Knowledge: the ultimate globalising factor

Knowledge accumulates collectively like a language and flows like water. It is common and generic, contextualised and diverse, fixed and flexible, autonomous and dependant, part excludable but scarcely commodifiable

Knowledge network or hegemonic hierarchy?

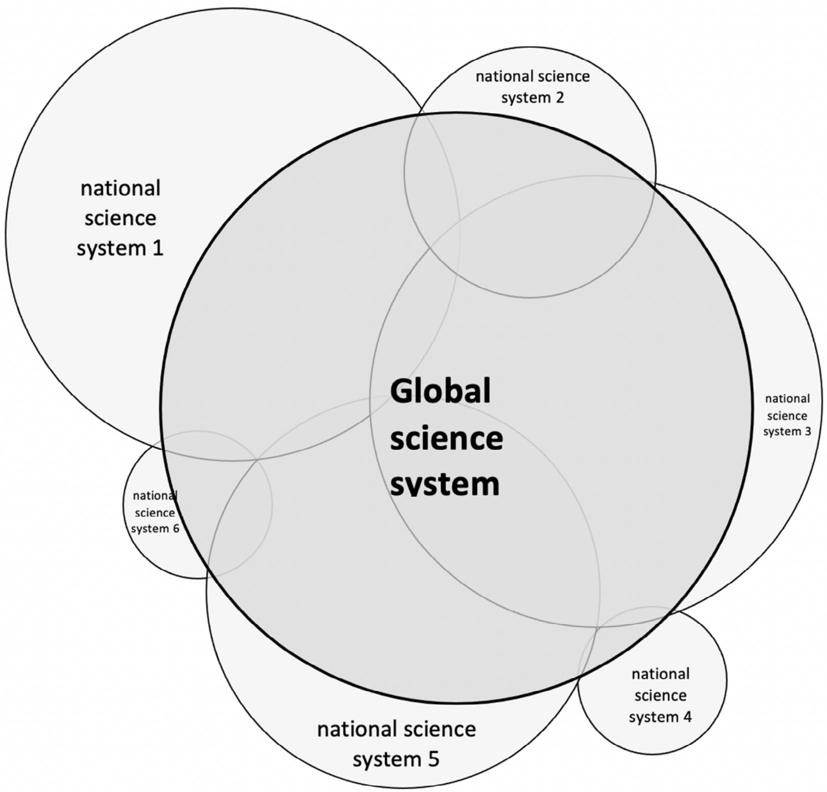
# Dynamism and power in global science

- The substance of science, the core ‘business’, is knowledge
- In higher education and scientific institutions the worldwide circuits of knowledge intersect with flows of money, relations of political power, and social allocation and valuation

  - Empirical tendencies in global science
  - Some key questions about global science

# A global science system has formed, based on the common pool of papers, and held together by extensive and growing cross-border citation and collaboration (joint papers) –

- the global science system is based on grass roots collaboration and has significant autonomy from national governments and national science systems – but the global system is ultimately supported by local and national funding and infrastructure
- many leading scientists wear two hats, (1) institutional/national and (2) disciplinary/global



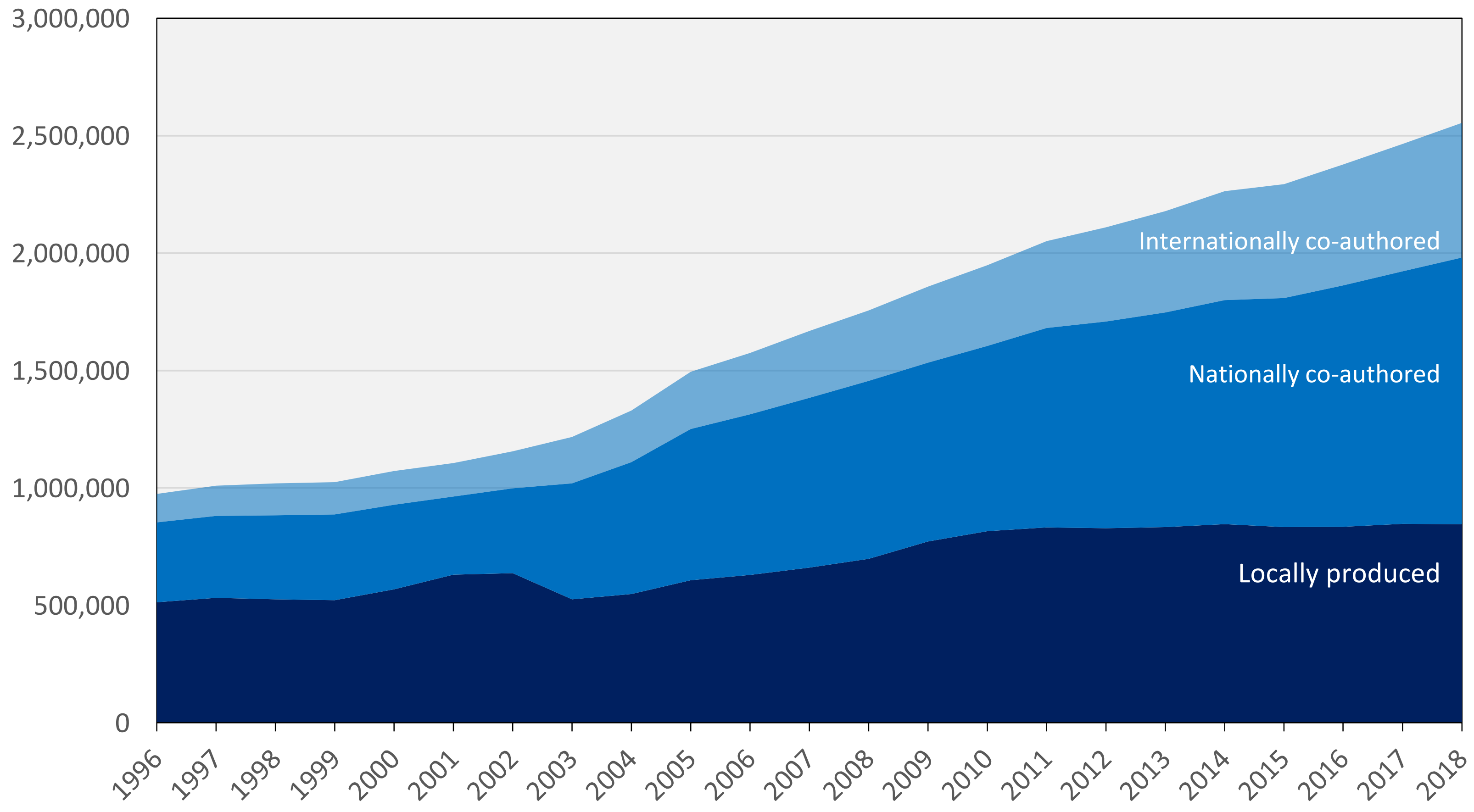
# Empirical tendencies

## The global science system has proven very dynamic

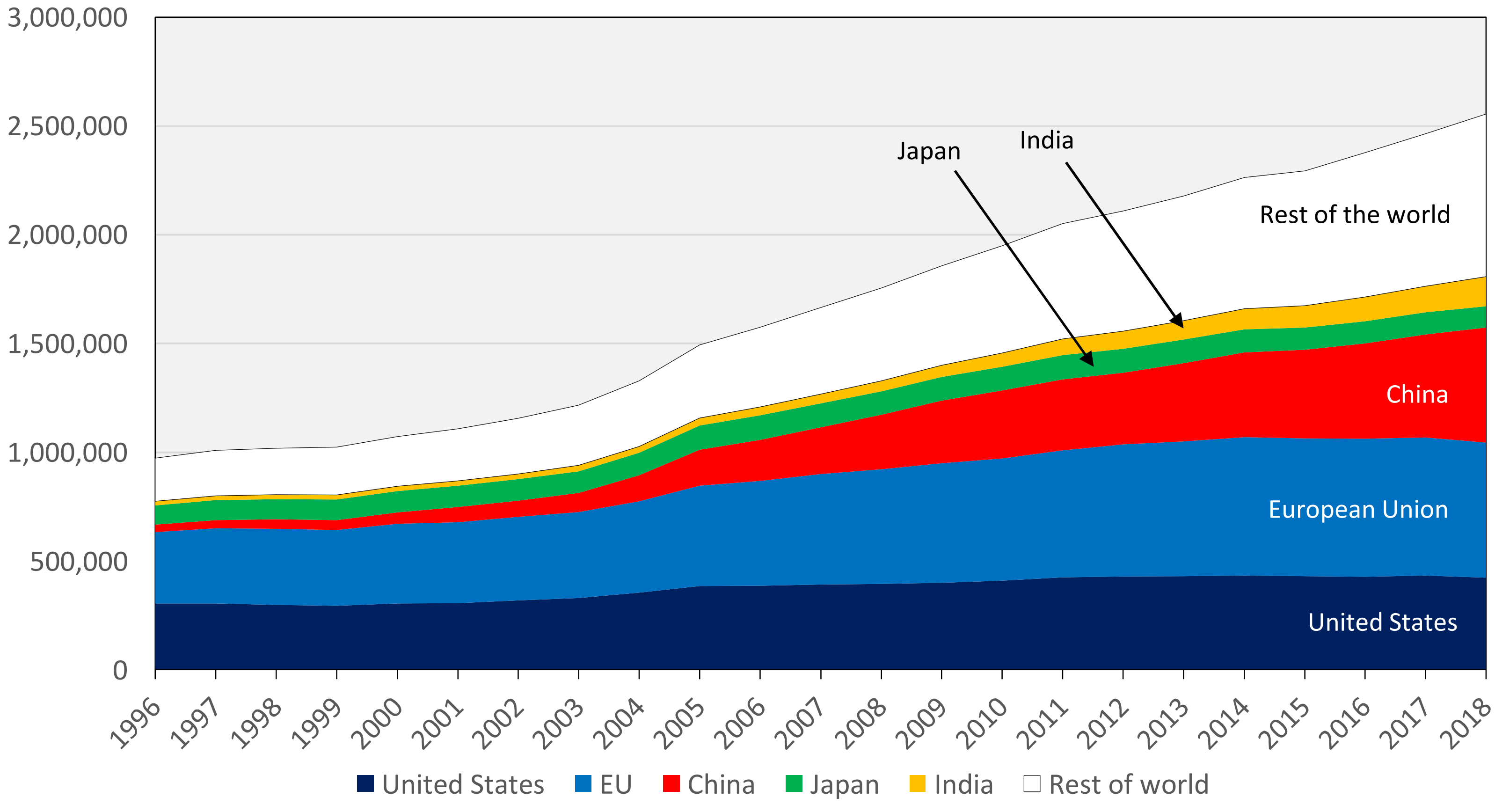
- *Growth:* Rapid increases in many countries in R&D spending and growth of published science papers at 5 per cent a year
- *Diversification:* Science no longer an oligopoly of North America, Europe and Japan. Spread of national science capacity to many more countries
- *Networked cooperation:* Rapid growth of co-authorship in science at both global and national levels
- *Pluralisation:* Widening of group of leading science countries, rise of China (though US science remains strong and globally central)
- *Global integration:* Increase in the weight and role of the global science system vis a vis national science systems

# GROWTH

# Number of science papers in Scopus, by type of collaboration, world: 1996-2018



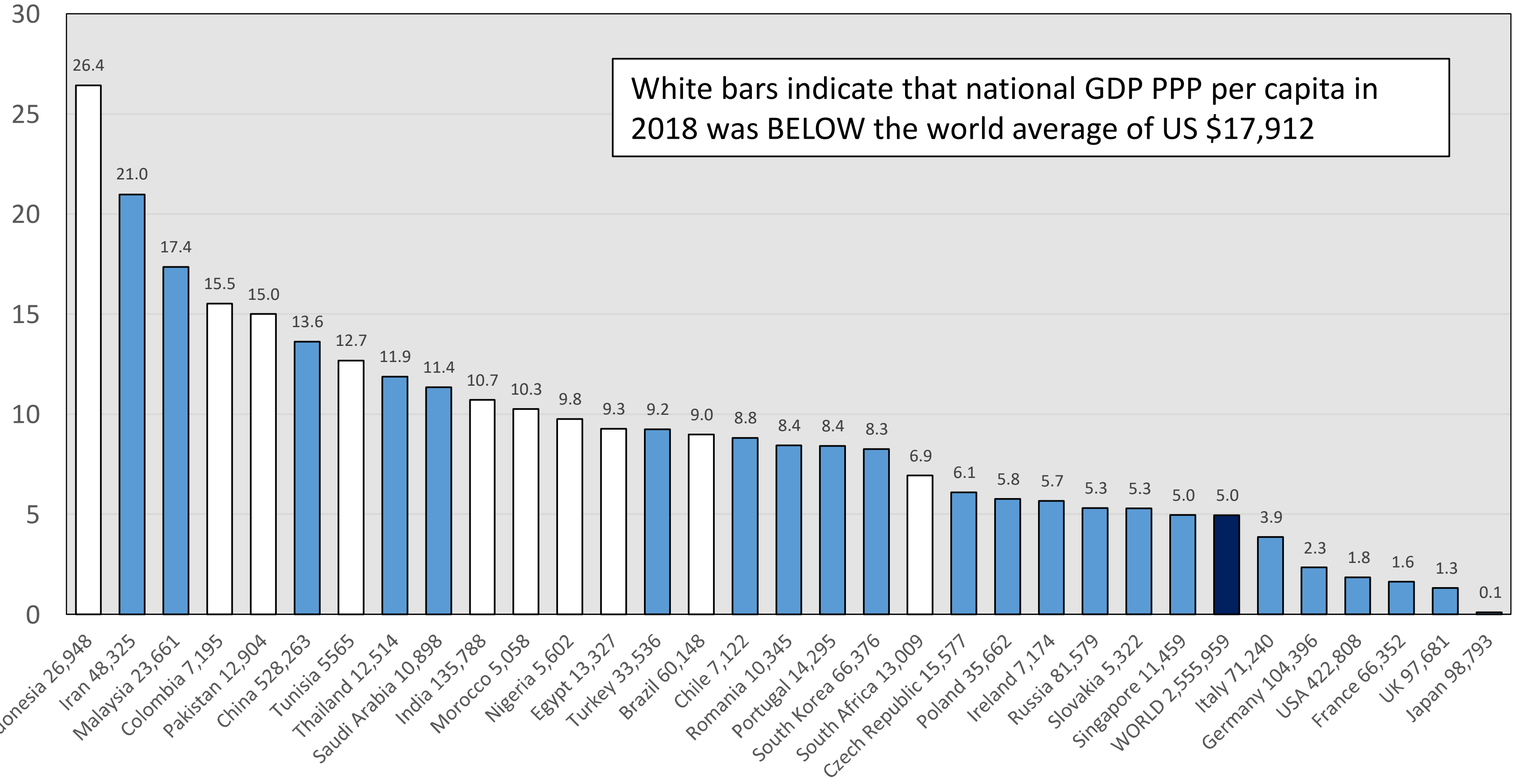
# Number of science papers in Scopus by large world region: 1996-2018



# DIVERSIFICATION

# World-wide spread of science systems

Average annual growth (%) in science papers: 2000-2018
Countries with growth rate above world average of 4.95% per year and producing more than 5000 papers in 2018

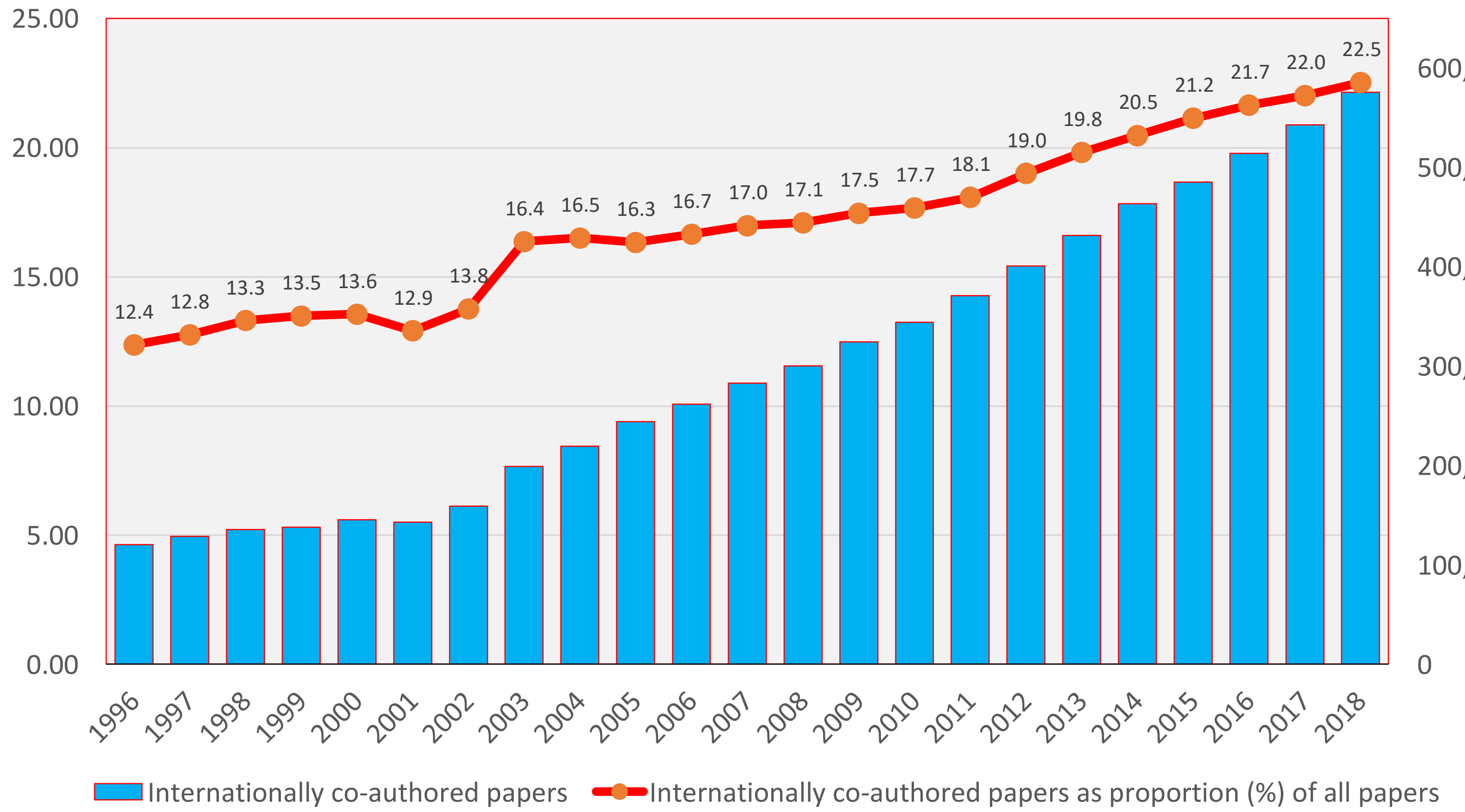


# Deconcentration of country shares of world science papers, 1987-2016

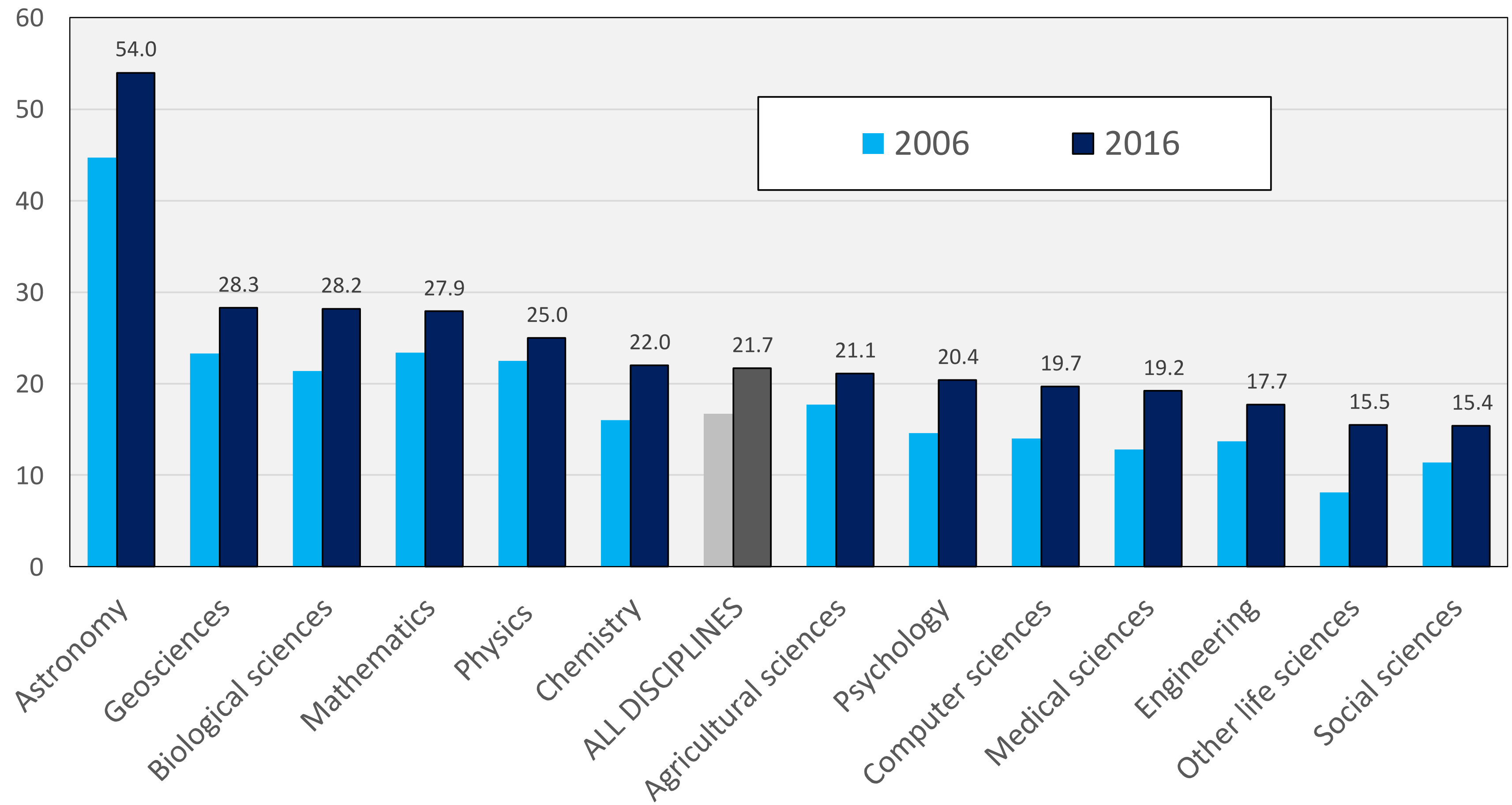
| | 1987 | 1997 | 2007 | 2017 |
|---|---|---|---|---|
| **number of countries with 50% of world science papers** | 3<br>USA, UK, Germany | 4<br>USA, Japan, Germany, UK | 5<br>USA, China, Japan, Germany, UK | 6<br>China, USA, India, Germany, Japan, UK |
| **number of countries with 75% of world science papers** | 9 | 11 | 14 | 16 |
| **number of countries with 90% of world science papers** | 20 | 23 | 26 | 32 |

# GROWTH OF GLOBAL COLLABORATION

# Growth in internationally co-authored science papers, all countries: 1996-2016



# Proportion of science papers that were internationally co-authored, by discipline group: 2006 and 2016



# Internationally co-authored papers 2018

## Country pairs of more than 9000 jointly-authored papers

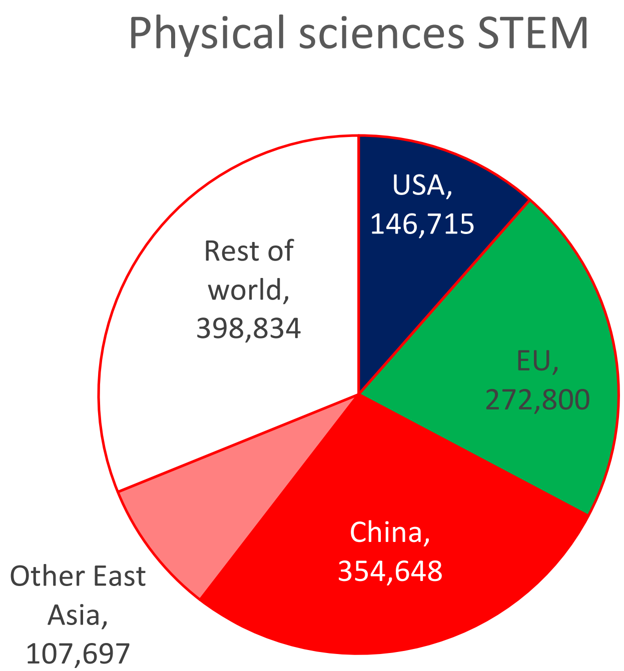
| Country pair | Joint papers |
|---|---|
| China-USA | 55,382 |
| UK-USA | 28,616 |
| Germany-USA | 23,616 |
| Canada-USA | 21,968 |
| France-USA | 15,422 |
| Germany-UK | 15,327 |
| China-UK | 14,763 |
| Australia-USA | 13,939 |
| Italy-USA | 13,804 |
| China-Australia | 13,138 |
| Japan-USA | 11,533 |
| Italy-UK | 11,198 |

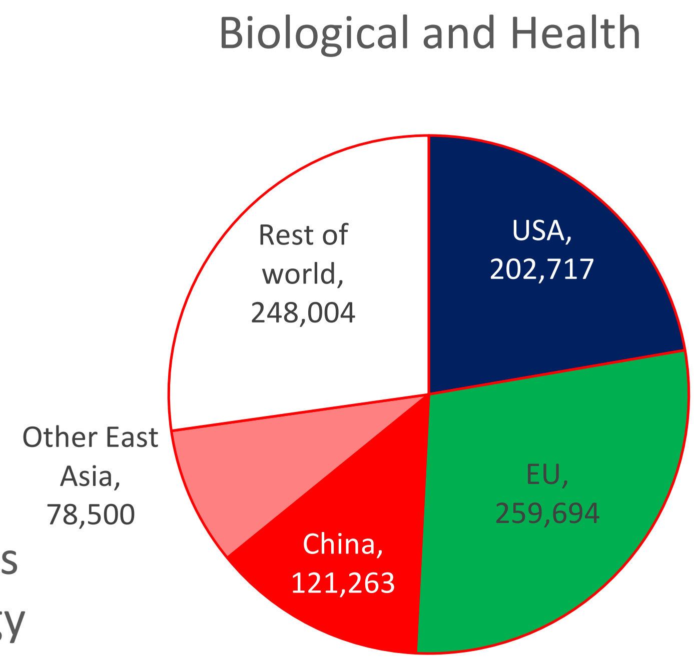
| Country pair | Joint papers |
|---|---|
| France-UK | 11,015 |
| **Germany-France** | **10,664** |
| Spain-USA | 10,236 |
| Australia-UK | 10,207 |
| Netherlands-USA | 9,984 |
| South Korea-USA | 9,761 |
| **Germany-Italy** | **9,729** |
| China-Canada | 9,449 |
| Switzerland-USA | 9,403 |
| **Germany-Switzerland** | **9,060** |
| **France-Italy** | **9,048** |
| Netherlands-UK | 8,880 |

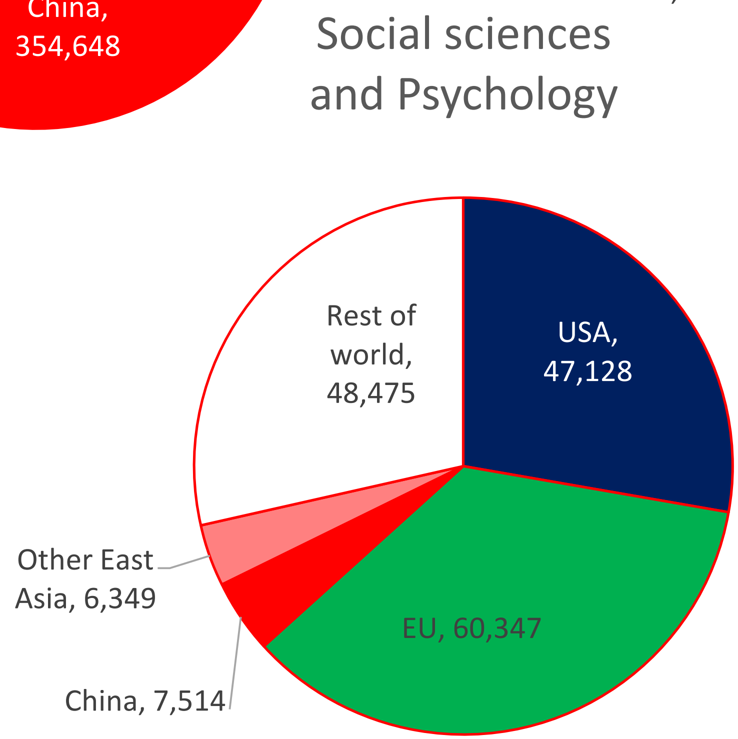
Data: US National Science Board

# MULTI-POLARITY: DIVERSIFICATION OF POWER

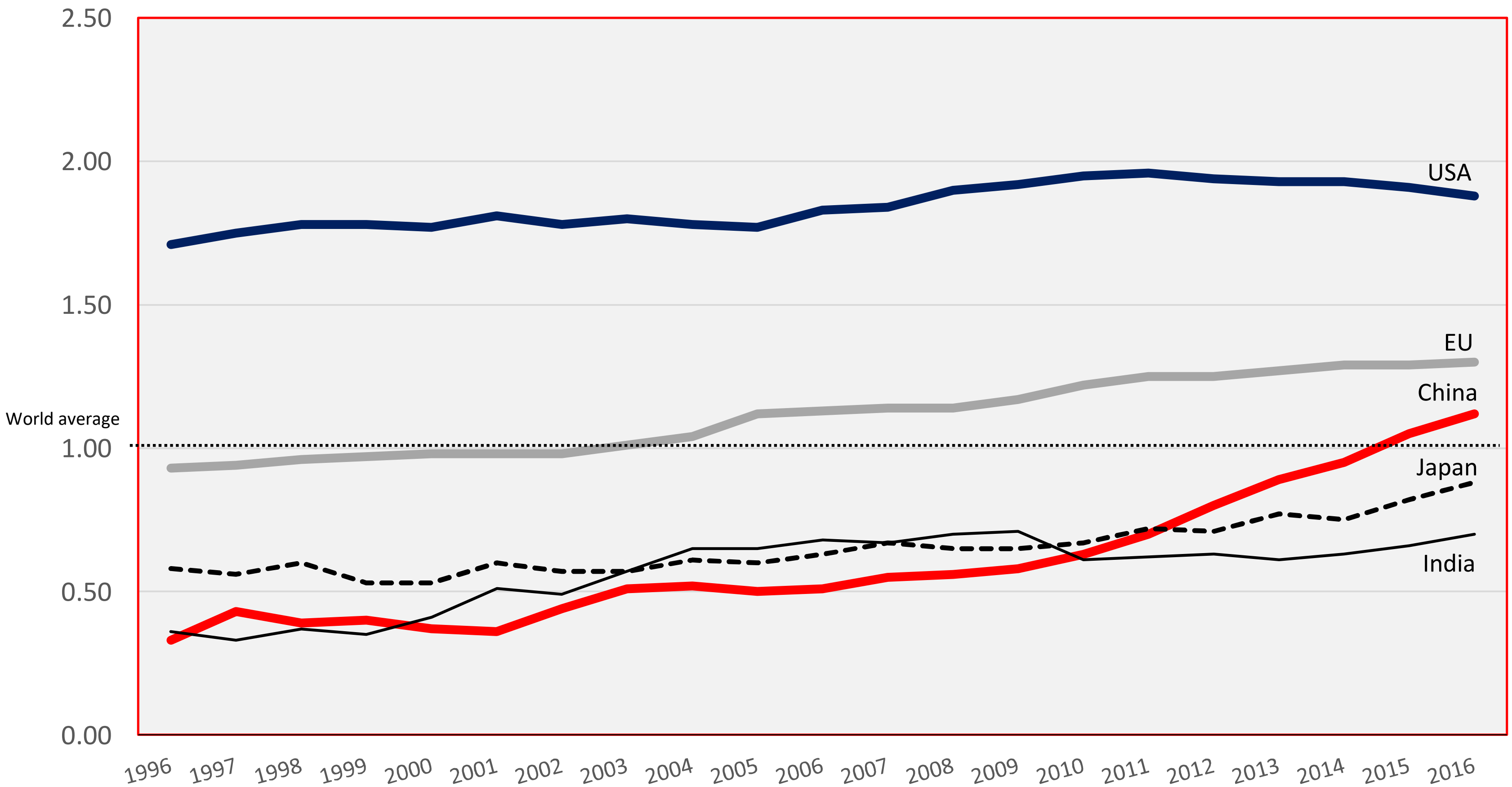
# Total papers, by large discipline cluster, 2018



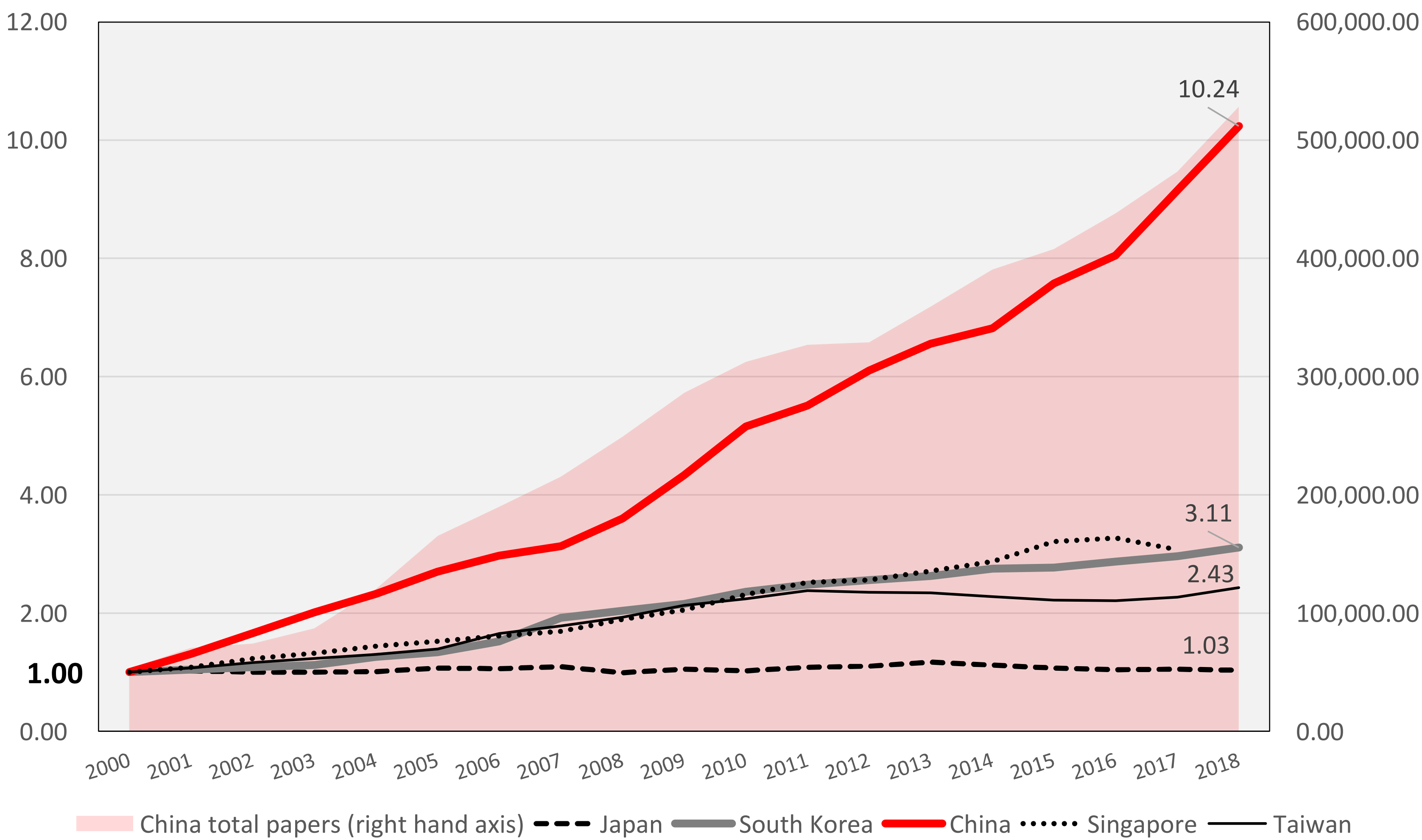



# Proportion (%) of all papers in world top 1% on the basis of citations, leading countries, 1996-2016 (world average = 1.00)



# Growth in spending on R&D in higher education, East Asia: 1996-2018



# Top universities in STEM research

(1) physical sciences and engineering, and (2) mathematics and complex computing, Papers in top 5 per cent of their field by citation rate, World: 2015-2018

| University | System | Physical sciences & engineering |
|---|---|---|
| Tsinghua U | CHINA | 830 |
| Massachusetts IT | USA | 687 |
| Zhejiang U | CHINA | 569 |
| Stanford U | USA | 563 |
| Nanyang TU | SINGAPORE | 533 |
| Harvard U | USA | 532 |
| U Calif., Berkeley | USA | 531 |
| U Science & T. | CHINA | 500 |
| Harbin IT | CHINA | 455 |
| Xi'an Jiaotong U | CHINA | 455 |
| Shanghai JT U | CHINA | 439 |
| U Cambridge | UK | 424 |
| Huazhong U S&T | CHINA | 419 |
| ETH Zurich | SWITZERLAND | 417 |

| University | System | Maths & computing |
|---|---|---|
| Tsinghua U | CHINA | 300 |
| Harbin IT | CHINA | 252 |
| U Electronic S&T | CHINA | 217 |
| Xidian U | CHINA | 201 |
| Beihang U | CHINA | 197 |
| Zhejiang U | CHINA | 197 |
| Huazhong U S&T | CHINA | 195 |
| Nanyang TU | SINGAPORE | 181 |
| Massachusetts IT | USA | 180 |
| Shanghai JT U | CHINA | 153 |
| Stanford U | USA | 151 |
| Northwestern P. U | CHINA | 149 |
| Southeastern U | CHINA | 148 |
| NU Singapore | SINGAPORE | 140 |

# Growth in high citation (top 5%) papers

## selected East Asian universities: 2006-09 to 2015-18

| University | | Top 5% papers 2006-2009 | Top 5% papers 2015-2018 | Growth 2006-09 to 2015-18 p.a. |
|---|---|---|---|---|
| Tsinghua U | CHINA | 401 | 1451 | 15.36% |
| Zhejiang U | CHINA | 335 | 1263 | 15.89% |
| Shanghai Jiao Tong U | CHINA | 299 | 1050 | 14.98% |
| Peking U | CHINA | 302 | 910 | 13.04% |
| Huazhong U S&T | CHINA | 117 | 874 | 25.04% |
| Harbin IT | CHINA | 180 | 790 | 17.86% |
| Sun Yat-sen U | CHINA | 154 | 742 | 19.09% |
| U Hong Kong | HONG KONG | 305 | 465 | 4.80% |
| National U Singapore | SINGAPORE | 511 | 948 | 7.11% |
| Nanyang Technological U | SINGAPORE | 290 | 861 | 12.85% |
| Tokyo U | JAPAN | 668 | 637 | - 0.53% |
| Seoul National U | STH. KOREA | 348 | 543 | 5.07% |
| National Taiwan U | TAIWAN | 273 | 303 | 1.17% |
| MIT | USA | 1221 | 1578 | 2.89% |
| ETH Zurich | SWITZERLAND | 667 | 933 | 3.80% |

Data: US NSB

# SOME KEY QUESTIONS

1. What drives cross-border collaboration?
2. Is global science shaping (dominating) national science?
3. Which narrative best describes global science?
   - National competition in innovation?
   - Global market of World-Class Universities?
   - Centre-periphery hierarchy of nations?
   - Flat network of scientists and research groups?
4. What determines science: states, markets or science?

# What drives cross-border collaboration?

- Collaboration is favoured by governments that see it as a source of capacity building and innovation benefits. Systems of incentives (e.g. financial rewards for publishing) encourage it.
- Yet cross-border authorship is practiced in disciplinary communities where it is shaped by logics of shared resources, division of labour within teams, and geographical and cultural proximity.
- Two primary causes are advanced
  - *Preferential attachment:* scientists follow the path of personal advantage, they seek partners from whom they gain status which assists their career
  - *Cognitive accumulation:* scientists are curiosity driven and follow a knowledge building path, seeking collaborators with whom they can do significant work

# Is global science increasingly autonomous, and dominant, *vis a vis* national science?

"… the international and national networks may be shaping each other in a process of co-evolution between the national institutional structure and the global network. The relative influences of national and international networks appear to vary among nations." (p. 11)

"Collaboration has grown for reasons independent of the needs and policies of the state .. This dynamic system, operating orthogonally to national systems, is increasingly difficult to influence and even less amenable to governance as it grows... nations must learn to manage and benefit from a network. Networks operate by reciprocity, exchange, incentives, trust, and openness…" (p. 2, p. 12)

Wagner, C., Park H. and Leydesdorff, L. (2015). The continuing growth of global cooperation networks in research: A conundrum for national governments. *PLoS ONE* 10 (7): e0131816. doi:10.1371/journal.pone.0131816

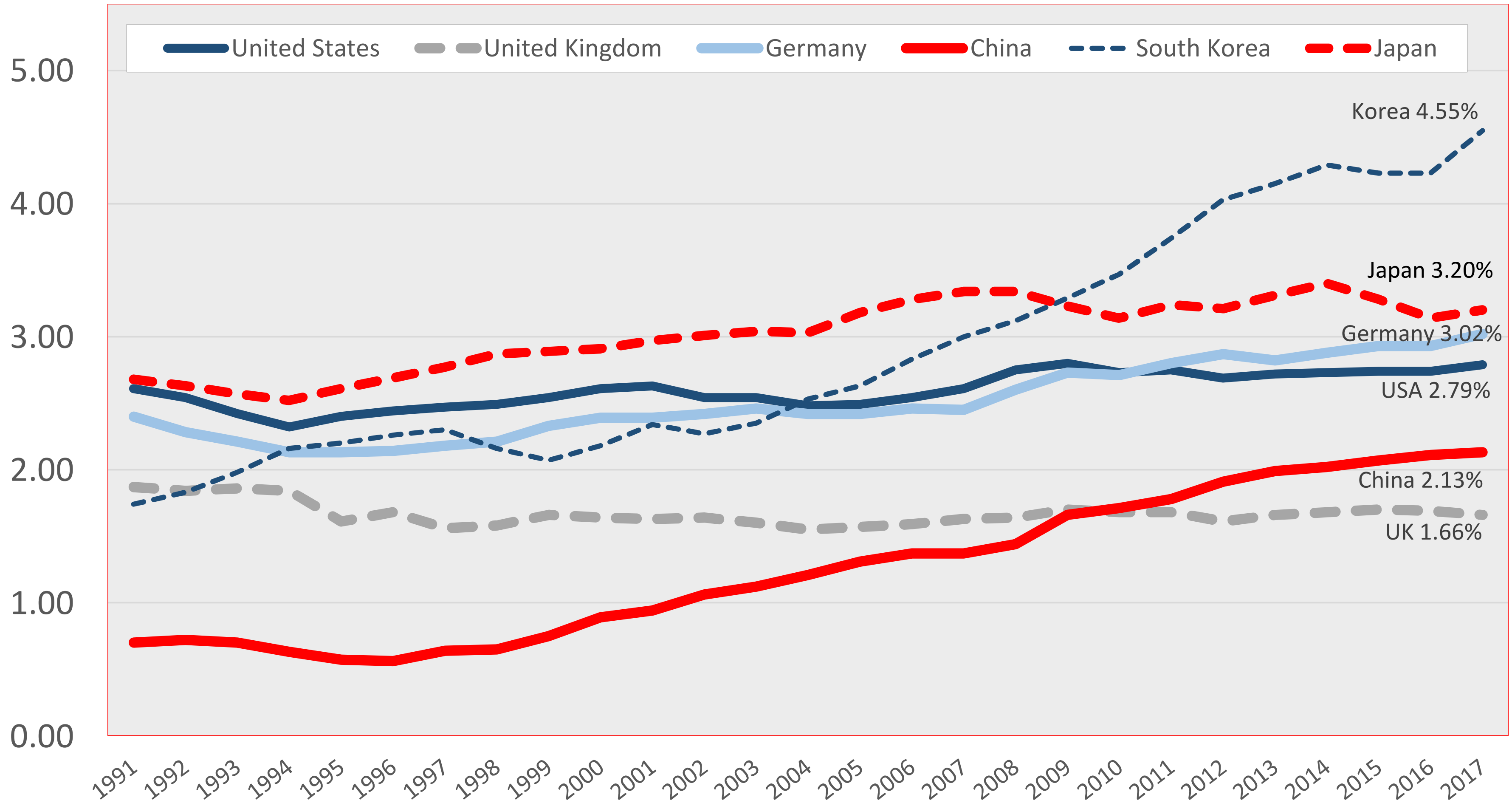
# The global research system? Which narrative

- Arms race of competing nations?
- Market of competing universities (WCUs)?
- A global hierarchy (and if so, a centre-periphery hierarchy?)
- An open and increasingly flat network that expands continually?

# AN ARMS RACE IN INNOVATION?

The technological nationalist explanation

# R&D as proportion (%) of GDP, 1991-2017:
USA, UK, Germany, China, Japan, South Korea




Data: OECD

# A GLOBAL MARKET OF COMPETING WCUs?

ACADEMIC RANKING OF WORLD UNIVERSITIES

ACADEMIC RANKING OF WORLD UNIVERSITIES

SINCE 2003

THE

Times Higher Education

WORLD UNIVERSITY RANKINGS

POWERED BY THOMSON REUTERS

QS

QS WORLD UNIVERSITY RANKINGS

# Papers in top 5% by citations 2015-18: Leiden

| university | country | Top 5% papers | all papers | % of all papers in top 5% |
|---|---|---|---|---|
| Harvard U | USA | 4282 | 33,722 | 12.7 |
| Stanford U | USA | 2078 | 16,161 | 12.9 |
| U Toronto | CANADA | 1691 | 22,995 | 7.4 |
| U Oxford | UK | 1610 | 15,353 | 10.5 |
| MIT | USA | 1578 | 10,563 | 14.9 |
| U Michigan | USA | 1473 | 18,598 | 7.9 |
| Tsinghua U | CHINA | 1451 | 19,902 | 7.3 |
| U College London | UK | 1424 | 14,742 | 9.7 |
| Johns Hopkins U | USA | 1407 | 17,215 | 8.2 |
| U Cambridge | UK | 1370 | 13,485 | 10.2 |
| U Washington Seattle | USA | 1329 | 14,730 | 9.0 |
| U California - Berkeley | USA | 1313 | 10,671 | 12.3 |
| U Pennsylvania | USA | 1266 | 13,414 | 9.4 |
| Zhejiang U | CHINA | 1263 | 23,510 | 5.4 |

# A CENTRE-PERIPHERY HIERARCHY

In which traditional leaders stay on top

# Centre-periphery model of worldwide higher education?

# The old dependency model is obsolete

- New science nations and groups emerge freely in the global science system without ‘gatekeeping’ by leading nations; many middle income and some lower income nations have viable science systems; emerging researchers network freely with emerging researchers in other countries
- The rise of East Asia and the growth of science in India, Iran, Brazil and elsewhere has blown Euro-American centrism out of the water
- There is more than one path to the development of science. Some emerging nations emphasise robust national capacity building and networks (e.g. Iran, South Korea); some build capacity primarily through global collaborations (e.g. Paraguay); some combine the two (e.g. China)

# More complex than centre-periphery suggests

More than one ‘centre’, networked groupings

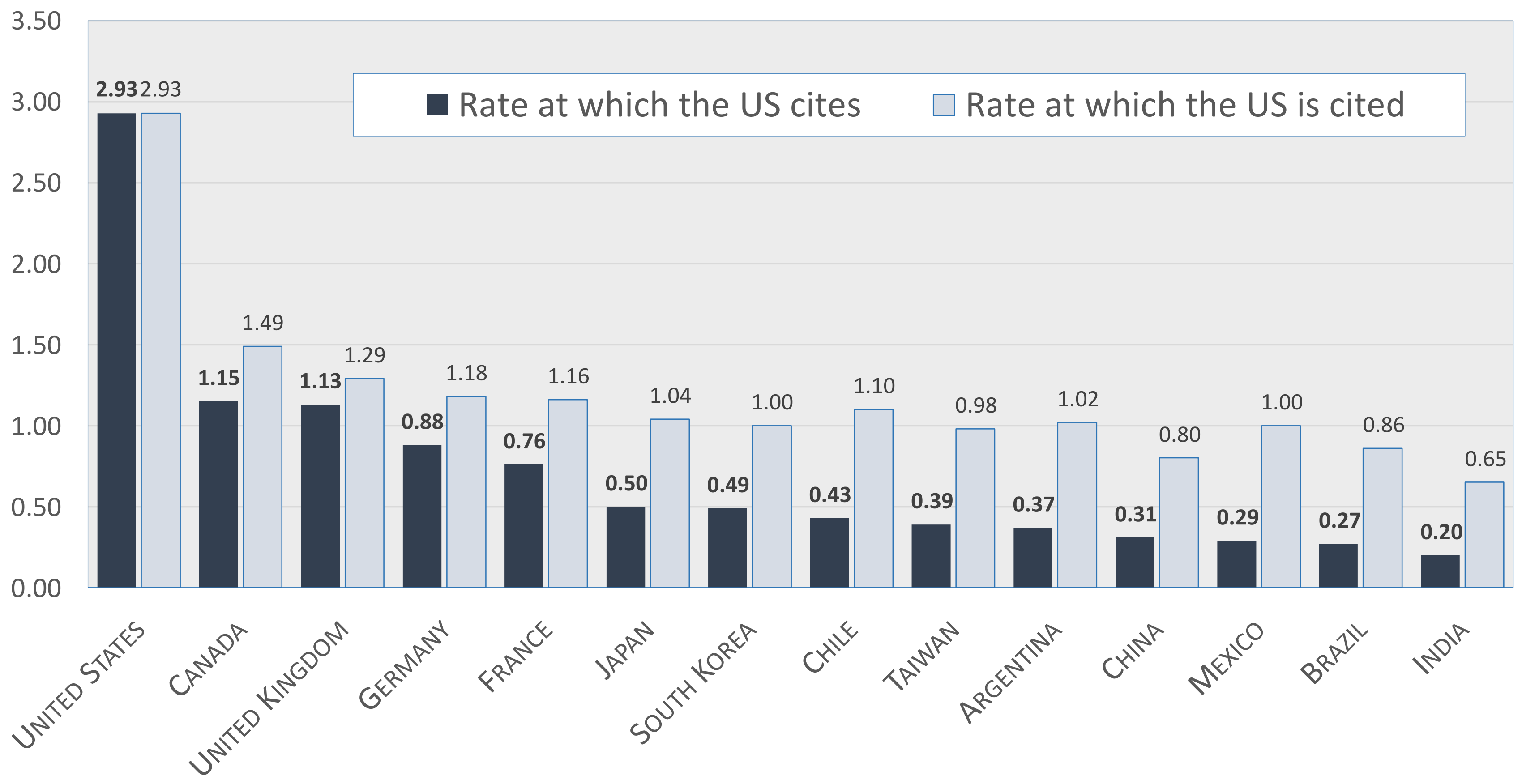
# A FLAT GLOBAL NETWORK?

# Networks are explanatory up to a point

- The dynamics of networks match those of knowledge itself; networks models provide the best explanation for the rapid growth of global science
- Global science has evolved towards more not less inclusion over time. Global science is open to new players and fosters agency and up till now, in much of the world, it seems to have become more independent of nations
- BUT science power is very unequal. Knowledge circuits are not organised on the basis of equality of respect. Anglo-American countries are very dominant. It is possible for any country with resources to become as strong science country but much harder to change (or even re-imagine) the dominant cultural patterns, centred on the leading universities, their personnel and their conventions, standards and language

# Hegemony: Who cites US, who is cited by US

The rate at which papers by authors from selected countries are cited by papers with authors from United States, compared to the rate that these countries cite United States authors, science and engineering papers, 2014. world average = 1.00

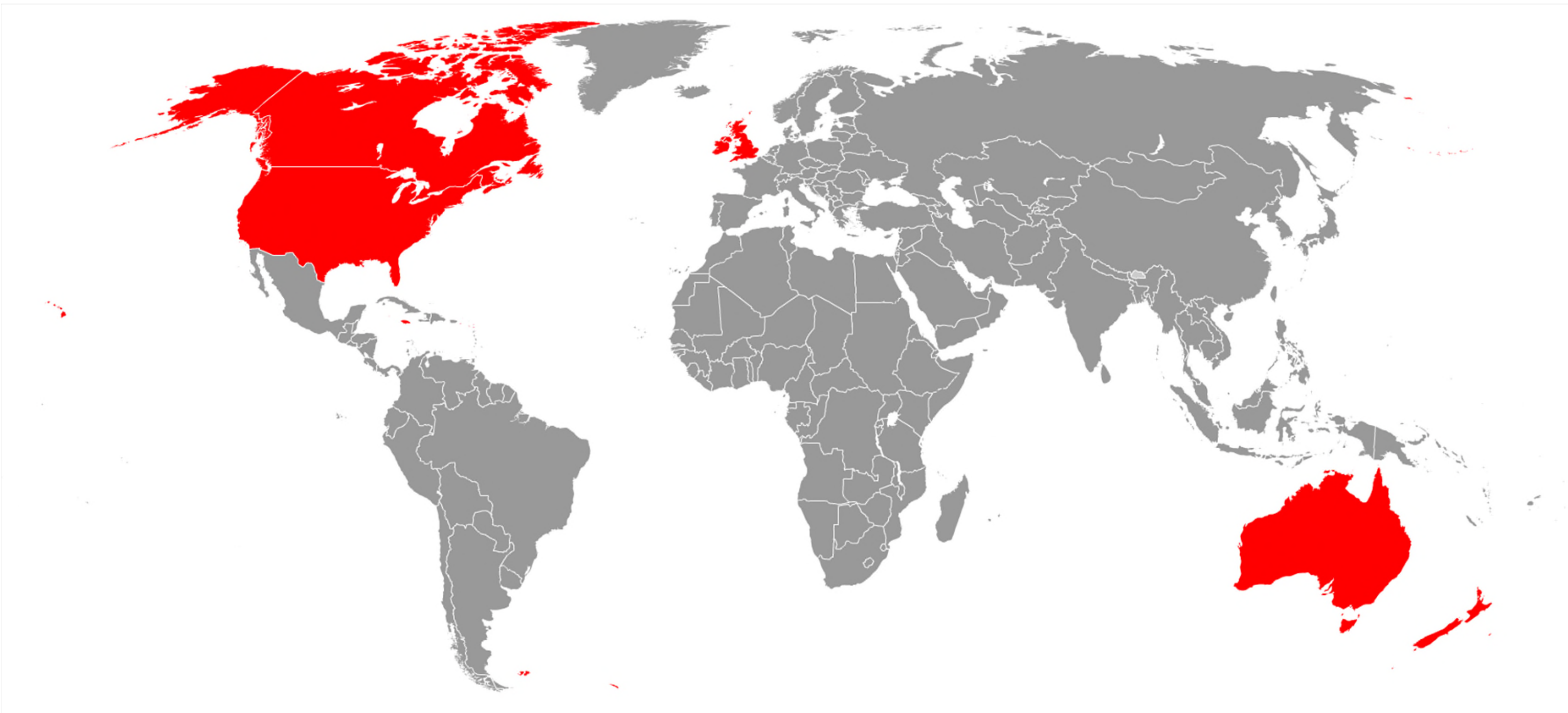


# First language speakers and total language speakers, Ethnologue 2018

| | L1 speakers (million) |
|---|---|
| Chinese (Mandarin) | 909 |
| Spanish | 442 |
| English | 378 |
| Hindi | 260 |
| Bengali | 243 |
| Portuguese | 223 |
| Russian | 154 |
| Western Punjabi | 93 |
| Javanese | 84 |
| Chinese (Wu) | 81 |
| Turkish | 79 |
| French | 77 |

| | L1 & L2 (million) |
|---|---|
| English | 1121 |
| Chinese (Mandarin) | 1107 |
| Hindi | 534 |
| Spanish | 513 |
| French | 285 |
| Standard Arabic | 274 |
| Russian | 265 |
| Bengali | 262 |
| Portuguese | 237 |
| Indonesian | 198 |
| Urdu | 163 |
| German | 132 |

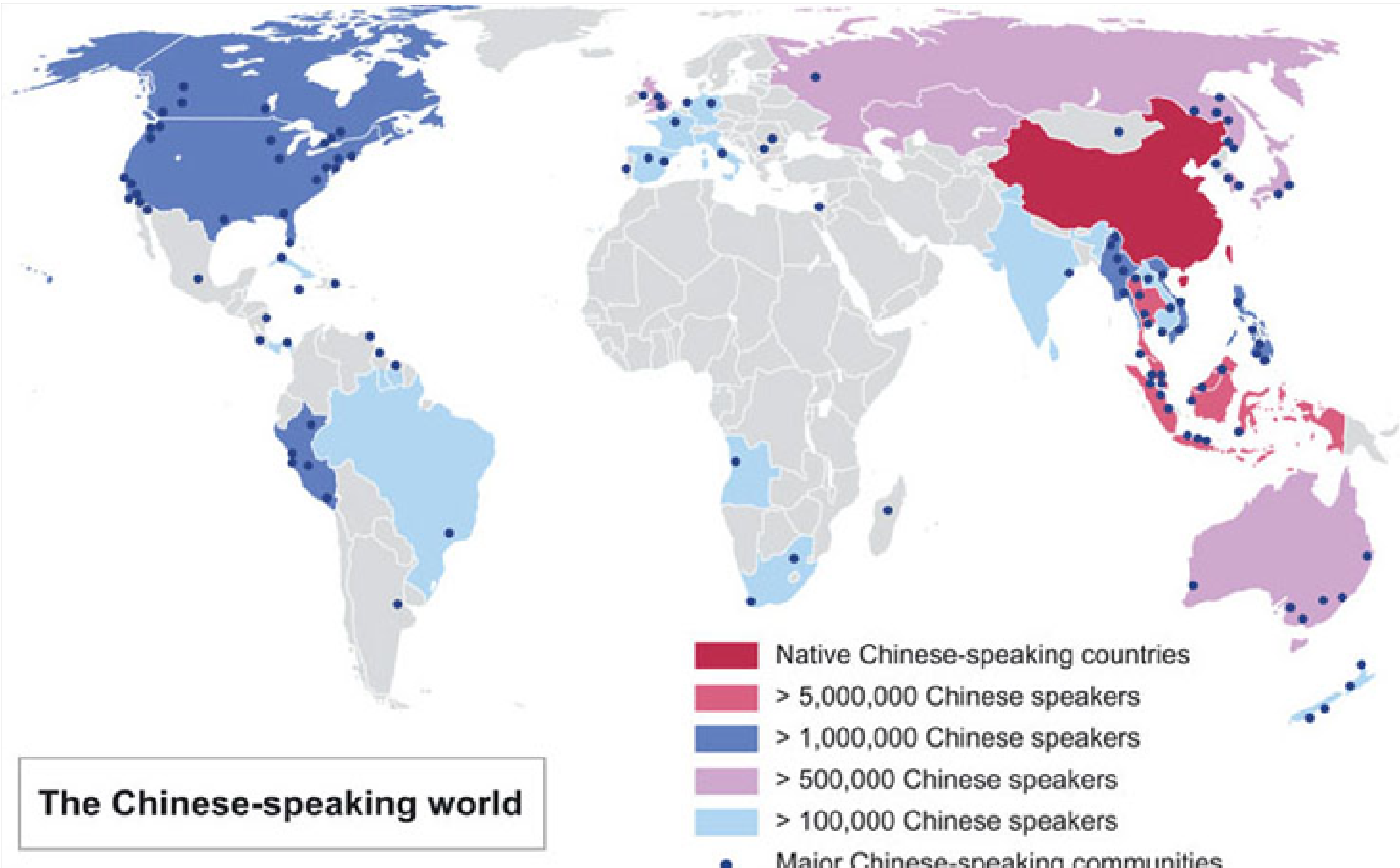
# Countries where over 50% of people are English first language speakers



# Shanghai ARWU top 10 countries, 2020

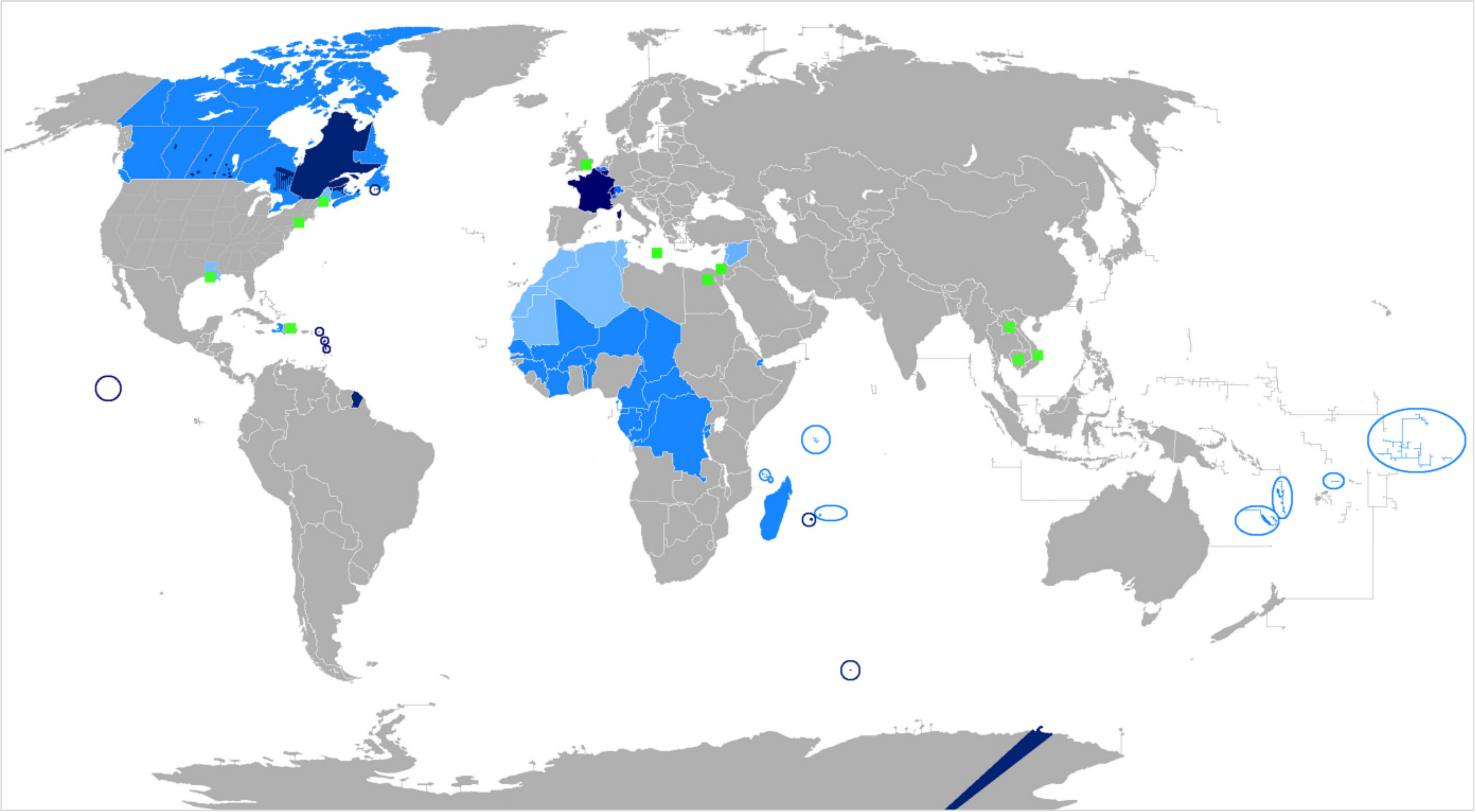
| | top 100 universities | top 500 universities |
|---|---|---|
| United States | 45 | 137 |
| United Kingdom | 8 | 36 |
| Australia | 7 | 23 |
| China (mainland only) | 6 | 71 |
| France | 5 | 17 |
| Switzerland | 5 | 8 |
| Germany | 4 | 30 |
| Canada | 4 | 19 |
| Netherlands | 4 | 12 |
| Japan | 3 | 14 |

# Chinese language use



# The Spanish speaking world

# The French speaking world



# Arabic speaking countries

# Is the science system ultimately autonomous or is it determined by nations and markets?

“ Scientists have had a particular need for functional differentiation, since they need room for provisional interpretations or hypotheses that they may wish to change with hindsight. In the longer run, the sciences can allow for normative control only over the conditions of the communication (e.g., resource allocations), but not over the substantive and reflexive contents of these communications. Thus, the differentiation from normative integration has been a functional requirement for the further development of natural philosophy, that is, the new sciences. This crucial conflict was fought in Western Europe between the appearance of Galileo’s Dialogo in 1632 and the publication of Newton’s Principia in 1687.”

- Loet Lydesdorff, Scientific communication and cognitive codification: Social systems theory and the sociology of scientific knowledge, *European Journal of Social Theory*, 10 (3), pp. 375-388

- The science system rests on the autonomy of individuals and disciplinary groups, and the autonomy of the system (e.g. freedom to communicate and work together)
- US-China tensions and the accompanying national ‘securitisation’ of international academic cooperation might change that
- Nazi Germany showed that (1) a determined state can break a strong science system, and (2) there are decisive limits to what science can achieve in the absence of the autonomy of individual scientists and the autonomy of the science system