Tsinghua University Institute of Education
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Higher education and science in a time of global rivalry and global cooperation

Imagining the global research system

Simon Marginson

Department of Education, University of Oxford
ESRC/HEFCE Centre for Global Higher Education
Higher School of Economics, Moscow

Higher education and science in a time of global rivalry and global cooperation

- Globalisation, global integration in research and the global/national interface
  - Two questions about the global research system
- Competing interpretations of global science
- Main tendencies in the global research system
  - Growth of R&D funding and scientific outputs
  - Spread of scientific capacity across the world
  - Growth of networked international collaboration (co-authorship)
  - Changing geo-politics: pluralisation of research power
- Global/national issues in research
- A preferred interpretation of the global research system

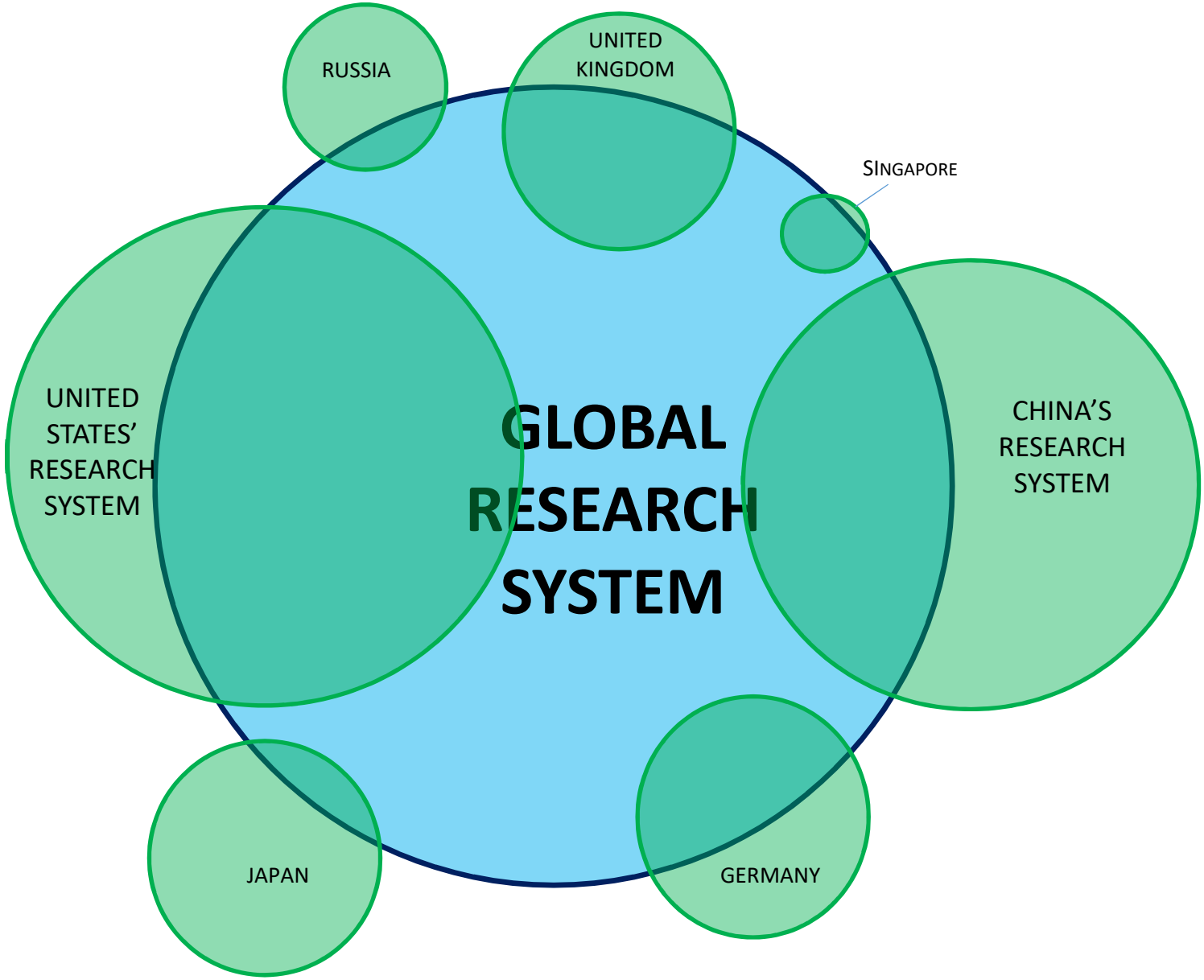
Global integration and transformation

- 'Globalisation' refers to *integration* on a worldwide or large regional basis, based on patterns of connection and exchange sufficiently regular and sustained to *transform* societies, or some aspect of them. Globalisation is associated with structures, agency and *causation* at the global level (e.g. global ecology)
- Nations and local institutions have agency and importance, but are not solely self-generating. Forces external to nations can be as important as forces within.
- People think within the "national container" so global systems (e.g. research) are poorly understood.

Sebastian Conrad (2016). *What is Global History?* Princeton University Press
Shahjahan, R. and Kezar, A. (2013). Beyond the 'national container': Addressing methodological nationalism in higher education research. *Educational Researcher*, 42 (1), pp. 20-29

The global research system

- The global research system consists of structures, institutions, agents and their activities: global publications, worldwide disciplinary forums and networks, and collaborations and citations that support the production and circulation of codified knowledge.
- It developed in the 1990s out of the Internet, synchronous data transfer and global publishing.
- It intersects with autonomous national research systems, to an extent that varies, without fully absorbing them.
- It is now the primary source of innovations, linking with industry in different countries at many points. Firms develop commercial knowledge goods out of research from anywhere, not just from their own countries.



"The choice of scale … always has normative implications"

- Conrad (2016), *What is Global History?,* p. 156

Global rivalry and global cooperation

- Since 2010 the globalisation of the economy has slowed, and the Trade ‘Cold War’ will slow it further.
- Global governance is embryonic and the prospects of advance towards a more integrated world polity have been set back by the growing international tension, especially between the United States and China.
- The possibility of a Technology ‘Cold War’ hangs over continued communicative globalisation. Will we have two global networks with limited interfaces between them?
- While international education continues to grow there are some downward pressures on mobility, notably into the US.
- However, the globalisation of culture, knowledge and science continues. Research networks are expanding

Two questions about the global research system

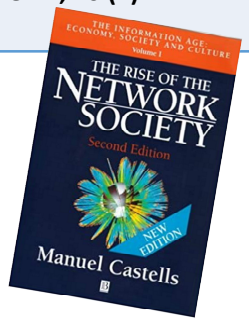
1. What are the main tendencies in the global research system?
2. What theorisation (interpretative framework) is most appropriate to explain the global research system?
   - research as global competition (of nations, of universities)
   - research as a global network
   - research as a hierarchical field of power, one that reflects the larger geo-political setting, as in world-systems theory
   - research as world-wide patterning based on a global script, as in institutional theory

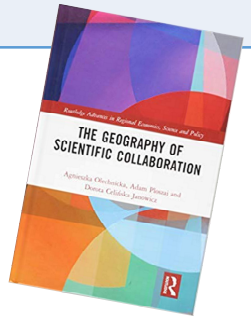
Alternative interpretations of the global research system

1. Global research is a *competition between countries* to secure advantage in the 'arms race in innovation.
2. Global research is a *competition between individual universities* for prestige, resources, students and talent.
3. Global research is a *network* of researchers, universities and countries, in which relations are open, cooperative and 'flat'. It expands continually in nodes, links and activities.
4. Global research is a *worldwide hierarchy* of power, like finance, export trade, the military or cinema. Countries at the global centre dominate and exploit the periphery.
5. Global research is patterned by a process of *universal imitation* based on a 'global script' from a 'world society' which embodies primarily Western/American practices

Which framework(s) fit global research?

Idea	**COMPETITION 1** Global research as an 'arms race' between nations investing in R&D (= innovation)	**COMPETITION 2** Global research as an ongoing contest between World Class Universities	**NETWORK** Global research as an open and ever-expanding structure of collaborative links	**'WORLD SYSTEM'** Global research as 'world-systems' hierarchy of Euro-American core and periphery nations	**'WORLD SOCIETY'** Global research patterned by imitation based on universal (and American) 'scripts'
Implied behaviour	Governments invest in research and foster rules and incentives that tie it closely to economy	Governments invest in top universities, greater science output signifies national capacity in innovation	Research and its innovation benefits are maximised in a regime of open networked global collaboration	Core nations send authoritative knowledge to periphery nations, pattern their activities and take their talent	Research institutions spread across the world in response to powerful model emanating from global centre
Examples of the narrative	Most nation-state policies on research	Global university rankings	**Wagner, C., Park H. and Leydesdorff, L. (2015). The continuing growth of global cooperation networks in research. *PLoS ONE*, 10 (7)**	**Olechnicka, A., Ploszaj, A. and Celinska-Janowicz, D. (2019). *The Geography of Scientific Collaboration*. Oxford: Routledge**	Papers by Stanford institutional theory group





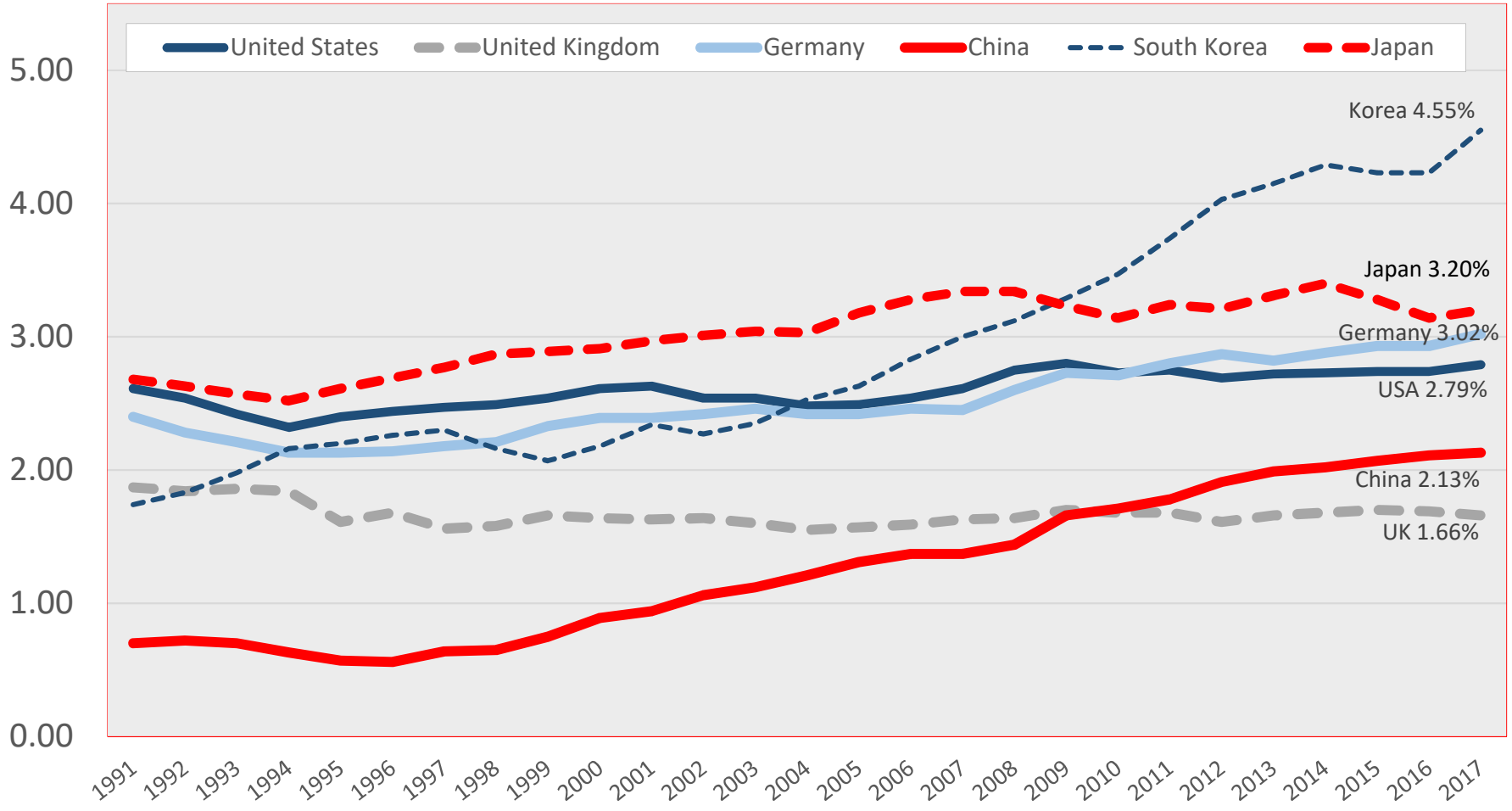
Main tendencies in global research system

- Growth of R&D funding
- Growth of scientific outputs
- Spread of scientific capacity across the world
- Growth of networked international collaboration (co-authorship)
- Changing geo-politics: pluralisation of science power

GROWTH OF R&D FUNDING AND RESOURCES FOR RESEARCH

R&D as proportion (%) of GDP, 1991-2017:

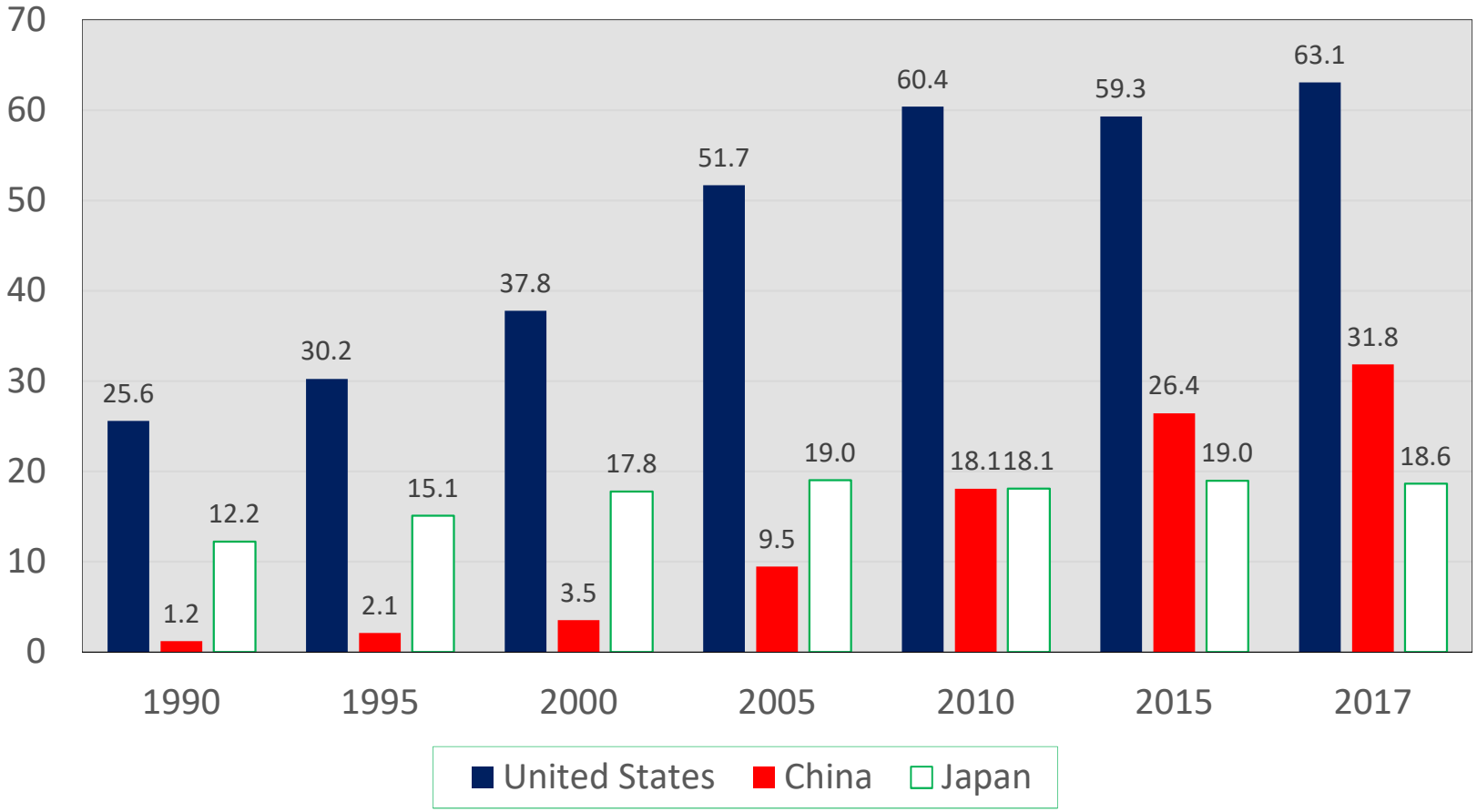
USA, UK, Germany, China, Japan, South Korea



Data: OECD

Spending on R&D in higher education: 1990-2015 and 2017

constant 2010 USD $billion PPP



Data: OECD

New doctoral degrees in largest doctorate producing countries: 2000 and 2014

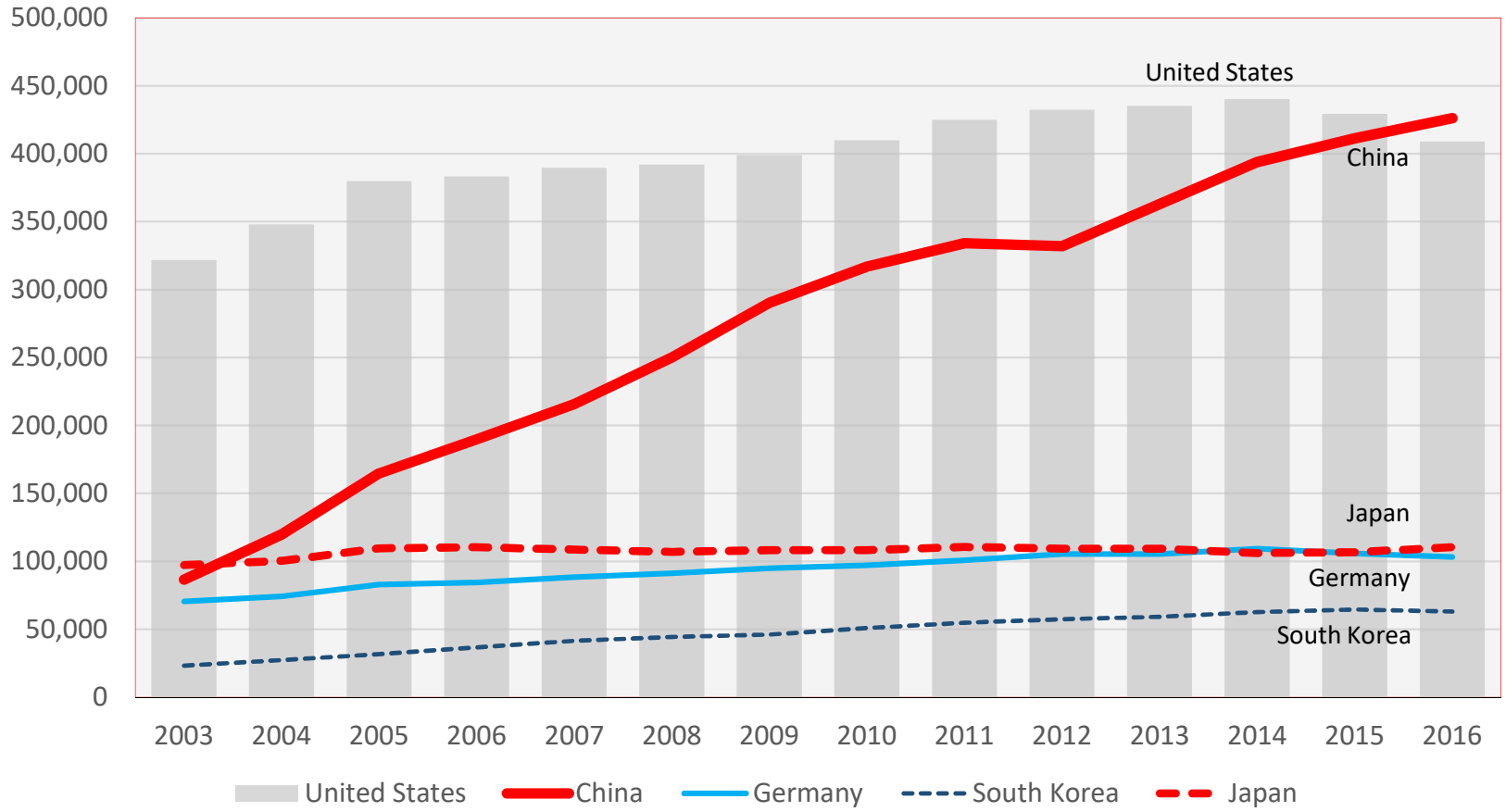
	Doctoral graduates 2000	Doctoral graduates 2014	Annual change 2000-2014
United States	44.947	67,591	3.0%
China	11,383	53,653	11.7%
Germany	25,780	28,147	0.6%
United Kingdom	11,566	25,020	5.7%
India	11,296	21,830	4.8%
Japan	15,357	15,045	- 0.2%
France	9903	13,729	2.4%
South Korea	6143	12,931	5.5%

Data: US National Science Board (NSB)

GROWTH OF TOTAL OUTPUT OF SCIENCE PAPERS

Annual number of published papers

United States, China, Germany, United Kingdom, Japan, South Korea: 2003-2016



Data: US NSB

Universities producing over 5000 papers and 200 high citation (top 5%) papers: 2006-07 to 2014-17

	2006-2009	2007-2010	2008-2011	2009-2012	2010-2013	2011-2014	2012-2015	2013-2016	2014-2017
5000 papers or more									
WORLD	131	139	144	152	167	185	196	209	215
CHINA	10	15	16	18	21	25	29	39	44
200 high citation papers or more (papers in top 5% of their research field)									
WORLD	197	203	212	226	243	258	267	277	291
CHINA	8	9	12	18	23	30	34	41	47

Data: Leiden ranking

Total science papers and papers in top 5% of research field by citation rate: Peking, Tsinghua and Zhejiang Universities: 2006-07 to 2014-17

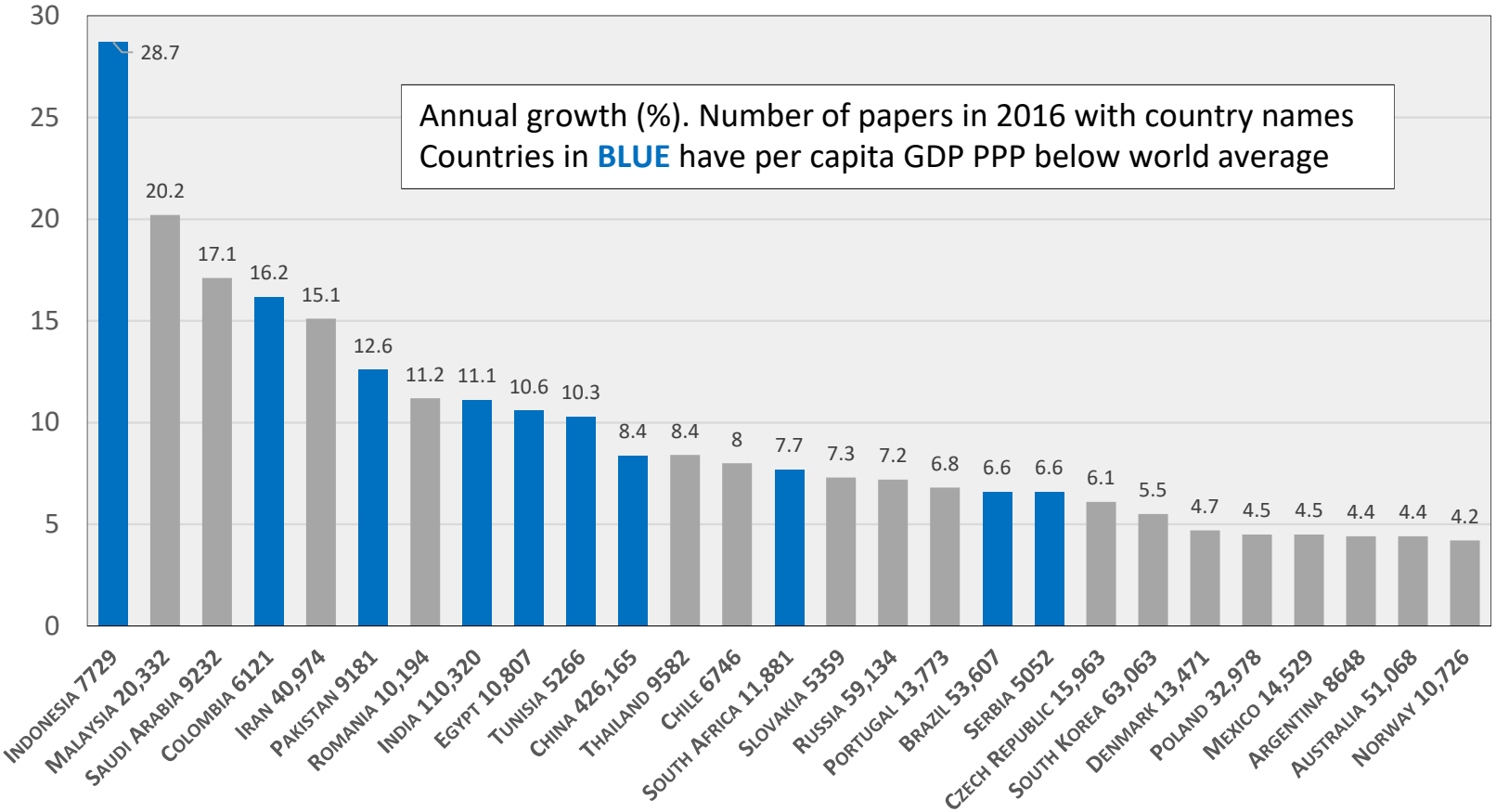
	2006-2009	2007-2010	2008-2011	2009-2012	2010-2013	2011-2014	2012-2015	2013-2016	2014-2017
Total number of papers in time period									
Zhejiang U	11,208	12,004	13,151	14,176	15,722	17,808	19,461	20,933	22,100
Tsinghua U	9515	9758	10,437	11,134	12,285	13,760	15,390	17,034	18,404
Peking U	7808	8605	9461	10,437	11,534	12,797	14,121	15,336	16,171
Number of papers in top 5% of their research field, by citation rate									
Zhejiang U	335	361	453	509	624	750	859	958	1092
Tsinghua U	402	450	491	546	633	763	939	1072	1270
Peking U	307	343	402	431	512	622	680	773	831

Data: Leiden ranking

SPREAD OF SCIENTIFIC CAPACITY ACROSS THE WORLD

Average annual rates of growth (%) in science papers: 2006-2016

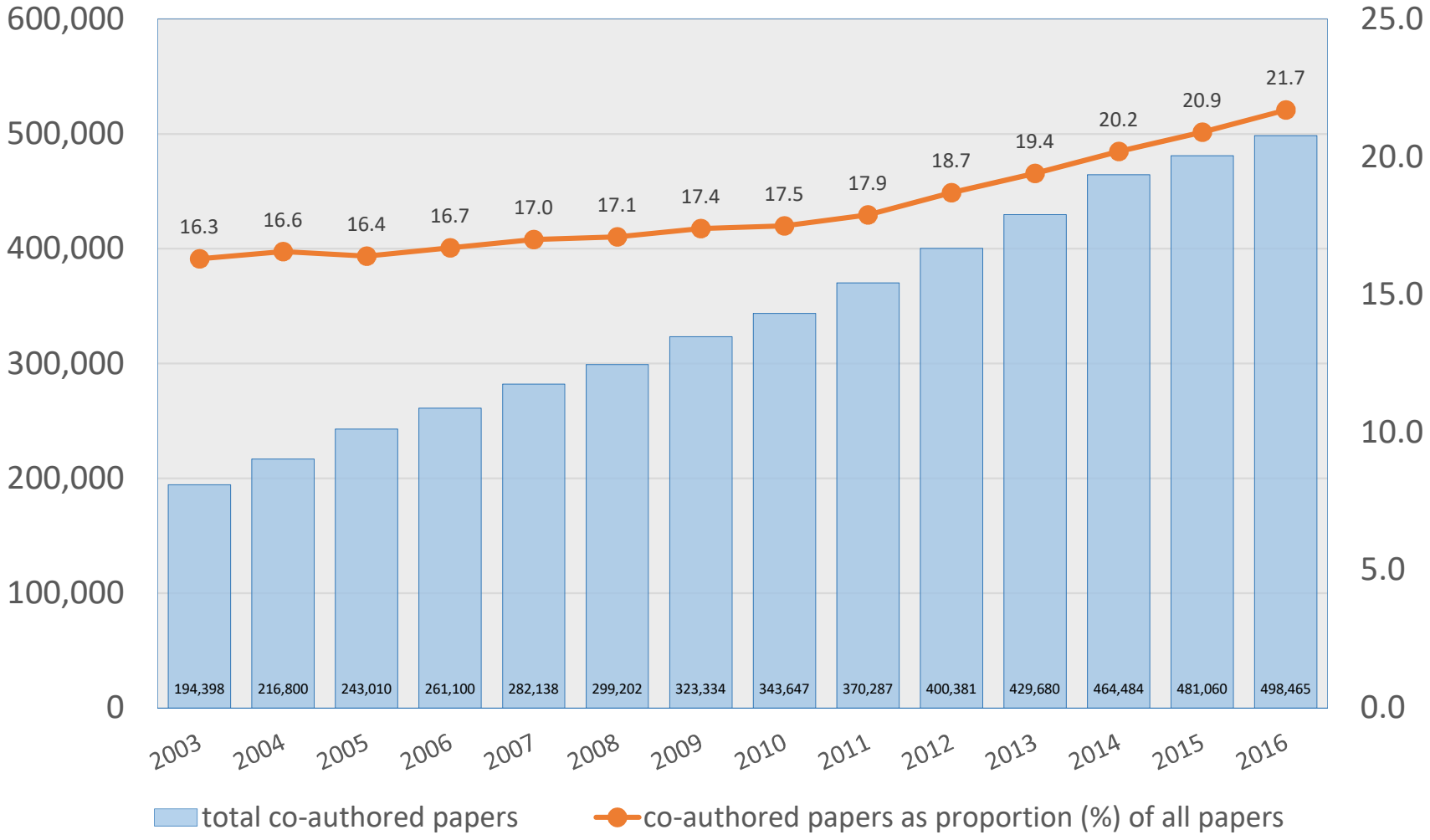
countries with growth rate above world average of 3.9% and producing more than 5000 papers in 2016



Data: US NSB

GROWTH OF NETWORKED INTERNATIONAL COLLABORATION

Growth in internationally co-authored science papers, all countries: 2003-2016



Data: US NSB

Proportion of all science papers that were internationally co-authored, selected countries: 2003 and 2016

Country	2003 %	2016 %
TEN LARGEST RESEARCH SYSTEMS		
United Kingdom	36.9	57.1
France	39.6	54.8
Germany	39.4	51.0
Italy	33.1	47.3
United States	23.3	37.0
Japan	18.9	27.9
South Korea	25.1	27.0
Russia	26.9	25.1
China	15.3	20.3
India	18.1	17.4

Country	2003 %	2016 %
STRONG SMALLER RESEARCH SYSTEMS		
Switzerland	54.5	69.2
Denmark	47.7	63.3
Singapore	35.0	62.8
Netherlands	44.7	61.8
Finland	41.2	60.4
SOME RECENTLY EMERGED SYSTEMS		
Saudi Arabia	34.5	76.8
Chile	52.7	61.7
Brazil	27.2	32.5
Iran	24.2	20.8

Data: US NSB

Proportion of all science papers that were internationally co-authored, selected universities: 2006-09 and 2014-17

Universities	2006-09 %	2014-17 %
NORTH AMERICA		
U Toronto	43.6	55.4
MIT	38.0	55.1
UC Berkeley	35.4	50.9
Harvard U	36.0	50.4
Stanford U	31.7	44.7
EUROPE		
ETH Zurich	59.0	69.3
U Cambridge	50.6	67.9
U Oxford	54.5	67.4
Heidelberg U	48.7	60.3

Universities	2006-09 %	2014-17 %
CHINA		
U Hong Kong	36.5	44.5
Peking U	32.6	37.1
Tsinghua U	22.8	34.8
Shanghai Jiao Tong U	20.9	30.3
Zhejiang U	21.8	29.5
EAST ASIA		
Nanyang TU	44.5	65.7
National U Singapore	46.6	65.1
U Tokyo	28.2	38.0
Seoul National U	25.1	29.5

Data: Leiden ranking

Larger national collaborations, 2016

Country pairs with over 6000 jointly-authored papers

Country pair	Joint papers
China-USA	**43,968**
UK-USA	25,858
Germany-USA	21,584
Canada-USA	19,704
France-USA	14,440
Germany-UK	14,200
Italy-USA	12,784
Australia-USA	12,127
Japan-USA	10,484
China-UK	**10,472**
France-Germany	10,084

Country pair	Joint papers
France-UK	10,079
Italy-UK	10,023
South Korea-USA	9553
Spain-USA	9530
Australia-China	**9246**
Netherlands-USA	9078
Australia-UK	8838
Germany-Italy	8821
Switzerland-USA	8455
Germany-Switzerland	8310
France-Italy	8182

Country pair	Joint papers
Netherlands-UK	8039
Germany-Netherl.	7746
Brazil-USA	7606
Canada-China	**7245**
Germany-Spain	6871
India-USA	6759
China-Japan	**6706**
Canada-UK	6685
China-Germany	**6419**
Sweden-USA	6383
France-Spain	6305

Data: US NSB

Above average intensity of cross-border collaboration in research, 2016

1.00 indicates that the number of co-authored publications between the pair of countries is at the level that is expected given their overall rates of collaboration with all countries. **1.50** indicates very high intensity of collaboration relative to the expected level, i.e. a significant 'bias' in favour of that pairing within the overall pattern of cross-border networks. **2.00** indicates relatively exceptional intensity

Data - US Science and Engineering Indicators, National Science Foundation

UNITED STATES	
Israel	1.33
South Korea	1.23
China	1.19
Canada	1.13
Taiwan	1.05
Mexico	1.04

CHINA	
Singapore	2.03
Taiwan	1.73
Pakistan	1.23
United States	1.19
Australia	1.15
Japan	1.09

JAPAN	
Thailand	3.28
Taiwan	2.16
South Korea	1.83
Hungary	1.57
Malaysia	1.56
Russia	1.11
Egypt	1.11
China	1.09
Poland	1.02
Czech Republic	1.02

Data: US NSB

Internationally mobile/ foreign [*] doctoral students as % of all doctoral students, 2015

Numbers in brackets = number of top 500 universities, ARWU 2018

Luxembourg (0)	87.0%
Switzerland (8)	54.3%
New Zealand (4)	46.2%
UK (39)	42.9%
Belgium (7)	42.3%
France (19)	40.1%
USA (139)	37.8%
Netherlands (11)	36.2%
Sweden (11)	34.0%
Australia (23)	33.8%
Denmark (5)	32.1%
Iceland (0)	31.6%

Austria (6)	27.0%
OECD average	**25.7%**
Ireland (4)	25.4%
Canada (18)	24.4%
Brazil* (6)	22.4%
Portugal (4)	21.2%
Norway (3)	20.5%
Finland (4)	19.9%
Japan (16)	18.2%
Czech Rep.* (1)	14.8%
Estonia (1)	10.7%
Germany (36)	9.1%

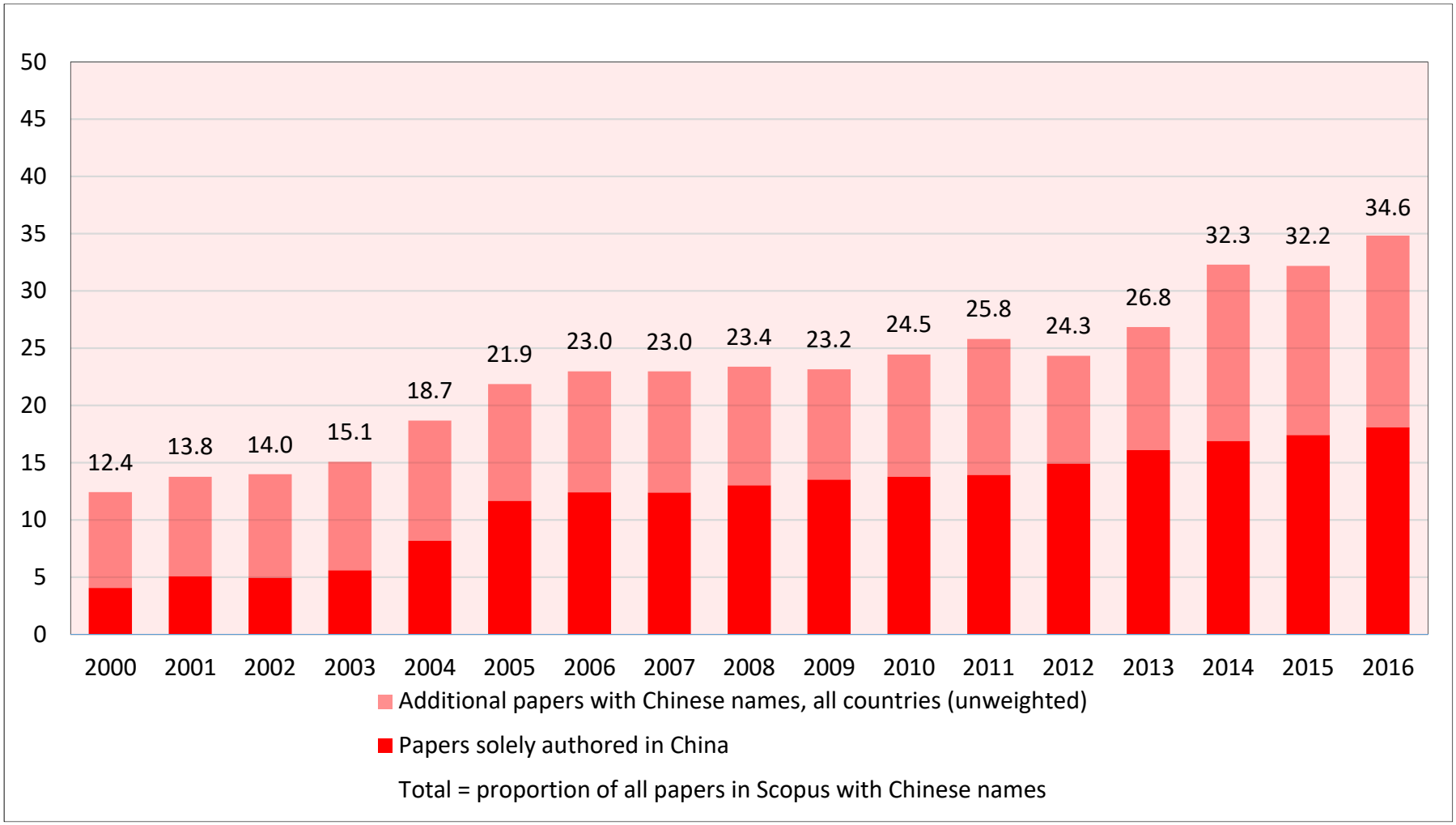
Slovak Rep.* (0)	9.1%
Latvia (0)	8.8%
South Korea* (10)	8.7%
Slovenia (1)	8.5%
Chile (2)	8.4%
Hungary (0)	7.2%
Turkey* (1)	6.5%
Israel* (6)	5.5%
Russian Fed.* (4)	4.5%
Mexico (1)	2.6%
Poland (2)	1.9%

Data: OECD

CHANGING GEO-POLITICS: PLURALISATION OF SCIENCE POWER

Growth of China-associated science papers

Proportion (%) of worldwide papers in Scopus: 2000-2016



Data: Xie and Freeman 2018

Growth in high citation (top 5%) papers

selected East Asian universities: 2006-09 to 2012-15

University		Top 5% papers 2006-2009	Top 5% papers 2014-2017	Growth 2006-09 to 2014-17 p.a.
Tsinghua U	CHINA	402	1270	15.46%
Zhejiang U	CHINA	335	1092	15.92%
Shanghai Jiao Tong U	CHINA	314	939	14.67%
Peking U	CHINA	307	831	13.26%
Huazhong UST	CHINA	114	693	25.31%
Harbin IT	CHINA	180	630	16.95%
U Hong Kong	HONG KONG SAR	308	424	4.08%
National U Singapore	SINGAPORE	513	890	7.13%
Nanyang Technological U	SINGAPORE	275	772	13.77%
Tokyo U	JAPAN	656	627	- 0.56%
Kyoto U	JAPAN	485	438	- 1.27%
Seoul National U	STH. KOREA	343	553	6.15%
National Taiwan U	TAIWAN	276	311	1.50%
MIT	USA	1226	1549	2.97%
U Cambridge	UK	1017	1324	3.35%

Data: US NSB

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: 2014-2017

University	System	Physical sciences & engineering
Tsinghua U	CHINA	776
MIT	USA	691
Stanford U	USA	598
UC, Berkeley	USA	580
Harvard U	USA	552
Zhejiang U	CHINA	509
Nanyang TU	SINGAPORE	503
U Science & T.	CHINA	452
U Cambridge	UK	449
Shanghai JTU	CHINA	398
ETH Zurich	SWITZERLAND	394
Peking U	CHINA	389
Imperial CL	UK	388
NU Singapore	SINGAPORE	384

University	System	Maths & computing
Tsinghua U	CHINA	236
Harbin IT	CHINA	182
Zhejiang U	CHINA	155
Huazhong U S&T	CHINA	153
U Electronic S&T	CHINA	143
Xidian U	CHINA	142
Beihang U	CHINA	141
MIT	USA	138
Nanyang TU	SINGAPORE	137
NU Singapore	SINGAPORE	137
Shanghai JTU	CHINA	130
City U HK	HK SAR	124
South East U	CHINA	123
Stanford U	USA	119

Data: Leiden ranking

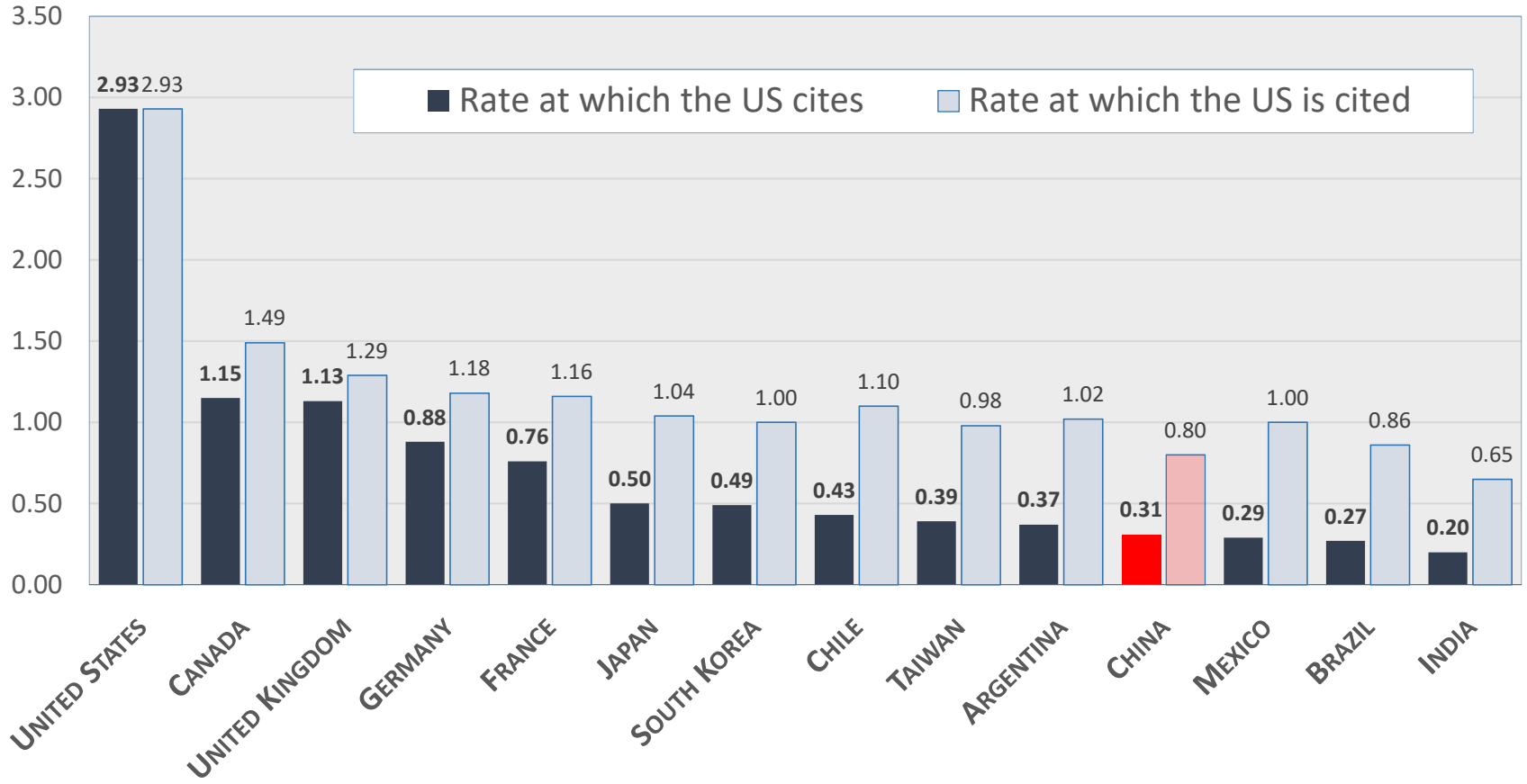
Number and proportion of papers in top 10% of their field by citation rate, five discipline clusters, ZJU, THU, PKU, UC Berkeley: 2014-17

	Number of papers in top 10% in 2014-17				Proportion of all papers that were in top 10%			
	Zhejiang	Tsinghua	Peking	Berkeley	Zhejiang %	Tsinghua %	Peking %	Berkeley %
Physical sciences and engineering	1017	1500	749	1040	11.7	13.5	12.9	23.3
Mathematics and computing	298	447	173	164	11.2	13.1	13.5	18.2
Biomedical and health sciences	545	188	477	483	7.6	11.6	7.3	21.0
Life and earth sciences	346	251	243	389	11.2	14.8	12.4	20.0
Social sciences and humanities	44	60	81	295	8.2	10.8	11.7	18.2
ALL DISCIPLINES	2250	2446	1713	2371	10.2	13.3	10.6	21.1

Data: Leiden ranking

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



Data: US NSB

CONCLUDING THOUGHTS

National and global

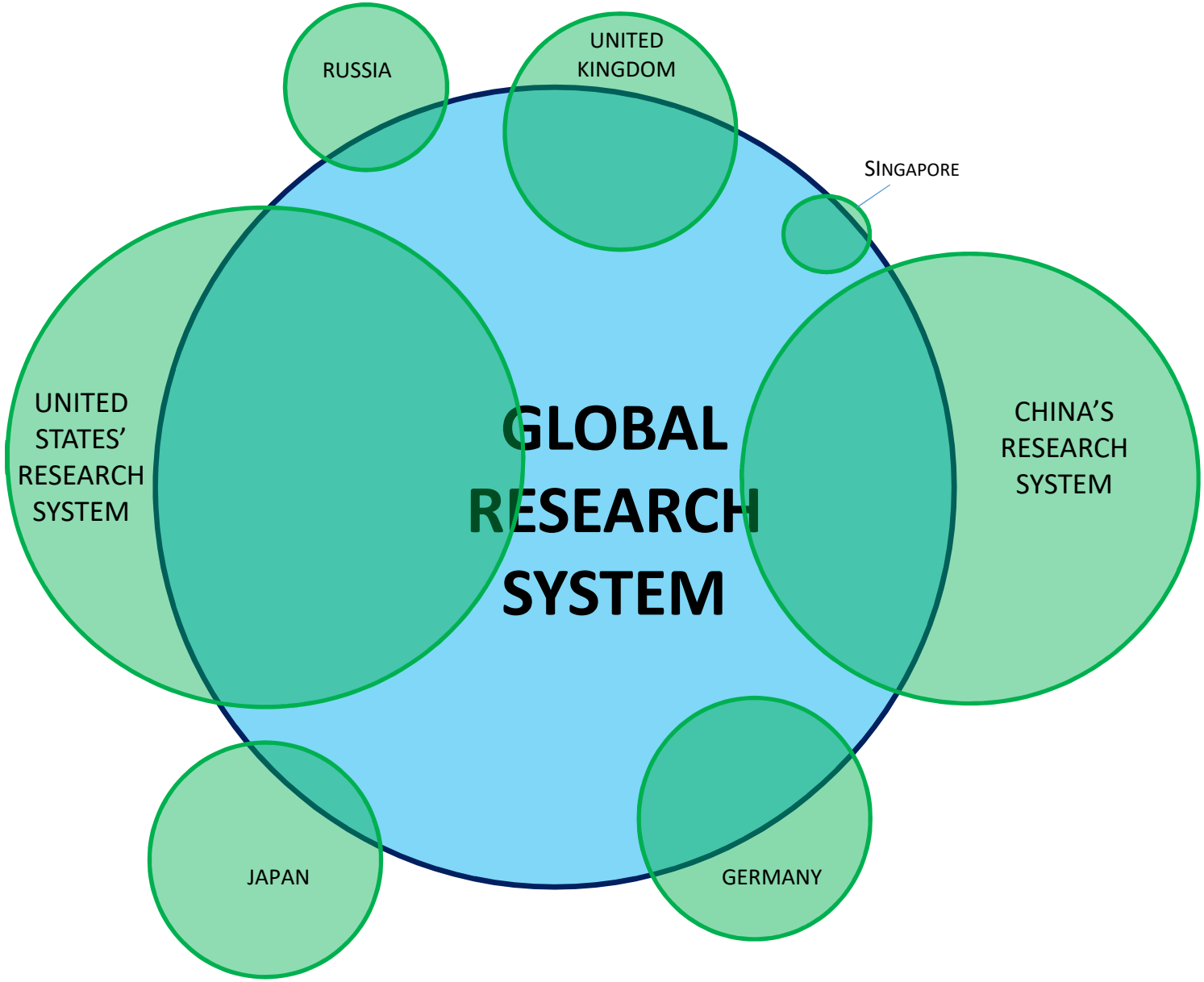
- The global research system is transformative. In over half of all countries, the pattern of national scientific activity is more determined by the pattern of global activity, than vice versa.

  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.

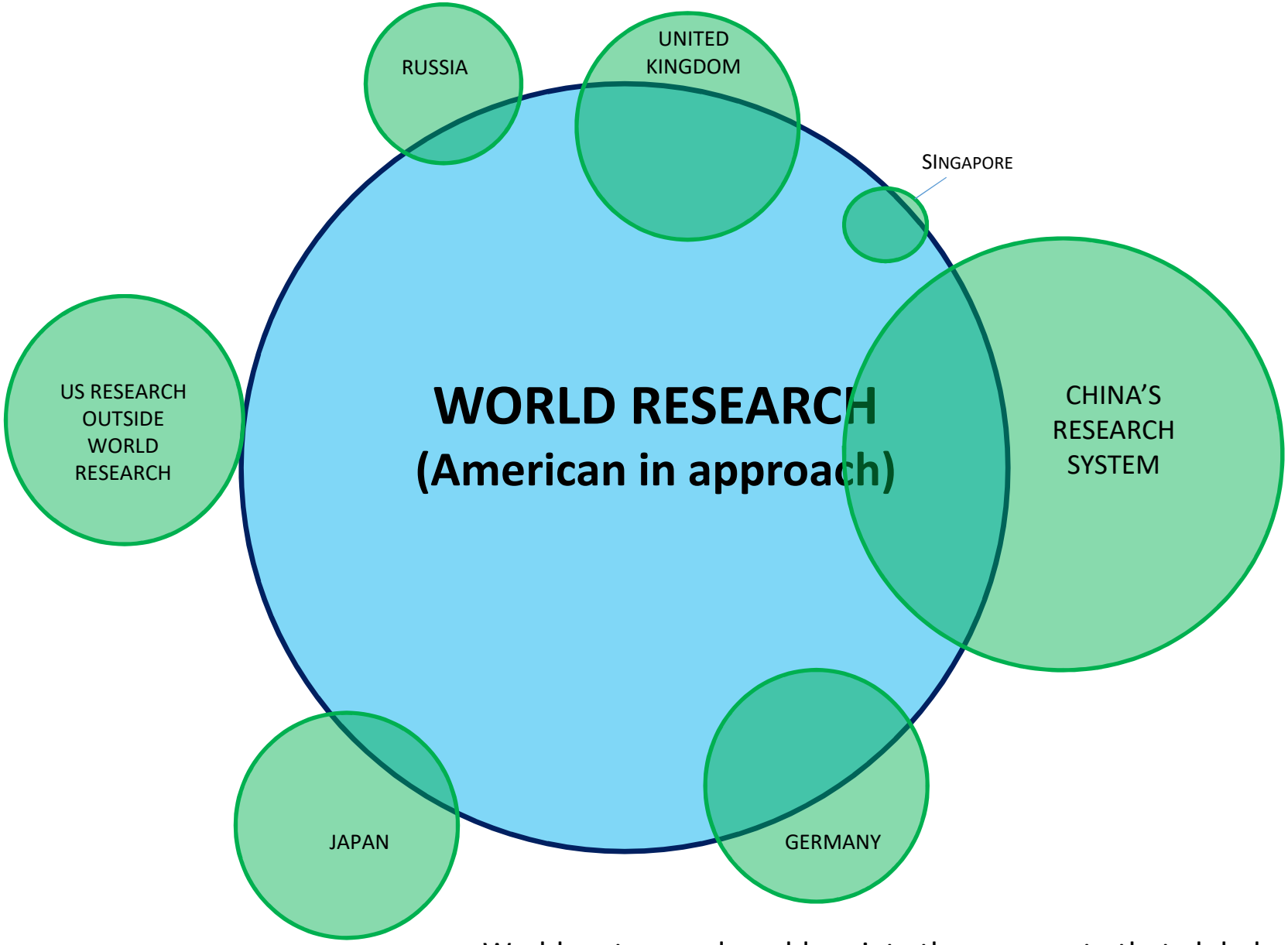
- Investment in science has no necessary correspondence to national industry – the investment 'leaks' into global system.
- Strong national pushback in Trump's restriction of mobility from Middle East and visa refusals for researchers from China. Migration now more politicised in many countries.
- Open access regime is gathering strength BUT New Cold War will take more science out of common global circulation.
- Doctoral studies by Xie Meng and Xin Xu point to global/ national dilemmas in social sciences and humanities in China.

Interpretative frameworks: the verdict

	COMPETITION 1	COMPETITION 2	NETWORK	WORLD-SYSTEM	WORLD SOCIETY
Growth of R&D and outputs	Yes. National arms race directly drives growth	Yes. WCU contest accumulates all-round growth	Yes. Networks naturally expand, fostering growth	? Unclear that global hierarchy needs growth	Yes. Diffusion of research activity drives growth
Spread of research nations	? Poorer nations not real players in an arms race	Yes. Aspiration for WCUs is very widespread	Yes. Expanding networks engage more countries	No. World-systems theory would suggest opposite	Yes. Worldwide imitation of research forms
Growth of research collaboration	No. Not much collaboration in an arms race	? WCU contest has limited scope for cooperation	Yes. Collaborative papers are classic networking activity	Yes, when it assists strong country dominance	Yes. Key medium for isomorphic behaviours
Pluralisation of global strength	Yes. Any nation can build capacity and gain ground	Yes. Any WCU can rise up via competition	Yes/no. Flatness means openness but not leadership	No. No place for more 'centres' in world system	No. There is one liberal, American world society
Continued US research hegemony	Yes. If US invests most in R&D it remains top dog	Yes. Global ranking uses American norms	No. Network theory cannot fully grasp hierarchy	Yes. World centre is Euro-American with no space for others	Yes, world script could be written by nothing else



Research in the global research system, occurring in many countries, is primarily globally not nationally driven



World-system and world society theory equate that global pool of activity with essentially American activity. Though it is true that American influence exceeds the American share of research

The centre-periphery model of the global research system

Altbach, P. G. (2009). Peripheries and centers: Research universities in developing countries. *Asia Pacific Education Review*, 10 (1), 15–27

A more complex model, with no single global centre, at least two very strong nodes, and networked groupings here and there