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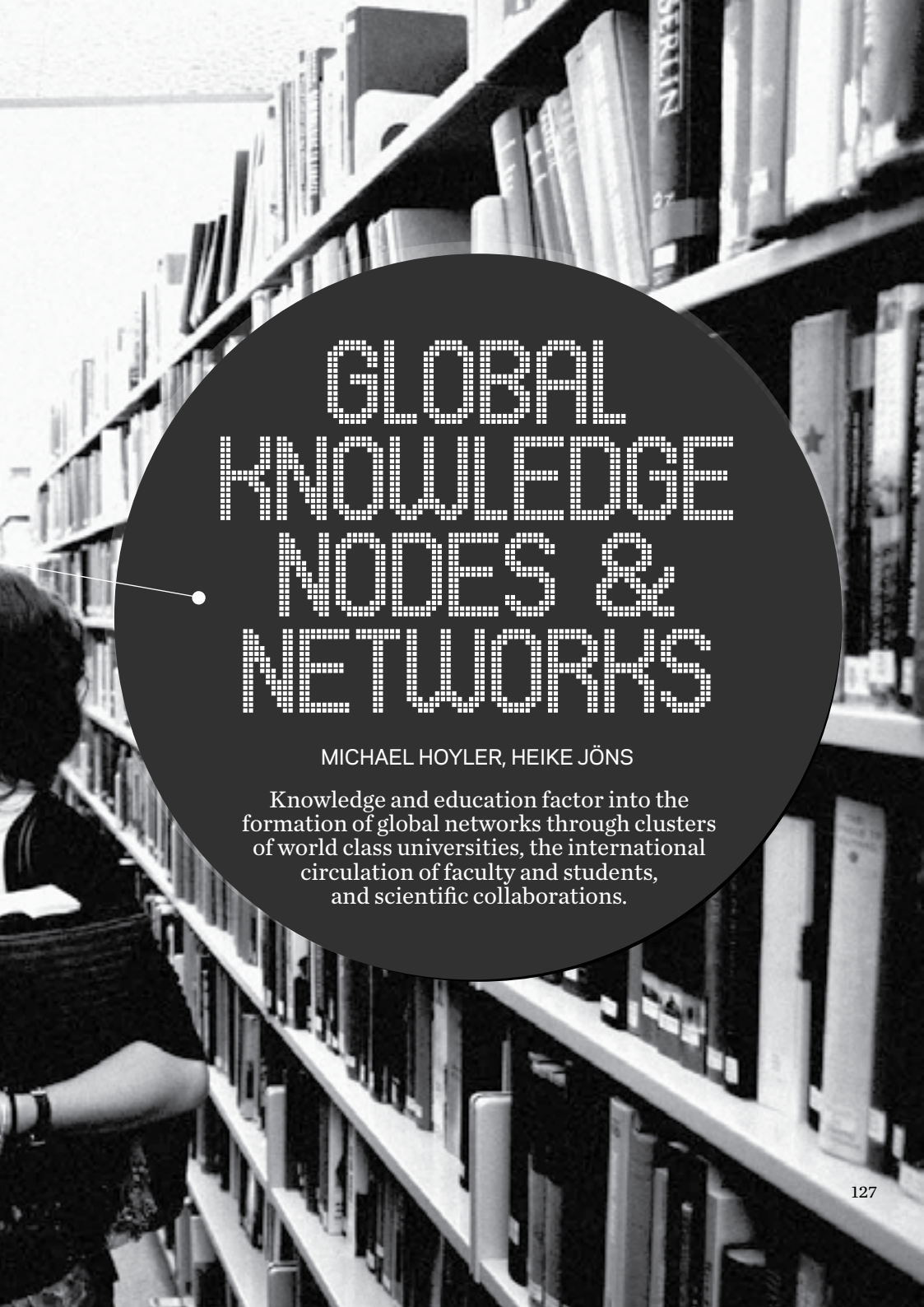


GLOBAL KNOWLEDGE NODES & NETWORKS

MICHAEL HOYLER, HEIKE JÖNS

Knowledge and education factor into the formation of global networks through clusters of world class universities, the international circulation of faculty and students, and scientific collaborations.

KNOWLEDGE AND EDUCATION ARE widely viewed as crucial resources in a globally operating economy. Cities and institutions, national governments and supranational organisations are all keen to attract innovative companies, promising students and competent researchers in order to position themselves favourably as 'knowledge hubs' within the global flows of professional expertise and learning. Higher education and research play a significant part in this process, as universities are not only seats of scientific and scholarly innovation but also educate future decision makers in business, public service and politics.

DEMAND FOR AUSTRALIAN HIGHER EDUCATION WILL INCREASE MORE THAN NINEFOLD FROM 2000 TO 2025, TO ABOUT ONE MILLION STUDENTS

In the past two decades, the globalisation agenda has led many governments and institutions of higher education to develop explicit strategies of 'internationalisation' as means of strengthening their (national or institutional) position as globally competitive knowledge nodes. These strategies include international research collaborations, the internationalisation of the curriculum, international student and staff exchanges, attracting promising young scholars and international star scientists, and forming international research and teaching consortia with institutions of similar disciplinary orientation and reputation. More recently, a number of universities have established branch campuses abroad to deliver offshore education in emerging centres of the global economy such as China and the Arab city states. Studies by IDP Education Australia suggest that the demand for Australian higher education will increase more than ninefold from 2000 to 2025, to about one million students. International onshore higher education in Australia is predicted to account for slightly more than half of this total demand, while the other 44% will be provided through offshore campuses and distance education.

In this chapter, we examine recent trends in the formation of global knowledge nodes and networks within higher education and research by focusing on three dimensions: first, institutional nodes as identified by world university rankings; second, the circulation of students and faculty; and, third, international collaboration in the natural and technical sciences. The analysis highlights the concentrated nature of higher education and research, whose leading centres are clustered within a relatively small number of countries in the richest regions of the world. We currently witness a process of dynamic restructuring in the global landscape of higher education and research that leads to the formation of new central nodes, and shapes flows of students and faculty as much as collaborative linkages across the world.

WORLD CLASS UNIVERSITIES

'World class universities' can be regarded as central nodes in global knowledge networks. They are usually defined as institutions that excel in research and teaching and enrich the cultural, intellectual and public life of the wider society. Identifying 'world class universities' is not straightforward, as most institutions of higher education contribute, often in highly specialised ways, to the creation of new knowledge, and many aspire to the 'world class' label. Since 2003, several attempts have been made to identify world class universities in annually published world university league tables that are based on a range of specific performance indicators. Drawing the attention to the most successful universities in the world (in terms of the indicators measured), these rankings have captured the attention and ambition of university managers, academics, employers, policy makers and the wider public. Universities that do well in these rankings advertise their positions in press releases and on their websites, while other universities adjust their strategic plans in order to join the club of world class universities in the future. Despite a variety of criticisms on the selection and weighting of the underlying ranking criteria, global university rankings provide important insights into the geographies of global higher education and research.

Mapping the locations of the Top 500 universities in the Shanghai Ranking for 2006 reveals striking global disparities between the Global North and the Global South. There are four major regional clusters of world class universities in North America, Europe, East Asia and Australia, and two minor regional clusters in South America and South Africa. Large parts of South America and Africa are without any university that scores on the main performance indicators as defined above, thus reflecting the well–known deep–seated asymmetries in the global economy.

Examining the locations of the Top 100 universities in comparison to the four subsequent tiers of 100 institutions, these global disparities become even more evident. There is no Top 100 university

in South America and Africa and also none in continental Asia. Within North America, clusters of Top 100 world universities concentrate in the northeast, the middle west and the south west, while the locations of world class universities in Europe are characterised by a centre–periphery structure. The Top 100 universities cluster in the south of England, in and around Paris, in southwest Germany and in northern Switzerland, while Spain, the south of Italy and east central Europe accommodate universities mainly ranked between 300 and 400.

Out of the 25 top ranked institutions, nineteen are located within the USA, four in the UK and two in Japan (FIGURE 1). The Top 500 universities in the world are located within 375 cities. Forty–five of these cities accommodate two institutions ranked in the Top 500 universities, 11 cities host three and 10 are home to four or more world class universities. Most of these institutions are located in Paris, Tokyo, London and New York, which corresponds well with the first tier of global cities as the command centres of the global economy (FIGURE 2). Hong Kong and Seoul are important intellectual nodes in Asia; Houston, Boston/Cambridge and Philadelphia are also significant agglomerations

How the Shanghai Ranking is made

Academic Ranking of World Universities, compiled by Shanghai Jiao Tong University since 2003, publishes a list of the Top 500 out of around 8,000 universities world–wide. The ranking is based on six indicators that aim to measure an institution's quality of research and education. In order to determine a university's ranking position, these indicators are added according to the following weights:

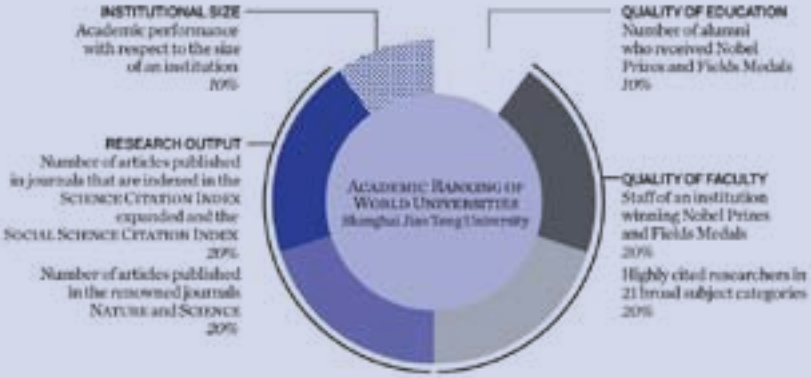


FIGURE 1
TOP 25 INSTITUTIONS IN THE SHANGHAI RANKING 2007

Source: Academic Ranking of World Universities 2006, Shanghai Jiao Tong University www.arwu.org

19 OF TOP 25 UNIVERSITIES ARE IN THE USA


No.16
UNIVERSITY OF
WISCONSON
48.8%
No.23
UNIVERSITY OF
TORONTO
42.8%
No.6
CALTEC
66%
No.9
UNIVERSITY OF
CHICAGO
58.6%
No.4
BERKLEY
72.1%
No.17
UNIVERSITY OF
WASHINGTON
48.8%
No.5
MIT
69.7%
No.1
HARVARD
100%
No.18
UCFC
47.7%
No.11
YALE
55.9%
17
23
18
3
4
16
9
5
1
11
24
6
15
8
7
12
20
13
14
No.3
STANFORD
72.5%
No.12
CORNELL
54.1%
No.7
COLUMBIA
61.8%
No.14
UCLA
50.4%
No.8
PRINCETON
58.6%
No.13
UCSD
50.5%
No.20
JOHN HOPKINS
46.6%
No.24
UNIVERSITY OF
ILLINOIS
42.5%
No.15
PENN STATE
50.1%

FIGURE 2
TOP 10 CITIES IN THE SHANGHAI RANKING 2006

Source: Academic Ranking of World Universities 2006, Shanghai Jiao Tong University www.arwu.org/

of world class universities in the USA, while Stockholm stands out as the third ranked urban centre of world class university clusters in Europe.

As the leading world class universities are closely associated with the most important business hubs in the world, it can be assumed that shifts in global economic power are mirrored in changes in the geographies of higher education and research. Accordingly, the growth of the Chinese economy goes hand–in–hand with the aspiration of Chinese universities to perform as well as the leading US research universities. In this context, it seems to be no accident that the first ranking of world universities was published by Shanghai Jia Tong University, as the global perspective helps Chinese universities to position themselves in relation to their global competitors and to identify areas in which academic performance could be improved.

An alternative world university ranking published by the Times Higher Education Supplement since 2004 (in the following: Times Higher Ranking) includes a peer review score that is based on annual surveys among academics. The latter are asked to rank the most prestigious universities in their region, which results in relatively high scores of universities across the world. The highest scoring institution was assigned a score of 100, while the score of all other institutions are

expressed as percentage of the top score. In China, Beijing University received by far the highest score (70%), followed by Tsing Hua University, Fudan University, China University of Science & Technology, Nanjing University and Shanghai Jiao Tong University, which received peer review scores between 45% and 31%. Beijing University is ranked second in the wider region together with the National University of Singapore and only topped by Tokyo University (72%).

In comparison with current citation practices, however, there is a considerable gap between the peer review and the citations per faculty scores in all universities of South East and East Asia (FIGURE 3). While the scientific performance at these universities is highly valued within the wider region, scientific articles produced in Japanese, Chinese and Singaporean universities are not as frequently cited internationally as work produced in American and European universities. This may

WORLD CLASS UNIVERSITIES ARE CLOSELY ASSOCIATED WITH THE MOST IMPORTANT BUSINESS HUBS IN THE WORLD

FIGURE 3
COMPARISON OF REPUTATION AND CITATIONS
Per Faculty Scores in Selected Universities in the Times Higher Ranking 2006

Source: Times Higher World University Rankings 2006, QS Quacquarelli Symonds Ltd. www.timeshighereducation.co.uk

2006 RANK	INSTITUTION	COUNTRY	PEER REVIEW SCORE	CITATIONS PER FACULTY SCORE
1	HARVARD UNIVERSITY	USA	93	39
8	UNIVERSITY OF CALIFORNIA, BERKELEY	USA	92	39
6	STANFORD UNIVERSITY	USA	82	55
14	BEIJING UNIVERSITY	CHINA	70	2
28	TSING HUA UNIVERSITY	CHINA	45	1
116	FUDAN UNIVERSITY	CHINA	39	2
16	AUSTRALIAN NATIONAL UNIVERSITY	AUSTRALIA	72	13
22	UNIVERSITY OF MELBOURNE	AUSTRALIA	72	7
35	UNIVERSITY OF SYDNEY	AUSTRALIA	65	8
19	NATIONAL UNIVERSITY OF SINGAPORE	SINGAPORE	70	8
61	NANYANG TECHNOLOGICAL UNIVERSITY	SINGAPORE	40	3

partly result from the type of measurement that uses citation data as recorded in Thomson's *Essential Science Database* but can also be attributed to different degrees of integration into the scientific citation circuits. However, as a similar gap can also be observed in Australian universities, it can be argued that the discrepancy between a high peer review score and a modest citations per faculty score in Chinese, Singaporean and Australian universities reveals their status as emerging world class universities in the sense that the citation rates are beginning to catch up with a growing reputation of these universities.

This argument is supported by a comparison of the scores for published scientific articles with those for highly cited researchers in the Top 500 universities of the Shanghai Ranking 2006: highly cited researchers are concentrated in a much smaller number of universities, as it takes time to build up the expertise and reputation to become a highly cited researcher. The discrepancy between scores is highest in the emerging Chinese world class universities, where academics have started to publish frequently in indexed journals but not many have yet emerged as highly cited scientific stars.

The analysis of 'world class universities' thus reveals the geographically uneven distribution and regional clustering of elite

knowledge nodes across the world and reflects long–term historical patterns in the establishment of the modern research university. The extent to which contemporary global higher education and research is characterised by changing power–geometries between the large and well–known universities in North America and Europe and the emerging world class universities in Asia will be further examined in the next section.

CIRCULATION OF STUDENTS AND FACULTY

In the second half of the 20th century, the USA was widely regarded as the world's largest magnet for highly skilled professionals. Up until today, the country attracts the highest number of international students in the world (590,167 in 2005) with a market share of 21.6%. Followed by the UK (318,399; 11.7%), Germany (259,797; 9.5%) and France (236,518; 8.7%), these four leading destination countries attract more than 50% of all international students. With India and China not included in these OECD figures, the countries that have raised their market share of international students considerably since 2000 are Australia, New Zealand, Canada, France, Russia and Japan, thus indicating a wider shift of student flows towards the Asia–Pacific region.

An analysis of the origin of these international students clearly reveals China's and India's growing importance in international academic exchange (FIGURE 4). Both countries provide the highest number of international students in the USA and the UK, while China also heads the ranking of sending countries in Germany and Australia. Apart from the increasing predominance of China and India, the geographies of sending countries in the six most important destination countries for international students are shaped by political, socio–economic, geographical and postcolonial relations. In the USA, most international students come from Asia and North America. In the UK, all ten most important sending countries are located in Asia, comprising mostly former British colonies, while France receives international students mostly from former French colonies in North Africa. After Morocco and Algeria, China is the third most important sending country for international students

INTERNATIONAL STUDENTS

17%
AUSTRALIA

3%
UNITED STATES

FIGURE 4

Top 10 sending places of origin & percentage of total international student enrolment

For top host destinations

Source: Institute of International Education (IIE), Atlas of Student Mobility, www.atlas.iienetwork.org

USA (2007)	
INDIA	14.4%
CHINA	11.6%
STH KOREA	10.7%
JAPAN	6.1%
TAIWAN	5.0%
CANADA	4.9%
MEXICO	2.4%
TURKEY	2.0%
THAILAND	1.5%
GERMANY	1.5%

UK (2007)	
CHINA	27.0%
INDIA	14.2%
MALAYSIA	8.8%
HONG KONG	5.9%
INDONESIA	5.1%
SINGAPORE	4.7%
STH KOREA	3.3%
THAILAND	2.8%
TAIWAN	2.2%
JAPAN	2.0%

GERMANY (2006)	
CHINA	11.0%
TURKEY	9.0%
POLAND	6.1%
BULGARIA	5.2%
RUSSIA	4.8%
UKRAINE	3.5%
MOROCCO	3.3%
ITALY	2.7%
FRANCE	2.4%
AUSTRIA	2.4%

FRANCE (2004)	
MOROCCO	13.8%
ALGERIA	9.4%
CHINA	4.8%
TUNISIA	4.1%
SENEGAL	3.5%
GERMANY	2.8%
CAMEROON	2.1%
ITALY	2.0%
LEBANON	2.0%
ROMANIA	1.9%

AUSTRALIA (2006)	
CHINA	13.3%
INDIA	6.4%
USA	5.9%
GERMANY	4.6%
FRANCE	4.5%
IRELAND	4.3%
GREECE	4.3%
MALAYSIA	3.2%
NIGERIA	3.0%
HONG KONG	2.6%

CHINA (2006)	
STH KOREA	30.7%
JAPAN	11.3%
USA	7.2%
VIETNAM	4.5%
INDONESIA	3.5%
INDIA	3.5%
THAILAND	3.4%
RUSSIA	3.1%
FRANCE	2.4%
PAKISTAN	2.0%

in France, and the European countries Germany, Italy and Romania are also included in the Top 10 sending countries. A more distinct European profile of international students can be found in Germany, where China is followed by Turkey (including second generation immigrants), a number of eastern European countries and the European neighbours Italy, France and Austria. China's international students mainly come from Asia and the United States, while Australia displays the most international profile with sending countries from Asia, North America, Europe and Africa among the Top 10.

Compared to the size of the total student body, Australia and New Zealand also have the highest shares of international students, followed by the European countries UK, Switzerland, Austria and France (FIGURE 5). Australia's share of international students of 17.3% compares to a much lower 3.4% of international students in the USA. Within the Top 200 world class universities as defined by the Times Higher Ranking 2006, 11 of 12 Australian universities are among the 50 most international institutions. The most international student body, however, is to be found at the London School of Economics, followed by the School of Oriental and African Studies (London), Curtin University of Technology (Perth), Ecole Polytechnique Fédérale de Lausanne, RMIT University (Melbourne), University of Wollongong (Wollongong, Australia), Cranfield University (Cranfield, UK), Geneva University, Imperial College London and Nanyang Technological University (Singapore) (FIGURE 3). The most international world class university in the USA is CALTECH in Los Angeles on rank 24. Most US universities have rather low international student scores and are dominated by high numbers of domestic students.

FIGURE 5
PERCENTAGE OF INTERNATIONAL STUDENTS ENROLLED IN TERTIARY EDUCATION
OECD countries, 2005

Source: OECD, Education at a Glance 2007, Table C3.1., www.oecd.org/edu/eag2007
Note: Missing data for Canada, Czech Republic, Germany, Iceland, Italy, Korea, Luxembourg, Mexico, Poland, Portugal, Turkey.

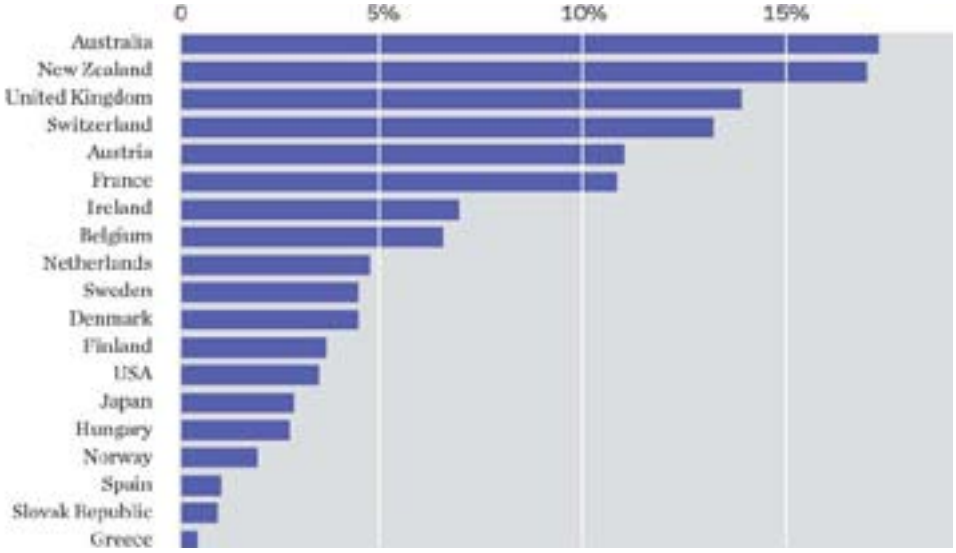


FIGURE 6
Top 10 Institutions of International Students in the Times Higher Ranking 2006

Source: Times Higher World University Rankings 2006, QS Quacquarelli Symonds Ltd. www.timeshighereducation.co.uk

2006 RANK	INSTITUTION	COUNTRY
1	LONDON SCHOOL OF ECONOMICS	UK
2	SCHOOL OF ORIENTAL AND AFRICAN STUDIES	UK
3	CURTIN UNIVERSITY OF TECHNOLOGY	AUSTRALIA
4	ECOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE	SWITZERLAND
5	RMIT UNIVERSITY	AUSTRALIA
6	UNIVERSITY OF WOLLONGONG	AUSTRALIA
7	CRANFIELD UNIVERSITY	UK
8	GENEVA UNIVERSITY	SWITZERLAND
9	IMPERIAL COLLEGE LONDON	UK
10	NANYANG TECHNOLOGICAL UNIVERSITY	SINGAPORE

International students are potential future academics and professionals. Whether they stay in the destination country of their studies, return to their country of origin or move to a third country, they are likely to establish transnational linkages and act as multipliers of international relations in their subsequent careers. A high share of international students thus indicates dynamic processes with potential future significance for the economy and wider society, particularly under conditions of contemporary globalisation. The high shares of international students in Australia, Singapore and Europe can thus be evaluated as a positive sign of internationalisation that also contributes to providing an international experience 'at home' for domestic students in these places. Equally important for establishing international linkages are the Chinese and Indian students that go to North America, Europe and Australia to study in one of the global centres of higher education and research. As many of these international students later return to their home countries to start academic and professional careers, they may in the long–term contribute to making their universities and companies more central players in the world economy.

For the USA, for example, Michael Finn shows in a study of stay rates of foreign doctorate recipients that 68% of those who received science and engineering doctorates in 2000 were still in the USA in 2005. Studies by AnnaLee Saxenian on Chinese and Indian–born engineers working in Silicon Valley reveal the complex transnational linkages of foreign–born highly skilled professionals who were educated in the USA. She argues convincingly that these individuals contribute to the development of information technology industries in their home countries by building entrepreneurial networks between firms in Silicon Valley and those in emerging technology regions across the world. Comparing data on Australia, Canada, the UK and the USA for 2002, the number of international students, who potentially provide such positive effects in their future careers, was highest in the metropolitan areas of New York and London as the leading global cities, followed by Los Angeles, Melbourne, Sydney, San Francisco, Boston, Washington, Chicago and Brisbane (FIGURE 7). Based on these and previous findings, it can be argued that international students reinforce the central status of global cities but also contribute to the formation of new central nodes in the world economy.

Another important strategy of internationalisation in higher education has long been the transnational exchange of faculty, whether this relates to temporary stays of less than one or two years, or to more permanent arrangements. Both visiting academics and foreign–born and/or foreign–educated academics with permanent posts provide international views and experiences to the majority of students that do not themselves study abroad. Some of the emerging world class universities in Asia and Australia stand out by their recruitment of international faculty, which is sometimes but not always related to their large number of international students as an important staffing source (FIGURE 8). According to the Times Higher Ranking 2006, the ten most international universities in terms of the percentage of international faculty are Macquarie

INTERNATIONAL STUDENTS REINFORCE THE CENTRAL STATUS OF GLOBAL CITIES BUT ALSO CONTRIBUTE TO THE FORMATION OF NEW CENTRAL NODES IN THE WORLD ECONOMY

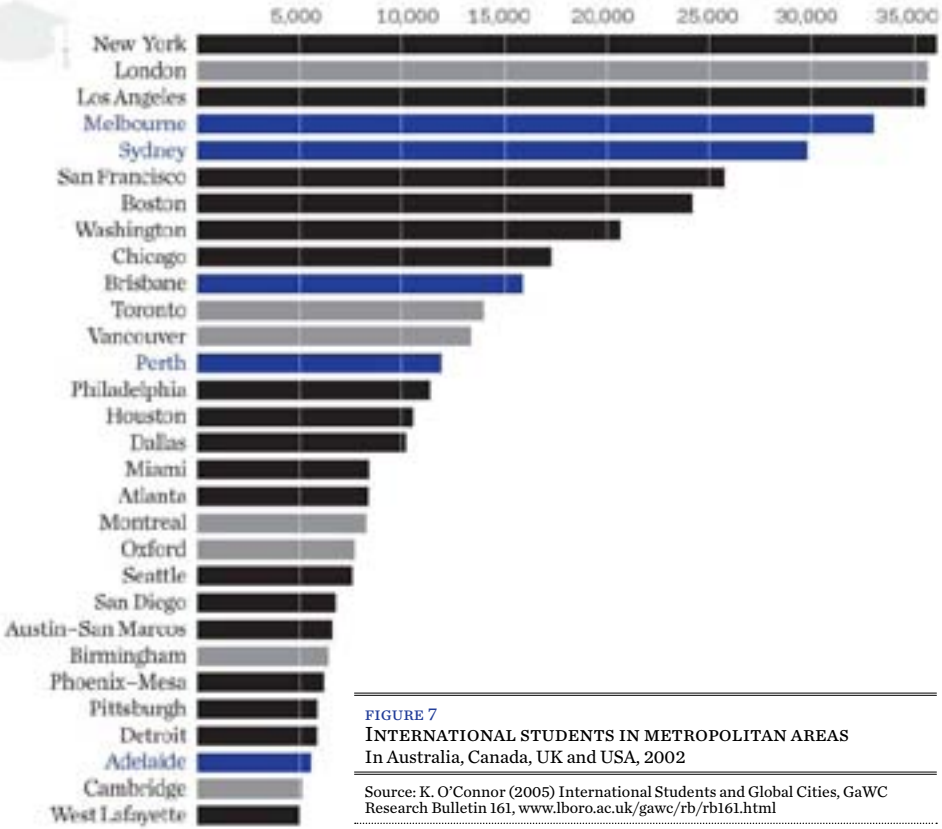


FIGURE 7
INTERNATIONAL STUDENTS IN METROPOLITAN AREAS
In Australia, Canada, UK and USA, 2002

Source: K. O'Connor (2005) International Students and Global Cities, GaWC Research Bulletin 161, www.lboro.ac.uk/gawc/rb/rb161.html

University (Sydney), Otago University (Dunedin), London School of Economics, ETH Zurich, University of Hong Kong, National University of Singapore, Nanyang Technological University (Singapore), Basel University, City University of Hong Kong and Hong Kong University of Science & Technology (FIGURE 8).

The recruitment of international faculty also helps to raise the global visibility of universities in terms of research performance indicators and international research collaborations as international scientists and scholars bring their academic expertise and contacts to the new institutions. The recruitment of international faculty has therefore been identified by several younger academic institutions as an important strategy for raising their position in world university

FIGURE 8
Top10 Institutions of International Faculty in the Times Higher Ranking 2006

Source: Times Higher World University Rankings 2006, QS Quacquarelli Symonds Ltd. www.timeshighereducation.co.uk

2006 RANK	INSTITUTION	COUNTRY
1	MACQUARIE UNIVERSITY	AUSTRALIA
2	OTAGO UNIVERSITY	NEW ZEALAND
3	LONDON SCHOOL OF ECONOMICS	UK
4	ETH ZURICH	SWITZERLAND
5	UNIVERSITY OF HONG KONG	HONG KONG
6	NATIONAL UNIVERSITY OF SINGAPORE	SINGAPORE
7	NANYANG TECHNOLOGICAL UNIVERSITY	SINGAPORE
8	BASEL UNIVERSITY	SWITZERLAND
9	CITY UNIVERSITY OF HONG KONG	HONG KONG
10	HONG KONG UNIVERSITY OF SCIENCE & TECHNOLOGY	HONG KONG

rankings that are dominated by the established universities in North America and Europe. Universities UK, the representation of the executive heads of all UK universities and some colleges of higher education, even speaks of 'Talent Wars' in their study on the international market for academic staff conducted in 2007. This policy briefing reveals that non–UK nationals accounted for 19.1% of all academic staff at UK universities in 2005–06; among the newly appointed staff this figure rose to 27%. Graduates represent one of the main sources for newly appointed academic staff (34%; other sectors UK: 42%; employed abroad: 21%), which highlights the significance of international students for the reproduction of academic staff in British higher education and research.

The reasons for a growing share of international faculty in Britain are manifold. Academic migrants are attracted by the academic reputation of UK universities, a favourable working environment, and long–term career prospects based on tenure–track positions. From the perspective of British higher education and research, international recruitment contributes to a globally competitive position based on high–quality staff but is also important for maintaining the current staff/student ratio as many UK graduates prefer financially more attractive positions outside the university system. British higher education and research is also influenced

by demographic change, although the consequences of the aging of faculty are less pressing than in the USA and Canada. In addition, the Labour government aims to raise the share of university students to 50% of the 18 to 30–year–olds by 2010. As the number of international students worldwide has been estimated to increase threefold from 2004 to 2025, the growing number of university students in Britain (and elsewhere) will not only require the filling of vacant academic posts but also the creation of new positions.

Sydney has the 5th highest number of international students

The geographies of international recruitment of faculty at British universities are shaped by strong linkages within Europe and the Commonwealth and with the USA. The most important countries of origin for international academic staff in the UK are Germany, Ireland, the USA, China, Italy, France, Greece, India, Australia and Spain (FIGURE 9). The majority of these academics are at an early stage of their career, and their shares vary significantly between different subjects (FIGURE 10). The highest share of international academic staff can be found in languages, physics, mathematics, computer science, engineering and the social sciences. While the advantages of lecturers from abroad are obvious in language studies, the SET disciplines (Science, Engineering, Technology) have been characterised by English as the *lingua franca* in the second half of the 20th century, a fact that makes international academic mobility easier in these subjects, which have seen a decline of interest by British graduates. As observed in previous statistics, the particularly large inflow of Chinese researchers to the UK at an early stage of their career mirrors the rapid economic and scientific advancement in this country during the past two decades.

The number of international academic staff at British universities is higher than the number of British academics leaving for permanent jobs abroad, which can be regarded as a positive sign for the international standing of British academia (2005–06: +4,220 academics). However, even British universities, many of which are ranked among the top 100 world class universities, are embedded within asymmetrical global power relations. Due to prestigious and highly attractive professorships at the leading research universities in the USA, the outflow of academic staff surmounts the inflow at the levels of both senior lecturers/senior researchers and professors (2005–06: –1,045).

Based on the study by Universities UK, the internationalisation through academic staff appears to be an important strategy for ensuring the international competitiveness of higher education

FIGURE 9

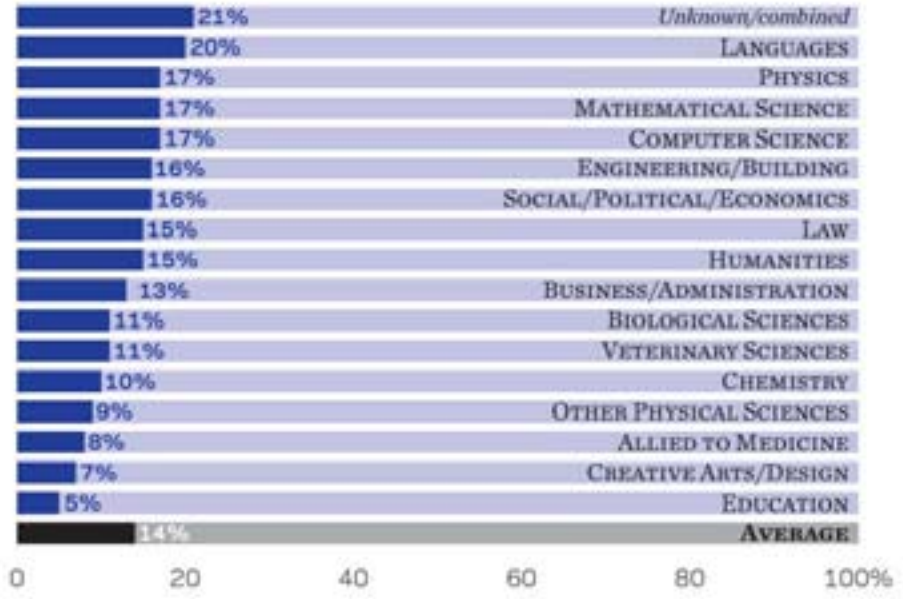
MAJOR NON–UK NATIONALITIES OF ACADEMIC STAFF IN UK HIGHER EDUCATION INSTITUTIONS

By career stage, 2005–06

Source: Universities UK (2007) Talent Wars: The International Market for Academic Staff, London (Policy Briefing), p. 8–9.

FIGURE 10
NON–UK NATIONALS AMONG PERMANENT UK ACADEMIC STAFF BY SUBJECT, 2004–05

Source: Universities UK (2007) Talent Wars: The International Market for Academic Staff, London (Policy Briefing), p. 11.



and research. However, as academics with roots in other countries might well return to these places, particularly if research conditions improve in the long run, it seems to be equally important to encourage national graduates to pursue an academic career, either in the country of origin or abroad. As many countries are currently reforming their systems of higher education and research in order to make them internationally more compatible and attractive, the competition for international students and academic staff is likely to intensify in the near future. A sensible strategy for academic institutions therefore seems to lie in balanced exchanges of incoming and outgoing undergraduates, postgraduates, post–docs, lecturers and professors in terms of temporary academic mobility (study abroad, research stays, visiting professorships) and permanent recruitment. Despite

FIGURE 11

OUTPUT OF SCIENCE AND ENGINEERING ARTICLES AND INTERNATIONAL CO–AUTHORSHIP, 1996–2000 AND 2001–2005

Source: J. Adams, K. Gurney and S. Marshall (2007) Patterns of International Collaboration for the UK and Leading Partners: A Report Commissioned by the UK Office of Science and Innovation, Leeds: Evidence Ltd, p. 10.

COUNTRY	1996-2000				2001-2005				CHANGE	
	OUTPUT		INTER–NATIONAL CO–AUTHORS		OUTPUT		INTER–NATIONAL CO–AUTHORS		OUTPUT	INTER–NATIONAL CO–AUTHORS
	1000s	%	1000s	%	1000s	%	1000s	%	% 96–00	% 96–00 to % 01–05
USA	1,262	**35**	245	**19**	1,352	**34**	335	**25**	**7**	**5**
JAPAN	329	**9**	54	**16**	361	**9**	77	**21**	**10**	**5**
UK	338	**9**	98	**29**	359	**9**	145	**40**	**6**	**11**
GERMANY	310	**9**	107	**34**	341	**8**	147	**43**	**10**	**9**
FRANCE	230	**6**	82	**36**	245	**6**	108	**44**	**7**	**8**
CHINA	102	**3**	26	**25**	210	**5**	54	**26**	**107**	**1**
CANADA	167	**5**	55	**33**	184	**5**	76	**41**	**10**	**8**
AUSTRALIA	101	**3**	31	**31**	117	**3**	47	**40**	**16**	**9**
INDIA	76	**2**	n.d.	**n.d.**	99	**2**	n.d.	**n.d.**	**30**	**n.d.**
WORLD	3,603	**100**	n.d.	**n.d.**	4,019	**100**	n.d.	**n.d.**	**n.d.**	**n.d.**

its evident significance, the international circulation of students and staff does not provide the only path to scientific excellence as the case of Japanese universities illustrates: Characterised by low scores of international students and faculty, Japanese universities are well represented among the Top 200 world class universities and even constitute the second most important urban agglomeration of world class universities in Tokyo (FIGURE 4).

INTERNATIONAL SCIENTIFIC COLLABORATION

Global knowledge networks in higher education and research are specifically well–researched in regard to international co–authorship in the natural and technical sciences. This is because science citation databases offer comprehensive data on joint publications in mostly English–speaking internationally peer–reviewed journals. Most of these data are analysed on the national level and thus reflect an aggregation of collaborative linkages between world class universities and other research institutions as discussed in the first section of this chapter. The following data refer to international collaboration in the natural and technical sciences, including clinical sciences, health and related subjects, biological sciences, environmental sciences, mathematics, physical sciences, and engineering. The emerging collaborative patterns thus concentrate on one particular type of international scientific collaboration, namely co–authorship of journal articles, and on the SET disciplines.

The worldwide output of research papers has increased by more than 10% between 1996–2000 and 2001–05 (figure 12). Among the nine countries with the most productive scientists, the growth of research output was highest in China, India and Australia, thus supporting the previously developed argument that these are highly dynamic places in the contemporary landscape of higher education and research. Between 2001–05, international collaboration accounted for 21% of the journal articles produced in Japan and 40% of the journal articles produced in the uk. Scientists based in smaller countries tend to engage more in international collaboration as those in larger countries (usa, China) as the latter have more opportunities to cooperate with colleagues at institutions in their own country. Even if China's share of internationally co–authored articles scarcely rose, the doubling of research output means that the number of internationally co–authored journal papers doubled as well. This immense increase in international scientific linkages of China is inextricably linked to the formation of world class universities and the intense transnational circulation of Chinese academics.

The dynamic changes in the amount of research output have a considerable impact on the global geographies of knowledge networks. For example, China provided 2% of international co–authors of US scientists and engineers in the periods 1981–85 and 1991–95. By 2001–05 this share had risen to 6.1%, making the country the sixth most important place of international co–authorship.

a) 1991–95

COUNTRY	USA	JAPAN	UK	GERMANY	FRANCE	CHINA	CANADA	AUSTRALIA
USA		8	10	10	8	2	10	3
JAPAN	40		7	7	4	4	5	2
UK	23	3		8	7	1	4	4
GERMANY	22	3	7		8	1	3	2
FRANCE	20	2	8	10		1	5	1
CHINA	28	11	7	9	5		6	3
CANADA	41	4	8	5	8	2		3
AUSTRALIA	29	4	16	7	4	2	6	

b) 2001–05

COUNTRY	USA	JAPAN	UK	GERMANY	FRANCE	CHINA	CANADA	AUSTRALIA
USA		9	13	13	8	6	12	5
JAPAN	40		9	10	6	11	5	4
UK	30	5		14	11	4	6	7
GERMANY	30	5	14		11	4	4	3
FRANCE	25	4	14	15		3	6	3
CHINA	38	16	10	10	5		7	7
CANADA	51	5	12	9	9	5		5
AUSTRALIA	34	6	21	9	6	8	8	

FIGURE 12
PATTERNS OF INTERNATIONAL CO–AUTHORSHIP IN SCIENTIFIC AND TECHNICAL RESEARCH 1991–95 and 2001–05 (percentages of total)

Source: a) National Science Board (ed.) (1998) Science and Engineering Indicators 1998, Arlington, VA: National Science Foundation, Appendix table 5–54; b) J. Adams, K. Gurney and S. Marshall (2007) Patterns of International Collaboration for the UK and Leading Partners: A Report Commissioned by the UK Office of Science and Innovation, Leeds: Evidence Ltd, p. 13.

This trend is likely to continue, thus potentially preparing a long–term shift of academic hegemony away from the USA. In the past two decades, the most important source countries for co–authors of US international articles have been Germany, the UK and Canada, while the collaborative links with the USA were considerably strengthened in all of the most productive countries except Japan between 1991–95 and 2001–05 (FIGURE 12). Scientific and technical research in Japan became rather more closely linked to China and Australia, thus contributing to the formation of an Asia–Pacific collaborative space. Within Europe, scientific collaboration between the UK, Germany and France grew considerably, thus reflecting the coalescence of universities in an emerging European higher education area.

CITIES AND METROPOLITAN AREAS THAT STRIVE TO DO WELL IN THIS CONTEST, NEED TO BE WELL NETWORKED AT DIFFERENT LEVELS, INCLUDING THE INFLOW AND OUTFLOW OF INTERNATIONAL STUDENTS AND FACULTY AT DIFFERENT STAGES OF THEIR CAREER

CONCLUSION:

Global knowledge nodes and networks in contemporary higher education and research cluster in the richest places in the world located in North America, Europe, South and East Asia and Australia. They correspond well with the network of global cities and economically leading metropolitan areas. Universities in South America and Africa are much less central in global networks of science and research that are defined by Anglo–American publication cultures in the natural and technical sciences. When researching the global knowledge economy, it is therefore important to remember that world university rankings and citation data only reflect practices highly appreciated in certain disciplines and places. Academic work in the arts and humanities and in other languages than English is most often underrepresented and thus undervalued in these global rankings.

The analysis of world class universities as identified by two prominent world university rankings, of the transnational circulation of students and faculty, and of international scientific collaboration between the scientifically most productive countries has revealed a dynamic process of restructuring in global higher education and research that can be characterised by a tension between the established centres of research excellence in the USA and Europe and emerging central knowledge nodes in China, India and Australia. Japanese universities belong to the long–established research centres but are at the same time part of growing linkages between emerging world class universities in Asia–Pacific. In the context of a growing internationalisation of higher education and research across the world, regional knowledge networks within Asia–Pacific and Europe have been strengthened in the past decade.

A striking feature of the current process of restructuring in global higher education and research has been the rise of Chinese universities. Trends in academic mobility of students and staff and international co–authorship hint at a possible long–term shift of academic hegemony away from the USA that will enhance international competition for students, qualified researchers and academic resources. Institutions, cities and metropolitan areas that strive to do well in this contest, need to be well networked at different levels, including the inflow and outflow of international students and faculty at different stages of their career. In the long–term, a potential problem for US research universities might result from a comparatively small academic diaspora abroad. Studies have shown that these academic diasporas provide important linkages for the transfer of knowledge and technology between different nodes in the knowledge economy, thus fostering the formation of new knowledge centres and keeping established centres up–to–date.