



GLOBAL RESEARCH REPORT

BRAZIL

Research and collaboration in the new geography of science

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THE NEW GEOGRAPHY OF SCIENCE:

RESEARCH AND COLLABORATION IN BRAZIL : JUNE 2009

INTRODUCTION

This report is the first in a new series launched by Thomson Reuters to inform policymakers about the changing dynamics of the global research base.

In 2006, Evidence, Ltd. published a report with UK think-tank Demos on the future of the UK's research collaboration with other countries. That report focused on the growth of the research base in China and the changing geography of research from a trans-Atlantic axis to a wider global network.

China is a key player in a grouping which policymakers call the 'BRIC countries': Brazil, Russia, India and China. This report builds further on that analysis by examining the state of play in another member: Brazil.

Brazil is an increasingly important and competitive research economy. Its research workforce capacity and R&D investment are expanding rapidly, offering many new possibilities in a diversifying research portfolio. It has received much less policy attention than China, however, and the research base in Latin America in general is unfamiliar to many in Europe and Asia.

The report shows that Brazil's output has doubled in ten years to 2007, part of a long-term trend of growth that far exceeds established G7 economies. Relative to the rest of the world, Brazil has exceptional capacity in biology-based disciplines and research related to natural resources.

Brazil's main international partners are led by G7 economies with very large research bases of their own. It also has excellent and fast growing links with Portugal, and appears to be a key player in an emerging regional network. The organizations which underpin this collaborative web are internationally excellent in their own countries.

International collaboration provides access to new ideas as well as knowledge, and the expanding BRIC economies will be a key source of this innovation. The compass of research and innovation is swinging more and more strongly to the east and south. Policymakers in well-established research economies need to understand what is happening and be prepared to engage with new research landscapes.

THE NEW GEOGRAPHY OF SCIENCE: RESEARCH AND COLLABORATION IN BRAZIL

Brazil is an exciting and innovative research-based economy, with a much longer history of cutting-edge technology than most people outside South America recognize. In the future, they remain ignorant at their peril. Brazil's research economy is expanding rapidly and strongly and its knowledge strength has led one well-informed think-tank to name it 'the natural knowledge economy.'

Peaks in the geography of knowledge and innovation

Demos's detailed and information-rich Brazil reportⁱⁱ draws attention to the 2005 launch of Empresa Brasileira de Aeronáutica's *Ipanema*, the world's first commercial aircraft to run solely on biofuels. What is less familiar is the story of Alberto Santos Dumont from Minas Gerais who claimed in 1906 to have built the world's first practical airplane following the Wright Brothers demonstration of the feasibility of powered flight.

Today, Brazil produces more than 40% of the world's bio-ethanol, a response to the government's *PróAlcool* bio-ethanol policy in 1975. It aims for more than three-quarters of its cars to run on biofuels, backed by its programmes for engine development. It is a major player in other innovation areas, drawing on its fantastic natural resources and its rich agricultural economy.

Annual increases in R&D spend

Headline numbers give pause for thought. Brazil has 190 million people and predicted 4.6% annual GDP growth prior to recent global crises. In 2007, its R&D expenditure reached \$US13 Billion (adjusted PPP): almost 1% of GDP. That is behind the USA and western European leaders and an OECD average over 2% but well ahead of anywhere else in Latin America and many European nations. It is now in a similar relative position to Portugal and not far behind Spain.

Increases in the pool of talent

Brazil has 0.92 researchers for every 1,000 workers. That is low compared to well-established G7 economies, typically around 6-8 researchers per thousand, but is entirely comparable with other large, growing research bases such as China. Brazil also produces over 500,000 new graduates and about 10,000 new PhD researchers each year, a similar number to France and South Korea. This is a ten-fold increase in twenty years: Brazil's research-skilled workforce is growing.

As in China and India, the most striking feature of the new geography of science is the sheer scale of investment and mobilization of people behind innovation that is underway, driven by a high-tech vision of how to succeed in the global economy.

Emerging indicators of research excellence

Does this investment yield results and change maps of research strength? It is starting to. Indicators of innovation can be hard to pin down, but scientific publications are one of the most useful places to start.ⁱⁱⁱ Thomson Reuters is the world's leading supplier of information about research publications and their citations. According to *ISI Web of Knowledge*SM, Latin America's share of the world's scientific papers rose from 1.7% in 1990 to 4.8% in 2008. In certain fields critical to technology and innovation, one of the most marked changes in this trend is the inexorable and steep rise of Brazil.

DATA ON RESEARCH

The data described in this report are drawn from the databases of Thomson Reuters, which regularly indexes data on articles in about 10,000 journals published world-wide. 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 look both at Brazil's internal research economy and at its 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.

Indicators of collaboration

Research collaboration is marked by a range of programs for investment in joint projects, in a multitude of formal and informal collaborative work, and in the emergence of new ideas fed by intellectual development on all sides of these partnerships.

Lists of joint projects are not, by themselves, a sufficient marker of the strength of relationships. Such projects may be substantive and depend on real and ongoing activity, but others represent an intellectual commitment that has yet to produce tangible results.

Money is a potentially strong marker, but the absence of funds set up specifically for international liaison means that many joint projects are funded at two home locations by national agencies and are functionally indistinguishable from other national research.

Publications are a pervasive currency
 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 the authors and the association between co-authoring nations can be checked and indexed.

BRAZIL AND RESEARCH PUBLICATIONS

In this report we will concentrate on the ten-year period from 1998-2007, but we will first put the rise of Brazil in context for a longer period.

Ten-fold growth in papers

The sheer publication volume change of Brazil is phenomenal. In 1981 there were about 2,000 papers with an author address for Brazil. In 2008

there will be about 20,000 papers. The rest of the world changed in that period as well, but that still represents a ten-fold increase in papers indexed by the same standard global database.

We can look at this another way, because the world literature is growing. We can index each country's share, by setting the volume of publication output on *Web of Science*® for each of a set of nations at a standard '100' in 1981, and then work forwards. Comparing Brazil to such well-established research nations as Japan, the UK, Germany and the USA we see how dramatically it has grown over more than 20 years and also how it leads the pack of 'Latin Tigers'.

Latin American partners also growing

The graph shows the impressive growth of Mexico and Argentina. With Brazil, these changes point towards a new axis of innovation for the 21st century. The UK and Germany have essentially held their share of world outputs, while the USA has actually grown at a slower pace than the rest of the world (a world total benchmark is included above for reference). Japan, having been the growth focus of the 1980s, has recently begun to slip back.

Where is Brazil focused?

Brazil's research base is growing. But where does its focus lie and how does this map to the rest of the world? This is an important question for observers, because we need to know where we can best engage with this vibrant research base – and no two growing economies are alike. If we look at China then we see an initial powering up of traditional core sciences and a recent shift towards life sciences and health. If we look at Ireland – the Celtic tiger – then the focus is on a strong clinical base, biotechnology, and nanoscience. Each country is different.

We looked at Brazil 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 exploration of the 250 specific *Web of Science*® fields.

Fields are scaled by journal groupings rather than by any measure equating to research activity so Clinical Medicine (14,408 Brazil addressed papers in 2003-2007) and other core sciences feature high on any list ranked by sheer scale.

FIGURE 1
 Brazil has increased its research output from about 8,000 to over 17,500 papers in ten years

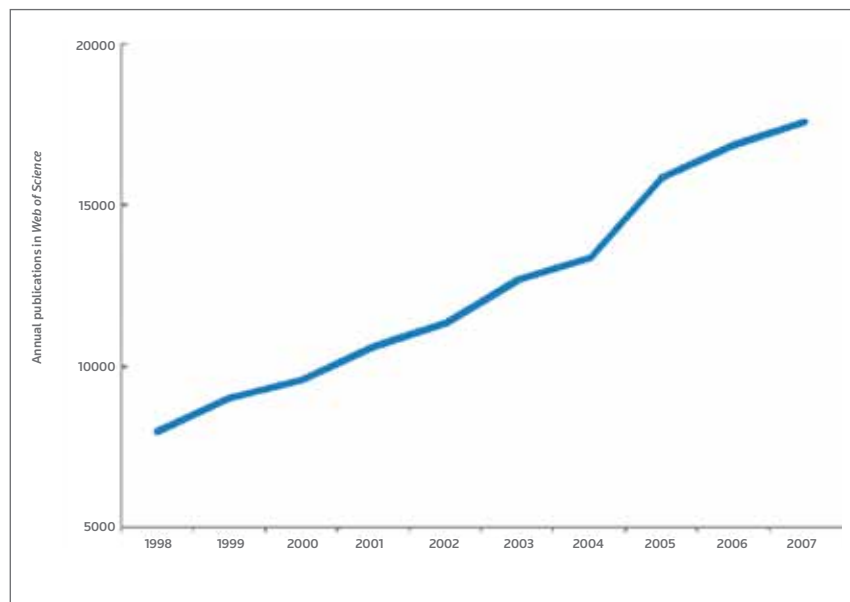
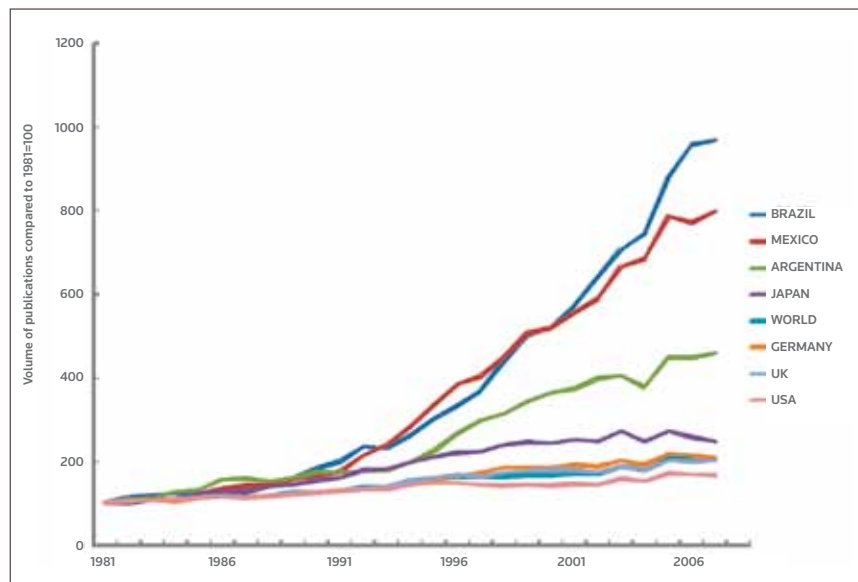


FIGURE 2
 Brazil's share of world output is growing increasingly rapidly



Physics (10,121 papers), Biology (10,006 papers for organismal biology and 5,240 in molecular biology) and Chemistry (9,635) all stand out.

Brazil produces 1.83% of world papers

But what if we scale against the balance in the rest of the world? With around 85,000 papers over five years, Brazil had about 1.83% of the world's papers published in journals indexed by Thomson Reuters

during 2003-2007. How did that share pan out across different subject areas?

Brazil's publications are analyzed here by *Essential Science Indicators* categories for two successive five-year periods. The top ten categories ranked by Brazil's share of world publications in 2003-2007 are shown.

TABLE 1
Share of world publications

	1998-2002		2008-2007		Rank	
	Count	Share(%)	Count	Share(%)	Share	Growth
Plant & Animal Science	5,857	2.62	10,006	3.91	1	1
Agricultural Sciences	2,155	3.07	3,308	3.72	2	9
Microbiology	1,438	2.2	2,192	2.86	3	8
Environment/Ecology	1,353	1.47	3,209	2.63	4	2
Pharmacology & Toxicology	1,156	1.65	2,152	2.55	5	3
Neuroscience & Behavior	2,106	1.68	3,394	2.4	6	6
Physics	8,645	2.28	10,121	2.28	7	22
Immunology	725	1.28	1,225	2.11	8	5
Space Science	1,000	1.95	1,208	2.08	9	20
Biology & Biochemistry	3,189	1.29	5,240	1.97	10	7

Brazil clearly has very real strength in life sciences, particularly related to natural resources. It really is the 'natural knowledge' economy. Both organismal biology and environment/ecology are ranked high on share relative to the global research base as a whole and high on growth between successive periods.

Important areas crossing into bio-medicine are also strongly represented.

Now, we can dig a little deeper and find out which more specific fields within these broad areas stand out as key parts of Brazil's research capacity.

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

Field	Share (% of world)	Volume (papers 2003-07)
Tropical Medicine	18.40	1,433
Parasitology	12.34	1,635
Multidisciplinary Agriculture	8.61	1,627
Oral Surgery & Medicine	8.19	2,203
Entomology	7.06	1,629
Dairy & Animal Sciences	6.49	1,617
Biology	6.43	1,999
Soil Sciences	5.84	947
Veterinary Sciences	5.79	3,421
Zoology	5.57	2,264

Brazil is, not surprisingly perhaps, a key player globally in two areas of critical importance to the health of its population: tropical medicine and parasitology. It authors or co-authors a very high percentage - in both cases more than one paper in ten - of the world's scientific publications in these areas.

As our broader view indicated, Brazil is also strong in areas related to animal and plant biology, agriculture and veterinary science. Its greater than 5% share of world publications has underpinned key economic sectors but also gives it the knowledge base to develop its 'natural knowledge'.

BRAZIL COLLABORATION – SPECIFIC PARTNERS

Key partner countries

Brazil's top ten research partners appear to have changed little over the last decade but this impression is superficial. The USA remains by far the largest partner; this is unsurprising, given its capacity to collaborate with an important regional neighbor. But Brazil also has strong links with three leading European research economies, each of which

co-author about 3% of Brazil's output. The UK and Germany have both increased their collaboration, with the UK overtaking France to move into second place. It is no surprise to find that many of Brazil's papers linked to one EU nation are also co-authored with others, a consequence of the EU's collaborative policy drive for research cohesion.

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

Papers collaborative with Brazil				Share (%) of Brazil Total
1998-2002		2003-2007		
USA	8,754	13,349	USA	11.1
France	2,773	4,162	UK	3.5
UK	2,628	4,131	France	3.4
Germany	2,249	3,727	Germany	3.1
Italy	1,403	2,358	Italy	2.0
Canada	1,294	2,382	Canada	2.0
Spain	1,245	2,313	Spain	1.9
Argentina	1,176	2,092	Argentina	1.7
Russia	790	1,381	Portugal	1.1
Japan	779	1,226	Netherlands	1.0
Netherlands	636	1,165	Japan	1.0
Portugal	634	953	Russia	0.8
Mexico	494	913	Mexico	0.8
Chile	457	795	Chile	0.7

There is change among the diversity of other nations with links to the Brazilian research base. Russia drops out of the top ten but remains an important partner. The Netherlands moves up. But one of the biggest movers is Portugal which has more than doubled its collaboration between the early and late five-year periods: a clear signal of the benefits of a shared language and cultural heritage

Regional partners

Regionally, Argentina, Mexico and Chile are favored partners. They show very high rates of growth in collaboration, well ahead of Europe and the USA but not higher than Canada which collaborates with a surprisingly high 2% of Brazil's papers. Perhaps these are all signs of an emerging American research network that extends well beyond the region's biggest player but may make the region a far more dynamic and stimulating target as a research partner for the rest of the world.

Links among the BRIC countries

What is noteworthy, given preoccupations about Asian tiger economies is the absence from the leader's table of China, India, and other nations. China and India are, in fact, not far outside the list and slightly behind Chile. It will be interesting to see whether a more significant BRIC partnership develops or whether these three rely primarily on the 'older' geography as they grow.

Limits to growth?

It will also be of policy interest to track the possible competition between BRIC nations for research partnerships. Rarely discussed, this may be a constraint to growth. The most attractive partner organizations can only support so many links, and existing partnerships may exclude the possibility of taking up new opportunities.

Collaboration across continents is expensive, in time as well as material resources. That cost is only worth paying if the benefits are significant. In research that means partnering with high quality organizations and leading research groups.

Key organizations

Who partners with Brazil? We looked at the ten years from 1998-2007 and counted the number of Brazilian authored papers with a co-author address for an identifiable organization elsewhere around the world. Those at the top of the list, the most frequent co-authoring institutions with Brazilian universities and institutes, include names familiar throughout the research world.

TABLE 4
International organizations collaborating frequently with Brazil

Organization	Country	Number of co-authored papers
Univ Texas	USA	1,021
Harvard Univ	USA	813
Univ Paris 06	France	792
Centre National de la Recherche Scientifique	France	756
McGill Univ	Canada	559
Imperial Coll London	UK	482
Istituto Nazionale di Fisica Nucleare	Italy	472
Univ Oxford	UK	442
Univ Toronto	Canada	424
Lund Univ	Sweden	423

The list in this Table is not a complete reflection of the top ten organizations: that would include some more universities from the USA. It has been selectively edited to give a more diverse flavor to the richness of Brazil's links. The spread we report includes

institutions which would, in their own countries, be regarded as key players contributing to international research excellence. This is a strong signal of the perceived rewards of working with Brazil.

INTERNATIONAL COLLABORATION: A SOURCE OF COMPARATIVE ADVANTAGE

Growth through collaboration, not competition

Against this backdrop, it is not surprising that there is a growing interest in the quantity and quality of research links with Brazil. Some view the rise of the BRIC nations as a threat, worrying that it will damage high-technology sectors in the USA and EU. But most policymakers recognize that science is not a zero-sum game: more in Asia and South America doesn't necessarily mean less in the old geography. Alongside new sources of competition, the rise of Brazil, China and, in the near future, India creates new opportunities for collaboration.

The cost of not making a commitment to partnership with Brazil will be significant in terms of both intellectual and economic development. Europe has benefited financially from trading goods in the past. The new 'must have' is knowledge, and Europe and the USA must be fully involved in its future trade, or become marginalized intellectually.

Gain through attitudes as well as knowledge

Brazil's profile, its sheer size, its improving excellence, and its interface with the rest of the international research base make it an essential partner in any future international research portfolio.

Its culture will be different, however, so a key task for research base managers in the North will be to ensure they have the mechanisms in place for their researchers to take advantage of opportunities to collaborate when they arise. They will learn from Brazil's 'why' and 'how' as well as 'what' is done.

Policymakers also recognize that collaboration is the best way of accessing the knowledge development and innovation that comes out of research investments made by other nations. It is part of knowledge networking. It is also a source of real gain, because joint projects benefit from joint intellectual investment and rich synergies. Collaborative research produces more highly cited publications.^{iv}

Despite the signs of increased collaboration, there is no room for complacency. Given the ambition and investment that Brazil, China, India, and other emerging players are pouring into science and innovation, collaboration should become a higher strategic priority for well-established research economies. Over time, the depth and quality of networks in South America and Asia are likely to become more crucial to sustaining global long-term scientific and economic success.

ENDNOTES AND REFERENCES

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^{iv} Roberts, Sir Gareth (2006). **International partnerships of research excellence.** The report, for the UK's Chief Scientific Adviser, explores collaboration between the UK and its major international partners: USA and Germany. It draws attention to the exceptional quality of research that involves international partnerships, providing gains to both parties. It also notes that there are relatively few sources of support dedicated to fostering international links, which is a barrier to further expansion at a time when such partnerships provide the scale to tackle major research challenges. It is available at <http://www.admin.ox.ac.uk/po/news/2005-06/may/4.shtml>

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