# What drives global science? The four competing narratives

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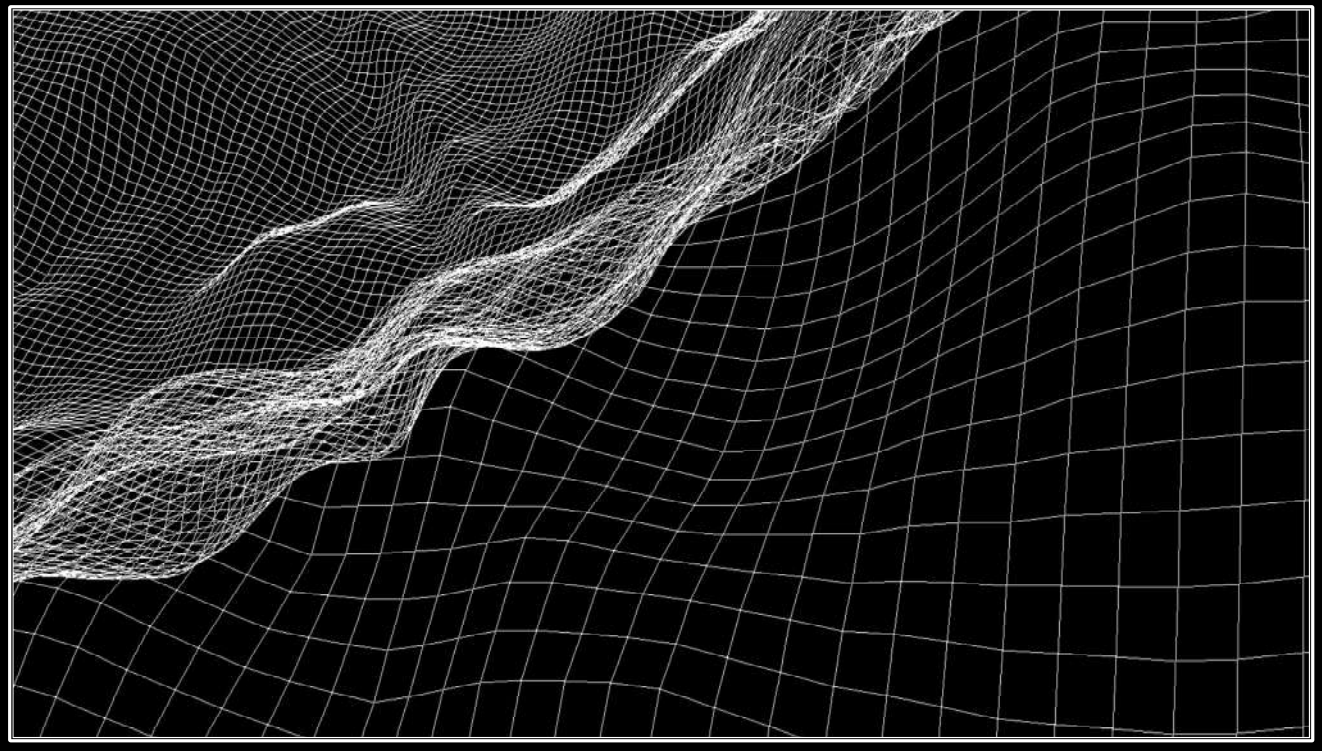
*CHER Asia, University of Hong Kong, 15 September 2021*



# After 1990 the Internet made possible the global science system

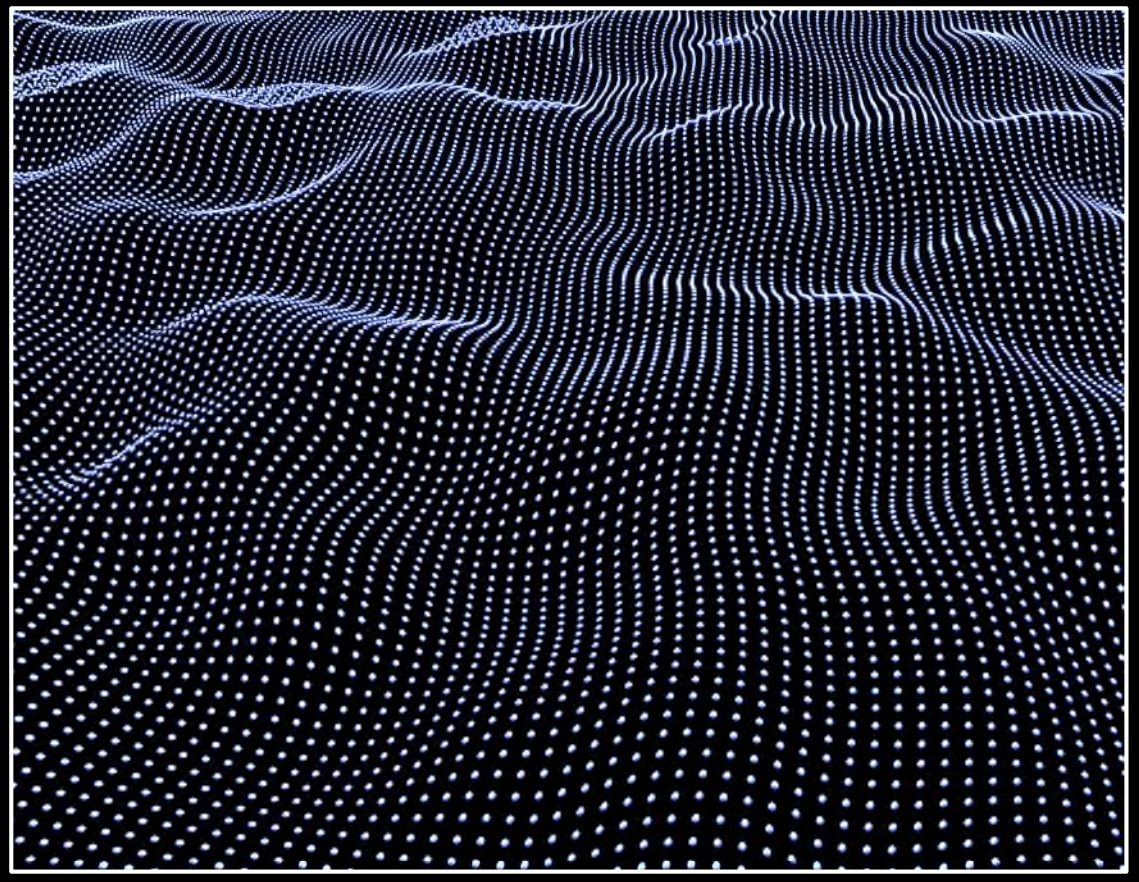
In *Theory of Society* Luhmann (2012) notes that the decisive step towards world society was ‘the full discovery of the globe as a closed sphere of meaningful communication’ (Volume 1, p. 85).

Electronically-mediated communication has made possible the birth and rapid expansion of a global science system, not driven by technology as such but by human agents.

# Not all knowledge is English-language or Western global science

- '… the understanding of the world by far exceeds the Western understanding of the world and therefore our knowledge of globalization is much less global than globalization itself… the more non-Western understandings of the world are identified, the more evident it becomes that there are still many others to be identified and hybrid understandings, mixing Western and non-Western components, are virtually infinite. Post-abyssal thinking thus stems from the idea that the diversity of the world is inexhaustible and that such diversity still lacks an adequate epistemology. In other words, the epistemological diversity of the world does not yet have a form. … Post-abyssal thinking confronts the monoculture of modern science with the ecology of knowledges'
- - Boaventrua de Susa Santos (2007). Beyond abyssal thinking: From global lines to ecologies of knowledges. *Review (Fernand Braudel Centre)*, 30 (1), pp. 64-66

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



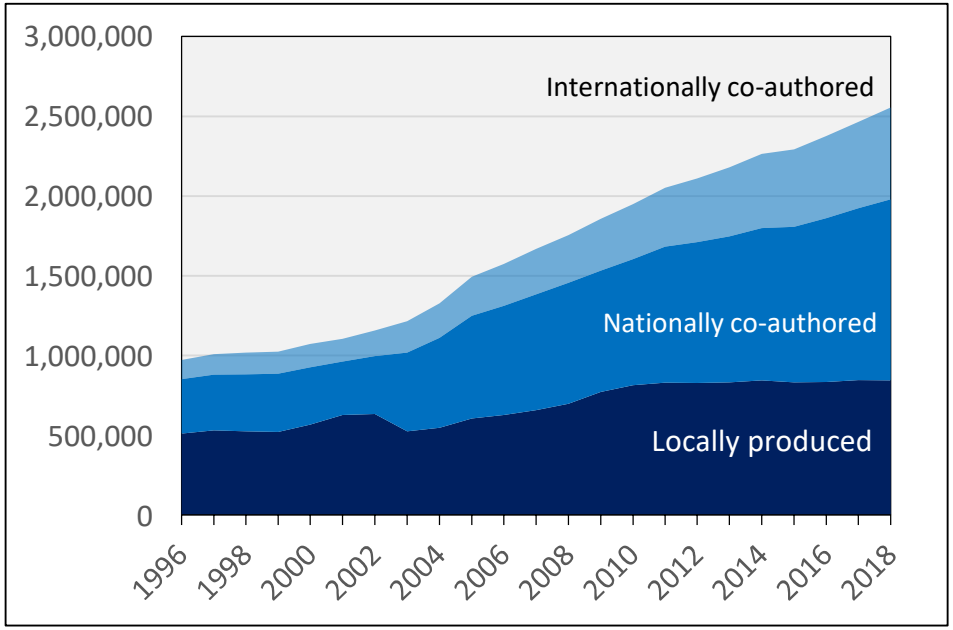
## *Rapid growth of science*

The global science system has spread in exceptionally dynamic fashion

- *Growth:* Rapid increases in many countries in R&D spending and growth of published science papers at 5 per cent a year since the year 2000
- *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 and a range (though US science remains very strong and globally central)
- *Global integration:* Increase in the role of the global science system vis a vis national science systems – some researchers argue that the global science system has become the primary driver of science

# GROWTH

Science papers in Scopus, by type of collaboration, world: 1996-2018




US National Science Board

# DIVERSIFICATION

The spread of research to more countries 1987-2017

| | 1987 | 1997 | 2007 | 2017 |
|---|---|---|---|---|
| Number of countries producing 50% of world science | 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 producing 90% of world science | 20 | 23 | 26 | 32 |

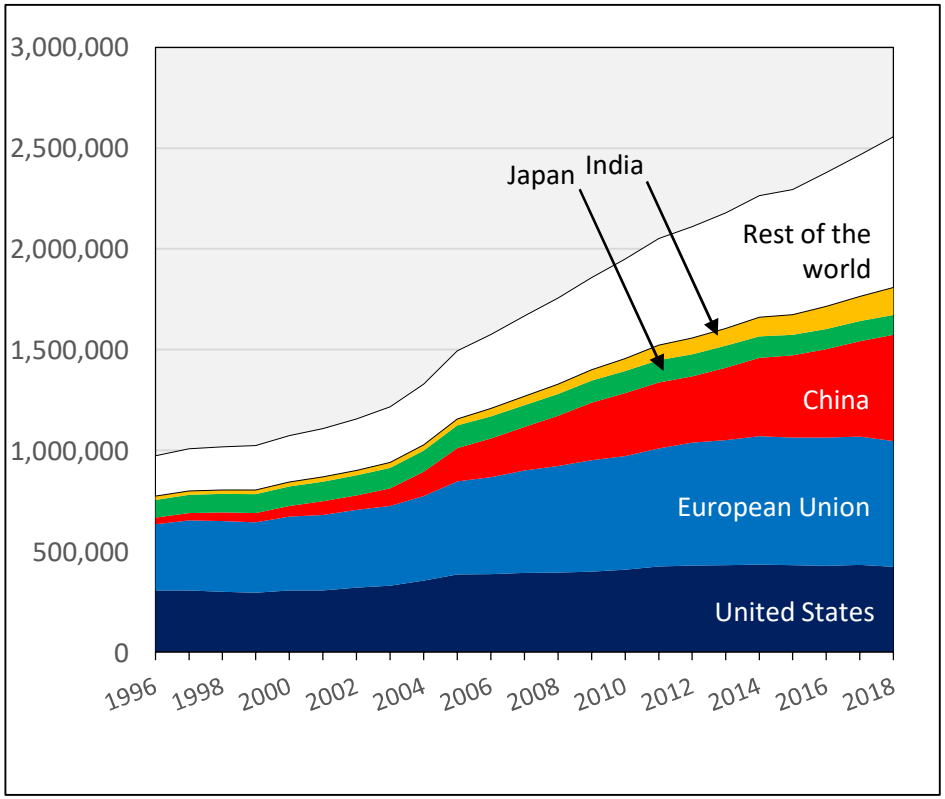
Web of Science and Scopus

# PLURALISATION OF POWER

‘The new swing of the pendulum … is going to lead to a world where no one will be dominant… What is different about our time is that globalization forces us to live all jumbled together and yet we have very different visions of what this common world should look like. [Political scientist] Charles Kupchan writes: “The next world will hardly be the first one in which the different great powers operate according to different conceptions of order. But, due to the onset of global interdependence, it will be the first time that such a diverse set of orders intensely and continuously interact with each other.”’

- Bruno Macaes, *The Rise of Eurasia*, 2018, p. 2.


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

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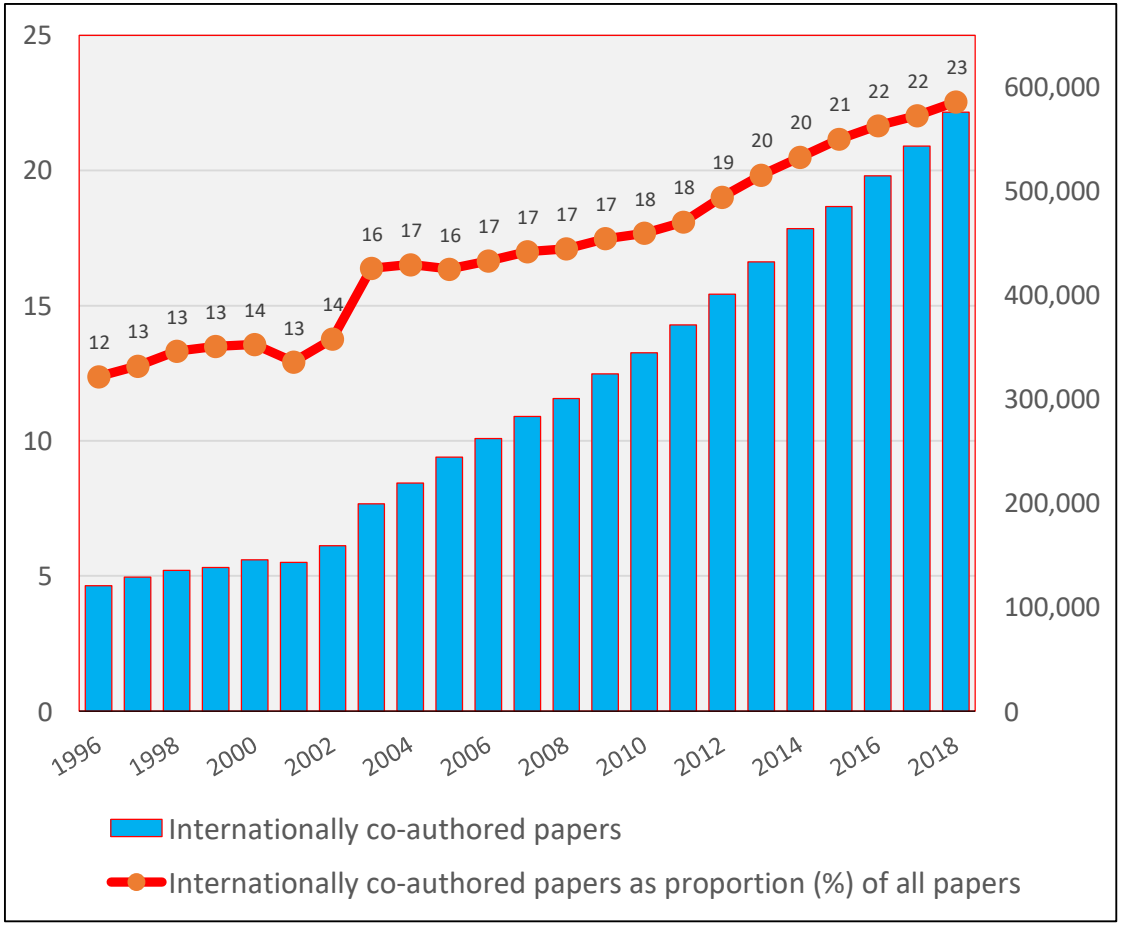
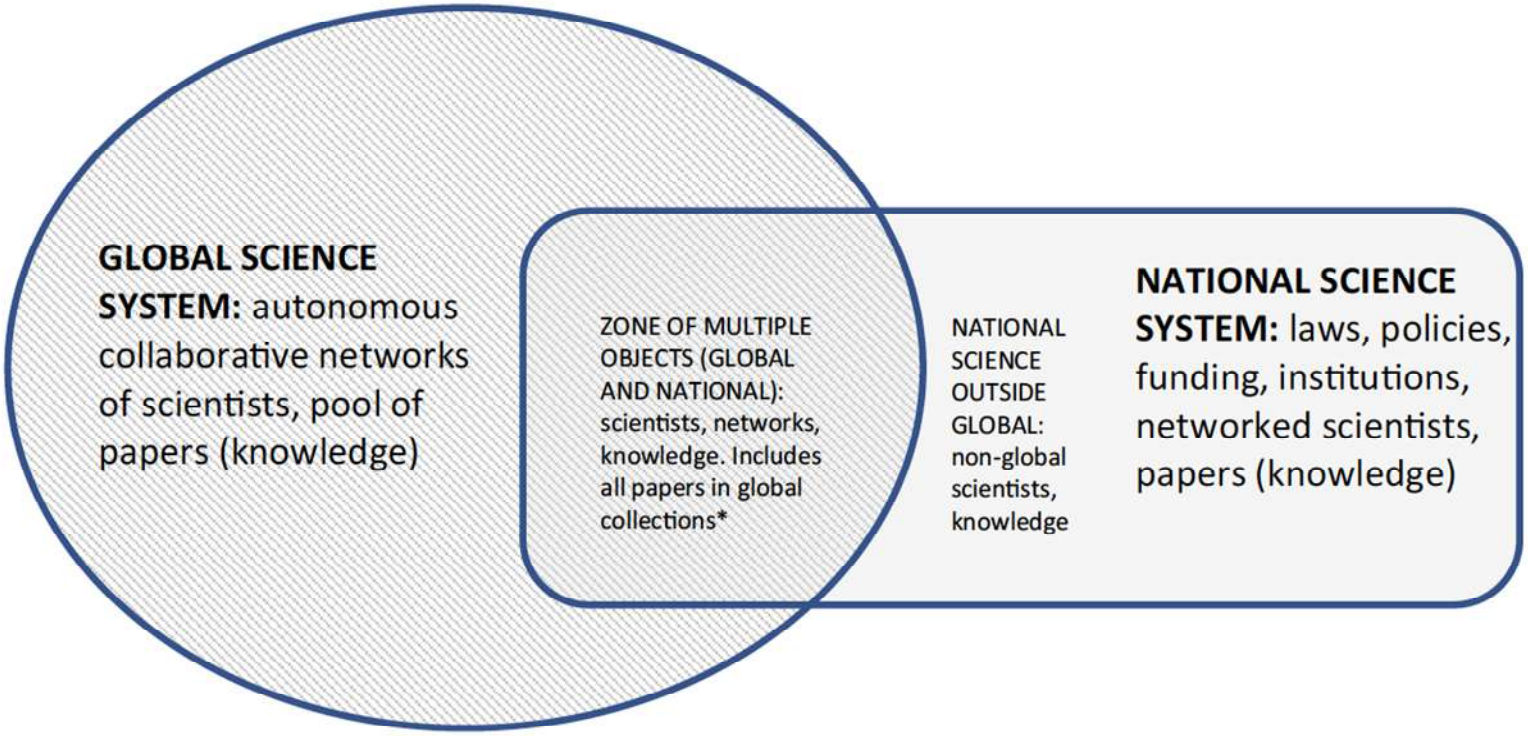
# RISING GLOBAL COLLABORATION

Internationally co-authored papers, all countries: 1996-2018



# The nation-state factor in science

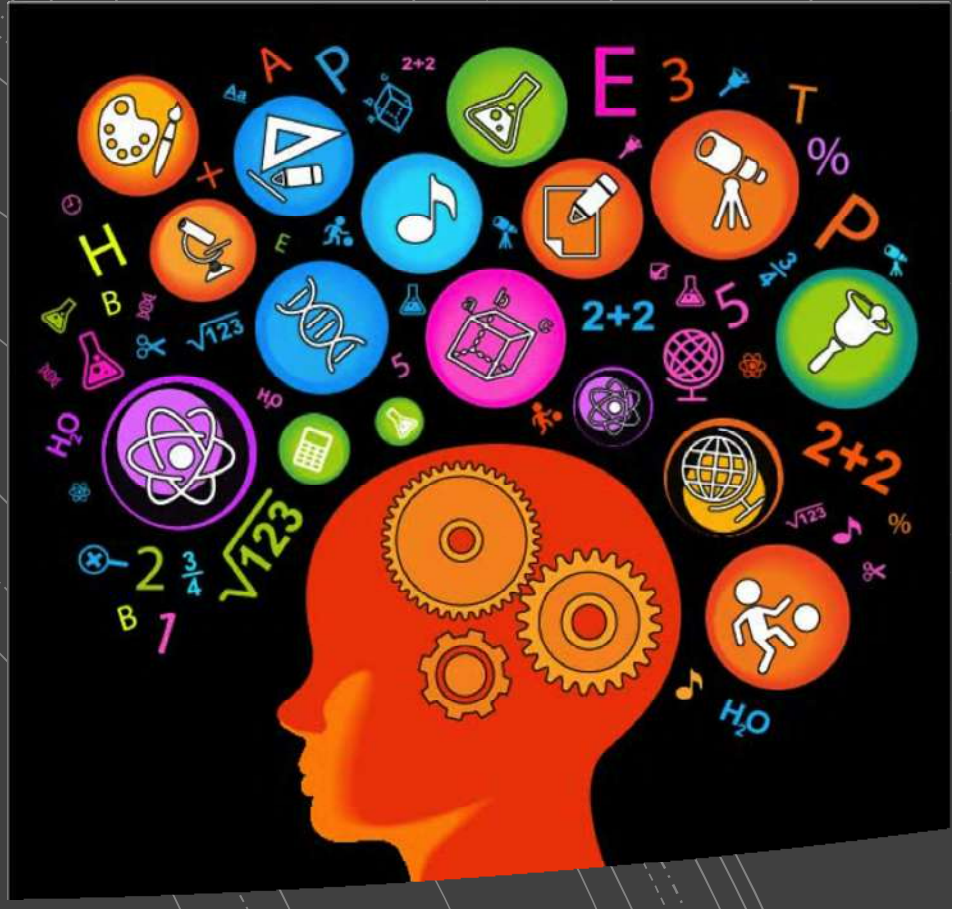



# Global science and national science: two distinct and overlapping science systems

- 'The global network has a culture, pathways, and norms of communication specific to its structure, and diverging from national, regional, or disciplinary norms' - Wagner, Whetsell and Leydesdorff, 2017, p. 1646.

# Differences between national and global science

| | Global science system | National science system |
|---|---|---|
| **Core components** | Knowledge, people, networked communications, norms and practices | Nation-state ordered and resourced institutional structure of science activity |
| **Enabling conditions** | Resources, institutions, and (often national) agencies/policies/rules | Political and economic stability and policy commitment to science activity |
| **Main functions** | Production and circulation of new knowledge via networked activity | Legal, political, financial conditions of science. Some knowledge, applications |
| **Boundary** | World society | Nation-state |
| **Normative centre** | No normative centre | Nation-state |
| **Knowledge contents** | Papers published in journals admitted by Web of Scienc and Scopus | Most contents of global journals plus further nationally circulated materials |
| **Social relational** | Collegial groups of scientists operating in networks | Government agencies, research organisations, networked scientists |
| **Collective loyalty** | Diffuse: disciplinary community as persons and as shared knowledge | Concentrated: national and institutional authorities |
| **Regulation** | Local self-regulation on the basis of global collegial scientific norms | National law, official regulation, policy, financing systems, cultural norms |
| **How this system affects the other system** | Knowledge potential of global science stimulates state funding | National resources, institutions and personnel underpin global science |



# What motivates global scientific collaboration?

- Cognitive accumulation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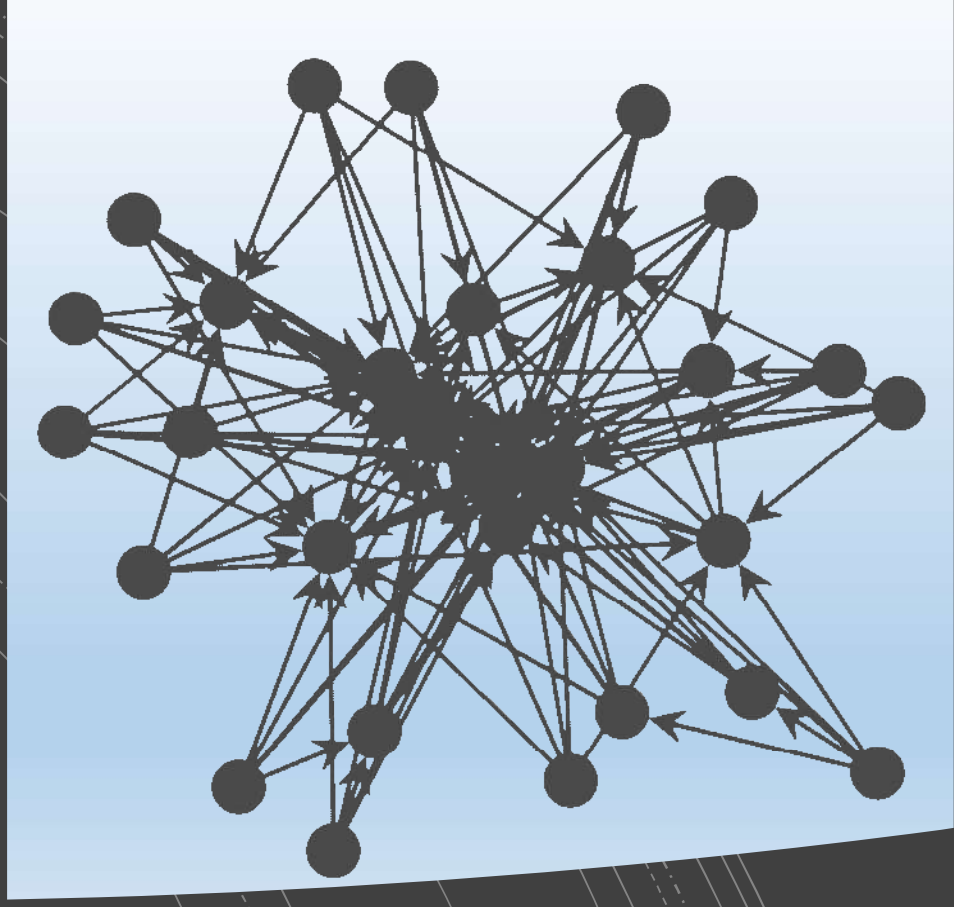
- Cognitive accumulation
- Intellectual or resource affinity



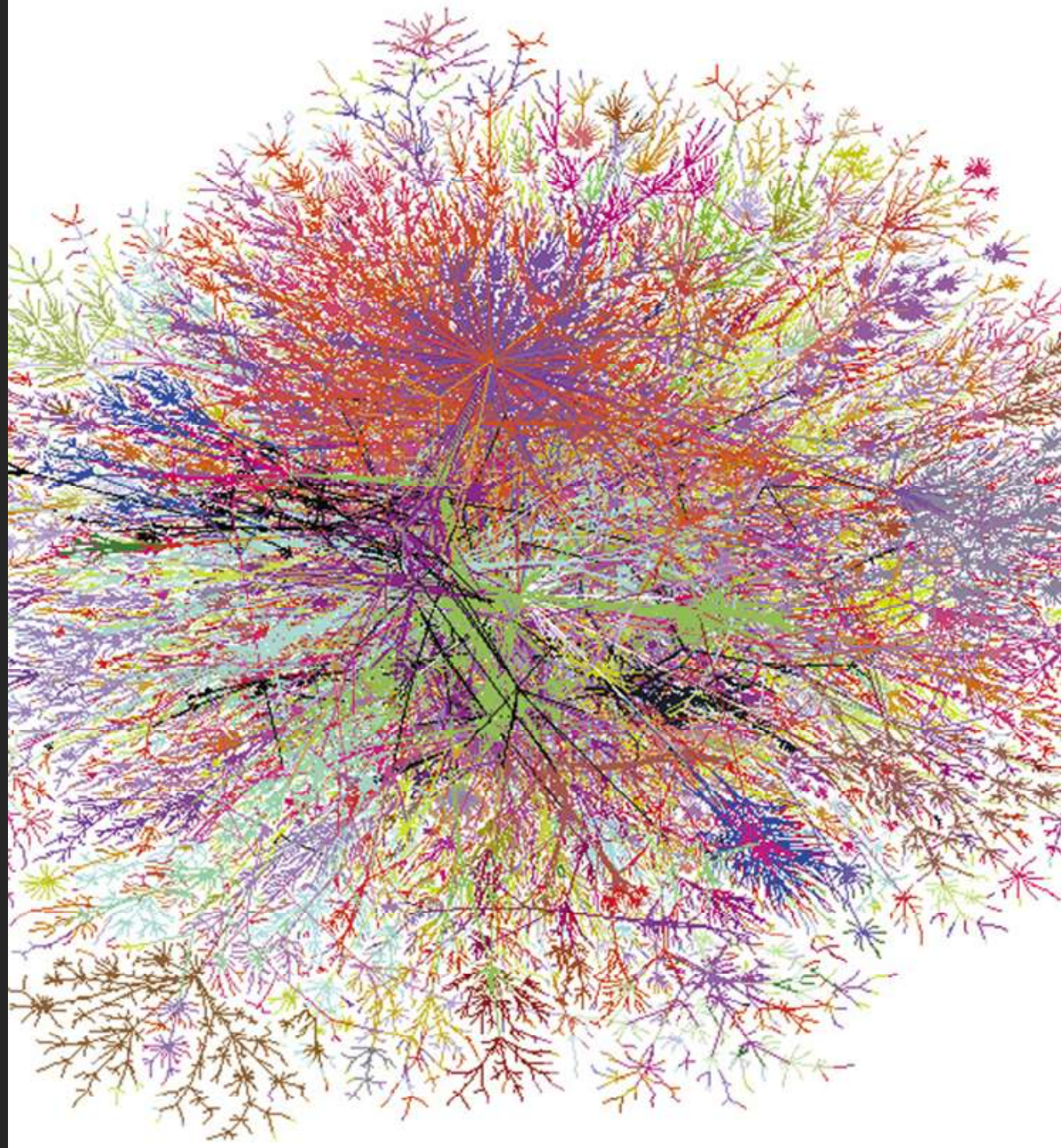
# What motivates global scientific collaboration?

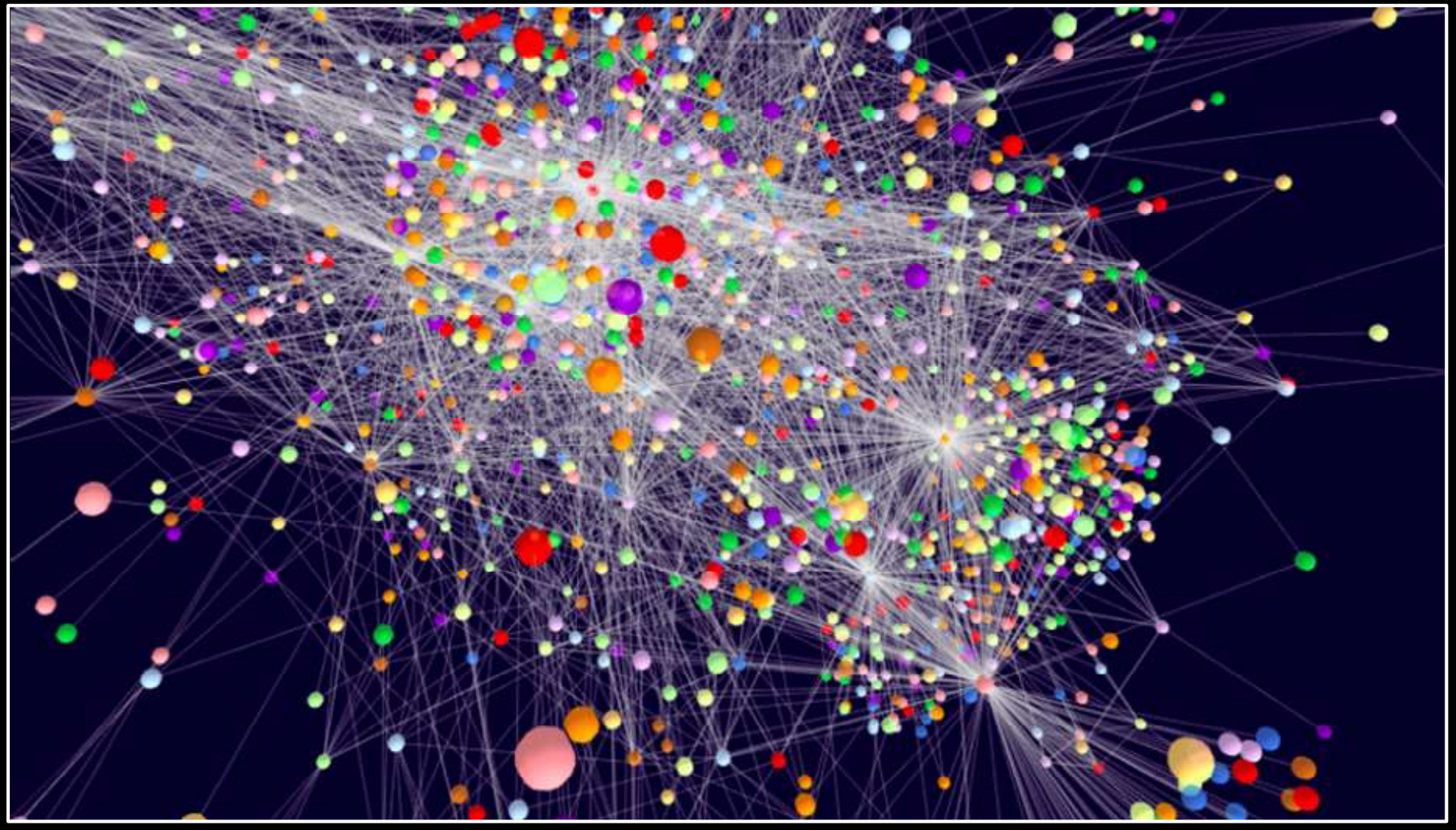
- Cognitive accumulation
- Intellectual or resource affinity
- Preferential attachment

# The global science system?

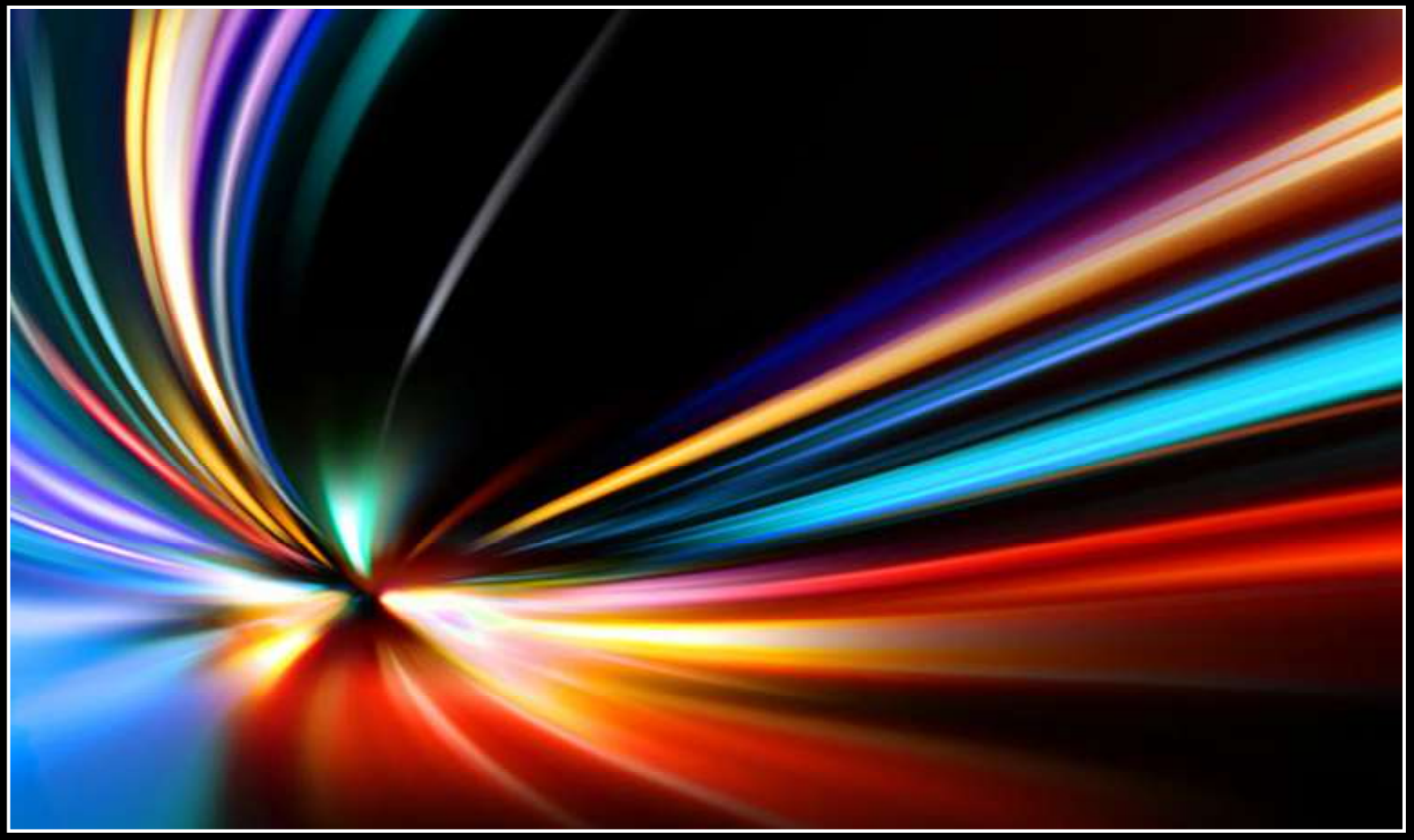
- An open and flat network that expands continually?
- National ‘arms race in innovation’?
- Global market of competing universities (World Class Universities, WCUs)?
- A centre-periphery world systems hierarchy?

## Narrative 1:
An open and flat network that expands continually





Network connectivity



Network dynamism

# Global science is flat?

'The organization may be more open to new members, since greater density of the network and the lowered in-betweenness measures suggest that fewer of the communications pass through the leading nodes or countries … international cooperation is particularly advantageous for less advanced countries …'

- 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)

# Reasserting the vertical

‘If hierarchy is neglected, preoccupation with connections may blur an accurate understanding … the network is embedded in structural inequalities, but the impression arises that it operates in a vacuum.’

- Conrad (2016), *What is Global History?,* pp. 70, 127.

Narrative 2:
National arms race in innovation


# Methodological nationalism traps us in the national container: we cannot see global science

‘”Methodological nationalism” is grounded in the belief that the nation/state/society is the natural social and political form of the modern world’ - Wimmer and Schiller (2002), p. 301

‘Conventional social theories operate within what can be called an internalist paradigm… social theories essentially treat societies as self-generating and assume that social change is always of a society’s own making. Global history, by contrast … recognises the impact of structures that extend past the boundaries of individual societies’ – Conrad (2016), pp. 88-89

# Is it valid to arbitrarily ascribe global science data to individual nations?

'The sciences develop internationally, but the funding is mainly national' - Bornmann, Adams and Leydesdorff, 2018, 931

'Comparisons are to a degree confounded because a large and growing fraction of scientific work involves international collaborations … Another concern is that there is an English language bias in the ISI data base, both in the journals included and in patterns of citation… Could this explain why the United States, United Kingdom and Canada do so much better than France, Germany, Italy and Japan?'

- Robert May 1997), The scientific wealth of nations, *Science*, 275, p. 795 – the article that launched international comparisons in science

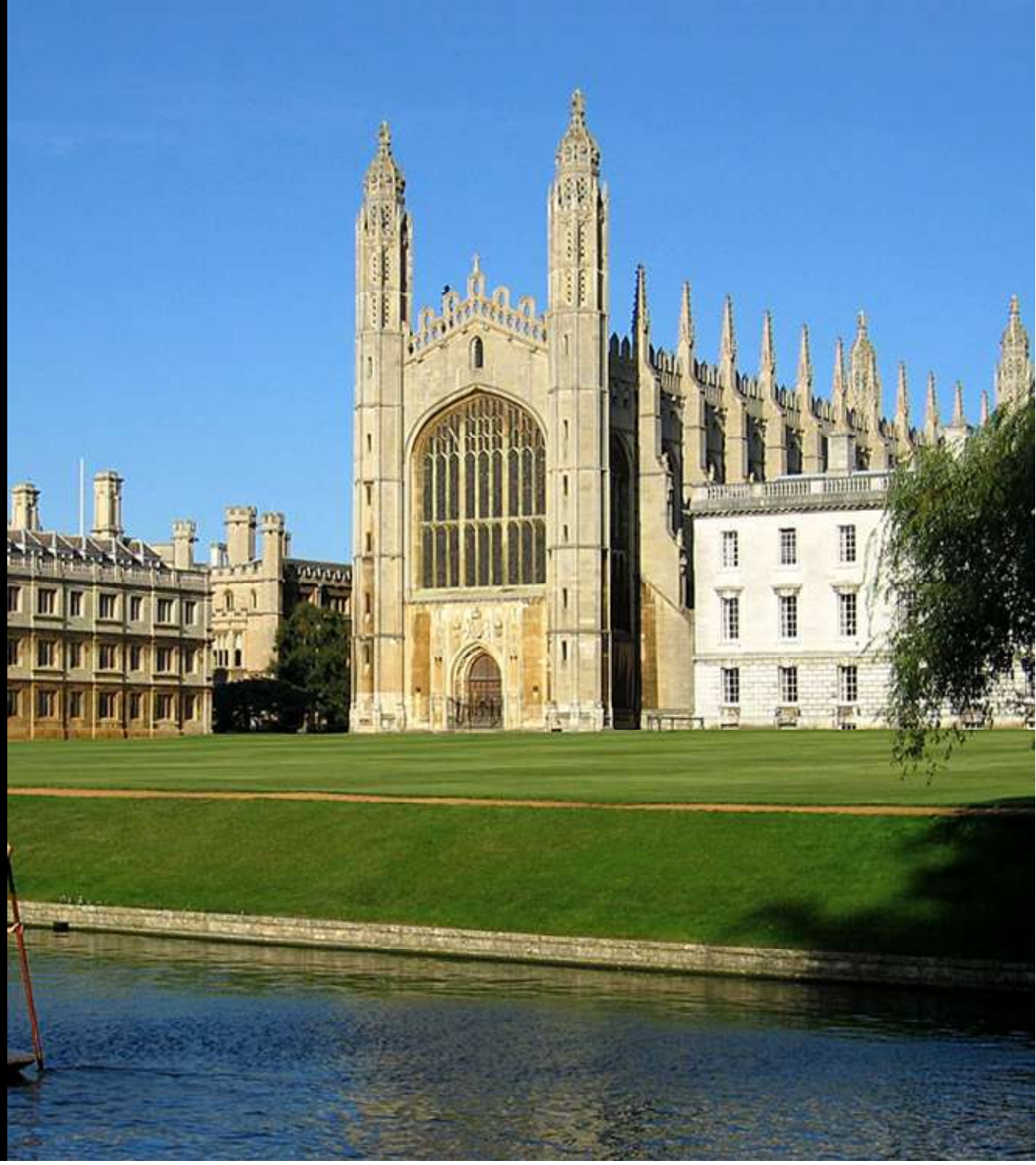
# Science to innovation to business profit?

*The myth of nation-based linear causality*

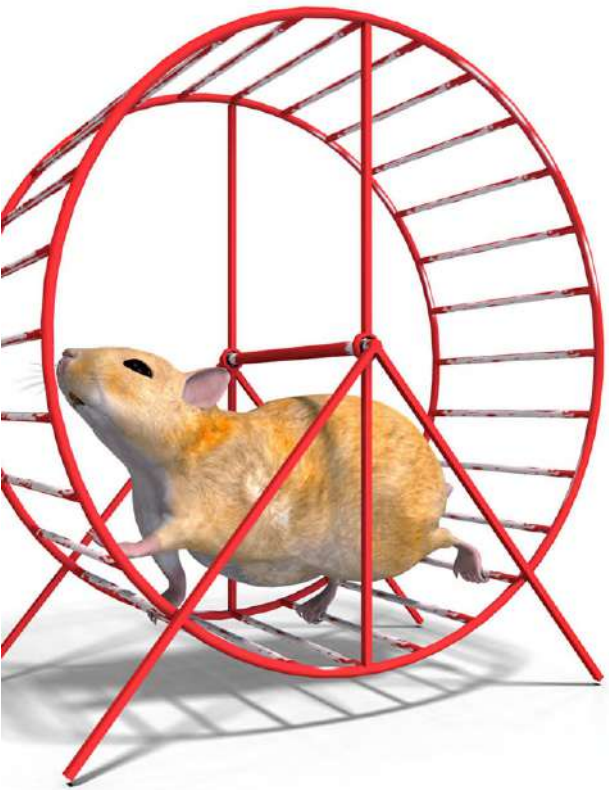
- Science enters a global pool: national science can be used by foreign not local capital
- Innovations by national industry can be sourced in foreign origin science
- Most research is 'altruistic', not focused on national economic development (e.g. research in medical and health sciences, social sciences)

- Richard Klavans and Kevin Boyack (2017). The research focus of nations: Economic vs. altruistic motivations. PLOS ONE, 12 (1)

# Narrative 3: Global market of ’World-Class Universities’



# The key role of science in global university rankings



| Rankings | Publication-related indicators as proportion % | Databases |
|---|---|---|
| Shanghai Jiaotong Academic Rankings of World Universities (China) | 70.0 | Clarivate Analytics' Web of Science |
| Times Higher Education World University Rankings (UK) | 38.5* | Elsevier's Scopus |
| QS World University Rankings (UK) | 20.0* | Elsevier's Scopus |
| Leiden Ranking (Netherlands) | 100.0 | Clarivate Analytics' Web of Science |
| Best Global Universities (US) | 72.5 | Clarivate Analytics' Web of Science |

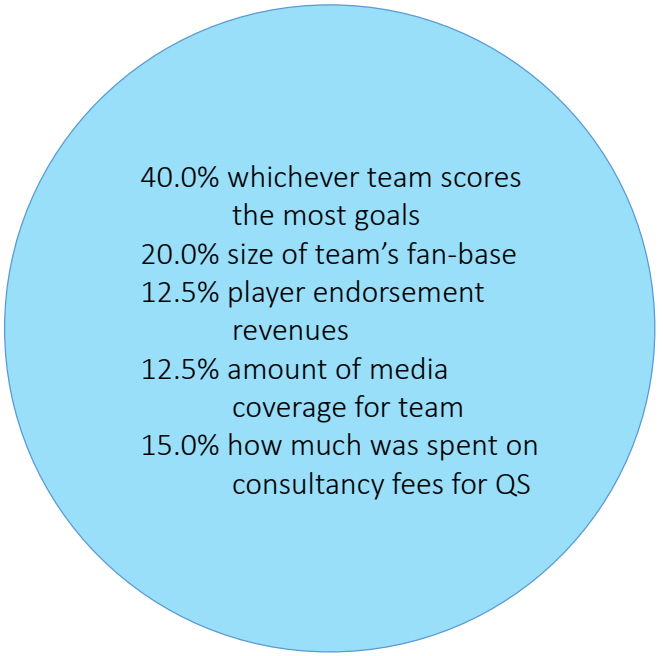
Source: The methodology pages on above rankings' websites, updated on 21-January-2021.
* Research performance has a further, indirect but important, effect through its impact on the surveys used by Times Higher and QS

# Composite multi-indicator approach to competitive science?

## University rankings methodology extended to World Cup in football

BORING TIRED OLD APPROACH
The winner is determined by -


*INNOVATIVE* RANKINGS APPROACH
The winner is determined by -




Composite multi-indicator rankings use arbitrary weightings of different elements of institutional activity. These weightings are untheorised. Why should, say, PhD student numbers be 5%, or high citation researchers 10%? Reverse those percentages and a very different rank order appears – which is the 'true' hierarchy in science?

# University rankings explain nothing about science, yet they order it

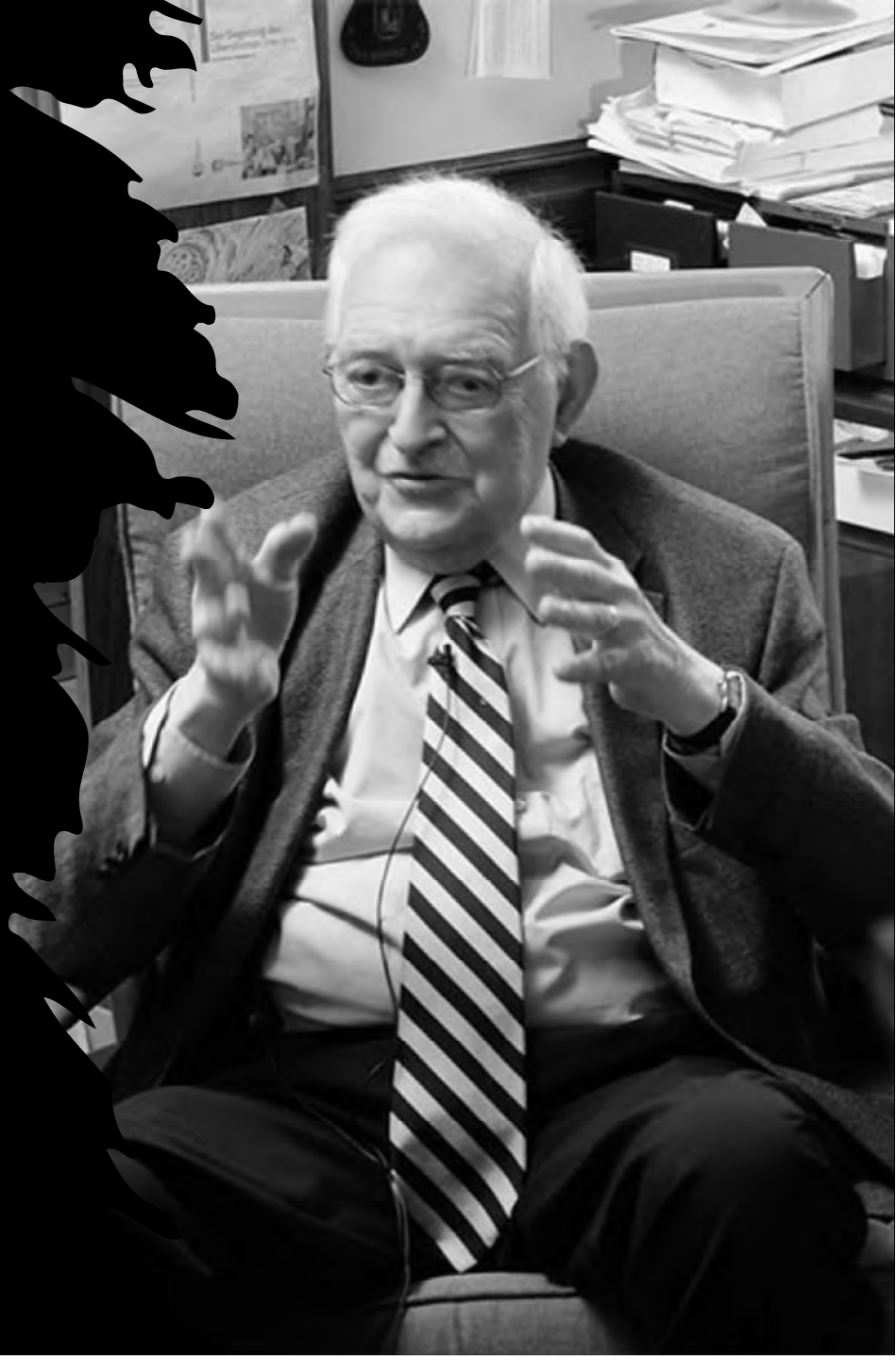
**Papers in the top 5% of the field by citation rate, 2016-19, Leiden ranking**

| university | country | Top 5% papers | all papers | % of all papers in top 5% |
|---|---|---|---|---|
| Harvard U | USA | 4230 | 34,234 | 12.4% |
| Stanford U | USA | 2117 | 16,454 | 12.9% |
| U Oxford | UK | 1696 | 16,088 | 10.5% |
| U Toronto | CANADA | 1691 | 23,454 | 7.2% |
| MIT | USA | 1586 | 10,507 | 15.1% |
| Tsinghua U | CHINA | 1574 | 21,225 | 7.4% |
| U Michigan | USA | 1490 | 18,756 | 7.9% |
| U Cambridge | UK | 1440 | 14,080 | 10.2% |
| Johns Hopkins U | USA | 1439 | 17,337 | 8.3% |
| U College London | UK | 1430 | 14,923 | 9.6% |
| Zhejiang U | CHINA | 1427 | 25,964 | 5.5% |
| U Pennsylvania | USA | 1290 | 13,568 | 9.5% |
| U Washington , Seattle | USA | 1288 | 14,807 | 8.7% |
| Columbia U | USA | 1234 | 12,558 | 9.8% |
| U California, Berkeley | USA | 1225 | 10,006 | 12.2% |

## **Narrative 4:** Global science as a centre-periphery hierarchy

# Wallerstein's world-systems theory and the centre-periphery model

- All nations are incorporated into an expanding Euro-American world-system grounded in the capitalist world-economy
- World-system is based on a three-way division of labor between countries (1) world 'centre' in US, parts of Western Europe, perhaps Japan, with strong states; (2) nations on 'periphery' where states are endemically weak or non-existent, controlled by foreign capital; and (3) nations of the intermediate 'semi-periphery', China, Korea, Russia, Australia, other Europe, etc
- Countries in the periphery and the intermediate semi-periphery are locked into position. It is very difficult to move from one category to another, because there is a zero-sum contest over a limited 'world-surplus'
- Individual nations do not have autonomy: 'There is no such thing as "national development"' (Wallerstein, 1974, p. 390).
- The world level solely consists of nation-states. There are no autonomous global relations that crisscross and combine nations (so an autonomous global science system as such is impossible)

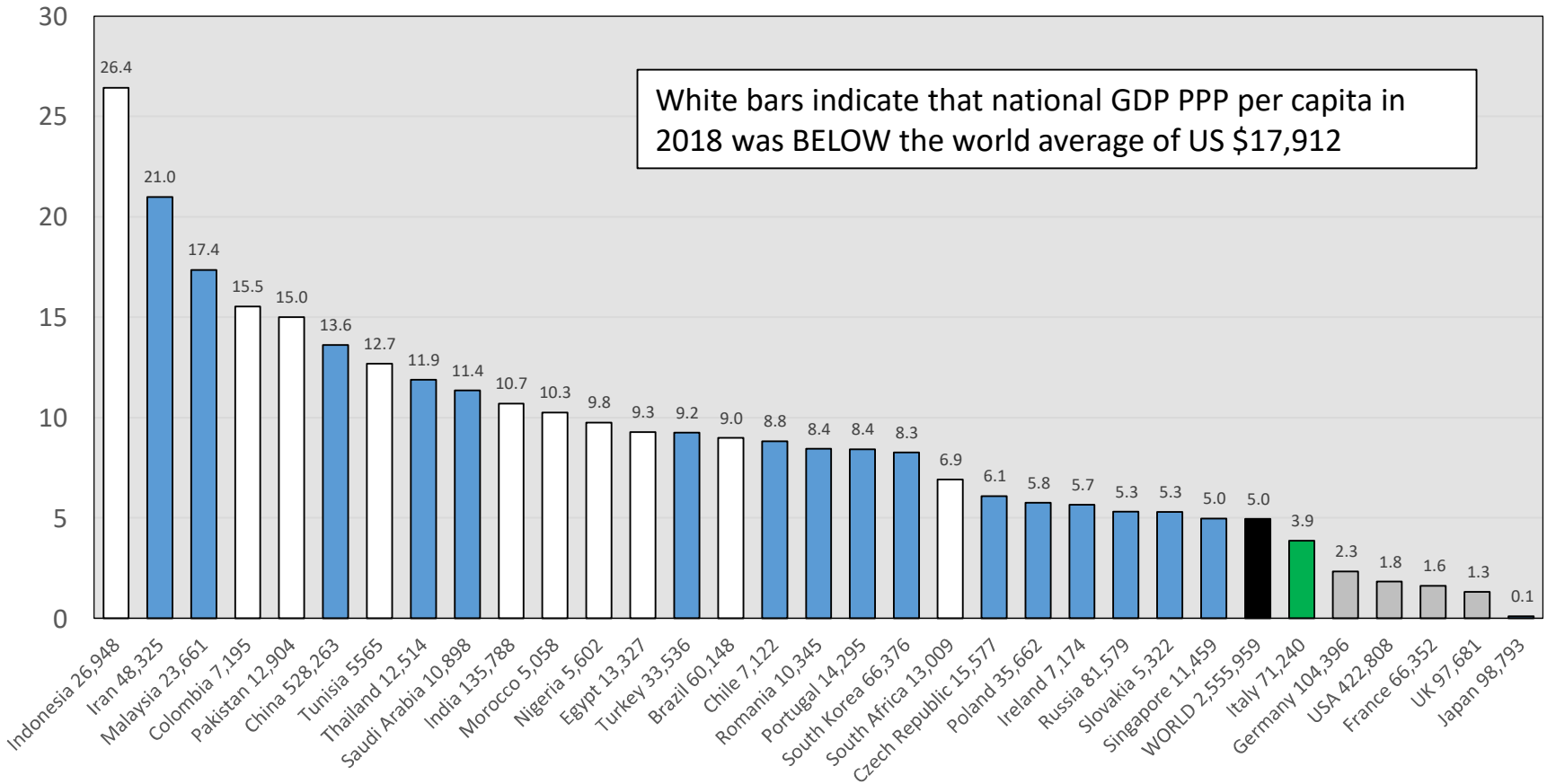


# But many countries in the 'periphery' are successfully developing science systems

## Average annual growth (%) in science papers: 2000-2018

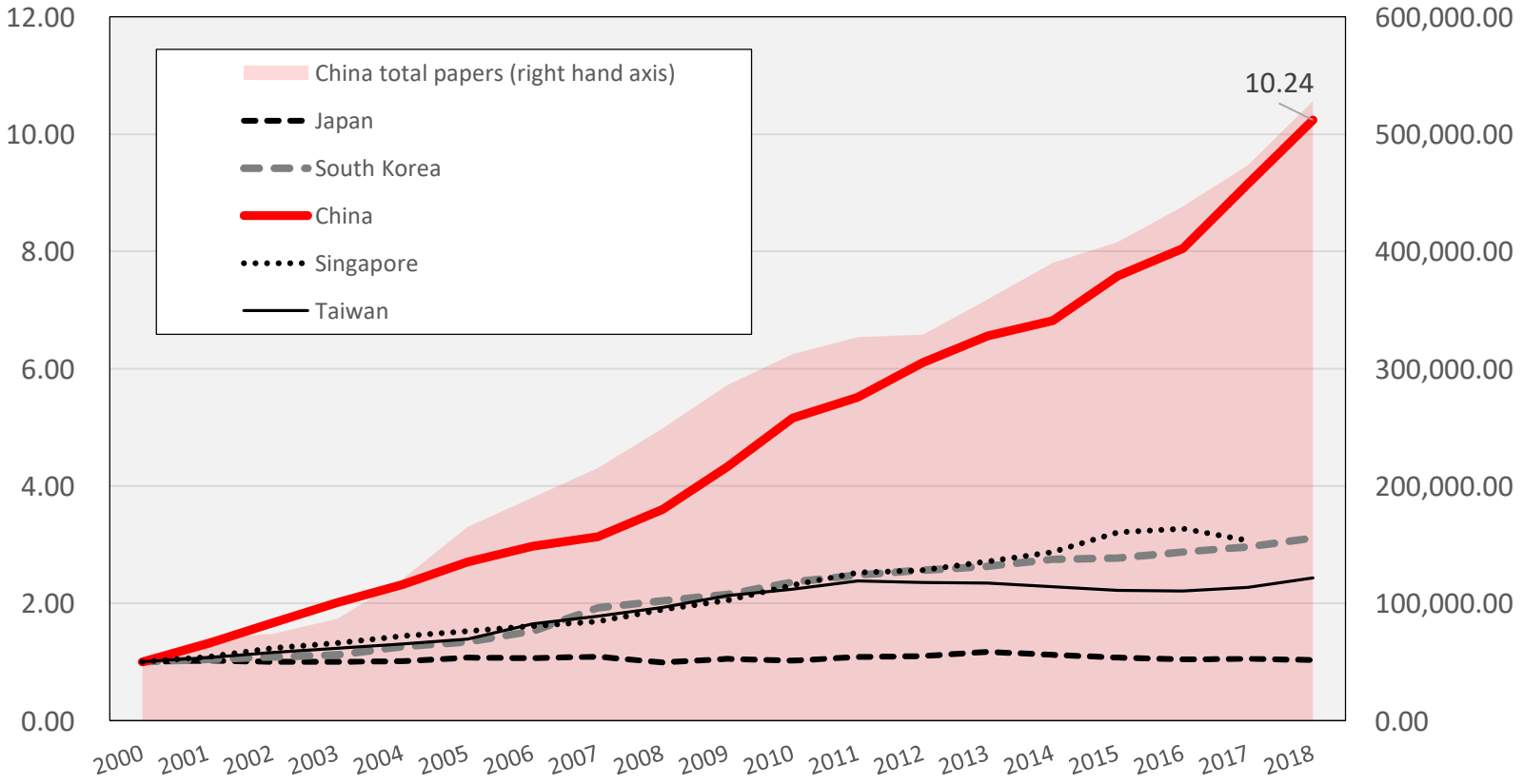
**Countries with science growth rate *above world average* of 4.95% per year and producing more than 5000 papers in 2018, plus six major science countries**

White bars indicate that national GDP PPP per capita in 2018 was BELOW the world average of US $17,912



# Chinese science has destroyed beliefs that the ‘West’ is more intrinsically creative

Spending on R&D in higher education, constant prices, East Asia: 2000-2018 (2000 = 1.00)



# 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: 2016-2019 *(Leiden ranking)*

| University | System | Physical sciences & engineering |
|---|---|---|
| Tsinghua U | CHINA | 909 |
| MIT | USA | 683 |
| Zhejiang U | CHINA | 622 |
| Nanyang TU | SINGAPORE | 566 |
| U Science & T. | CHINA | 556 |
| Harbin IT | CHINA | 545 |
| Stanford U | USA | 541 |
| Shanghai JT U | CHINA | 513 |
| Xi'an Jiaotong U | CHINA | 512 |
| Huazhong U S&T | CHINA | 502 |
| Harvard U | USA | 487 |
| National U | SINGAPORE | 455 |
| U Calif., Berkeley | USA | 449 |
| Peking U | CHINA | 444 |

| University | System | Maths & computing |
|---|---|---|
| Tsinghua U | CHINA | 292 |
| U Electronic S&T | CHINA | 275 |
| Harbin IT | CHINA | 269 |
| Huazhong U S&T | CHINA | 231 |
| Xidian U | CHINA | 221 |
| Beihang U | CHINA | 215 |
| MIT | USA | 205 |
| Zhejiang U | CHINA | 194 |
| Southeastern U | CHINA | 193 |
| Nanyang TU | SINGAPORE | 187 |
| Shanghai JT U | CHINA | 178 |
| Northwestern P. U | CHINA | 164 |
| Wuhan U | CHINA | 161 |
| Beijing IT | CHINA | 159 |

# The centre-periphery model in science studies: *Ignoring reality*

- The singular world-economic structure of world-systems theory negates: (1) the autonomy of global relations, (2) the autonomy and agency of nations and persons, and (3) the potency of context and culture, as distinct from economics
- The centre-periphery model --
  - Does not usefully explain rapid growth of scientific papers and networked collaboration, and the element of 'flatness' in scientific networks that enables the building of scientific initiatives in new and developing science countries
  - Does not explain explosive and simultaneous growth of science in many countries on the named 'periphery' and 'semi-periphery'
  - Does not explain the rapid development of free-standing links between countries in the 'periphery'
  - Does not explain the rise of China and East Asia in science, and India which is now the third largest producer of science after China and US
  - Cannot adequately explain the motivations of scientists, who have epistemic projects and personal values in common, across borders
- Nations are not locked in by Euro-American power, the scientists and their agency are also not wholly contained by nations. Centre-periphery theory gives all power to neo-imperialism and underestimates the different agencies of both emerging nations, and scientists themselves.

# The four narratives of global science: the test of explanation

| Narrative | Characteristic of global science that requires explanation | | | | |
|---|---|---|---|---|---|
| | Rapid growth of papers | Spreading to many nations | Growth of co-authorship | Multi-polarity | Hierarchy, inequality |
| Global science as a pan-national network of scientists | YES | YES | YES | WEAK | NO |
| Global science as an arms race in innovation between nations | WEAK | WEAK | NO | WEAK | YES |
| Global science as a global market of 'World-Class Universities' | WEAK | WEAK | NO | WEAK | YES |
| Global science as a centre-periphery hierarchy of nations | NO | NO | NO | NO | YES |

# Conclusions

- The global science system is naturally open and partially autonomous
- Both its horizontal and vertical dimensions are essential to understanding global science: it can be theorised as a network articulated by
  - scientific nodes of unequal capability, whose agency is a function of nodal resources, connectedness, and scientific activity/production
  - hegemonic power that stratifies, and includes/excludes, knowledge
  - arbitrary state and regional interventions, through funding, policy and regulation; and episodic interventions by market forces
- States affect science through (1) actions that directly shape the network and its connections (e.g. US migration policy, or Internet in China), and (2) actions that shape local nodes and activity (e.g. resourcing)
- Neither politics nor economics permanently suborn collegial scientific conversations, which are sustained by networked epistemic sociability
- In the firm Anglo-American hegemony that grips global science, it is the science communities themselves, plus the commercial bibliometric companies, that exercise the homogenising role, locking out more diverse knowledge, agendas and agents
- If linguistic plurality and reciprocal translation were normalised, and bibliometrics began to open up to a fuller range of disciplines and forms of output, much could change in global science.

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