendall Square, housing over 150 biotech and infotech companies in a previously rundown post-industrial area of Cambridge
- Formal entrepreneurial programs at MIT were started in the 1970's largely due to alumni efforts to organize them.
- Over 30% of these companies are manufacturing firms, compared to 11% nationwide, with a high propensity to export to global markets

Source: MIT data in Kaufmann Foundation Study MIT study executive summary

Triple Helix—Origins in Regional Development Strategies



In the 1950s, North Carolina was home to a deteriorating economic base rooted in tobacco, furniture manufacturing, small-scale farming and textiles, and had the second-lowest per capita income in the US. The state's economic future was highly uncertain.

Sources: Photo, Dorothea Lange, Library of Congress; text, www.rtp.org

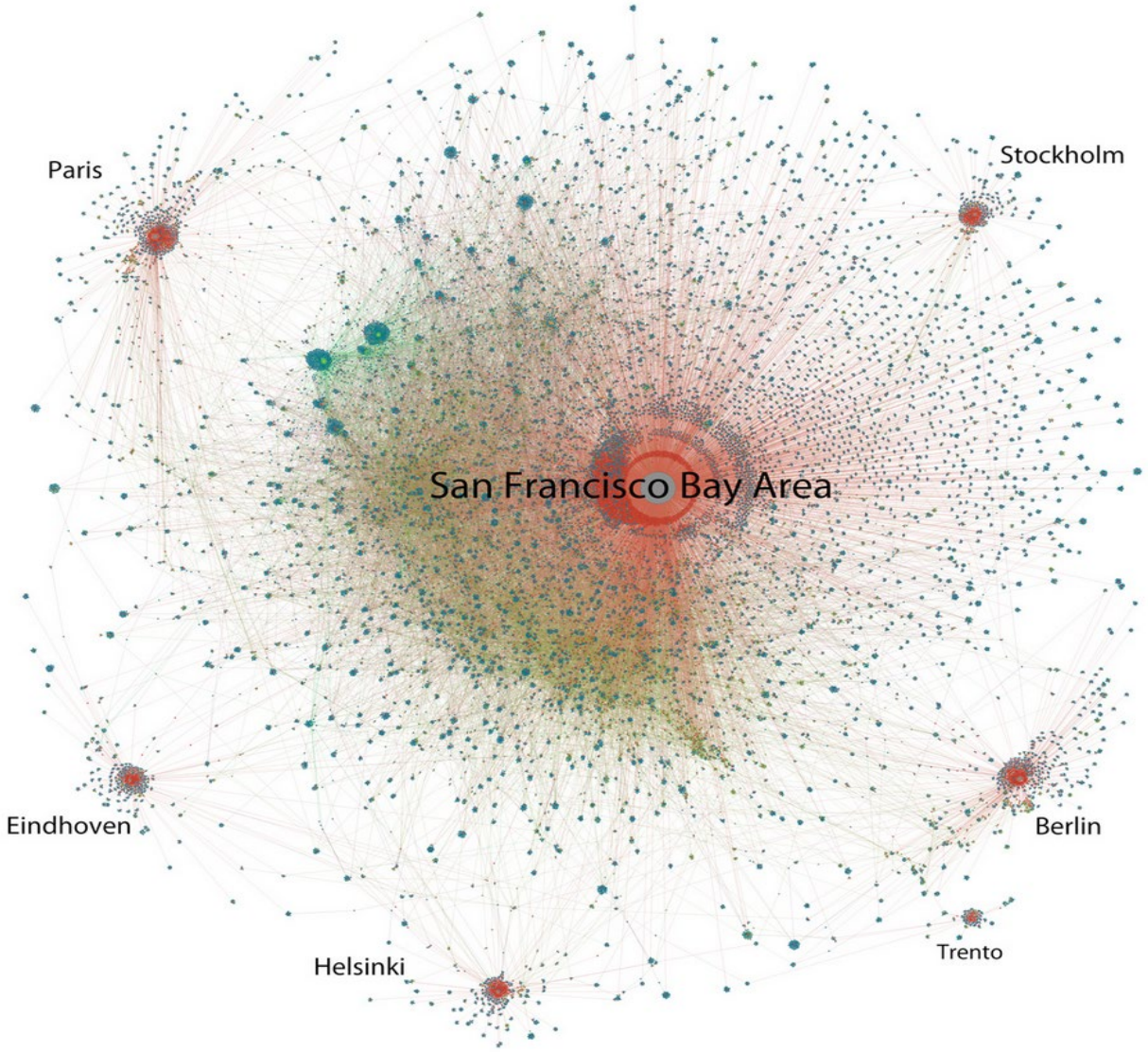
Research Triangle Park—The Mission

"The Research Triangle is the marriage of North Carolina's ideals for higher education and its hopes for material progress"

- High levels of integration between industry, university, and local/state govt.
- Multiple alliances
- Frequent conferences, events, sharing
- Accelerator and incubator space
- Work with voluntary organizations/NGO's
- 40% of 170 resident companies have fewer than 10 employees

Source: www.rtp.org

Key Considerations for Cities to Make Their Case



- **In what areas** does your region have a **critical mass** of talent?
- In which institutions and sectors is that talent concentrated?
- **How connected** are the **key players**?

Source: Innovation Center Denmark on study of networks between EIT ICT labs

Why Innovate?

Industries

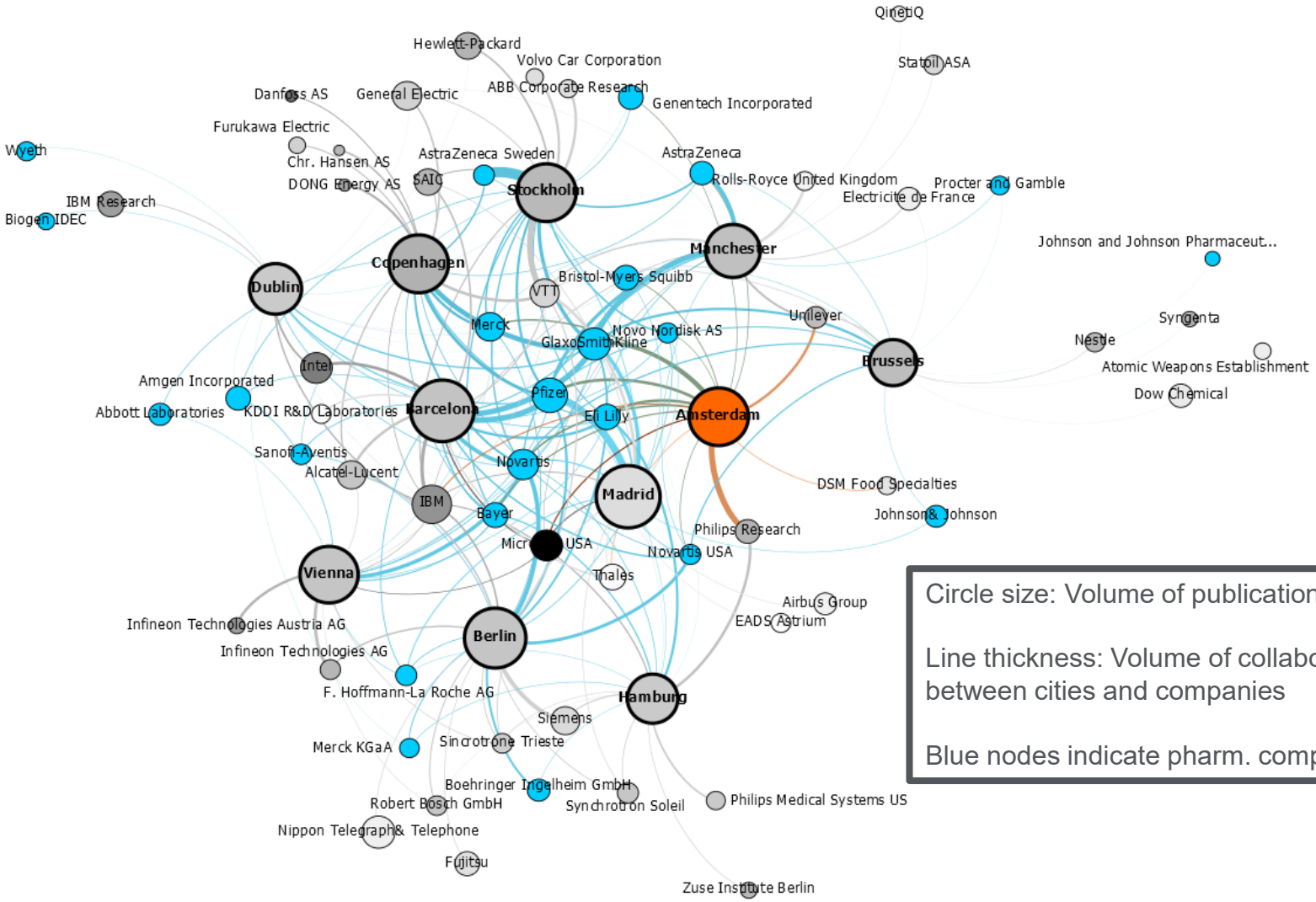
Andhra CM Naidu announces 'Silicon City' near Tirupati, promises one lakh jobs

The announcement came as Naidu laid the foundation for China-based electronics major TCL's unit in Tirupati

TNM Staff | Thursday, December 20, 2018 - 16:17

Follow @thenewsminute

Pharmaceutical companies at the center of Amsterdam and other cities' corporate collaboration networks

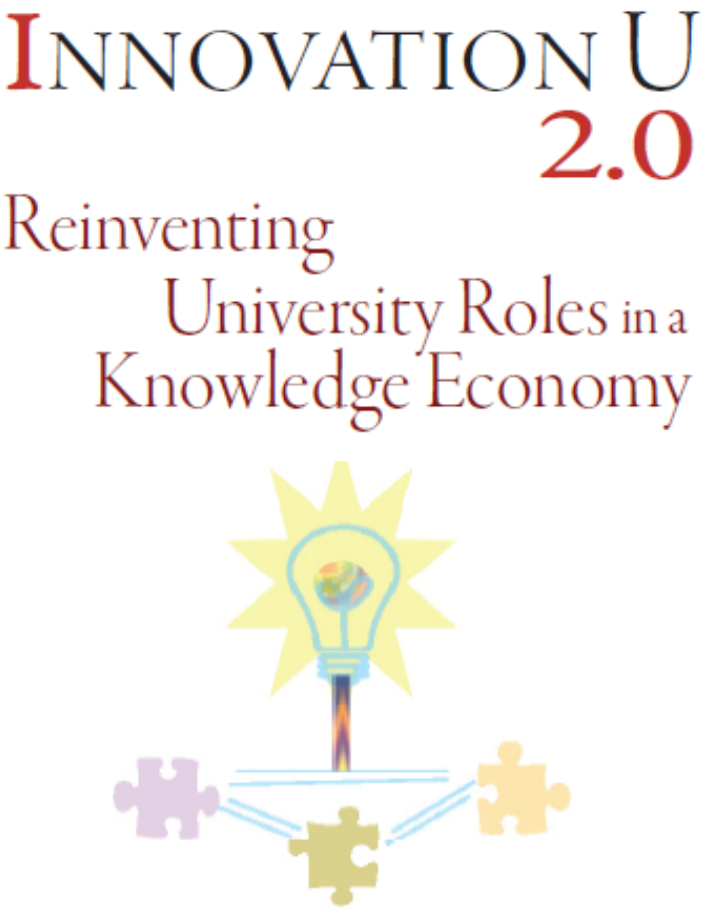


Circle size: Volume of publications 2009-13

Line thickness: Volume of collaboration between cities and companies

Blue nodes indicate pharm. companies

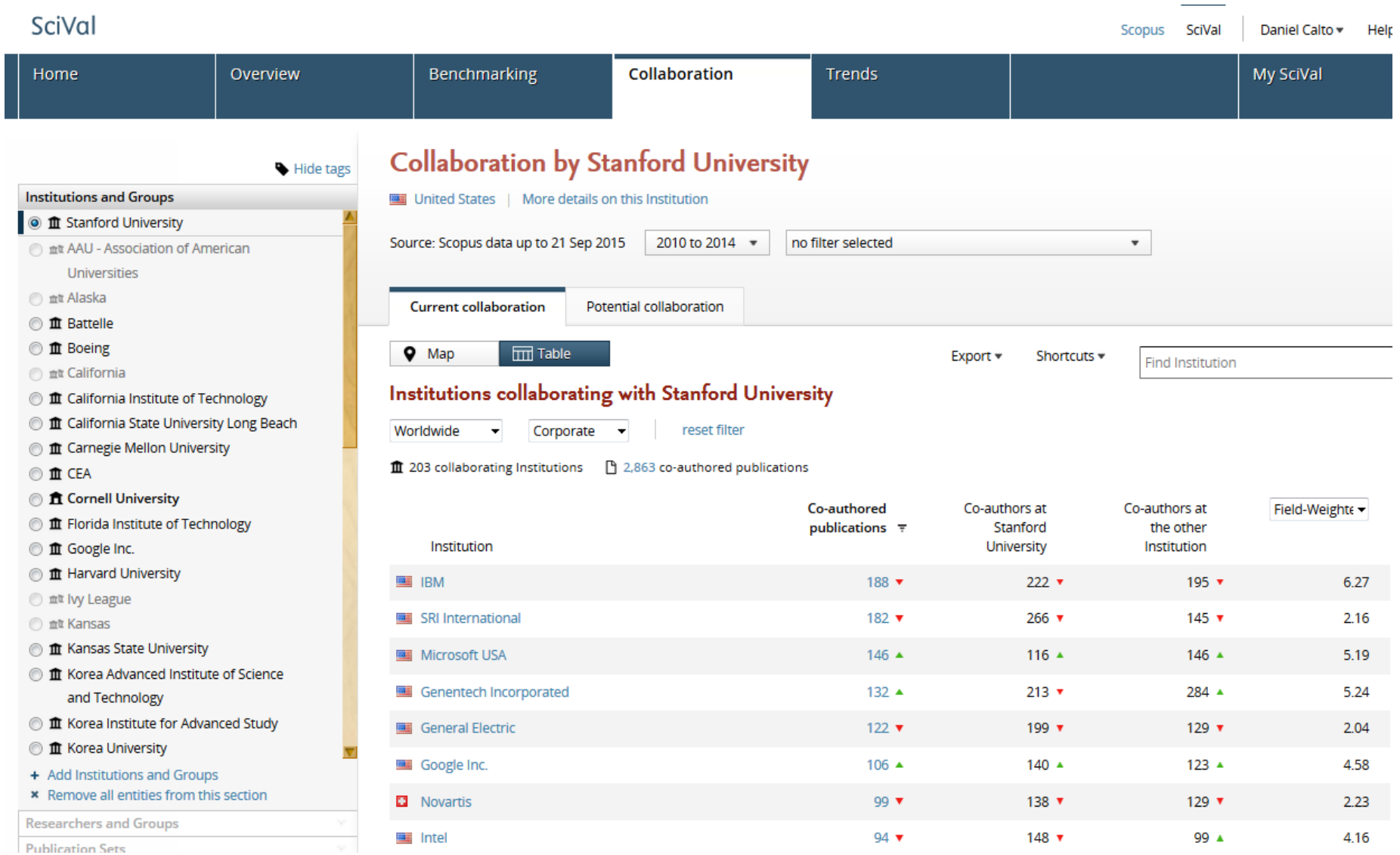
Innovation in Different Geographies



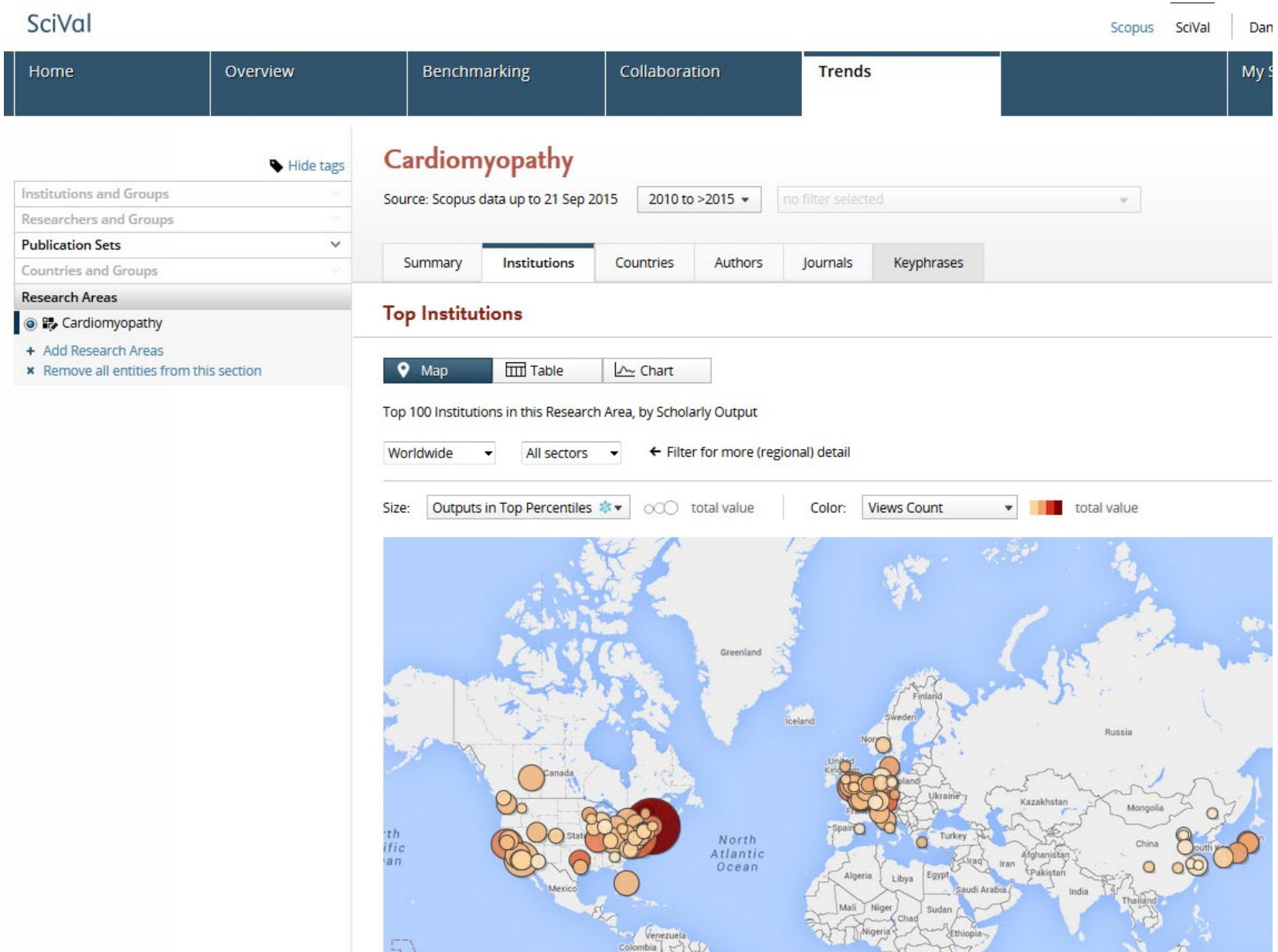
CONTENTS

FOREWORD vii
ACKNOWLEDGEMENTS ix
INTRODUCTION 1
CASES
Arizona State University 19
Brigham Young University 39
California Institute of Technology 51
Carnegie Mellon University 69
Clemson University 91
University of Florida 109
Georgia Institute of Technology 127
Massachusetts Institute of Technology 145
North Carolina State University 171
Purdue University 189
Stanford University 205
University of Utah 225

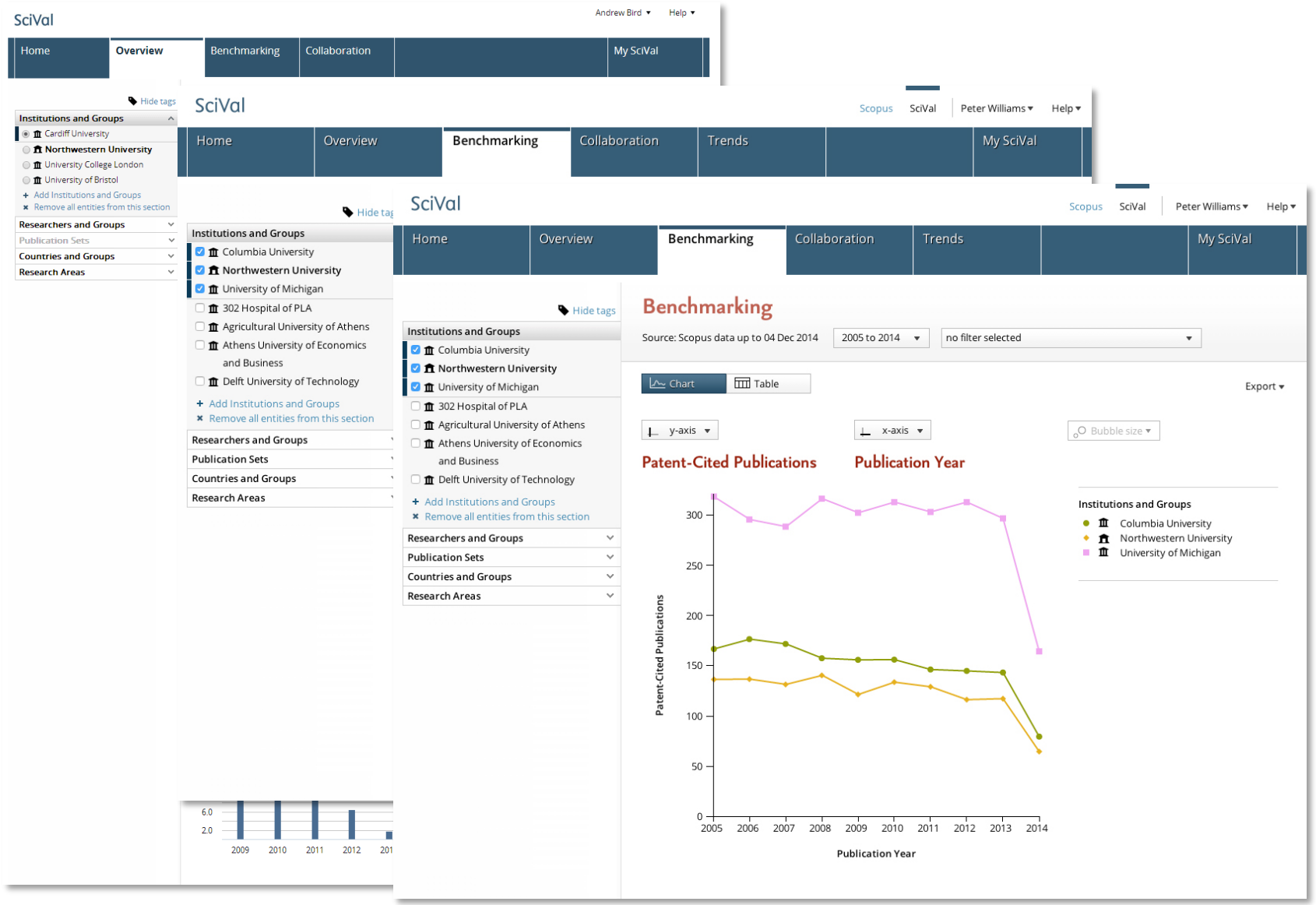
Economic and Societal Impact Metrics – University-Industry Co-Authorship



Economic and Societal Impact Metrics – Usage Data – Abstract Downloads by Originating Institution



Economic and Societal Impact Metrics – Patent-Cited Publications

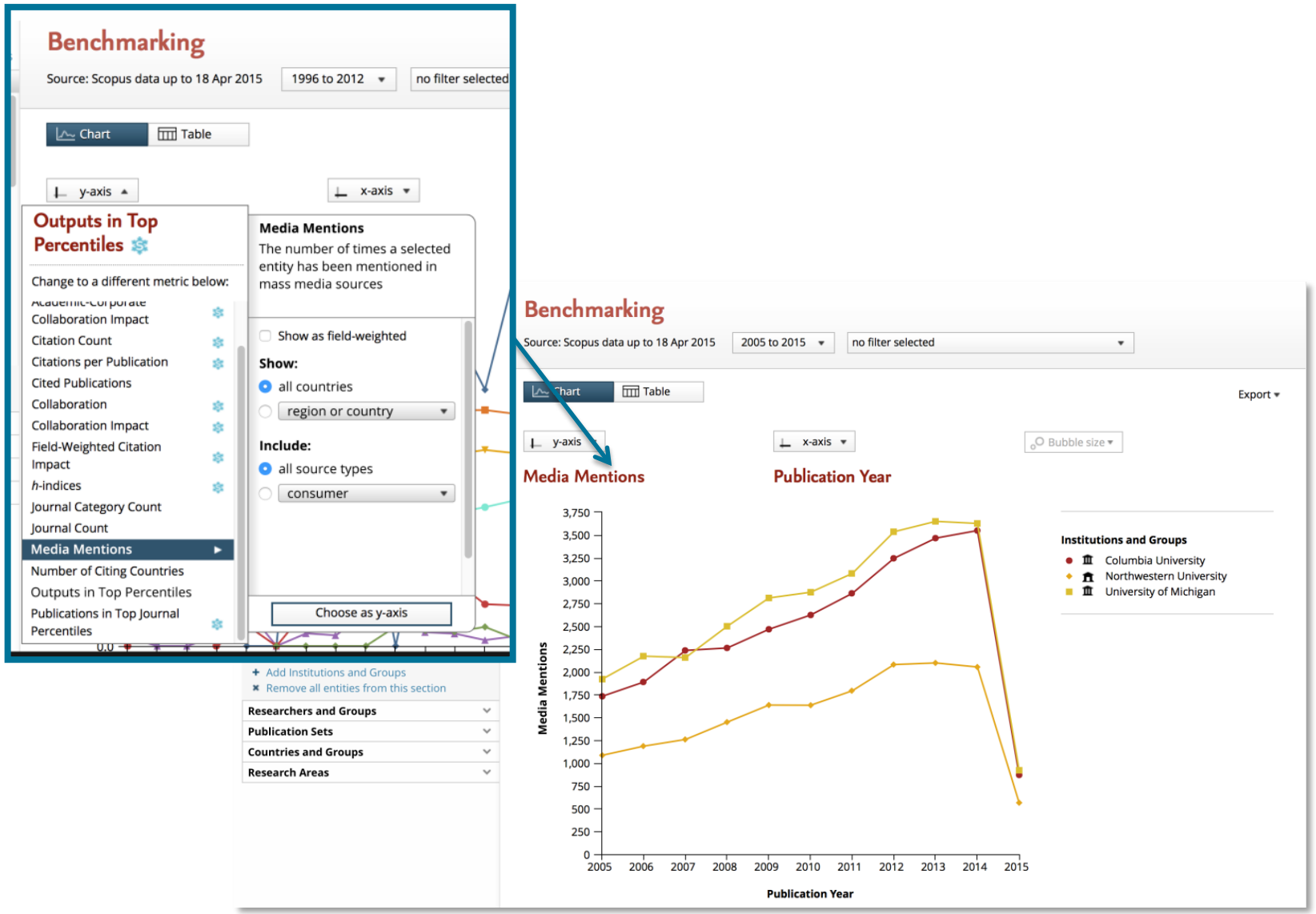


Economic and Societal Impact Metrics– Institutional Media Mentions

- **Newsflo** helps researchers and academic institutions to measure the wider impact of their work by tracking and analyzing media coverage of their publications and findings
- Acquired by Elsevier in January 2015

Matches more than **150,000 articles per day**, based on white list of keywords

Economic and Societal Impact Metrics – Institutional Media Mentions



Data Sources, Tools, and Technologies

Elsevier has a unique vantage point on research

Each year

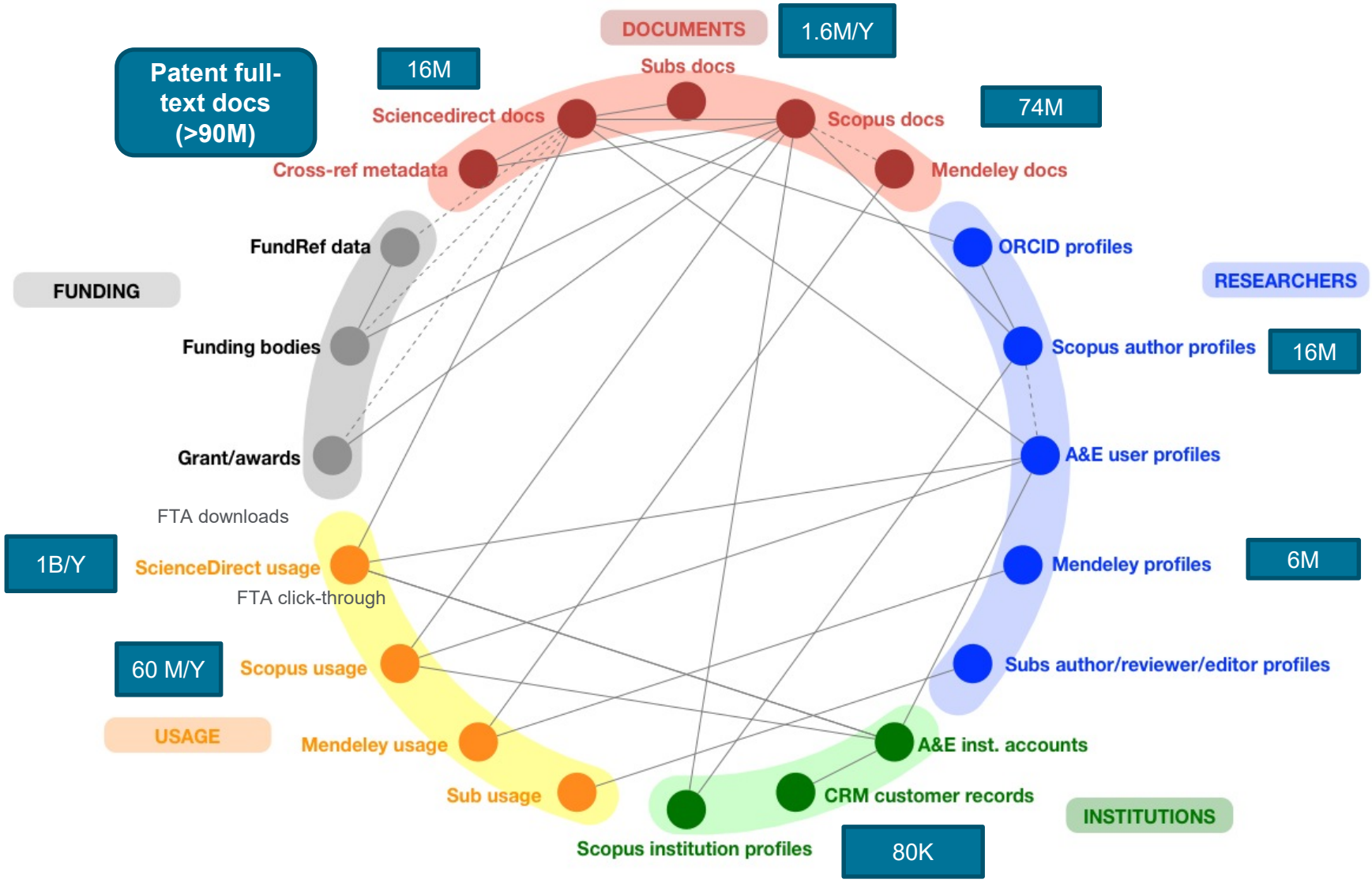
- 1.4 million article manuscripts received by ~2,500 journals (all offer Open Access options)
- 430,000 new articles published, in addition to 11M existing articles
- 2,500 new books published

Primary publishing

- ScienceDirect: 1B digital article downloads
- Scopus: 75M records, 23,500 titles, 5,000 publishers, 700M citations
- SciVal: 75 trillion metrics values
- Pure: current research information system: >200,000 researchers supported
- Mendeley: 6M users globally
- Grants:7,000 sponsors, 20,000+ active opportunities, ~5M awarded grants
- Patents: >93m records, 100 patent offices
- Compounds: 22M compounds, 35M reactions; 3.3M molecular facts
- Drug information: 16k branded drugs; 12k generic drugs

Derived and aggregated data

What Data Do We Bring to the Table?



Scopus Coverage Summary

Global Representation means global discovery

Across all subjects and content types

Scopus includes content from more than 5,000 publishers and 105 countries

- 40 different languages covered
- Updated daily
- Multiple regional content types covered (journals, conferences, books, book series)

Number of Journals by subject area*

- **Physical Sciences** 12,806
- **Health Sciences** 14,264
- **Social Sciences** 11,573
- **Life Sciences** 7,128

Journals	Conferences	Books
23,576 Active peer-reviewed journals**	**106K** Conference events	**742** Book series
308 Trade journals	**9M** Conference papers	**38K** Volumes
4,157 Active Gold OA Journals (Listed DOAJ and/or ROAD)	Mainly Engineering and Computer Sciences	**1.64M** Book Items
229,640 Articles in Press		**195K** Stand-alone books
Full metadata, abstracts and cited references		Focus on Social Sciences and A&H

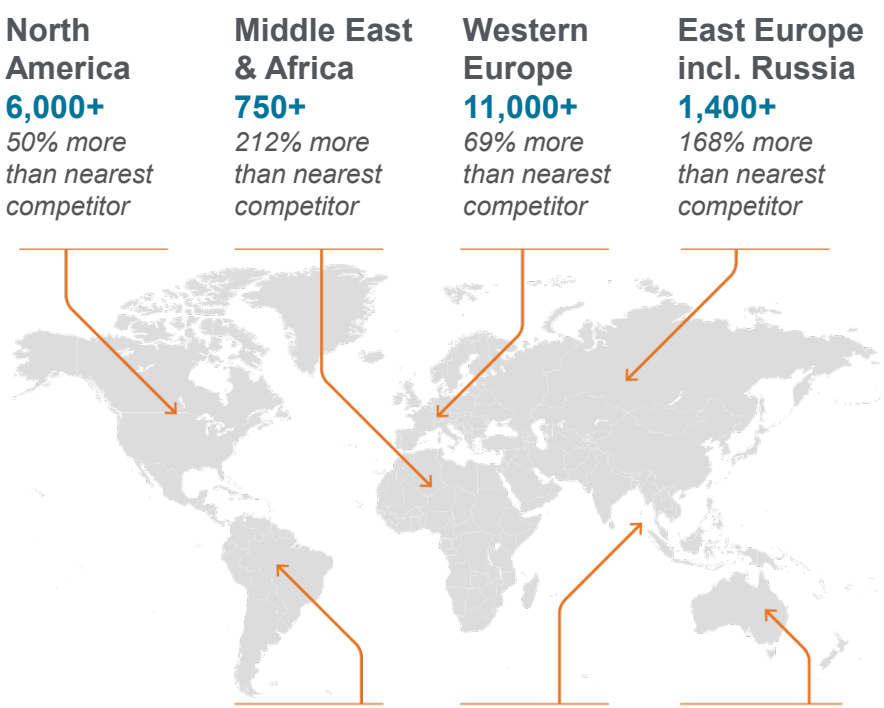
Source: Scopus.com, April 2019

*Journals may be classified in multiple subject areas—these figures include both active and inactive titles

** Excludes currently inactive titles—total number of titles in Scopus is 38,379

Global Representation means global discovery

Across all subjects and content types



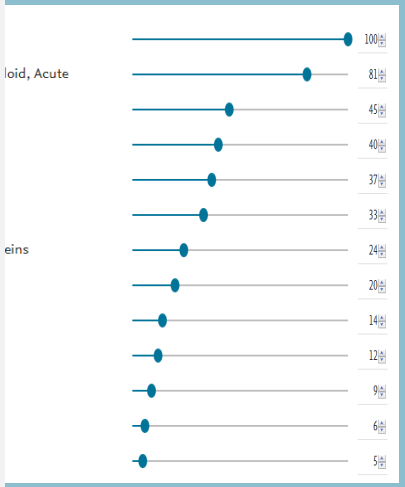
Global Representation
(number of titles)

Natural Language Processing Applied to Text

From Natural Language to Structured Semantic Machine-Readable Text

Source Text → **Text processing pipeline** → **Semantic by Thesauri** → **Concepts Extraction** → **Fingerprint**

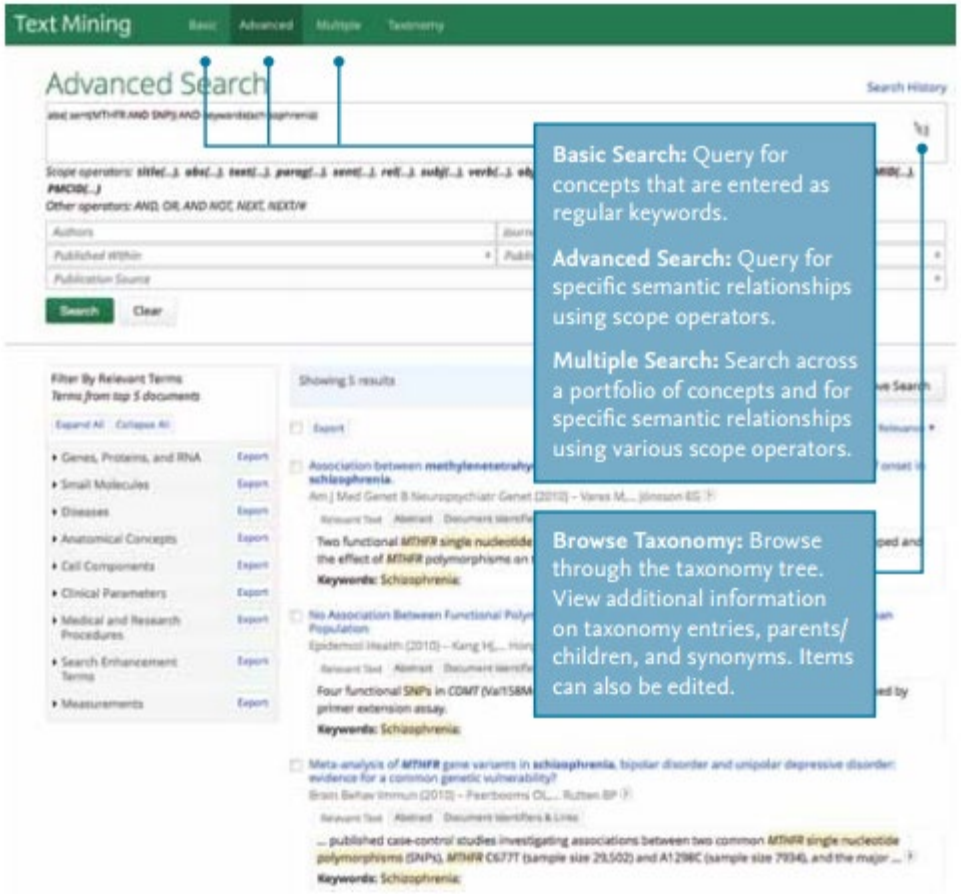
Domain	Thesaurus/Vocabulary
Life Sciences	MeSH thesaurus
Physics	NASA thesaurus
Agriculture	NAL thesaurus
Economics	STW thesaurus, Eco Humanities vocabulary
Social Sciences	Gesis thesaurus
Mathematics	Cambridge Math thesaurus, Math vocabulary
Geosciences	Geobase thesaurus
Engineering	Compendex thesaurus
Humanities	Humanities vocabulary
Compounds (Chemistry)	Compendex thesaurus, MeSH thesaurus



- Any text can be … applications to …
- Fingerprints are generated from the title and abstract
- Natural Language Processing techniques are applied

…xt. Each concept is …s suitable for the scientific area of the text.
- Concepts are weighted to create a precise summary of the text's meaning.

Text mining capabilities



Input

Content (ca. 7 million items)

New content added weekly from public and commercial sources

- Abstracts
- Full-text articles
- Conference proceedings
- Grants
- Clinical Trials
- Patents
- Internal Data

Taxonomy

Keywords and data are extracted from the content, including

- Drug names
- Measurements
- Disease names
- Research methods
- Treatment methods

NLP Engine

Natural language queries find semantic relationships like:

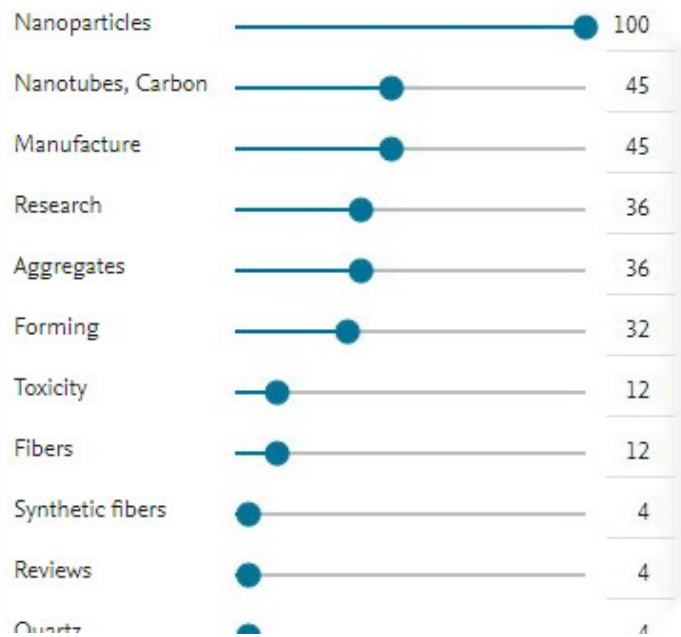
- "Drugs that reduce blood pressure"
- "Synthesis of Thalidomide"
- "Pathogenesis of cancer"
- "Resistance to linezolid"

Output

Output formats suit various user work flows

FPE In Action--Expert Lookup—Global Expertise Search

Abstract: Carbon nanotubes (CNT) are an important new class of technological materials that have numerous novel and useful properties. The forecast increase in manufacture makes it likely that increasing human exposure will occur, and as a result, CNT are beginning to come under toxicological scrutiny. This review seeks to set out the toxicological paradigms applicable to the toxicity of inhaled CNT, building on the toxicological database on nanoparticles (NP) and fibers. Relevant workplace regulation regarding exposure is also considered in the light of our knowledge of CNT. CNT could have features of both NP and conventional fibers, and so the current paradigm for fiber toxicology, which is based on mineral fibers and synthetic vitreous fibers, is discussed. The NP toxicology paradigm is also discussed in relation to CNT. The available peer-reviewed literature suggests that CNT may have unusual toxicity properties. In particular, CNT seem to have a special ability to stimulate mesenchymal cell growth and to cause granuloma formation and fibrogenesis. In several studies, CNT have more adverse effects than the same mass of NP carbon and quartz, the latter a commonly used benchmark of particle toxicity. There is, however, no definitive inhalation study available that would avoid the potential for artifactual effects due to large mats and aggregates forming during instillation exposure procedures. Studies also show that CNT may exhibit some of their effects through oxidative stress and inflammation. CNT



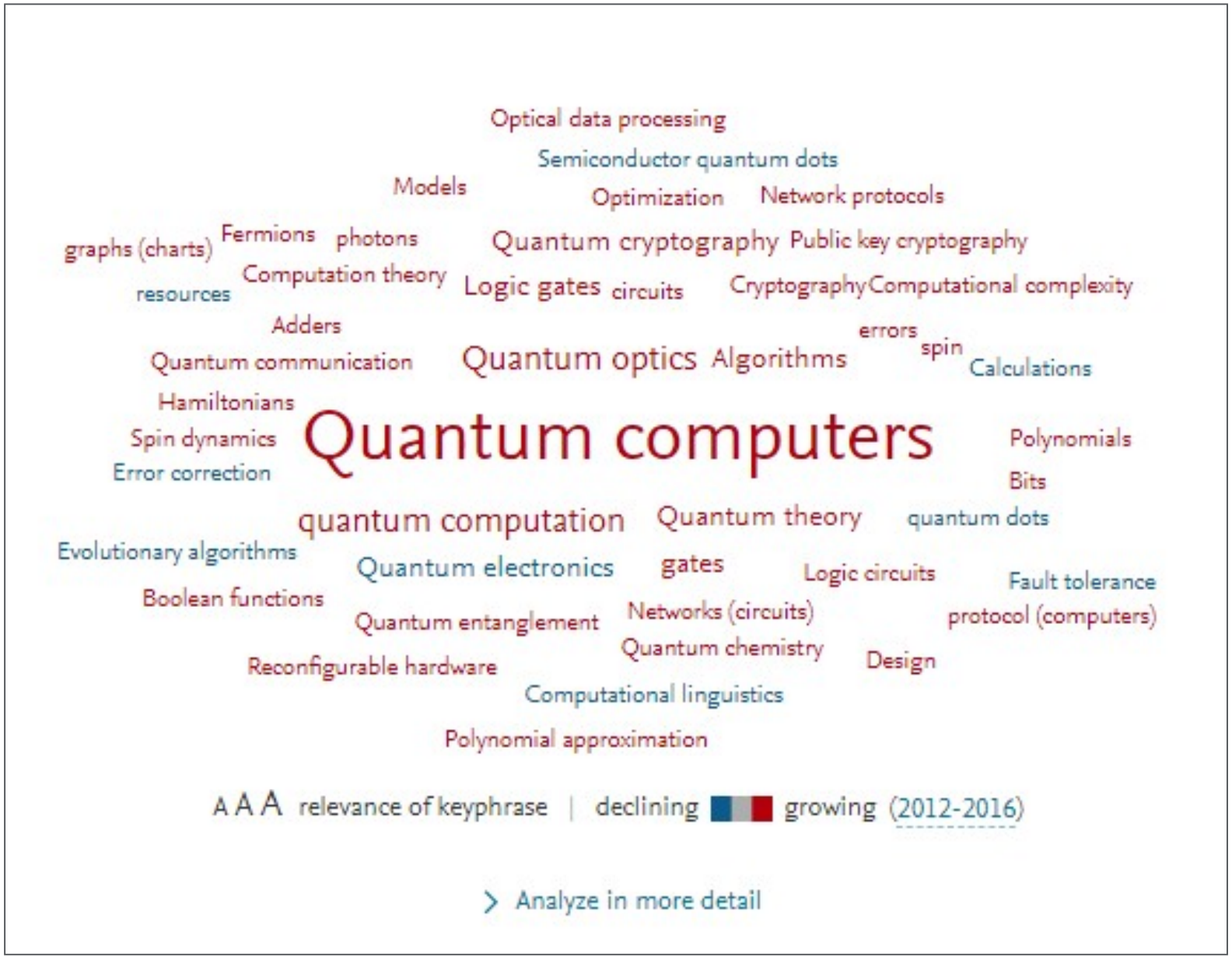
Fingerprints Nanoparticles, Manufacture, Nanotubes, Carbon, Research, Aggregates,

200 experts based on Chemistry thesaurus

Search within results

Rank	Name	Institution	Matching pub.	First author	Last author	Total pub.	h-Index
	Thomas D. Pollard	Yale University	2	1	1	146	97
	Michael P. Sheetz	Mechanobiology Ins...	3	0	2	183	96
	James A. Spudich	Stanford University ...	2	0	0	107	72
	Fei Wei	Tsinghua University	2	0	1	478	66
	H. Lee Sweeney	University of Florida...	3	0	1	162	64
	Jean François Joanny	Universite Paris Sor...	2	0	0	157	61
	James R. Sellers	National Heart, Lun...	4	0	2	111	60
	Shouzhuo Yao	Hunan Normal Uni...	3	0	2	566	60

FPE in Action: SciVal



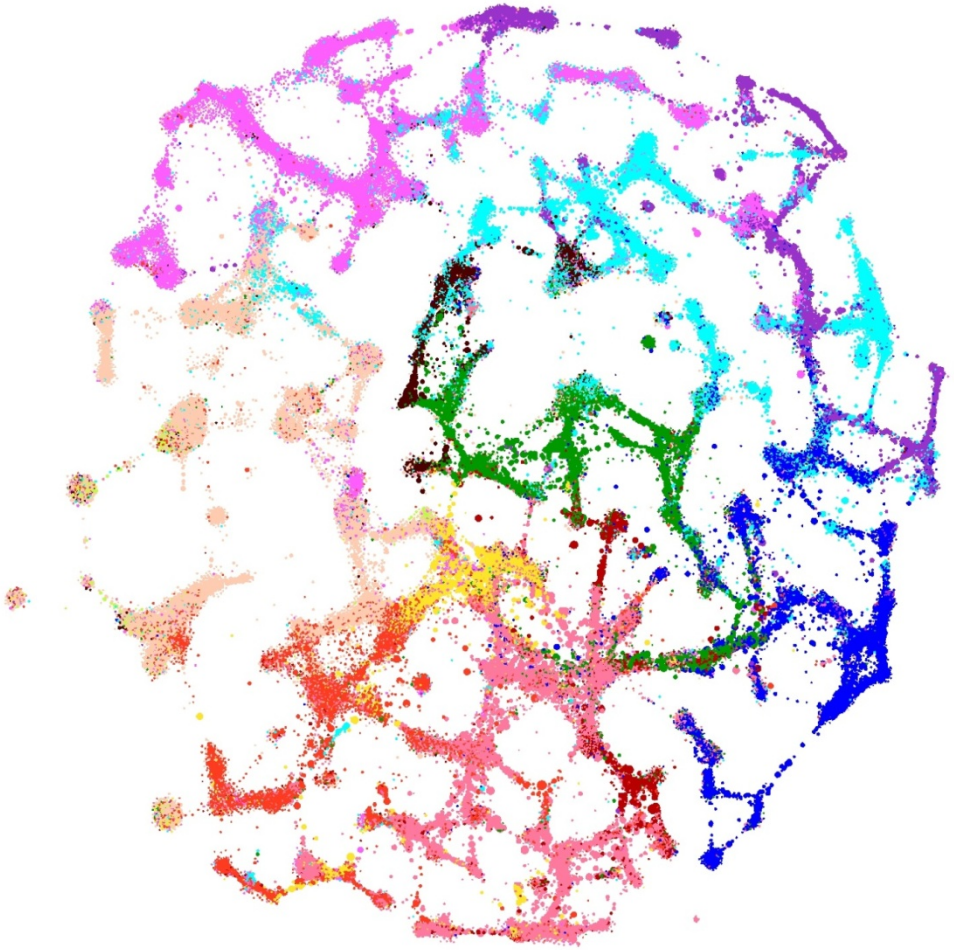
Topics of Prominence—Topic Modelling and Analysis

History of Topic Modelling Using Abstracts/Citation Databases

- **Research Fronts (1985)** 2% coverage 10,000 clusters
- **Research Communities** 4% coverage 35,000 clusters
- **Distinctive Competencies** 15% coverage 200,000 clusters
- **Topics** 95% coverage 100,000 clusters
- **Topic Prominence (2017)** Predicts funding
  - Full coverage and accurately models supply of and demand for science

Example model and map

- Using 2013-10 datacut (source data 1996-2012)
- 582 million citing-cited pairs, 24.6 million source EID, 23.8 million cited non-indexed EID
- Calculated relatedness for 582 million pairs
- Ran SLM using resolution of 3×10^{-5}
- A few clusters with <50 items were merged with larger clusters
- Result – 97,726 clusters (topics)



Klavans, R. and K.W. Boyack, Research portfolio analysis and topic prominence. Journal of Informetrics, 2017 (under review).

Topic Modelling Design and Structure

Needs

- Coverage: A complete list of topics in science
- Granularity: Topics that are of the appropriate size and number
- Accuracy: Accurate topics that contain the right papers
- Stability: Topics with realistic dynamics

Structure

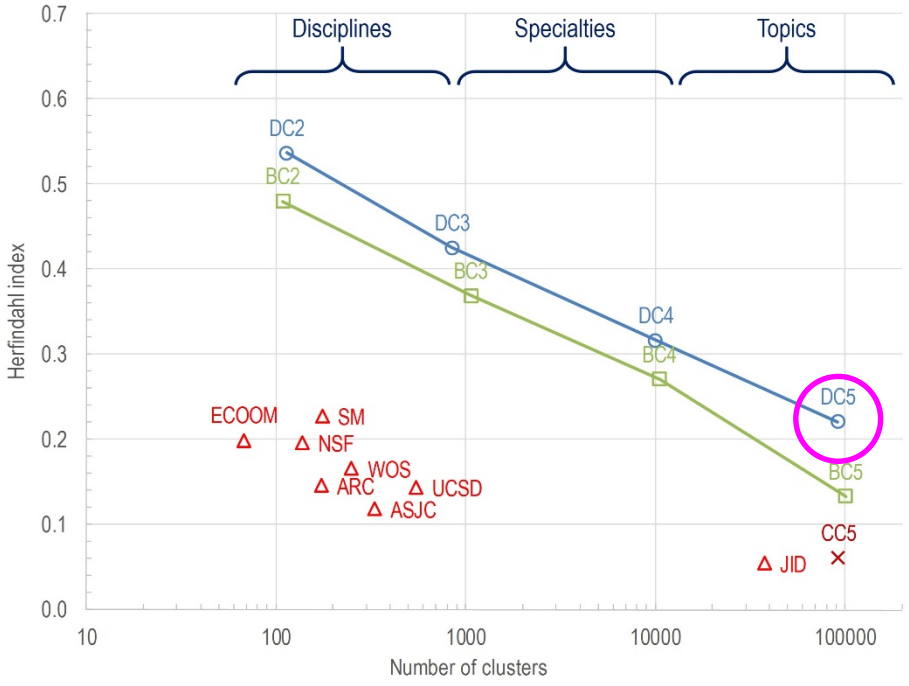
- Based on needs, aimed at portfolio analysis, we choose to identify roughly 100,000 topics in science using direct citation on the citation linkages (including those to cited non-indexed items) in the full Scopus database

Number of topics

- NEEDS
  - Granularity: Topics that are of the appropriate size and number
  - Most analysis done using (~250-350) journal subject categories
  - While this is OK for some tasks, it is not sufficient for portfolio analysis
  - Researchers and funding program officers can differentiate between 100,000 topics
  - Early work on scientific specialties suggested that they were comprised on average of about 100 authors
  - 10,000,000 Scopus authorIDs have published in the last 4 years
  - This suggests around 100,000 topics in science
  - For portfolio analysis, use around 100,000 topics

Design needs and choices

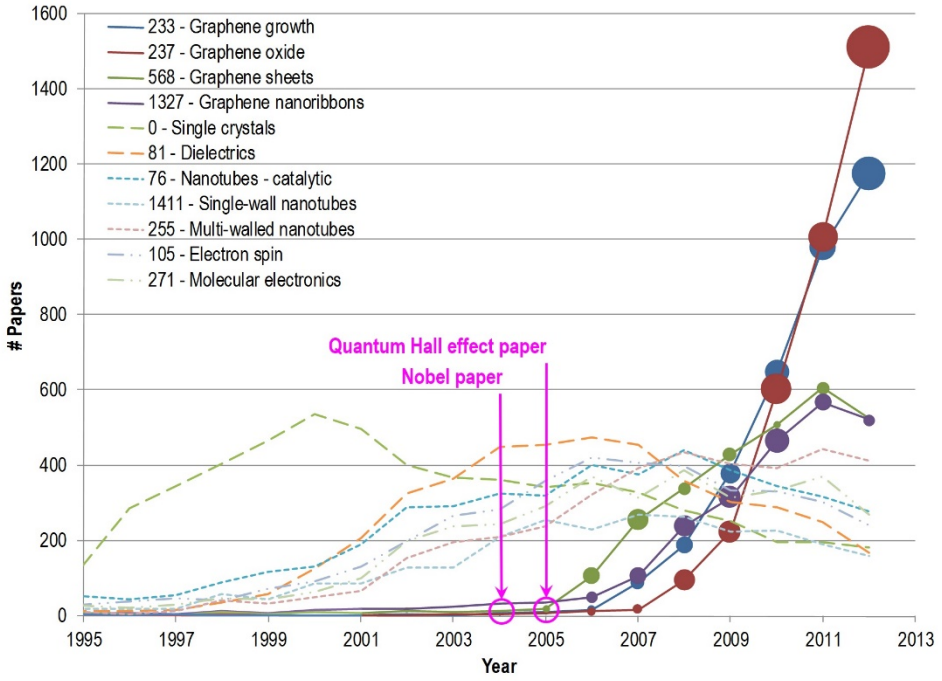
- NEEDS
  - Accuracy: Accurate topics that contain the right papers
  - Comprehensive analysis at scale shows that topics based on direct citation are far more accurate than those based on bibliographic coupling or co-citation
  - Also, they are much more accurate than journal categories
  - Use topics identified using direct citation



Klavans, R. and K.W. Boyack, Which type of citation analysis generates the most accurate taxonomy of scientific and technical knowledge? JASIST, 2017. 68(4): p. 984-998.

Design needs and choices

- NEEDS
  - Stability: Topics with realistic dynamics
  - Paper overlaps from year-to-year are unstable; only half of papers cited n times in one year are cited at the same level the next year
  - Topics created using bibliographic coupling or co-citation are inherently unstable; most new topics disappear after one or two years
  - Topics created using direct citation have realistic dynamics; low birth and death rates, s-curve histories



Boyack, K.W. and R. Klavans, R. Creation and analysis of large-scale bibliometric networks. Springer Handbook of Science and Technology Indicators, 2018 (to appear).

Single topic characterization for 97,000 Topics

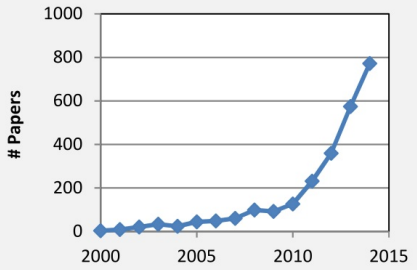
DC5 7909

FOM: 2.9852 (98.07%); CPP: 21.069

ENGNG; DC4:20; DC3:269; DC2:23; REG:105

TOP PHRASES (2011-2015)	score
1 anode material	20
2 anode materials	20
3 batteries LIBs	20
4 capacity retention	20
5 cycling stability	20
6 discharge capacity	20
7 electrochemical performances	20
8 electrode materials	20
9 electron microscopy	20
10 graphene oxide	20

IDIOSYNCRATIC PHRASES (2011-2015)	score
1 mA g⁻¹	60.97
2 batteries LIBs	40.07
3 superior electrochemical	30.01
4 lithium storage	22.27
5 anode materials	16.07
6 anode material	15.77
7 mAh g⁻¹	15.65
8 reversible capacity	15.13
9 metal oxides	13.96
10 conversion reaction	12.85



TOP CATEGORIES (2011-2015)	score
1 Nanoscience & Nanotechnology	0.98
2 Energy	0.78
3 Materials	0.27
4 General Chemistry	0.05
5 Unclassified	0.04
6 Physical Chemistry	0.03
7 Inorganic & Nuclear Chemistry	0.03
8 Organic Chemistry	0.01
9 Chemical Physics	0.01
10 Applied Physics	0.01

TOP SOURCES (2011-2015)	score
1 electrochim acta	2.96
2 j mater chem a	2.85
3 j power sources	1.78
4 nano energy	1.13
5 acs appl mater interfaces	0.78
6 rsc adv	0.59
7 nanoscale	0.45
8 j mater chem	0.43
9 mater lett	0.41
10 j alloys compd	0.26

TOP INSTITUTIONS (2011-2015)	count
1 Nanyang Technological University	130
2 University of Science and Technology of	108
3 Shandong University	115
4 XiangTan University	37
5 CAS - Changchun Institute of Applied Ch	40
6 China Three Gorges University	30
7 University of Wollongong	49
8 Anhui University of Technology	24
9 Zhejiang Normal University	26
10 CAS - Shanghai Institute of Ceramics	24

TOP AUTHORS (2011-2015)	score
1 Ni S. (China Three Gorges University)	29
2 Qian Y. (University of Science and Techn	44
3 Yang X. (China Three Gorges University)	29
4 Ma J. (China Three Gorges University)	14
5 Lv X. (China Three Gorges University)	14
6 Pereira N. (Rutgers University)	14
7 Amatucci G.G. (Rutgers University)	19
8 Xiong Q.Q. ()	16
9 Zhang J. (China Three Gorges University	10
10 Xiong S. (Shandong University)	19

REPRESENTATIVE PAPERS (2011-2014)	ncited
1 Reddy M.V. (2013) Metal oxides and oxysalts as anode materials for Li ion batteries. Chemical Reviews	530
2 Zhu X. (2011) Nanostructured reduced graphene oxide/Fe2O3 composite as a high-performance anode mater	514
3 Ji L. (2011) Recent developments in nanostructured anode materials for rechargeable lithium-ion batteries. En	576
4 Wang Z. (2012) Assembling carbon-coated Î±-Fe2O3 hollow nanohorns on the CNT backbone for superior lith	270
5 Wang J.-Z. (2011) Graphene-encapsulated fe3O4 nanoparticles with 3d laminated structure as superior anode	230
6 Wang B. (2011) Quasiemulsion-templated formation of Î±-Fe2O3 hollow spheres with enhanced lithium storag	350
7 Sun B. (2011) MnO/C core-shell nanorods as high capacity anode materials for lithium-ion batteries. Journal o	118
8 Deng Y. (2011) One-pot synthesis of ZnFe2O4/C hollow spheres as superior anode materials for lithium ion ba	106
9 Jin S. (2011) Facile synthesis of hierarchically structured Fe3O4/carbon micro-flowers and their application to	127
10 Wu H.B. (2012) Nanostructured metal oxide-based materials as advanced anodes for lithium-ion batteries. Na	324

Topic Prominence—How is It Calculated?

Table 2. Factor loadings and scoring coefficients used to calculate topic prominence.

	Factor 1	Factor 2	Normalized Score
L:Citations	0.837	- 0.244	0.495
L:Views	0.812	- 0.262	0.391
L:CiteScore	0.653	0.154	0.114
L:Authors	0.593	0.334	(not used)
Vitality	0.441	0.269	(not used)

- Factor 1 has an eigenvalue of 2.33 (very high), suggesting that the composite indicator should include Citations, Views, Citescore

- Other formulations with more features were tested, but they did not have greater explanatory power than the 3-feature indicator

- $P_j = 0.495\ (C_j - mean(C_j))/stdev(C_j) + 0.391\ (V_j - mean(V_j))/stdev(V_j) + 0.114\ (CS_j - mean(CS_j))/stdev(CS_j)$,

Topics of Prominence—Highly Correlated with Funding

- Funding divided into two time periods (2008-10, 2011-13)
- Prominence was calculated as of 2010

Table 4. Correlation matrix for variables considered in the funding prediction analysis.

	L:Fund1113	L:Fund0810	Prominence	Vitality	L:Authors
L:Fund1113	1.000				
L:Fund0810	0.837	1.000			
Prominence	0.606	0.616	1.000		
Vitality	0.166	0.162	0.314	1.000	
L:Authors	0.160	0.171	0.242	0.202	1.000

- Funding in two time periods is extremely highly correlated
- Prominence is highly correlated with funding in both time periods

Summary

- We have created an accurate model with nearly 100,000 topics that is suitable for portfolio analysis
    - The methodology can be easily reproduced, but requires a full database
- We have created a topic-level indicator – Prominence – that is strongly correlated with funding levels
- Funding per author increases with increasing topic prominence
- Topics and their prominence help stakeholders in the research system to have the knowledge necessary to make better portfolio decisions

Topics of Prominence Paper References

Klavans, R. and Boyack, K.W. Which Type of Citation Analysis Generates the Most Accurate Taxonomy of Scientific and Technical Knowledge? Journal of the Association for Information Science and Technology, 68(4):984–998, 2017

Klavans, R., & Boyack, K. W. (2017). Research portfolio analysis and topic prominence. Journal of Informetrics, Volume 11, Issue 4, November 2017, Pages 1158-1174.

Boyack, K.W. and R. Klavans, R. Creation and analysis of large-scale bibliometric networks. Springer Handbook of Science and Technology Indicators, 2018 (to appear).

Richard Klavans, SciTech Strategies, Inc., Wayne, PA 19087. E-mail: rklavans@mapofscience.com

Kevin W. Boyack, SciTech Strategies, Inc., Albuquerque, NM 87122. E-mail: kboyack@mapofscience.com

Topics of Prominence—Country-Level and Links to Manufacturing Capabilities

United States—Country Output

United States

2012 to 2016 | no subject area filter selected | ASJC | Data sources

Summary | Topics | Awarded Grants | Published | Viewed | Cited | Economic Impact | Authors | Institutions

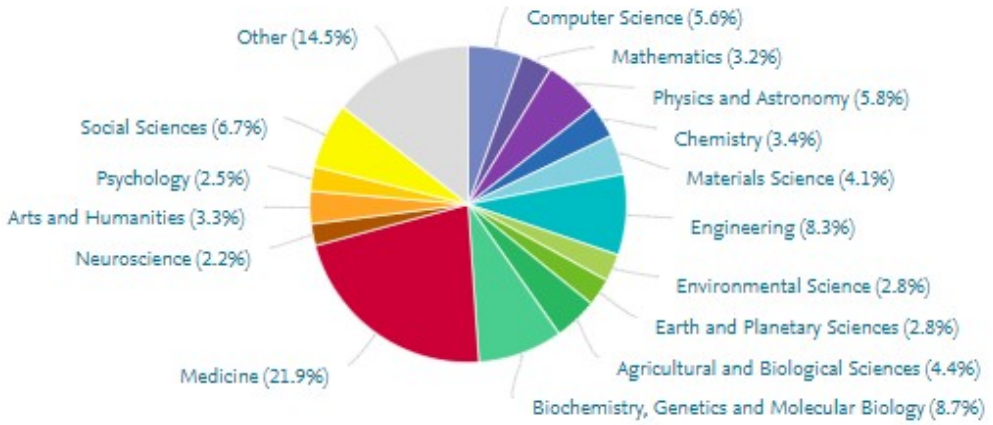
Overall research performance

Download page as PDF | Export

Publications	Citations	Authors	Field-Weighted Citation Impact	Citations per Publication
3,210,189 ▼	24,767,636	2,560,062 ▲	1.47	7.7

View list of publications

+ Add to Reporting



› Analyze in more detail

United States—Topics of Prominence

United States

2012 to 2017 | no filter selected | ASJC | Data s

Summary | Topics | Awarded Grants | Published | Viewed | Cited | Economic Impact | Authors | Institutions

Browse Topics

Exp

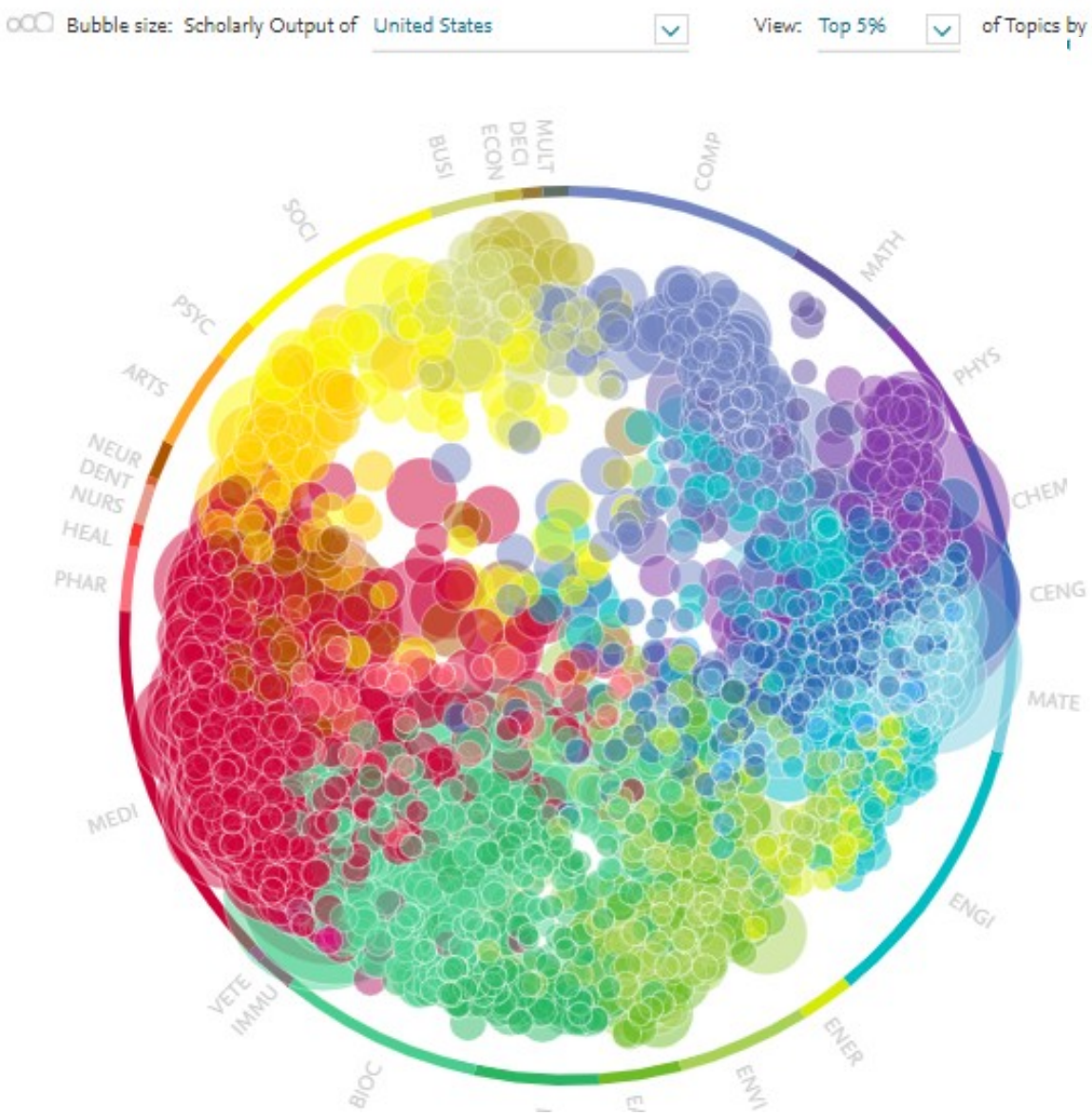
Researchers in the United States have contributed to 90,988 topics between 2012 to 2017

Table | Wheel

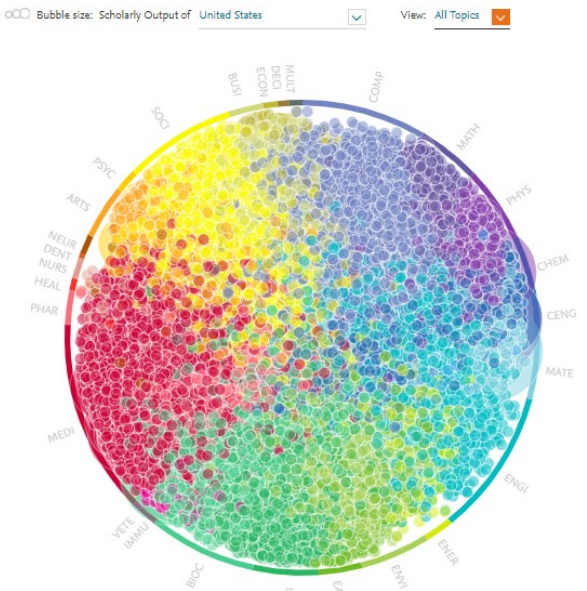
Search this Country's Topics

Topic	In this Country: Scholarly Output	In this Country: Publication Share	In this Country: Field-Weighted Citation Impact	Worldwide: Prominence percentile
Molybdenum compounds; Monolayers; dichalcogenides TMDs ... T.63	2,013	35.51% ▼	5.42	99.999
Analgesics, Opioid; Prescriptions; opioid prescriptions ... T.248	1,989	69.59% ▲	2.53	99.762
Genome; RNA, Guide; effector nucleases ... T.456	1,829	45.49% ▼	5.94	99.998
Immunotherapy; Melanoma; immune-related adverse ... T.403	1,765	44.81% ▼	9.96	99.991
Brain; Magnetic Resonance Imaging; network DMN ... T.219	1,689	47.19% ▼	2.97	99.940
Hepacivirus; Hepatitis C; direct acting ... T.608	1,606	47.54% ▼	4.65	99.955
Sports; Athletes; sport-related concussion ... T.952	1,560	71.33% ▲	2.29	99.725
Heart-Assist Devices; Heart Failure; pump thrombosis ... T.121	1,555	60.93% ▼	1.69	99.229
planet; planets; planet candidates ... T.131	1,545	62.15% ▲	2.18	99.740
Hemorrhagic Fever, Ebola; Ebolavirus; ebola virus ... T.182	1,518	46.06% ▼	3.35	99.968

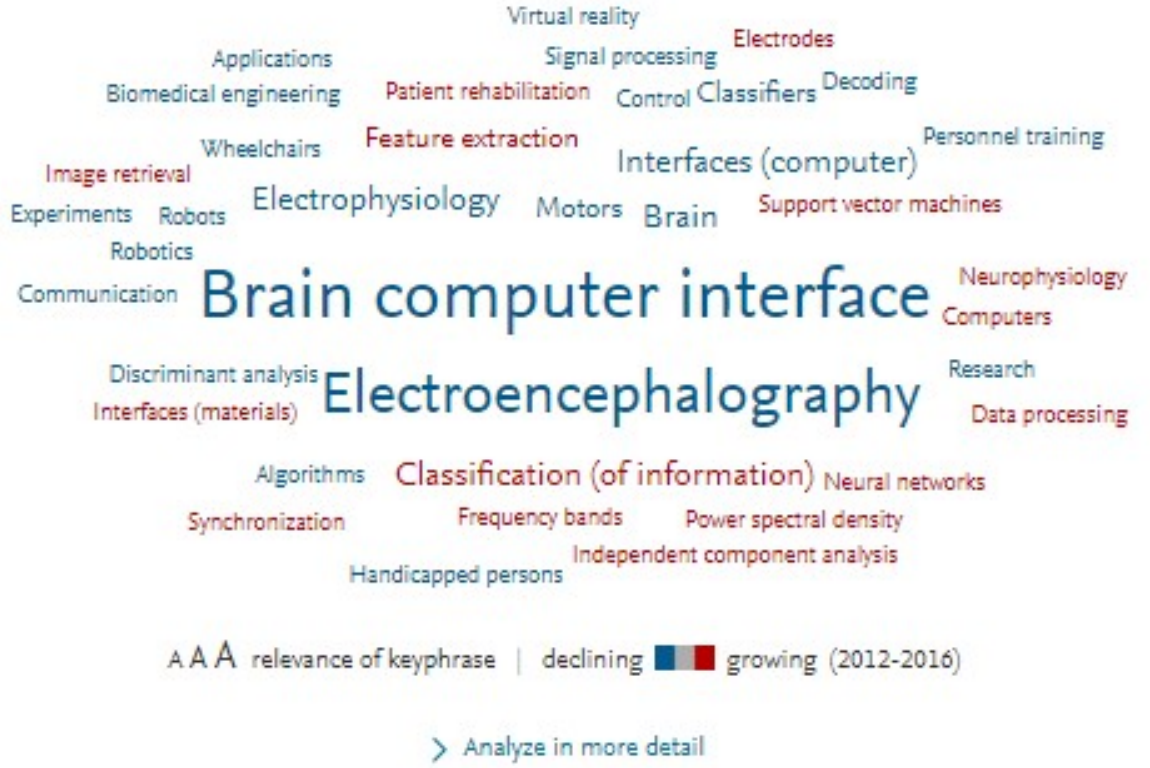
United States—Topics of Prominence—Top 5%

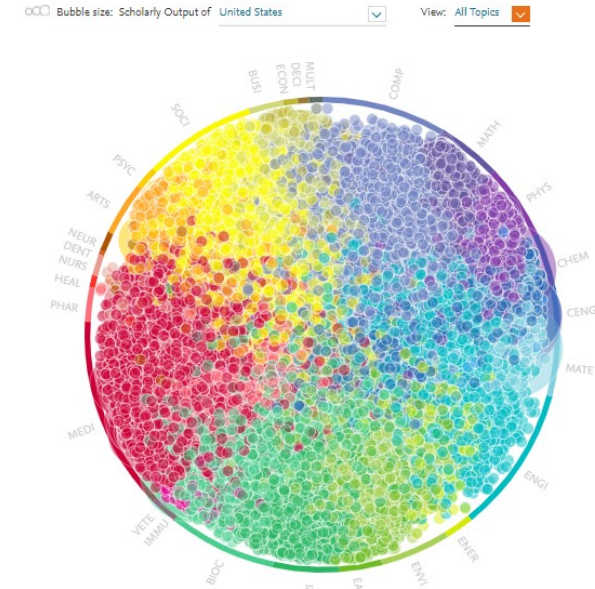


All Topics
(85,193 of 95,696 total topics)



Semantic Word Cloud by Topic





Leading Institutions in High-Throughput Genetic Sequencing

Genome; High-Throughput Nucleotide S

2012 to 2016 | no subject area filter selected | ASJC

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphras

Top Institutions

Worldwide | All sectors | ← Filter for more (regional) detail

Map | Table | Chart

Top 100 Institutions in this Topic, by Scholarly Output

Size: Scholarly Output | total value | Color: Views Cour

Organic light emitting diodes (OLED); Phosphorescence; Light emission T.158

2012 to 2016 | no subject area filter selected | ASJC

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases

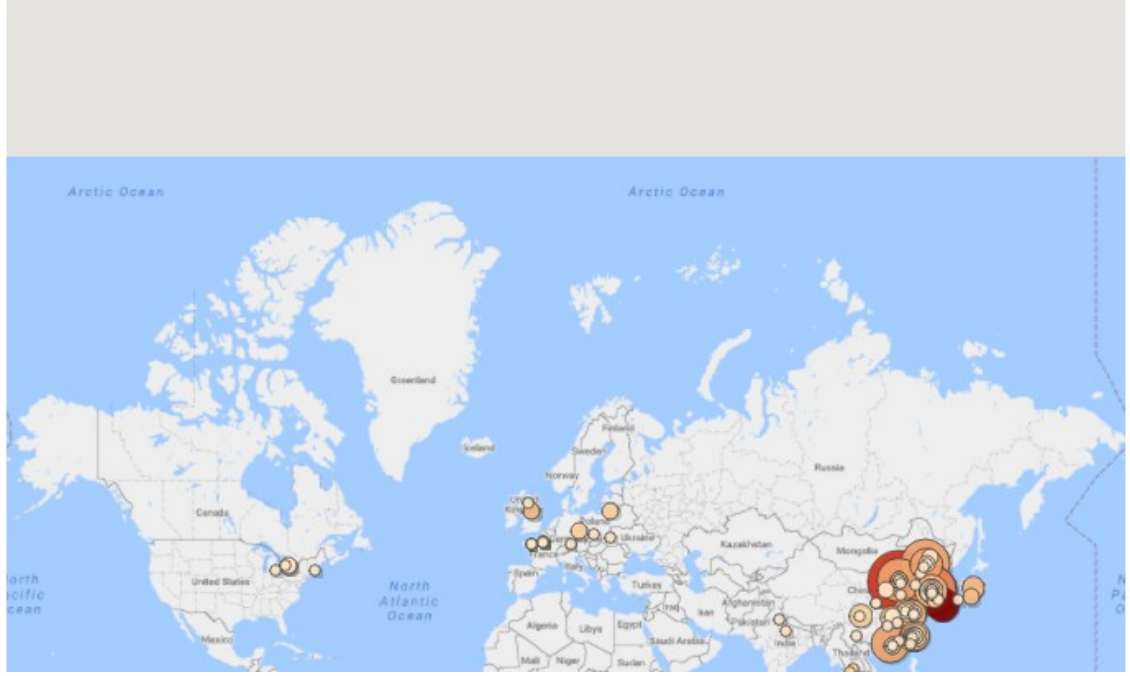
Top Institutions

Worldwide | All sectors | ← Filter for more (regional) detail

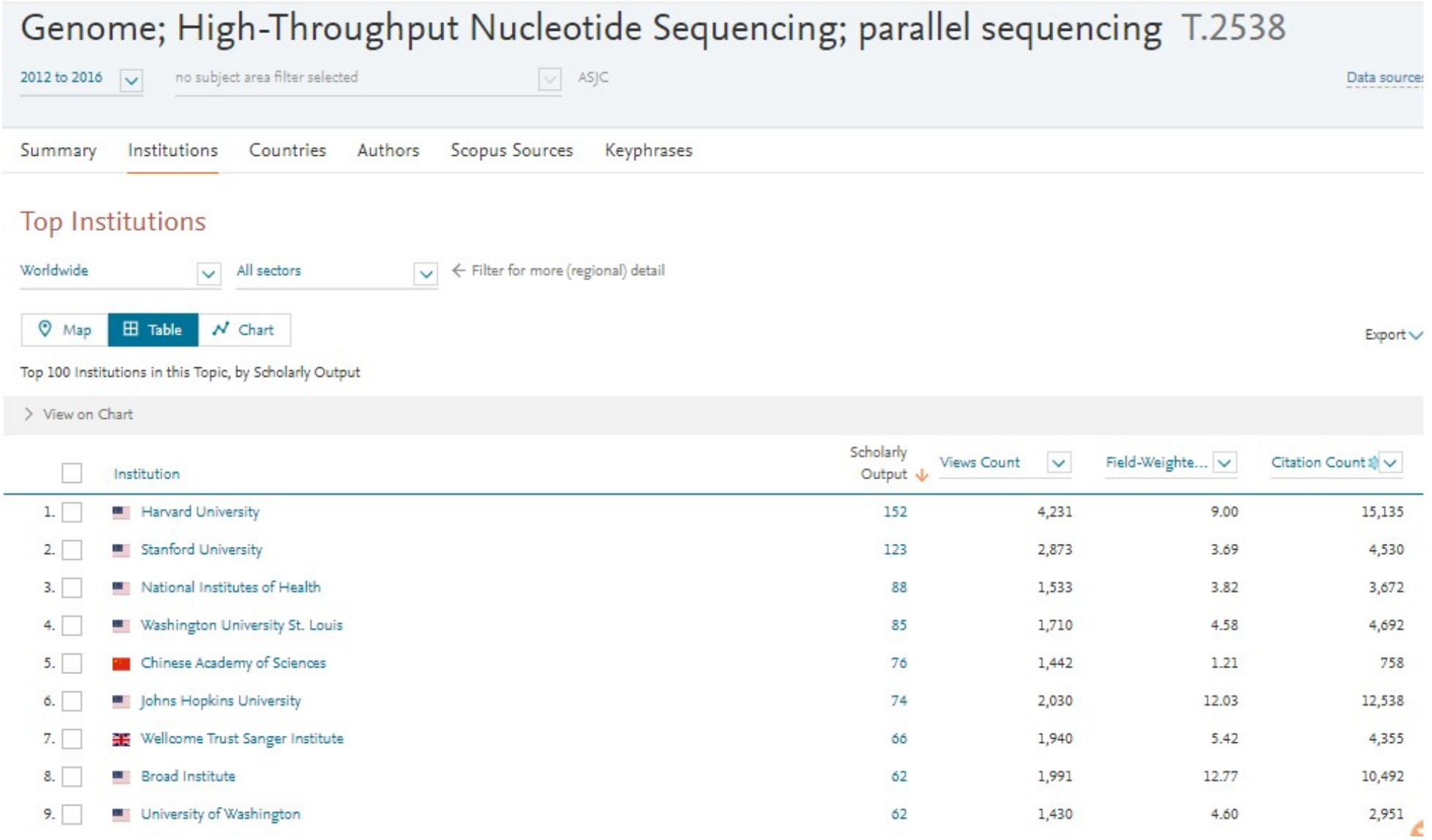
Map | Table | Chart

Top 100 Institutions in this Topic, by Scholarly Output

Size: Scholarly Output | total value | Color: Views Count | total value



Leading Institutions in High-Throughput Genetic Sequencing



Genome; High-Throughput Nucleotide Sequencing; parallel sequencing T.2538

2012 to 2016 | no subject area filter selected | ASJC | Data sources

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases

Top Institutions

Worldwide | All sectors | ← Filter for more (regional) detail

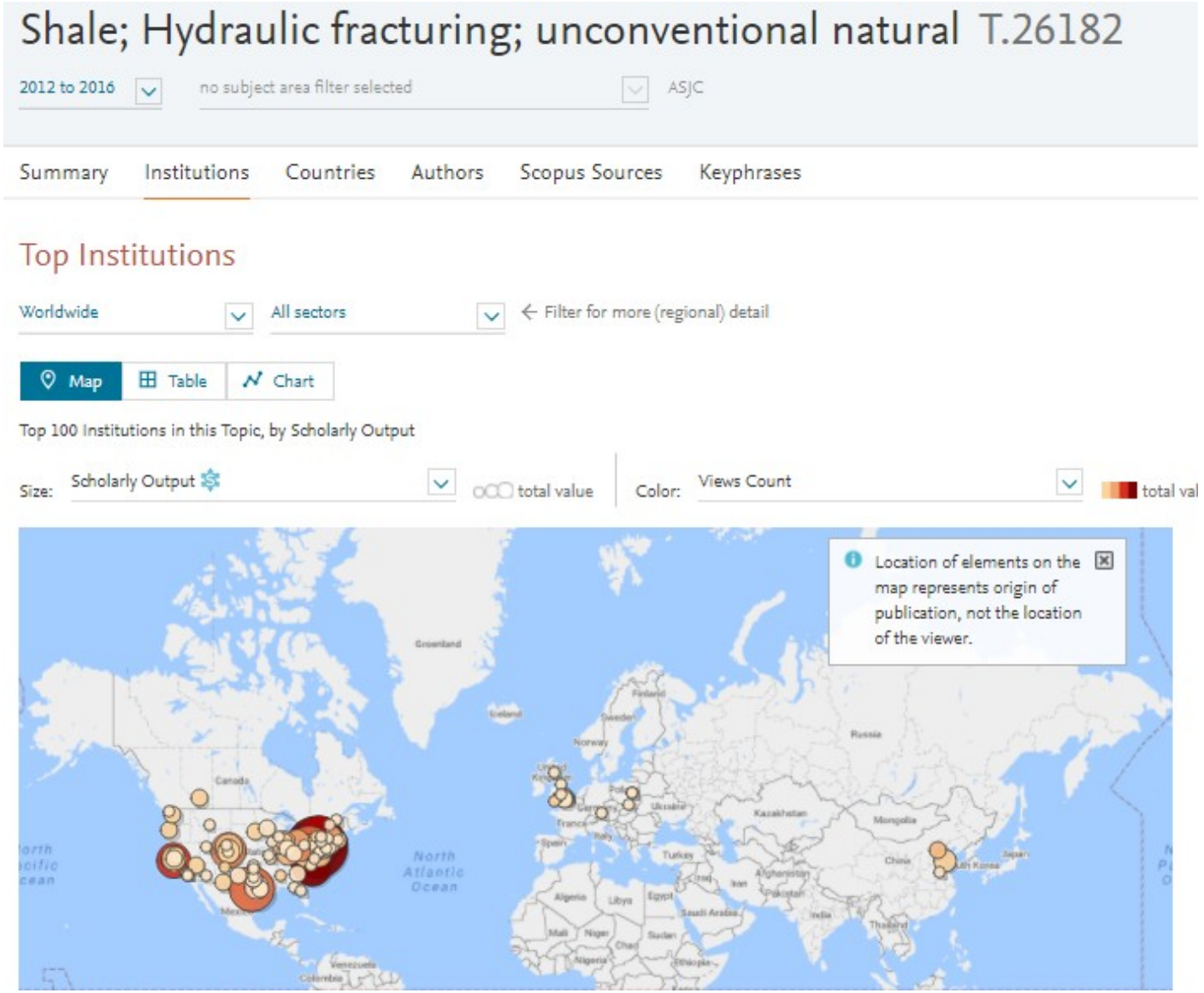
Map | Table | Chart | Export

Top 100 Institutions in this Topic, by Scholarly Output

> View on Chart

	Institution	Scholarly Output	Views Count	Field-Weighte...	Citation Count
1.	Harvard University	152	4,231	9.00	15,135
2.	Stanford University	123	2,873	3.69	4,530
3.	National Institutes of Health	88	1,533	3.82	3,672
4.	Washington University St. Louis	85	1,710	4.58	4,692
5.	Chinese Academy of Sciences	76	1,442	1.21	758
6.	Johns Hopkins University	74	2,030	12.03	12,538
7.	Wellcome Trust Sanger Institute	66	1,940	5.42	4,355
8.	Broad Institute	62	1,991	12.77	10,492
9.	University of Washington	62	1,430	4.60	2,951

US Topics of Prominence—Shale, Hydraulic Fracturing



US Topics of Prominence—Shale, Hydraulic Fracturing

Shale; Hydraulic fracturing; unconventional natural T.26182

2012 to 2016 | no subject area filter selected | ASJC | Data source

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases

Top Institutions

Worldwide | All sectors | ← Filter for more (regional) detail

Map | Table | Chart | Export

Top 100 Institutions in this Topic, by Scholarly Output

> View on Chart

	Institution	Scholarly Output	Views Count	Field-Weighte...	Citation Count
1.	Pennsylvania State University	45	3,275	5.86	1,389
2.	University of Pittsburgh	36	3,441	5.63	1,325
3.	Cornell University	31	2,778	3.81	952
4.	Carnegie Mellon University	30	1,760	3.59	749
5.	University of Texas at Austin	29	1,881	3.37	869
6.	Duke University	27	3,468	4.32	1,537
7.	West Virginia University	22	581	2.09	145
8.	National Energy Technology Laboratory	20	978	2.62	349
9.	Stanford University	19	2,444	3.38	925

Strategies and Tools for Smaller Universities and Metros

Why Innovate?

Industries

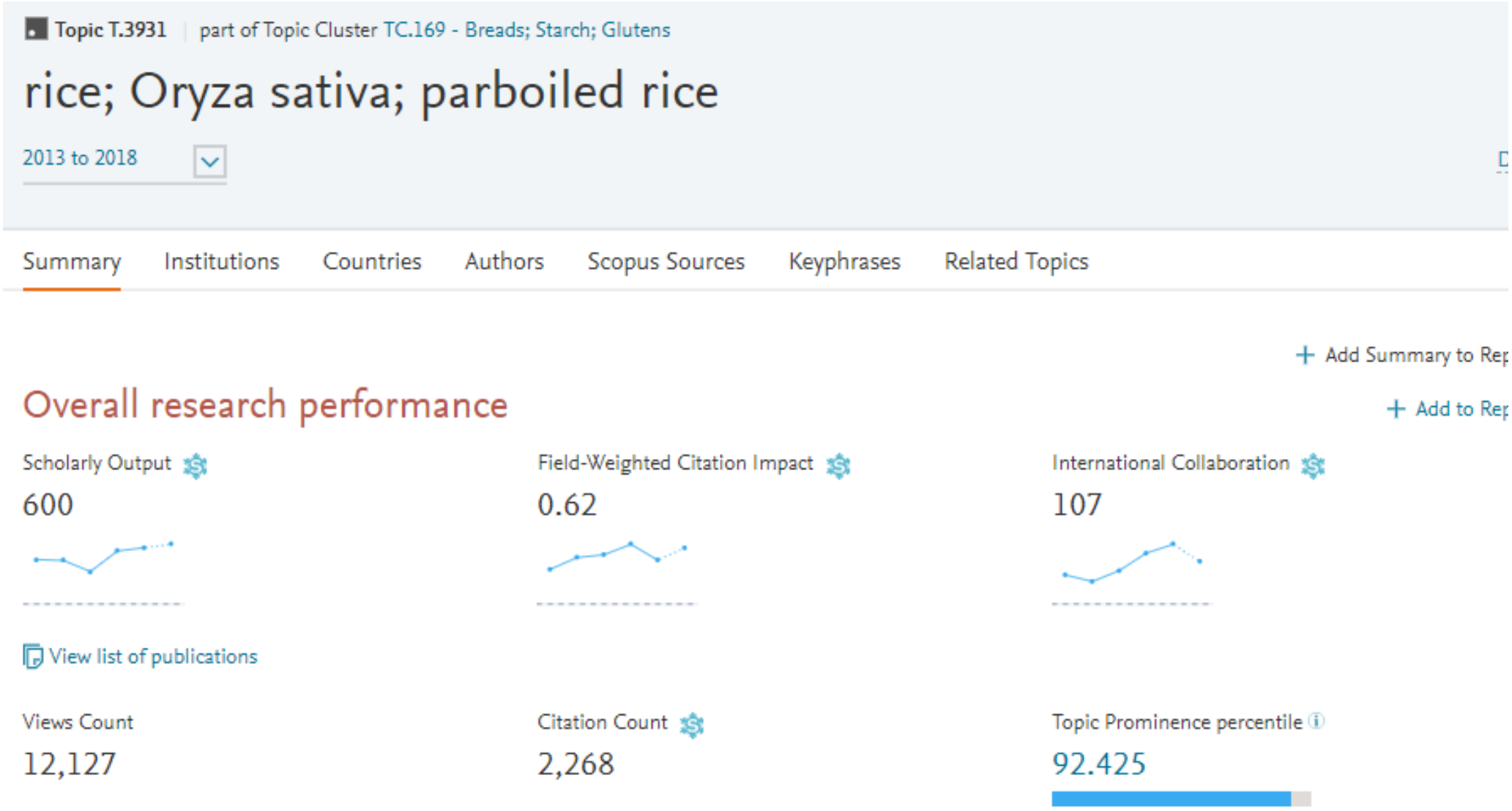
Andhra CM Naidu announces 'Silicon City' near Tirupati, promises one lakh jobs

The announcement came as Naidu laid the foundation for China-based electronics major TCL's unit in Tirupati

TNM Staff | Thursday, December 20, 2018 - 16:17

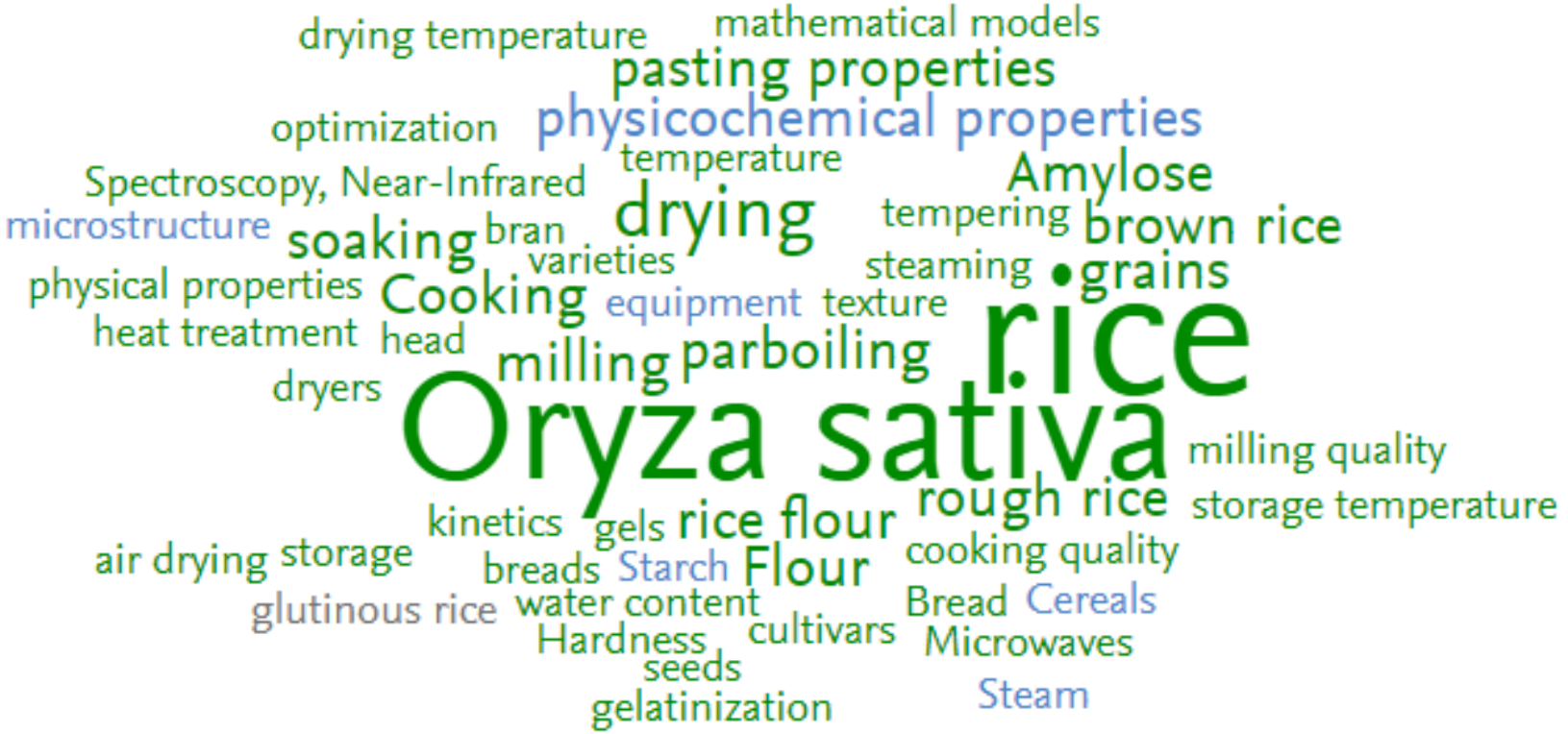
Follow @thenewsminute

The Relevance of Universities to Local and Regional Economy



The Relevance of Universities to Local and Regional Economy

Top 50 keyphrases by relevance, based on 600 publications | Learn about keyphrase calculations ↗



The Relevance of Universities to Local and Regional Economy

rice; Oryza sativa; parboiled rice

2013 to 2018 Data

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases | Related Topics

Top Institutions

Worldwide | All sectors

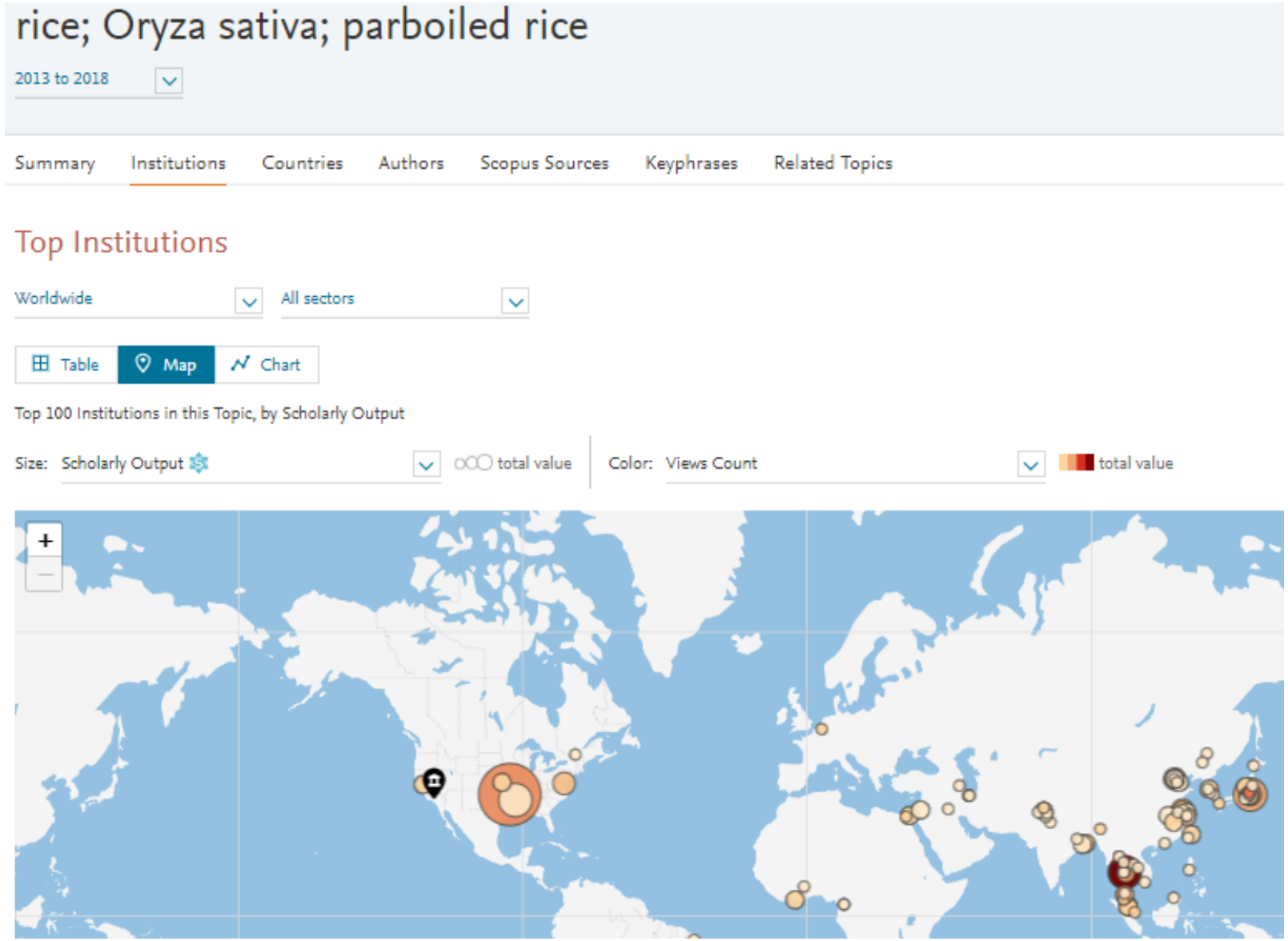
Table | Map | Chart + Add to Reporting Export

Top 100 Institutions in this Topic, by Scholarly Output

View on Chart

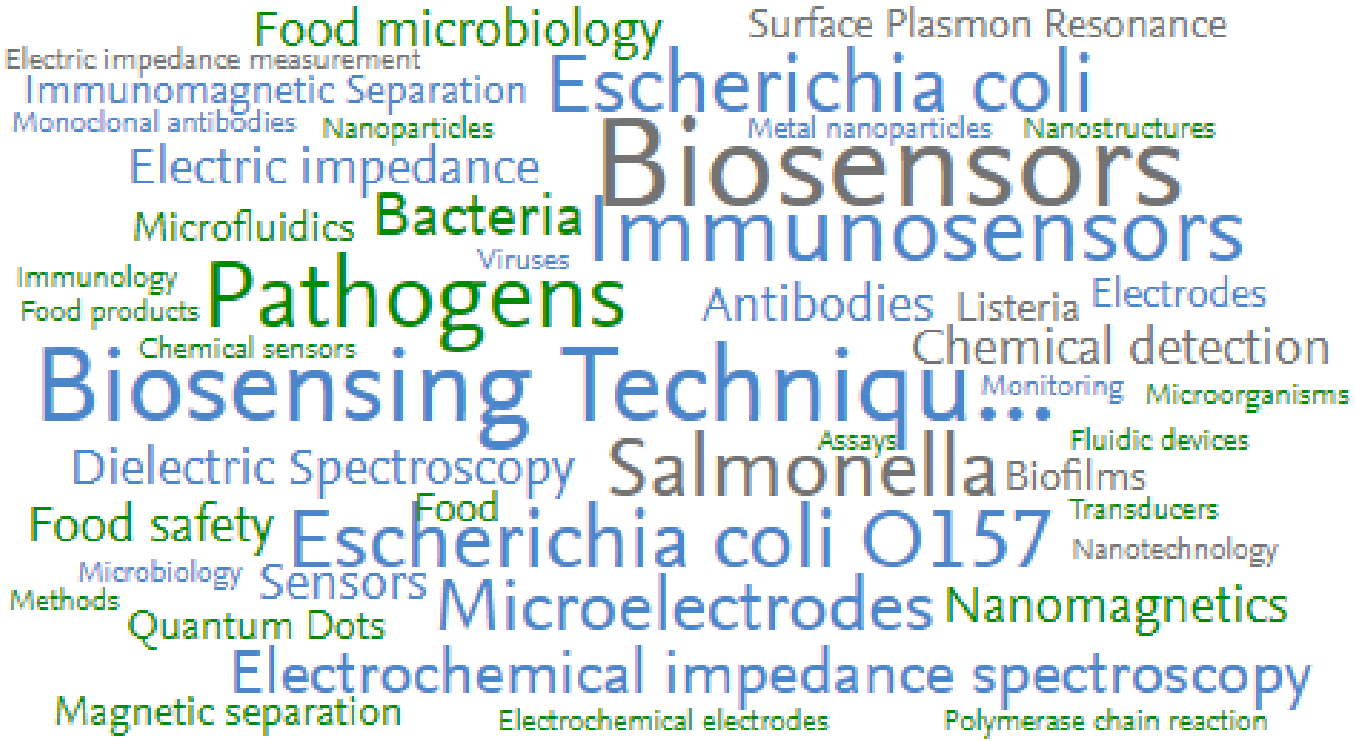
	Institution	Scholarly Output	Views Count	Field-Weight...	Citation Count
1.	University of Arkansas	57	569	0.62	170
2.	Kasetsart University	25	1,184	0.66	123
3.	University of Arkansas Little Rock	24	115	0.73	54
4.	National Agricultural Research Centers Japan	23	377	0.42	106
5.	King Mongkut's University of Technology Thonburi	20	1,069	0.67	109
6.	United States Department of Agriculture	17	298	0.93	103

The Relevance of Universities to Local and Reasonable Economy



The Relevance of Universities to Local and Reasonable Economy

The Relevance of Universities to Local and Reasonable Economy



A A A relevance of keyphrase | declining A A A growing (2013-2017)

> Analyze in more detail

The Relevance of Universities to Local and Reasonable Economy

Biosensors; Immunosensors; foodborne pathogens

2013 to 2018

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases | Related Topics

Top Institutions

Worldwide | All sectors

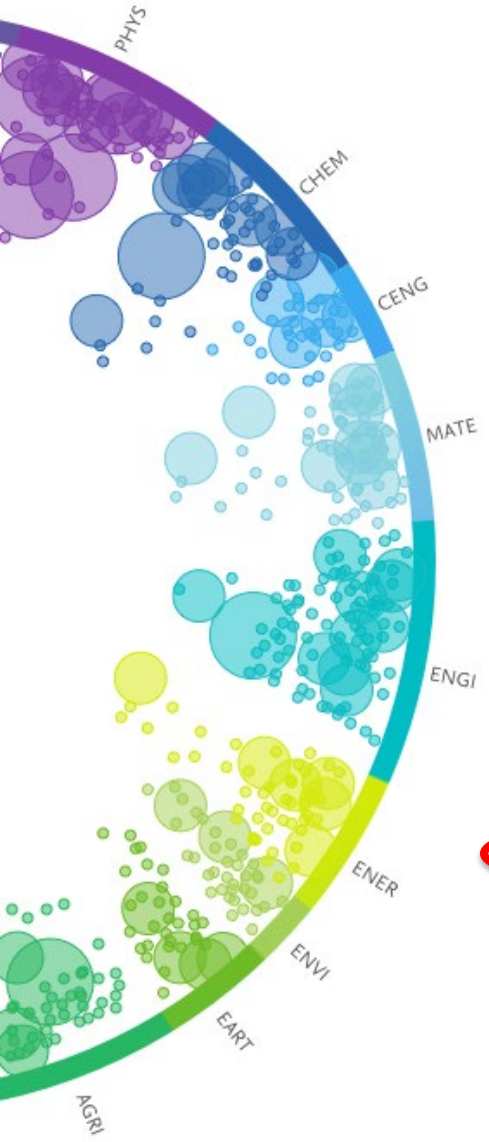
Table | Map | Chart

Top 100 Institutions in this Topic, by Scholarly Output

View on Chart

	Institution	Scholarly Output	Views Count	Field-Weight...
1.	Ministry of Education China	31	969	1.77
2.	University of Arkansas	28	2,121	1.47
3.	Zhejiang University	20	832	1.28
4.	Chinese Academy of Sciences	19	961	1.58
5.	China Agricultural University	16	530	2.17
6.	Nanchang University	16	681	2.28
7.	CSIC	14	1,048	1.75
8.	Ministry of Agriculture of the People's Republic of China	14	500	2.17
9.	CNRS	11	455	1.43

Wayne State University--Topics



Wayne State University

461-470 (QS) · 351–400 (THE) · 301-400 (ARWU) | United States | More details on this Institution

2012 to 2016 | no subject area filter selected | ASJC

Summary | Topics | Awarded Grants | Collaboration | Published | Viewed | Cited | Economic Impact | Societal Impact | Authors

Browse Topics

Researchers at Wayne State University have contributed to 6,613 topics between 2012 to 2016

Table | Wheel

Search this Institution's To

Topic	At this Institution: Scholarly Output	Publication Share	Worldwide: Prominence
quarks; production; asymmetry ... T.1868	108	11.05% ▲	98.009 percentile
collisions; jets; quarks ... T.649	92	8.31% ▲	97.712 percentile
jets; production; collisions ... T.1026	92	6.31% ▲	99.757 percentile
collisions; ionic collisions; flow ... T.633	79	5.16% ▲	99.229 percentile
Daptomycin; Vancomycin; Methicillin-Resistant Staphylococcus aureus ... T.4002	55	6.10% ▼	97.041 percentile
Iron; Brain; Multiple Sclerosis ... T.6947	48	6.29% ▲	98.011 percentile
dissociation; Protonation; cations ... T.12611	48	19.51% ▲	89.322 percentile
Chorioamnionitis; Premature Birth; Amniotic Fluid ... T.3128	47	8.45% ▲	96.122 percentile
supersymmetry; collisions; jets ... T.23456	47	11.96% ▲	97.206 percentile

Wayne State University--Topics

Daptomycin; Vancomycin; Methicillin-Resistant Staphylococcus aureus T.4002

2012 to 2016 | no subject area filter selected | ASJC

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases

Top Institutions

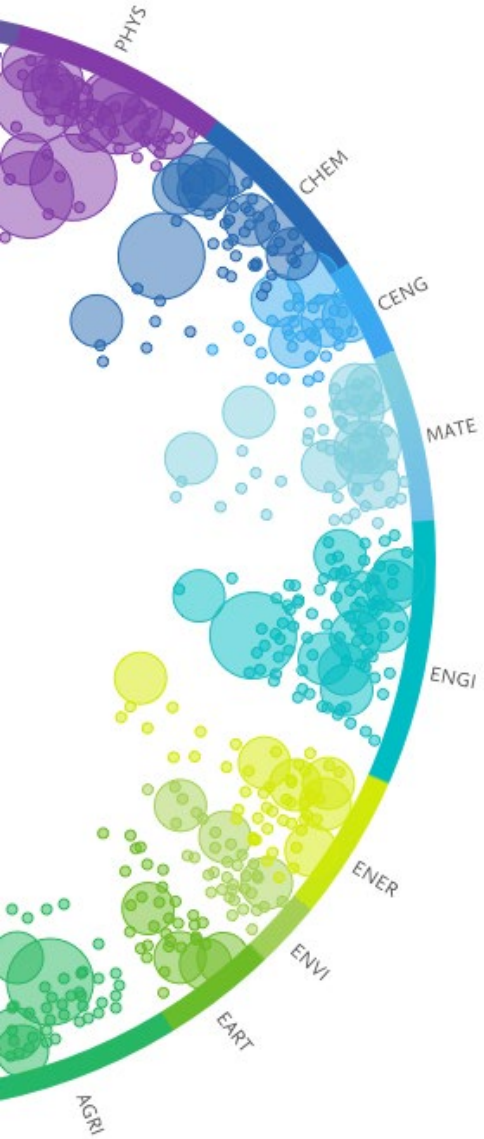
Worldwide | All sectors | ← Filter for more (regional) detail

Map | Table | Chart

Top 100 Institutions in this Topic, by Scholarly Output

Size: Scholarly Output total value | Color: Views Count total value

Wayne State University--Topics



Daptomycin; Vancomycin; Methicillin-Resistant Staphylococcus aureus T.4002

Daptomycin; Vancomycin; Methicillin-Resistant Staphylococcus aureus T.4002

2012 to 2016 | no subject area filter selected | ASJC | Data sourc

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases

Top Institutions

Worldwide | Corporate | reset filter

Map | Table | Chart

Export

Top 100 Institutions in this Topic, by Scholarly Output

View on Chart

	Institution	Scholarly Output	Views Count	Field-Weighte...	Citation Count
1.	Cubist Pharmaceuticals, Inc.	40	422	2.17	672
2.	Novartis	10	112	2.15	117
3.	Merck	7	52	1.97	30
4.	Kitasato Institute	1	1	0.00	0
5.	Philips HealthTech	1	2	0.50	3
6.	Shionogi & Co., Ltd.	1	21	0.50	6
9.	Monash University	19	264	2.00	289
10.	Universitat Autonoma de Barcelona	19	182	1.72	181
11.	Harvard University	17	260	2.66	398

Microsoft USA--Topics

Microsoft USA

United States | More details on this Institution

2012 to 2016 | no subject area filter selected | ASJC | Data sou

Summary | Topics | Awarded Grants | Collaboration | Published | Viewed | Cited | Economic Impact | Societal Impact | Authors

Browse Topics

Expo

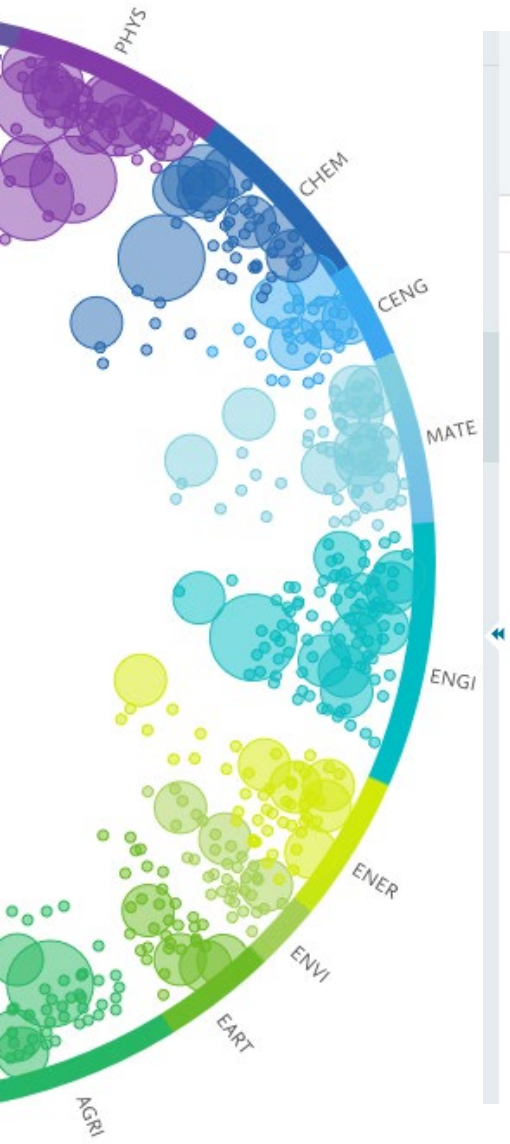
Researchers at Microsoft USA have contributed to 1,465 topics between 2012 to 2016

Table | Wheel

Search this Institution's Topics

Topic	At this Institution: Scholarly Output	At this Institution: Publication Share	World: Prominence
Search engines; Information retrieval; search logs ... T.3454	112	13.05%	95.814 percentile
Earnings; Machine design; truthful mechanisms ... T.4366	84	11.19%	95.844 percentile
Verification; Model checking; loop invariants ... T.2248	67	7.75%	93.932 percentile
Algorithms; Computer vision; feature transform ... T.250	65	1.29%	99.714 percentile
Models; Research; crowd workers ... T.10075	58	3.87%	99.374 percentile
Speech recognition; Neural networks; discriminative training ... T.6136	52	9.30%	95.997 percentile

Top Global Institutions—Verification, Model Checking



Model checking; Verification; Interpolation T.9134

2012 to 2016 | no subject area filter selected | ASJC | Data sourc

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases

Top Institutions

Worldwide | All sectors | ← Filter for more (regional) detail

Map | Table | Chart | Export

Top 100 Institutions in this Topic, by Scholarly Output

> View on Chart

	Institution	Scholarly Output	Views Count	Field-Weighte...	Citation Count
1.	University of Passau	40	181	6.42	366
2.	Microsoft USA	39	178	3.94	403
3.	University of Oxford	36	141	2.18	133
4.	University of Lugano	34	162	2.05	198
5.	Carnegie Mellon University	32	165	4.02	224
6.	Vienna University of Technology	26	83	1.56	90
7.	University of Freiburg	24	63	4.18	171
8.	Fondazione Bruno Kessler	19	111	6.13	310
9.	University of Chieti	18	168	2.06	91
10.	CNR	17	161	2.18	91

Top US Institutions—Verification, Model Checking

Model checking; Verification; Interpolation T.9134

2012 to 2016 | no subject area filter selected | ASJC | Data sources

Summary | Institutions | Countries | Authors | Scopus Sources | Keyphrases

Top Institutions

North America | United States | All sectors | reset filter

Map | Table | Chart | Export

Top 100 Institutions in this Topic, by Scholarly Output

View on Chart

	Institution	Scholarly Output	Views Count	Field-Weighte...	Citation Count
1.	Microsoft USA	39	178	3.94	403
2.	Carnegie Mellon University	32	165	4.02	224
3.	NASA Ames Research Center	11	46	2.07	39
4.	University of California at Berkeley	11	27	3.56	68
5.	University of Colorado Boulder	9	28	1.53	52
6.	Princeton University	8	25	0.75	19
7.	Stanford University	8	58	3.85	80
8.	University of Illinois at Urbana-Champaign	7	32	4.19	48
9.	IBM Research	6	8	2.08	24
10.	New York University	6	9	2.03	27
11.	College of William and Mary	5	35	2.88	46
12.	Intel	5	16	1.25	20
13.	SRI International	5	18	1.27	4

Top US Institutions—Verification, Model Checking

Publications at Carnegie Mellon University

Within: **Model checking; Verification; Interpolation** T.9134 | Year range: 2012 to 2016

Expor

Authors

- **All authors**
- Gurfinkel, A. 24
- Chaki, S. 8
- Kahsai, T. 8
- Albarghouthi, A. 5
- Chechik, M. 5

Show more

Institutions

- **All institutions**
- Carnegie Mellon University 32
- University of Toronto 5
- NASA Ames Research Center 4
- Technion-Israel Institute of Technology 4
- ONERA 3

Show more

- Countries
- Scopus Sources
- Subject Areas
- Publication years
- Publication types

32 publications

Title	Authors	Year	Scopus Source	Citations
Whale: An interpolation-based algorithm for inter-procedural verification View abstract View in Scopus	Albarghouthi, A., Gurfinkel, A., Chechik, M.	2012	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	26
UFO: Verification with interpolants and abstract interpretation: (Competition contribution) View abstract View in Scopus	Albarghouthi, A., Gurfinkel, A., Li, Y. and 2 more	2013	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	18
SMT-based model checking for recursive programs View abstract View in Scopus	Komuravelli, A., Gurfinkel, A., Chaki, S.	2014	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	18
Automatic abstraction in SMT-based unbounded software model checking View abstract View in Scopus	Komuravelli, A., Gurfinkel, A., Chaki, S. and 1 more	2013	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	16
From under-approximations to over-approximations and back View abstract View in Scopus	Albarghouthi, A., Gurfinkel, A., Chechik, M.	2012	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	15
Ufo: A framework for abstraction- and interpolation-based software verification View abstract View in Scopus	Albarghouthi, A., Li, Y., Gurfinkel, A. and 1 more	2012	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	14
Regression verification for multi-threaded programs View abstract View in Scopus	Chaki, S., Gurfinkel, A., Strichman, O.	2012	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	11
Horn clause solvers for program verification View abstract View in Scopus	Bjørner, N., Gurfinkel, A., McMillan, K. and 1 more	2015	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	10

Strategies for Smaller Universities and Cities

Virginia Polytechnic Institute and State University

338th (QS ↗) · 251-300 (THE ↗) · 201-300 (ARWU ↗) | United States | More details on this Institution

2013 to 2018 | no subject area filter selected | ASJC

Summary | Topics & Topic Clusters | Collaboration | Published | Viewed | Cited | Authors | Economic Impact | Societal Impact | Awarded Grants

Overall research performance

Scholarly Output
27,452 ▲
View list of publications

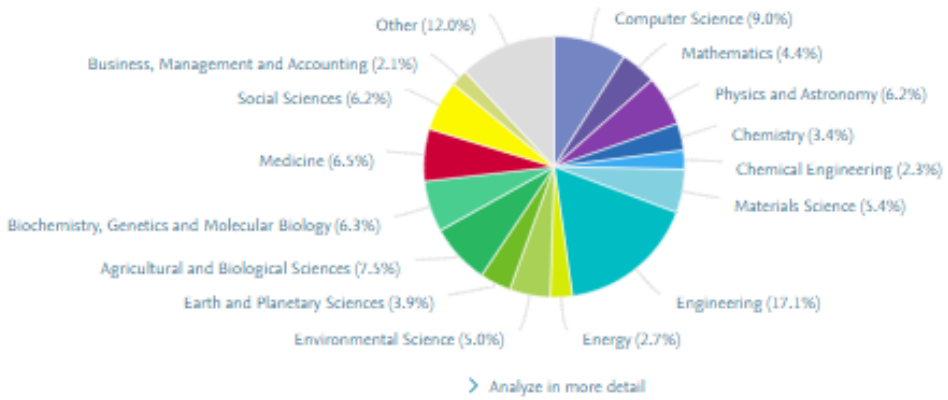
Authors
12,740 ▲

Field-Weighted Citation Impact
1.57

Citation Count
249,296

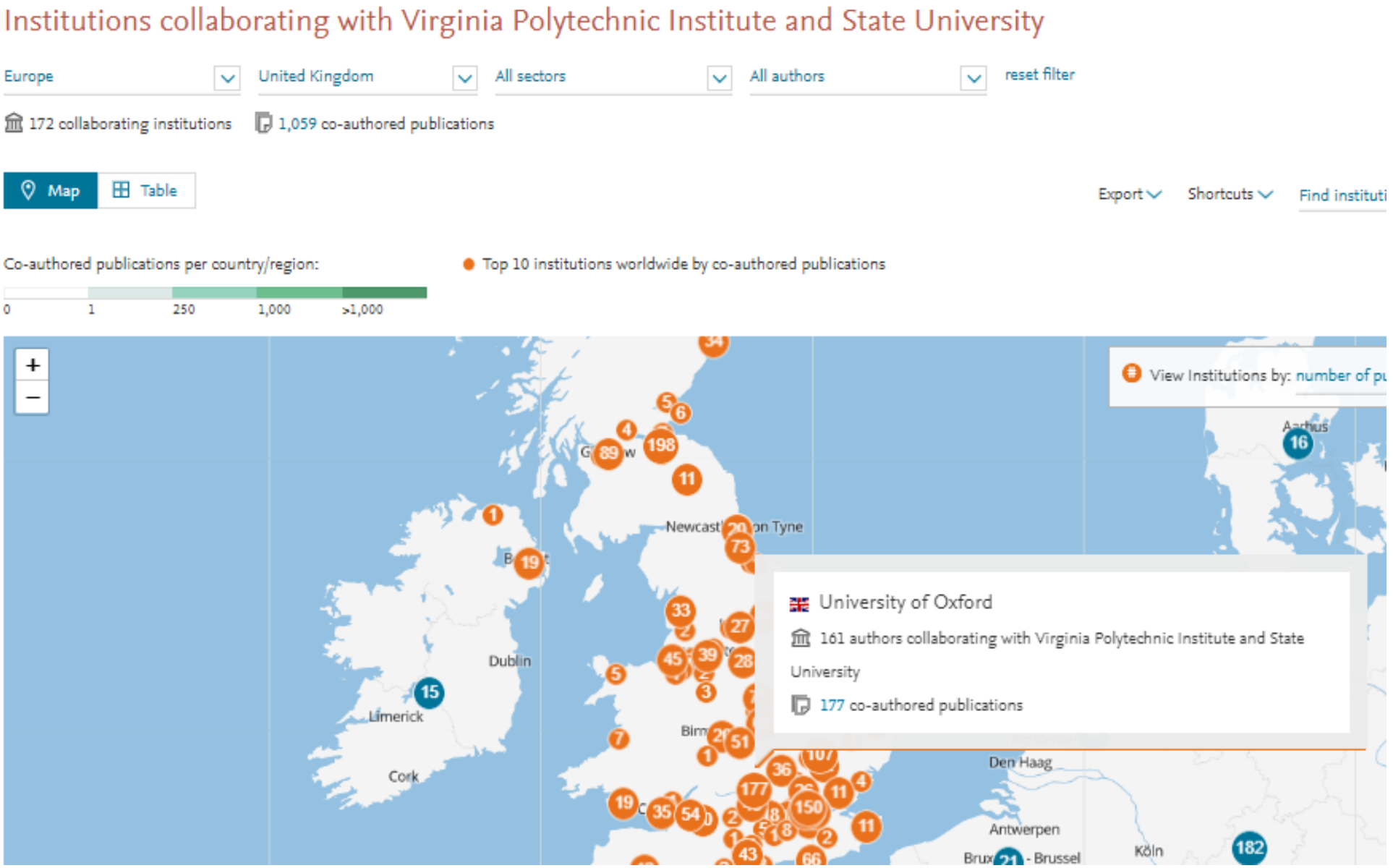
Citations per Publication
9.1

h5-index
95



Analyze in more detail

Collaboration Strategies for Smaller Universities and Cities



Virginia Tech Collaborations with Oxford University

Collaboration with the University of Oxford

Year range: 2013 to 2018

Export Shortcuts

Overview | Current co–authors | Potential co–authors

+ Add to Reporting

	Virginia Polytechnic Institute and State University	Co–authored	University of Oxford
	105 ▲ co–authors with the University of Oxford	177 ▲ publications	161 ▲ co–authors with Virginia Polytechnic Institute and State University
	1.57 Field–Weighted Citation Impact	14.96 Field–Weighted Citation Impact	2.32 Field–Weighted Citation Impact
Authors	12,740 ▲	–	33,360 ▲
Scholarly Output	27,452 ▲	–	81,041 ▲
Views count (from Scopus)	503,379	22,153	1,899,177
Field–Weighted Views Impact	1.19	13.80	1.67
Citation Count	249,296	11,749	1,361,470

Show more

Virginia Tech Collaborations with Oxford University

Collaboration with the University of Oxford

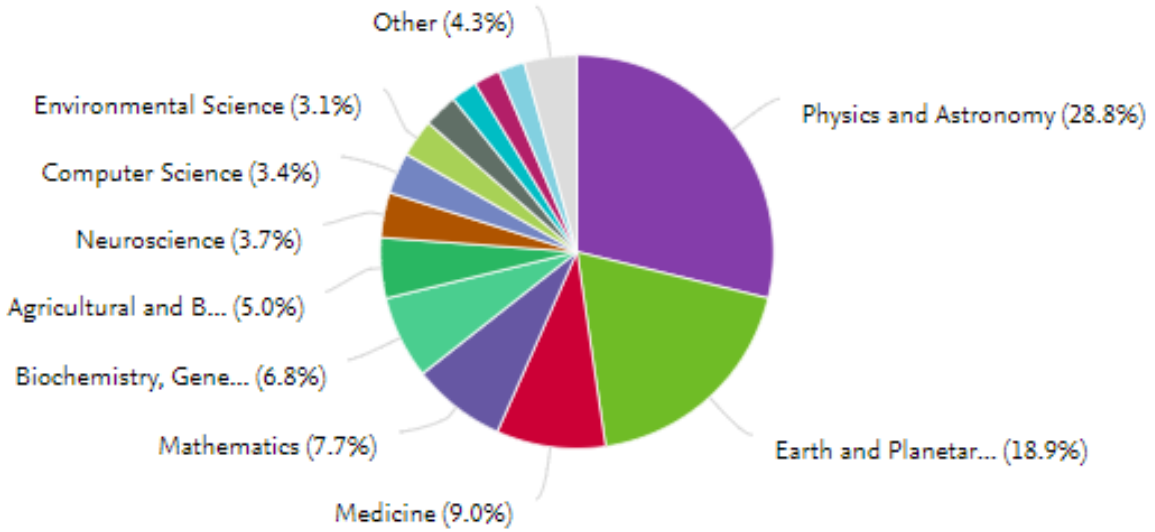
Year range: 2013 to 2018

Overview | Current co–authors | Potential co–authors

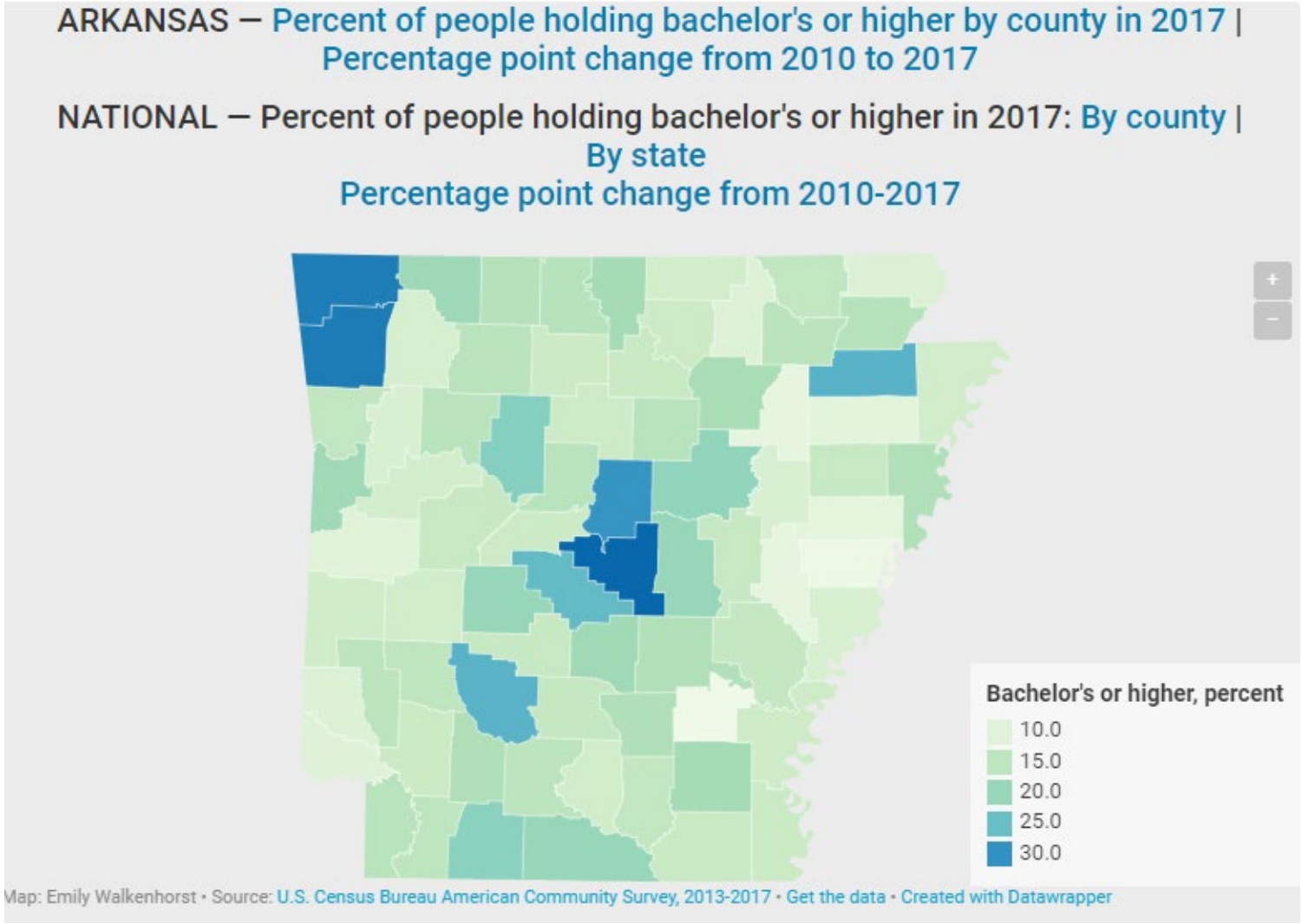
Show more

Co-authored publications by Subject Area

Pie chart | Bar chart



Data Analysis--Economic Development Strategies for Small Cities



Northwest Arkansas Democrat Gazette 10 December 2018
https://www.arkansasonline.com/news/2018/dec/10/arkansas-improves-its-rate-of-degrees-2/

Economic Development Strategies for Small Cities

- http://icic.org/blog/5-strategies/

5 strategies for small cities

1. **Development of entrepreneurial ecosystem**
2. **Human capital investments driving new economic growth**
3. **Strong social capital—including young people**
4. **Strong quality of place—placemaking**
5. **Dedications to progress and reinvestment**

Economic Development Strategies for Small Cities

- http://icic.org/blog/5-strategies/

5 strategies for small cities

1. **Development of entrepreneurial ecosystem**
2. **Human capital investments driving new economic growth**
3. **Strong social capital—including young people**
4. **Strong quality of place—placemaking**
5. **Dedications to progress and reinvestment**

Economic Development Strategies for Small Cities

Other key factors

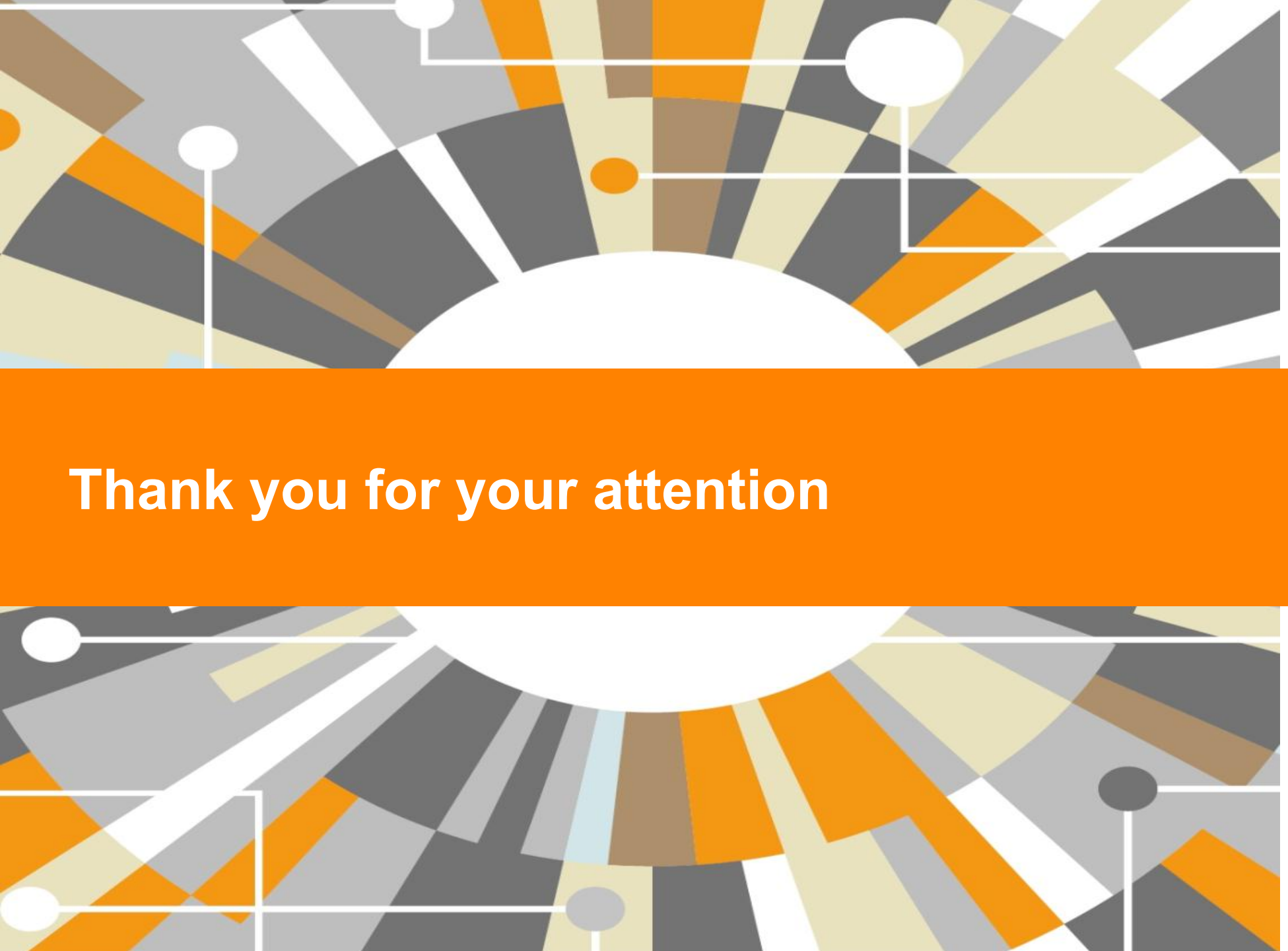
1. Strong Leadership
2. Ability to Compromise
3. Understand your competitive advantages
4. Be creative

Economic Development Strategies for Small Cities

The New York Times

In Blue-Collar Toledo, Ohio, a Windfall of Chinese Investments

The location of Toledo and its low housing costs have helped lure Chinese investment.
Joshua Lott for The New York Times



Thank you for your attention

ELSEVIER

Empowering Knowledge