GLOBAL RESEARCH REPORT
UNITED STATES

NOVEMBER 2010

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The US is no longer the Colossus of Science, dominating the research landscape in its production of scientific papers, that it was 30 years ago. It now shares this realm, on an increasingly equal basis, with the EU27 and Asia-Pacific. In terms of relative citation impact — an indicator of utility, influence, significance and similar concepts — the US still holds a commanding but eroding peak position. Europe is beginning to match US performance in citation impact, and analysts are likely to be tempted to predict that, in a decade or two, Asian nations will do so as well.

INTRODUCTION

This Global Research Report is part of an occasional series produced by Thomson Reuters to inform policymakers about the changing landscape and dynamics of the global research base. Previous reports examined the scientific enterprises of the so-called "BRIC" countries: Brazil, Russia, India, and China. The BRIC is an influential group of populous economies with massive economic potential. Subsequent reports considered Japan as well as two resource-rich regions, Australia/New Zealand and Africa, and added to our picture of key players in the global research enterprise.

These reports draw attention to the strengthening of the global research base and a changing geography of those who publish in the internationally influential journals indexed by Thomson Reuters. Historically, however, that index has been dominated by one particular country, and it is to the United States (the US) that we now turn our attention.

The US, by virtue of its size, its sustained investment in research and development, and the high quality of its educational system, has held a dominant role in science worldwide since Vannevar Bush's influential and widely respected report at the end of the Second World War on 'Science — the Endless Frontier'[i]. In the 21st century, however, the US finds itself in a rapidly changing environment. Globalization and increased competition, especially from the rapidly developing BRIC nations, now characterize the global geography of research.

How does this affect the current US position, its relative activity in different fields of endeavor, and the status of its great research universities? In this report we draw attention to the relative concentration of US research: by discipline, where it has an exceptional focus of activity in the life sciences and health; and by location, where there has been an increasing concentration of activity within an elite group of US research universities.

THE US AND RESEARCH PUBLICATIONS

Three decades ago, US scientists fielded nearly 40% of the papers in the journals indexed by Thomson Reuters in the *Web of Science*SM. That dataset represents a cross-section of the leading international research literature, with a database maintained to constant and well-publicized standards. In the current version of the *Web of Science*, the share of the world literature which carries a US author or co-author address is down to some 29%. During the same period, the European Union nations (the EU27, following the accession of countries in the former Eastern bloc) increased their share of research papers moderately, from 33% to 36%, surpassing the US in the mid 1990s.

The most dramatic development, however, has been the steady and accelerating rise in research contributed by nations in the Asia-Pacific region — from about 13% in 1981 to 31% in 2009. The year 2008 witnessed Asian nations matching the output of the US, and now they have exceeded the US output. It should also be noted that Asian nations as a group surpassed the US in R&D investments in 2008. That year, Asia's investment was $US 387 billion, that of the US was $US 384 billion, and the comparable figure for the EU27 was $US 280 billion.

Of course, all regions have published more papers each year: there has been no decline for any in the number of papers published. The changing figures for world share reflect the relative rate at which regions and nations have increased their production of research papers. Asia-Pacific, as a region, has raised its volume of publishable research at a faster rate than the more mature research enterprises of the US and the EU27. And it has been Taiwan, South Korea, Australia, India, and especially China that have driven the remarkable rise in Asian research output. As we described in our earlier Global Research Report on China, Thomson Reuters recorded 1,745 papers from that country in 1981 but 127,075 in 2009, representing an astonishing change in world share from 0.4% to 10.9%. China is now second to the US, the largest single-nation producer, and will likely surpass the EU27 nations in research paper output in the next decade.

THE US RESEARCH PORTFOLIO

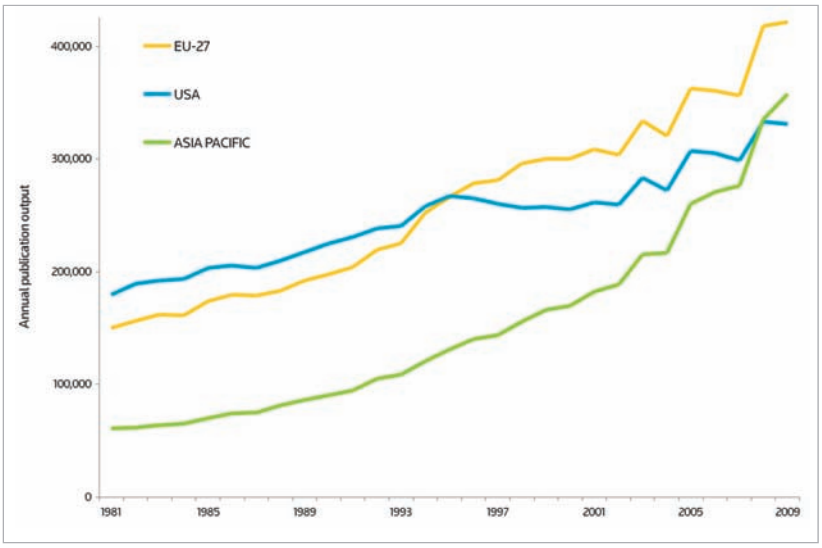
White House Science Advisor John Holdren, addressing a recent meeting of the American Association of the Advancement of Science, observed that "We can't expect to be number one in everything indefinitely." That comment sparked controversy among some who interpreted this view as a lowering of research aspirations for US government leaders. Others saw the remark as nothing more than an acknowledgement of reality, especially in light of the increasing globalization of research and the rise of many more nations now competing at the frontiers of science.

It should not be thought that research portfolios are evenly balanced across all regions. Different decisions are made according to a country's history, economy, and natural resources. With regard to specific fields, over the past two decades the US, in its federal funding for basic and applied research, has increased its investments in favor of the biological sciences, from about 40% then to about 50% currently[ii]. In particular, funding for the National Institutes of Health, part of Health and Human Services, has increased faster than has funding for research channeled through the National Science Foundation, the Department of Energy, the Department of Defense, NASA, and others. Political dynamics have favored this trend, owing to popular support for funding research that addresses cancer, cardiovascular disease, and other medical conditions.

This skewed investment in the biological and biomedical sciences was already noted in an international study by the UK's Science Policy Research Unit in the 1980s. As a result, US research in the physical sciences and engineering has taken a back seat to the biological sciences just at the time when Asian nations are focusing on and investing substantial sums in engineering, physical sciences, and technology. Moreover, it is in the physical sciences (including engineering and computer sciences) that a large number of US graduate degree recipients are foreign-born. Those who remain in

FIGURE 1

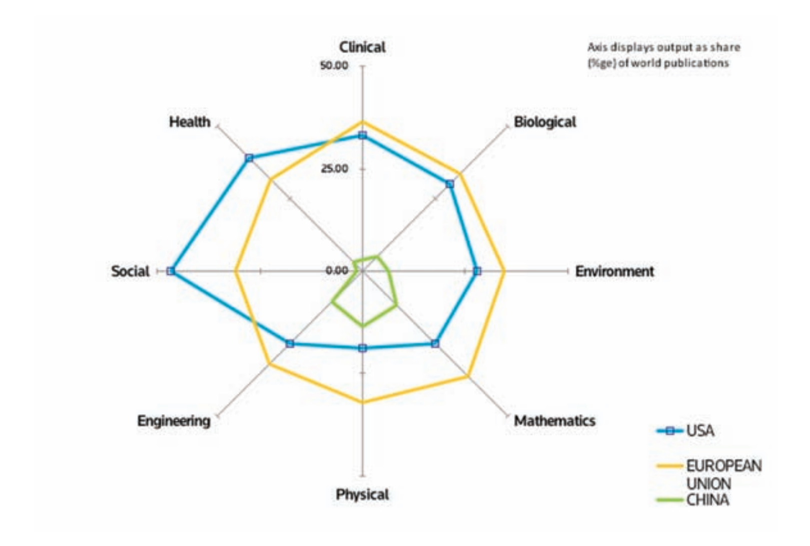
Annual total output of journal papers in all research fields for the United States, the European Union (EU27) group of nations, and for Asia-Pacific nations as represented in the Thomson Reuters *InCites*™ database, 1981-2009



Source: Thomson Reuters *Web of Science*SM

FIGURE 2

Research Footprint® of output by selected regions and countries. The radial axes display share of world output in percentage terms, for the period 2004-2008



Source: Thomson Reuters *Web of Science*SM

the US create significant domestic benefit, but those who leave the US after graduation constitute a loss of the kinds of highly-skilled professionals who will contribute to creating innovation in any modern, knowledge-based economy in which they are employed.

The Research Footprint® in Figure 2 shows that over a recent five-year period China's output remained much smaller than the US. It also had a relative focus skewed to the physical sciences, mathematics, and engineering. By contrast, the US had a skewed — and arguably disproportionate — contribution to health-related research and the social sciences. Both these profiles may be compared with that of EU27 nations, which as a group support significant complementarity and a balanced spread of research across major fields.

Perceptions shaped by past experience are nearly always "behind the curve." When presented with the volume trends highlighted in Figure 1 above, many — not just in the US — express surprise. But an important corrective to the notion of a decline in US research is the consideration of research influence or impact. Relative volume of output reflects activity and capacity in a field, but is nothing without the quality that leads to academic, economic, and social impact.

On a per paper basis, the average influence of US papers, as measured by relative citation impact indexed for field and year of publication, has maintained the country's lead over other regions and nations, remaining through the last three decades at some 40% above the world average. Over the last two decades, some EU nations have begun to close the citation impact gap with the US. The United Kingdom (UK) has now nearly matched the US overall. In some fields (including agricultural sciences, ecology and environmental sciences, molecular biology and genetics, and pharmacology) the average impact of UK publications exceeds the US.

Japan, by contrast, has held a fairly steady position in citation impact and is now approximately at the world average whereas Asia-Pacific nations as a group currently register a relative citation impact score at 20% below the world average. On the other hand, specific Asian nations — South Korea, China, and India — have dramatically increased their citation impact in the last decade.

In summary, the US is no longer the Colossus of Science, dominating the research landscape in its production of scientific papers, that it was 30 years ago. It now shares this realm, on an increasingly equal basis, with the EU27 and Asia-Pacific. In terms of relative citation impact — an indicator of utility, influence, significance and similar concepts — the US still holds a commanding but eroding peak position. Europe is beginning to match US performance in citation impact, and analysts are likely to be tempted to predict that, in a decade or two, Asian nations will do so as well.

A CHANGING BALANCE ACROSS RESEARCH DISCIPLINES

The research performance of the US and other countries can be seen to vary by field, as illustrated in their Research Footprint® (Figure 2).

Underpinning the current situation is a longer history. Whereas the US has sustained its exceptionally strong investment in health-related research and biomedical sciences, many of the Asian tigers, and now China, have developed a different research economy more closely associated with their strong industrial manufacturing base.

The following three Figures compare the publication outputs of the US, the EU27, and Asia-Pacific in three main areas of research with strong relevance to innovation and the economy. These are Materials science, Engineering, and Molecular biology & genetics. These are also areas where the dynamics of growth show clear and contrasting patterns.

It is evident that Asia Pacific is on a rising trajectory for publications in Materials science, which has taken the region past the US in 1996 and the EU in 2000. Europe has sustained and slightly enhanced the output levels it reached in the 1990s, but the US appears to have dropped back to a plateau that in 2009 barely reprises its output of 1994.

China (as a key player within the Asia-Pacific group) shows the most dramatic change. Asia's output overtook the US in the mid-1990s but China itself exceeded the US in materials science papers in 2004, and by 2009 it held a 23% world share. This was from just 0.3% of world share in 1981. The US achieved its peak world share in Materials sciences in 1994 at 31%, but declined to 15% in 2009, its 30-year nadir. The EU consistently stood above the US in world share in the field, reaching a high of 38% world share in 2001, and ended 2009 with a share twice that of the US.

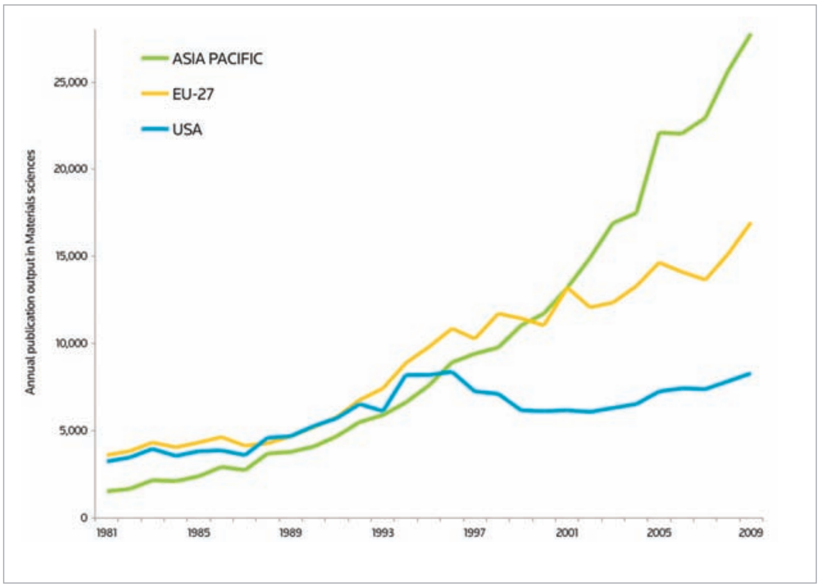
Relative citation impact for the US in Materials science is higher than it is in the related and underpinning areas of basic science (physics and chemistry) but impact dropped significantly in the 1990s before recovering and, by 2005-2009, stood at 73% above world average. The EU relative citation impact was 10% above world average in 1981-1985, declined to 7% below the average in 1988-1992, and thereafter recovered to end at 12% above the average in 2005-2009. China's relative citation impact finished 22% below world average in 2005-2009 but had noticeably improved over the past decade. Note that this is only an average: the best of Asia-Pacific — and Chinese — research is well above world average impact.

Engineering is of particular interest for the US. It has been reported that 9 of 10 working engineers will soon be active outside the US. And within the US, more than 50% of the recipients of doctoral degrees in engineering are foreign born. (The most recent statistics, however, point to an increase in the number of US freshmen who choose engineering as a major). Over the last three decades, the US world share in engineering papers has been cut almost in half, from 38% in 1981 to 21% in 2009. The EU27 surpassed the US in output in 1997, and as of 2009 held a 33% share of the field. The key story in Figure 4, however, is again about the rise of output in Asia, which matched US output by 2000, passed it in 2002, and then overtook the combined EU27 in 2005 on an ever steeper upwards trajectory. Within Asia, the picture for China is equally dynamic. In 1981 China claimed a modest 0.5% of world engineering papers, but by 2009 the figure was 15%. Projection suggests that China's output will pass the US by 2012.

Engineering papers from China are now competitive in their average influence with those of the US and especially with those of the EU. In terms of relative citation impact, the US and the EU had generally stable scores over the last three decades. Despite some variation, both ended 2009 near where they began. The US performed at 25% more than the world average in 2005-2009, whereas the EU's comparable index was 5% more than the world average. China, which was 42% below world average in engineering in relative citation impact in 1981-1985, recorded an average score just 6% below the world benchmark in 2005-2009 but with many individual papers well above that mark.

FIGURE 3

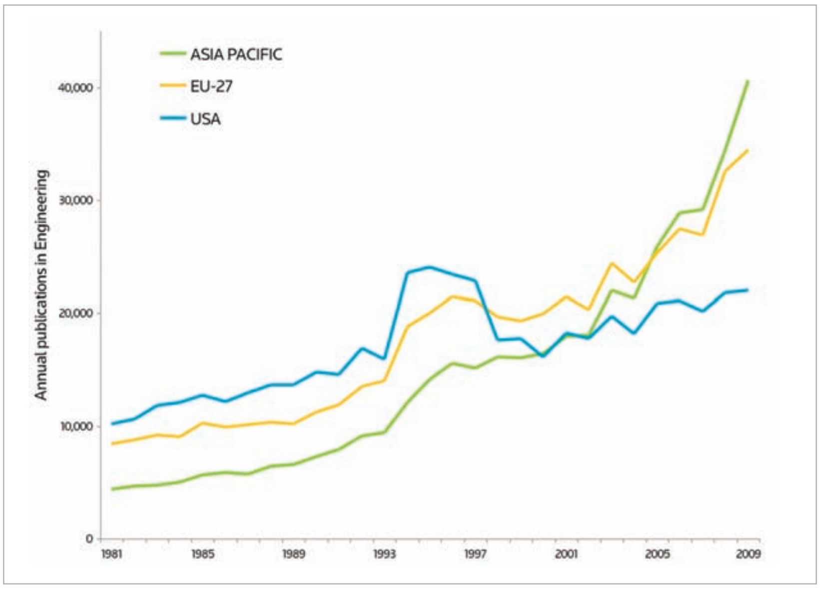
Annual publication output in Materials sciences



Source: Thomson Reuters *Web of Science*SM

FIGURE 4

Annual publication output in Engineering



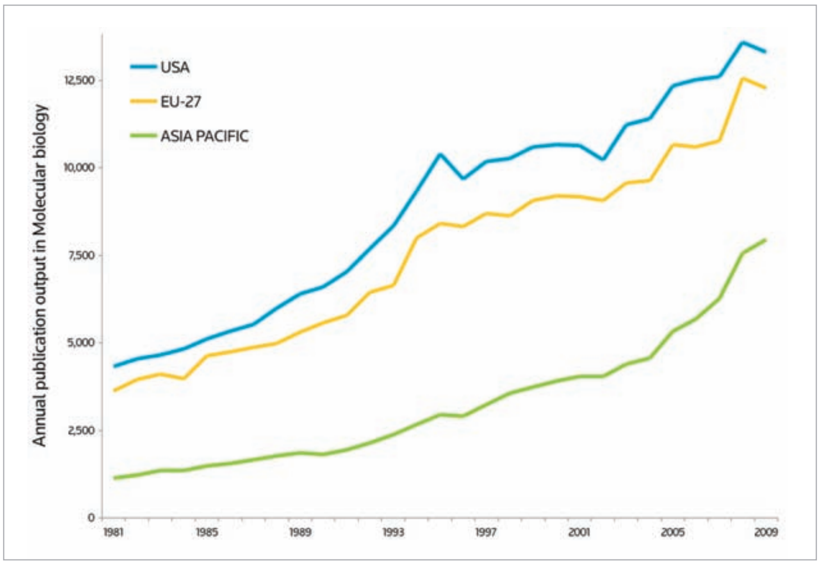
Source: Thomson Reuters *Web of Science*SM

A similar story would be told for mathematics. In physics, too, the trend for the US in terms of world share is distinctly downward, and stands at about 22% as of 2009. Chemistry offers a similar history of share and relative impact. The US claimed a 24% share in 1981, but was down to 18% as of 2009. China made rapid gains from a 0.3% world share in 1981 to 20% in 2009 and its chemistry output passed that of the US in 2007.

The picture in biological sciences (Figure 5 is an example) looks different to that in the physical sciences. The Asian tiger nations and China started their research rise in disciplines strongly linked to their domestic manufacturing base. This is the growth pattern reflected in Figures 3 (Materials) and 4 (Engineering). Now, investment is shifting into life sciences, medicine, and even social sciences. These will be the most rapid growth areas of the next decade, because this is where the Asia-Pacific nations have the greatest opportunity for expansion from their current position. Singapore is already recognized as having developed a highly competitive biotechnology base,

FIGURE 5

Annual publication output in Molecular biology & genetics



Source: Thomson Reuters *Web of Science*SM

with strong economic potential. Its achievements will likely be reflected in emerging research groups in other institutions across the region.

For the US, the top fields in relative impact are microbiology, biochemistry, and clinical medicine. These are research areas in which Figures 2 and 5 show that it currently retains a high share of world publication activity. Commentators suggest that we are moving into an era when the biomedical sciences will provide the richest areas for economic innovation and growth. The US would at one time have been expected to be the unquestioned champion in leading that growth. But then again the US would at one time have been the unquestioned leader in manufacturing and engineering. If history shows that the latter pattern is no longer true then perhaps expectations for future US innovation and economic development deriving from the biological sciences may also rest on uncertain foundations.

PUBLICATION ACTIVITY IN US RESEARCH UNIVERSITIES

The US rightly claims many of the finest research institutions in the world. That has been true for the last 60 years, and it remains so today. When one examines research output in terms of papers across all fields in the sciences and social sciences and published in journals indexed by Thomson Reuters over the last decade, 11 of the top 20 institutions were located in the US. Most of these include a medical school.

Outside the US, the first, second, fourth and twelfth largest producers were, not surprisingly, the Chinese Academy of Sciences, the Russian Academy of Sciences, the German Max Planck Society, and the French National Center for Scientific Research (CNRS), each a network of individual research institutes. Other world leading organisations in terms of output were, in order: University of Tokyo (5), University of Toronto (6), Kyoto University (14), University of Oxford (16), and University College London (17).

So the US has an impressive output in terms of its national volume. But what these data also suggest is that national output must be relatively concentrated because so many individual US institutions feature in a world list of research producers.

Thomson Reuters data record research publications from over 300 Higher Education Institutions (HEIs) in the US. The most prolific 25 each produces well over 1% of total US outputs, while the 61 US members of the Association of American Universities (AAU) alone accounted for 56% of US outputs in the five year period to 2009.

Table 1 shows that the US research base is indeed concentrated. The comparison between the most recent five-year period and an earlier period (1981-1985) shows that this concentration has increased over time. That may not appear dramatic, but then it has increased from an already concentrated starting point.

The AAU accounts for 56% of outputs in 2005-2009. It also accounts for 58% of all federally funded research provided to colleges and universities ($US 18.1 billion in federal academic research expenditures in FY2008), and its staff include over 80% of all university faculty members who are members of the prestigious US National Academies (3,200 academic researchers in 2007). AAU institutions also have a notable track record in such esteem indicators as the Nobel prizes.

Change at the institutional level has been gradual (Figure 6), but that is unsurprising given the competitive nature of the publication process. For Harvard, at the top of Table 1, the change is much clearer: it increased its share in every quinquennium across the analysis, which is an extraordinary dominance.

The institutions in Table 1 account for about one-third of a total US output which includes a wide range of research institutes and national laboratories as well as 300 other HE institutions. The overall outcome for the AAU, which is quite clear in Figure 6, confirms that individual institutional increases are not – or not largely - the effect of increased collaboration. If share of US output has increased among the most research-active institutions then it has likely decreased among the less research intensive except insofar as they are collaborative partners. It has also likely decreased among the non-university research laboratories. In other words, the US research base is now somewhat less diverse than it once was.

TABLE 1
Publication output by the most prolific US universities for the five-year period 2005-2009, compared with their output in the five-year period 1981-1985.

1981-1985			2005-2009	
Total papers	Share US (%)	Institution	Total papers	Share US (%)
469,201	48.49	AAU	905,522	56.1
25,630	2.65	Harvard University	68,146	4.22
13,071	1.35	University Michigan	33,084	2.05
10,567	1.09	Johns Hopkins University	31,503	1.95
16,941	1.75	University California Los Angeles	31,108	1.93
12,841	1.33	University Washington	30,320	1.88
13,366	1.38	Stanford University	28,318	1.75
10,248	1.06	University California San Diego	27,265	1.69
15,176	1.57	University California Berkeley	27,021	1.67
11,646	1.20	University Pennsylvania	26,579	1.65
10,691	1.10	Columbia University	26,427	1.64
10,219	1.06	University Maryland	25,844	1.60
14,419	1.49	University Minnesota	25,497	1.58
13,919	1.44	University Wisconsin Madison	24,553	1.52
14,222	1.47	Cornell University	23,483	1.45
10,166	1.05	University Florida	23,226	1.44
7,483	0.77	University Pittsburgh	22,457	1.39
9,490	0.98	University California Davis	22,362	1.38
7,880	0.81	Duke University	21,954	1.36
8,715	0.90	Penn State University	21,689	1.34
11,150	1.15	Yale University	21,676	1.34
8,792	0.91	Ohio State University	21,380	1.32
8,889	0.92	University Colorado system	21,066	1.30
10,027	1.04	University California San Francisco	20,691	1.28
11,651	1.20	MIT	20,609	1.28
6,975	0.72	Texas A&M University system	19,432	1.20

Source: Thomson Reuters *Web of Science*[SM]

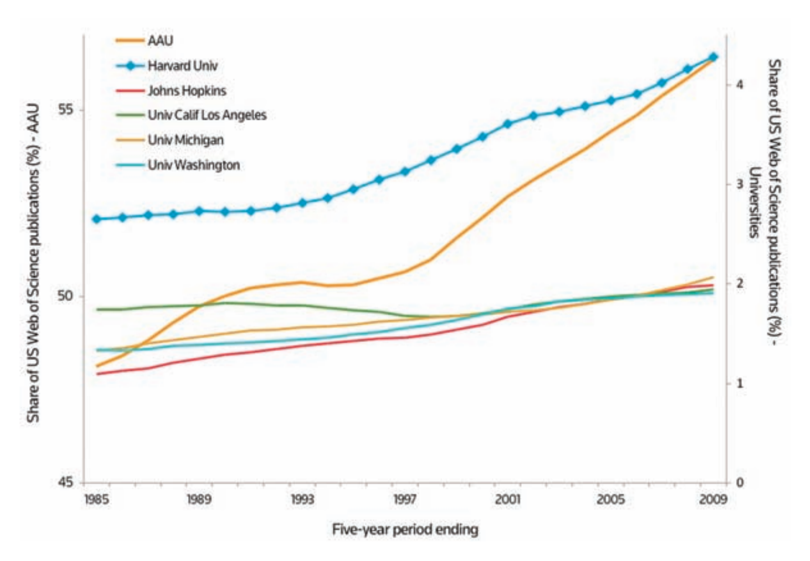
We can look in detail at the US institutions that produce the most frequently cited papers. A number of perspectives can be taken on such data, for example by looking at the institutions that have the highest impact irrespective of volume. The latter list includes some excellent specialist institutions, headed by the Whitehead Institute and the Cold Spring Harbor Laboratory. Alternatively, we could look at a restricted view, of institutions producing papers that are amongst the top 1% world-wide by relative impact. For this report, we have looked at the average relative citation impact (normalized for field and year of publication) of the total output of those institutions that produced at least 2,000 papers per year in 2009.

The individual institutions in Table 2 have improved their relative citation impact since 1981-1985, but not all have done so since 1993-1997. Most of the 'gain' in impact relative to the rest of the world was in the earlier part of the analytical period. For the AAU, and also for the US university research base as a whole, average citation impact has essentially remained constant, within a margin of error. That means that while the highest ranking institutions have moved ahead, the system average has not followed.

During the last decade, the top 20 US universities ranked by total citations received 47% of all citations to US papers. By citation impact, those institutions averaged 22.08 citations per paper, or 42.3% higher than the overall US average of 15.52 citations. Taking an average across the relative citation impact in Table 2 (which takes into account the different citation rates for the various disciplines in which these institutions specialize), the top 20 have a 36% higher impact than the US University research base generally. So, by any measure, these institutions represent a significant concentration of US research power.

FIGURE 6

Change in share of total US publication output for the AAU (left-hand axis) and for the five most prolific US universities (right-hand axis) in successive five-year periods from 1981-1985 to 2005-2009



Source: Thomson Reuters *Web of Science*SM

A different assessment of the stature of US universities is available in the recently released World University Rankings of the Times Higher Education magazine (London)[iii]. These data were collected and analyzed by Thomson Reuters for the magazine and include not only publication and citation measures but also assessments of teaching and research as well as consideration of industry funding and international diversity. In this analysis, which casts its net farther and wider than bibliometric indicators alone, 15 of the top 20 were U.S. institutions: Harvard (1), Caltech (2), MIT (3), Stanford (4), Princeton University (5), Berkeley (8), Yale (10), UCLA (11), Chicago (12), Johns Hopkins (13), Cornell University (14), Michigan (16), Columbia (18), Pennsylvania (19), and Carnegie Mellon University (20). The non-U.S. universities in the top 20 and their ranks were: Cambridge and Oxford (tied at 6), Imperial College London (9), the Swiss Federal Institute of Technology or ETH (15), and Toronto (17).

Concentration of US research output and excellence has increased over the last thirty years (Table 1). Fifteen of the top US institutions are located on the East and West coasts (Table 2). How does this compare with other countries?

TABLE 2

The US universities (producing at least 2,000 journal articles in the most recent year) with the highest average relative citation impact for 2005-2009, with comparative impact data for two earlier five-year periods. A score of 1.00 represents the average citation impact for the world, considering the field and year of published papers. Data are also shown for the AAU and for US universities as a whole.

Institution	1981-85	1993-97	2005-09
MIT	2.14	2.16	2.28
CALTECH	2.13	2.02	2.18
Princeton University	2.19	2.07	2.11
University California Santa Barbara	1.75	2.28	2.04
Stanford University	2.05	2.08	1.96
Harvard University	1.98	2.14	1.94
University California Berkeley	1.79	1.77	1.92
University Colorado Boulder	1.67	1.65	1.86
University Chicago	1.98	1.92	1.85
University Washington	1.78	1.76	1.82
University Pennsylvania	1.62	1.73	1.77
University California San Francisco	1.86	1.89	1.76
Johns Hopkins University	1.69	1.85	1.74
Columbia University	1.70	1.83	1.74
University California Los Angeles	1.62	1.61	1.74
Northwestern University	1.62	1.69	1.73
Boston University	1.35	1.59	1.71
Yale University	1.91	1.89	1.71
University Rochester	1.46	1.60	1.71
AAU	**1.51**	**1.55**	**1.49**
US UNIVERSITY average	**1.37**	**1.40**	**1.37**

Source: Thomson Reuters *Web of Science*SM

Cambridge University, Oxford University, University College London, and Imperial College each account for around 6% of UK research outputs; they have each increased their share of UK research outputs over the last thirty years; they are located within 50 miles of one another in the South-East quarter of England. That looks pretty concentrated, but the UK research base is much smaller than the US. In fact, the sixteen most prolific UK universities — a group that accounts for about 58% of research grants and contracts and 57% of the research publications — are spread throughout the UK regions.

This 'group of 16' might be deemed equivalent to the AAU in share of national research activity. It not a formal group, just one ranked by share, but it would be one-quarter the size of the AAU. By contrast, the UK's GDP is just one-sixth that of the US and its expenditure on R&D (GERD in OECD parlance) is about one-tenth. In 2007, the UK spent $US 32.9 Billion GERD while the US spent $US 310 Billion. So, if the US research base were distributed in the same way as that of the UK, then we would expect that roughly 57 to 58% of input and output to be spread across a much larger group than the AAU. The AAU's members are not necessarily the largest institutions, so in capacity terms this is an even more marked level of concentration.

SUMMARY

The current state of scientific research in the United States remains strong, with significant funding (some 2.8% of GDP, relatively more than key competitors), excellent academic institutions that are a magnet for the best minds worldwide, and a talented workforce that leads the globe in the quality of its collective research efforts, innovations, and results.

The diverse perspectives in this report demonstrate the leadership role in research held by US universities. At the top end, it would seem the US research enterprise is still going from strength to strength. The leading institutions continue to assert an exceptional dominance when compared to leading research institutions in Europe or in Asia.

But there are signs that the concentrated apex of the US university system is not pulling the rest of the research base in its wake. The US research base appears to be more concentrated than the UK, its most research-competitive comparator. The UK is part of a regional grouping that has maintained its share of world outputs in the face of growing global competition. The UK has also improved its comparative international research performance over the last quarter-century. In contrast, the US is losing share and its relative international research competitiveness is being challenged.

The US benefits from globalization in its ability to attract world-class scientists and its increasing interactions and collaborations with researchers in other nations. But it also faces significant challenges. The US and member nations of the EU (as well as Japan) have mature scientific enterprises. A highly respected educator from a past generation wisely noted, "Nations, like people, are freer to sketch and plan when institutions have yet to be built and resources are still uncommitted than at a later stage when the die has been cast and one must live with what one has chosen." The US and the EU have already "cast the die" whereas developing nations such as China, India, and Brazil are building a foundation for the future. These emerging nations will increase their investments in research as a percentage of GDP, which are usually still relatively modest. Competition can only increase.

The US National Academies' outstanding 2007 audit and report 'Rising Above the Gathering Storm'[iv] summarized the educational and innovation challenges that the US faces and drew attention to underlying issues in the US science and engineering education system. Is there an argument that the structure of the US research base may also be a contributory factor to its current position? A key question must be whether a concentrated group of outstanding research institutions, which lead any number of international tables by their achievements, are providing the creative knowledge solution required by present circumstances. Are the challenges described by the National Academies best answered by such concentration, or does the response to the challenge of agile knowledge economies elsewhere in the world require an equally agile and innovative response, supported by a more pervasive network of US institutions to draw on the talent spread across the 50 States?

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