



# GLOBAL RESEARCH REPORT **CHINA**

Research and collaboration in the new geography of science

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JONATHAN ADAMS  
CHRISTOPHER KING  
NAN MA

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## THE AUTHORS

Jonathan Adams is Director, Research Evaluation.

He was a founding Director of Evidence Ltd, the UK specialist on research performance analysis and interpretation.

Christopher King is Editor of Science Watch ([ScienceWatch.com](http://ScienceWatch.com)),

a newsletter and web resource tracking trends and performance in basic research.

Nan Ma is Science and Solution Consultant in the China office, Healthcare & Science business of Thomson Reuters.

She has an extensive academic background in information science and a Ph.D. in management science.

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Evidence Ltd, a Thomson Reuters company

103 Clarendon Road, Leeds LS2 9DF, UK

T/ +44 113 384 5680

F/ +44 113 384 5874

E/ [enquiries@evidence.co.uk](mailto:enquiries@evidence.co.uk)

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# THE NEW GEOGRAPHY OF SCIENCE:

RESEARCH AND COLLABORATION IN CHINA : NOVEMBER 2009

## INTRODUCTION

This report is part of a series launched by Thomson Reuters to inform policymakers about the changing landscape and dynamics of the global research base.

Previous Global Research Reports have examined Brazil and India, two constituents of the so-called "BRIC" group of nations, the others being Russia and China, that are beginning to build on their vast resources and potential in becoming significant players in the world economy. As their influence becomes felt economically so their impact also becomes apparent in research and innovation. That impact is changing the world map of research: it creates a new geography of science. Here, we turn our attention to the stunning growth and global impact of research in China.

Since the Chinese economic reform started in 1978, China has emerged from a poor developing country to become the second-largest economy in the world after the United States of America. Already, more than half of the nation's technologies, including atomic energy, space science, high-energy physics, biology, computer science, and information technology, have reached or are close to a recognizable international level of achievement. In space science, for example, the successful launch in October 2003 of the "Shenzhou V" manned spacecraft made China the third country to master manned spaceflight technology. The 'Moon Probe' project started in February 2004 forecasts that China will soon launch unmanned probes to the moon and is targeted to gather moon soil samples before 2020.

China's Gross Expenditure on R&D (GERD) increased rapidly between 1995 and 2006, whether measured in current or constant prices. It was maintained at just under 1% of Gross Domestic Product (GDP) during a period when China's GDP was growing at a phenomenal speed. Data from the Organisation for Economic Cooperation and Development (OECD) show that China now ranks third worldwide in volume of GERD,

just behind the USA and Japan but ahead of individual member states of the EU.<sup>1</sup> The annual average growth rate for GERD in China in the decade to 2005 has therefore been impressive, at only slightly less than 18%. This rate is much higher than that recorded in the OECD countries and China is now the largest contributor to GERD in non-OECD countries.<sup>2</sup>

Since the 1980s, China has formulated a series of national programs for science and technology research and development, with the strategic aim of improving the country's competitiveness in science and technology. The Key Technologies Research and Development Program, the 863 Program, and the 973 Program form the main body of state programs for science and technology. The Spark and the Torch programs have been important for raising China's strength in this area.

Institutions of higher education, of course, constitute a key element in China's national innovation system. These institutions have experienced rapid growth in the last 20 years. Statistics from the Ministry of Education show that the current number of students studying in Chinese universities has reached 25 million, a five-fold increase in only nine years. Initiatives targeting higher education such as Project 211, launched in 1995, and Project 985, launched in 1998, aim at cultivating a high-level elite for national economic and social development strategies. Currently, China has more than 1,700 standard institutions of higher education, and about 6% of them are Project 211 institutions. Such schools take on the responsibility of training four-fifths of doctoral students, two-thirds of graduate students, half of students abroad, and one-third of undergraduates. These institutions offer 85% of the State's key subjects, hold 96% of the State's key laboratories, and utilize 70% of scientific research funding.<sup>3</sup> This is a powerful force for knowledge development, exploitation and innovation.

# THE NEW GEOGRAPHY OF SCIENCE: RESEARCH AND COLLABORATION IN CHINA

## DATA ON RESEARCH

The data analyzed in this report are drawn from the databases of Thomson Reuters, which regularly indexes data on articles in about 10,500 journals published worldwide. Numerous studies have confirmed that Thomson Reuters data-management policy ensures that its databases cover serials regarded by researchers as the most significant in their field.

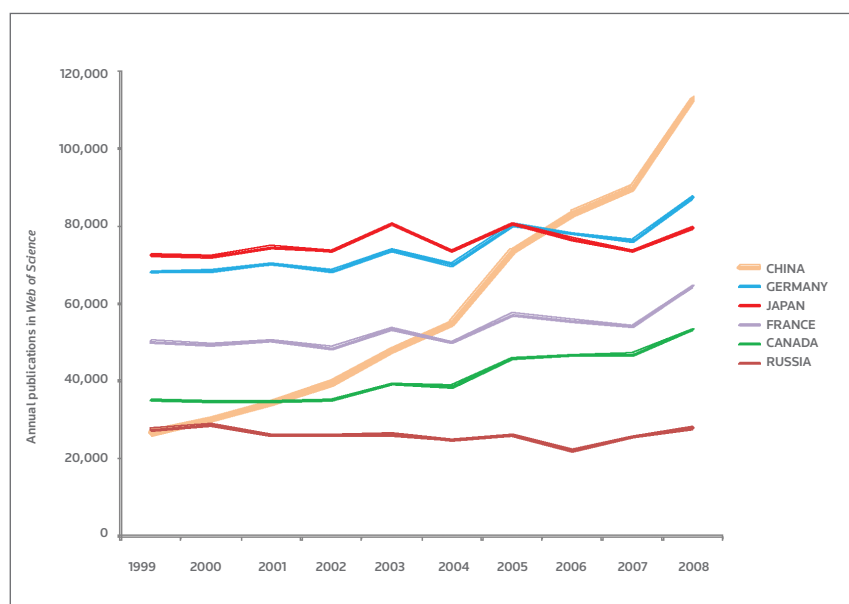
The Thomson Reuters data allow us to examine China's particular areas of concentration and strength, as well as the nation's international links. International collaboration is an important marker of the significance of research activity to partners and of those other countries' ability to engage with the domestic research base.

Joint projects, and specific data on funding for joint research, are valuable information but tend to be collated inconsistently and incompletely. By contrast, joint publications are a sound and valid marker. Publication data are readily available, cover a wide range of countries, and can be grouped by year and subject. Every research paper includes the names and addresses of the authors. Thus, both the country of origin of authors and the association between co-authoring nations can be indexed and evaluated.

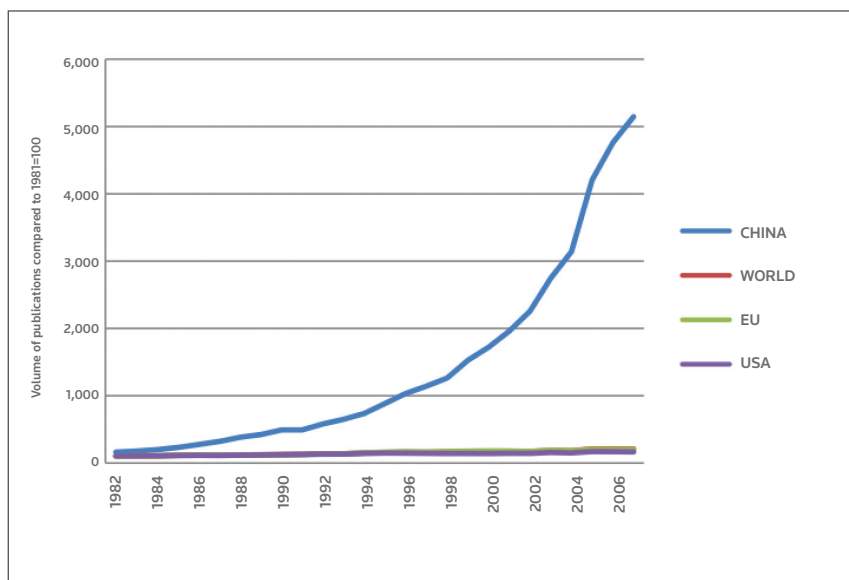
## CHINA AND RESEARCH PUBLICATIONS

Beginning around the mid-1990s, China's output of scientific reports expanded dramatically, commencing a steep upward trajectory that has only increased in recent years. Figure 1, covering the years 1999 to 2008, captures the increase in the annual number of Thomson Reuters-indexed papers featuring at least one author address in China.

**FIGURE 1**  
China's research output has increased dramatically since 1999 while most nations remained fairly stable. During the same period the USA increased its output from 265,000 to 340,000 publications per year, an increase of around 30% compared to China's more than four-fold growth.



**FIGURE 2**  
China's recent year-by-year growth dwarfs that displayed by the US and the world overall



From just over 20,000 papers in 1998, China's output increased to upwards of 112,000 papers by 2008 —with the nation more than doubling its output since 2004 alone. By the measure of annual output, China surpassed Japan, the UK and Germany in 2006 and now stands second only to the USA.

China's growth can be assessed in another way, because the world literature indexed by Thomson Reuters is growing. We can index each country's "relative growth" by setting the volume of publication output on *Web of Science*® at a standard "100" in 1981, and then work forwards. In Figure 2 we compare China's relative growth against three benchmarks: the overall world figure and the USA and the European Union as the historically major research regions. The analysis charts each entity's year-by-year rise over its respective starting point.

As in Figure 1, China's comparative growth is striking, far outstripping that of the rest of the world. As a consequence the USA and the EU actually grow at a slower rate than the world baseline—precisely because of China's impact on that baseline. Figure 2 also shows that what many commentators noted as the start of China's research rise in the 1990s can clearly be tracked back into the 1980s in Thomson Reuters data. And the curve seems to be showing only marginal signs of slowing, still heading to overtake the USA itself within the next decade.

### Where is China focused?

China's explosive growth in research output in recent years is evident. But in what fields, specifically, has this growth been manifest, and how do these areas of concentration map to the rest of the world?

We examined China from two different levels of focus: first, a broad overview across the twenty-two major areas in Thomson Reuters *Essential Science Indicators*™; then, a more detailed examination based on the 250 specific subfields covered in the *Web of Science*.

In a recent five-year period, China produced roughly 400,000 papers in all fields of science, accounting for approximately 8.5% of the world's papers published in journals indexed by Thomson Reuters. In Table 1, we examine how that share has panned out across different subject areas.

China's publications are analyzed here by *Essential Science Indicators* categories for two successive five-year periods. The top sixteen categories, ranked by China's share of world publications in 2004-2008 are shown, with comparative figures for the previous 1999-2003 period.

Immediately evident is China's concentration in the physical sciences and technology, with Materials Science, Chemistry, and Physics predominant. This is China's traditional core strength rooted in an economy which still has a preponderance of

heavy industry and primary manufacturing. What is also clear, however, is that this relative level of investment in materials and related physical sciences will provide China with a strong innovation platform in modernizing those industries. As the right-hand column attests, however, output in these fields has also grown comparatively slowly between the successive five-year periods.

Looking to the future, the notable growth areas are grouped in the bottom of the table, with Agricultural Sciences displaying the highest growth (perhaps expected, for the world's most populous nation and its attendant food demands) and life-sciences fields such as Immunology, Microbiology, and Molecular Biology & Genetics expanding the most rapidly in terms of paper output. This will be both an opportunity for those economies which already

**TABLE 1**  
China's share of world publications in selected main fields covered by Thomson Reuters

Field	1999-2003		2004-2008		Rank	
	Count	Share(%)	Count	Share(%)	Share	Growth
Materials Science	20,847	12.22	48,210	20.83	1	12
Chemistry	44,573	9.29	99,206	16.90	2	15
Physics	31,103	7.97	66,153	14.16	3	17
Mathematics	7,321	7.37	16,029	12.82	4	16
Engineering	19,343	6.42	43,162	10.92	5	14
Computer Science	3,943	4.54	16,009	10.66	6	4
Geosciences	5,322	4.95	12,673	9.30	7	11
Pharmacology & Toxicology	2,259	3.11	6,614	7.28	8	7
Environment/Ecology	3,171	3.26	9,032	6.85	9	8
Space Science	2,055	3.80	3,514	5.89	10	21
Biology & Biochemistry	6,697	2.66	15,971	5.86	11	10
Plant & Animal Science	5,915	2.61	14,646	5.42	12	9
Agricultural Sciences	1,082	1.48	4,872	4.88	13	1
Microbiology	921	1.38	3,863	4.74	14	3
Molec. Biology & Genetics	1,642	1.43	6,210	4.49	15	5
Immunology	493	0.87	2,114	3.51	16	2

invest heavily in these areas, and would like to collaborate with China in its new research venture, and a challenge as the fruits of this research are applied to innovative processes and products.

For a closer analysis of China's areas of concentration, we can turn to the numerous subfields covered in the *Web of Science*. Table 2 lists ten specialty areas according to China's share of world output in each for 2004-2008.

Table 2 underscores China's historical strength in the physical sciences and particularly in materials, with its shares of world output in the fields of Crystallography and Metallurgy & Metallurgical Engineering both topping 30%, an index of exceptional domination of a research area. The nation's concentration in materials comes into

sharper focus farther down the list, as the sub-specialties of Composites, Ceramics, and Polymer Science emerge, with China also registering a strong presence in a broader "multidisciplinary" category of materials research.

What will be interesting over the next few years is to see which fields in biomedical disciplines begin to rise up this table and exactly where China chooses to invest and where it starts to deliver international quality research outcomes. This will be important market intelligence not only for pharmaceutical and other health-related companies but also for those universities and research organizations which will look to partner with leading Chinese institutions in order to learn about these discoveries.

**TABLE 2**  
China's share of world output in ten fields in Web of Science

Field	Share (% of world)	Volume (papers 2004-08)
Crystallography	31.67	14,322
Metallurgy & Metallurgical Engineering	31.24	16,624
Multidisciplinary Physics	22.12	23,422
Applied Mathematics	21.06	16,058
Materials: Composites	19.88	3,070
Materials: Ceramics	19.83	5,204
Polymer Science	19.25	13,022
Materials: Multidisciplinary	19.02	38,468
Inorganic & Nuclear Chemistry	18.07	10,470
Multidisciplinary Chemistry	16.94	24,315

## COLLABORATION WITH CHINA

Table 3 lists China's international research partners over the last decade, ranked by number of collaborative papers in two successive five-year periods. Here the USA stands out in terms of frequency of co-authorship, with US-based authors contributing to nearly 9% of papers from China-based institutions between 2004 and 2008.

The roster of contributing nations has remained largely stable between the five-year periods, although Italy and Russia have slipped slightly in

recent years, while Sweden and the Netherlands have moved higher. Aside from Japan, Singapore currently occupies the highest rung of regional collaborators.

For many countries, such as the USA and the UK, the volume of collaboration with China more than doubled between the first and second five-year periods. Collaboration with France and Germany grew more slowly. But the regional expansion is notable. While collaboration with Japan grew

**TABLE 3**  
China's leading international research partners in the last decade

Papers collaborative with China				Share (%) of China Total
1999-2003		2004-2008		
USA	16,389	USA	39,428	8.9
Japan	7,251	Japan	13,418	3.0
Germany	4,480	UK	9,987	2.3
UK	4,433	Germany	8,263	1.9
Canada	2,806	Canada	7,547	1.7
Australia	2,796	Australia	7,116	1.6
France	2,196	France	4,997	1.1
Singapore	1,782	Singapore	4,635	1.0
South Korea	1,565	South Korea	4,485	1.0
Taiwan	1,471	Taiwan	3,219	.73
Italy	1,221	Sweden	2,311	.52
Russia	1,042	Netherlands	2,261	.51
Netherlands	970	Italy	2,114	.48
Sweden	944	Russia	1,880	.43



slowly, collaboration with South Korea and Singapore almost trebled and collaboration with Australia expanded at well above the China average.

We noted in a previous report, on India, that there were signs of an emerging Asia-regional network. The evidence here seems to bear that out.

Singapore also occupies a prominent place in Table 4, which presents a selection of international

organizations that have collaborated with China institutions on notably high numbers of papers in the last five years. The list is not a complete reflection of just the top ten organizations, but has been selected to give a fuller flavor to the diverse richness of China's research links.

**TABLE 4**  
International organizations collaborating frequently with China

Organization	Country	Number of co-authored papers
National University of Singapore	Singapore	3,145
University of Texas	USA	2,045
University of Tokyo	Japan	2,039
Harvard University	USA	1,568
University of Sydney	Australia	1,432
Imperial College London	UK	987
Centre National de la Recherche Scientifique	France	973
Seoul National University	South Korea	957
Istituto Nazionale di Fisica Nucleare	Italy	930
McGill University	Canada	918

## OVERVIEW

The effect of China on the world economy, and the interest of global leaders in its policies and plans, is mirrored in its national research profile. The growth of its research investment has had a measurable effect on the balance of research investment and growth globally. Its four-fold increase in research publications over a decade means that no field of endeavor has been unaffected. The direction it takes in the future will be equally significant.

The bulk of China's effort and its growth thus far has been concentrated in core technology and related physical sciences. It has an exceptional share of activity in areas such as the materials sciences. For some countries this has been an area of relatively low investment because they have been switching into higher value industries around biotechnology. But China's grip on innovative materials is likely to have far-reaching effects. It is difficult to see developments in industrial sectors that draw on these technologies that will not directly or indirectly depend on the knowledge coming out of China's research. The critical part of this may not be only the detailed facts. It will be in the understanding of what has lain behind the research that is actually reported. That comes only from collaboration.

China's new areas of investment take it along a different path. What is evident in the Thomson Reuters data is the pattern of rapid growth now in areas where China has had less presence in the past: biological and medical sciences. If growth is as rapid

and substantial and the outcomes are as effective as they have been in other fields then the impact of this new research on gene and protein research and process innovation will be profound and pervasive. European and North American institutions will want to be part of this.

Thus far the growth of the Chinese research base has been marked by an equal growth in collaboration. These are opportunities that must not be squandered, although the expansion of such opportunities may make it difficult for potential partners to find the capacity to keep up with the pace that China sets. But it is important to emphasize a point we have made in other reports: collaboration is not just about a better understanding of what was discovered. It is fundamentally about the why and the how that appears not on the printed page but only at the laboratory bench.

China's expanding regional collaborations send another signal. Asia-Pacific nations are entirely happy to work with another's excellent research bases now. They no longer depend on links to traditional G8 partners to help their knowledge development. When Europe and the USA visit China they can only do so as equal partners. The question that may then be put to them is what they can bring to the partnership to make it worth China's while to share.

### ENDNOTES AND REFERENCES

<sup>1</sup>Evidence Thomson Reuters report to the UK Department for Business, Innovation & Skills, October 2009.

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**Science Head Offices**

**Americas**

Philadelphia +1 800 336 4474  
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