Industrial R&D still suffers from a lack of government support, even though the situation has improved radically over the past eight years.

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5 · Brazil

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INTRODUCTION

Brazil is the largest and most populous country in Latin America, with an estimated 190 million inhabitants. It is also the ninth-largest country in the world in terms of purchasing power and an emerging economy on the world scene. If the global economic recession triggered by the subprime crisis in the USA in 2008 slowed down business spending on research and development (R&D) somewhat in 2009, there was no noticeable decrease in the government sector. The impact of the global economic recession seems to be already over in Brazil, with the economy expected to grow by 7% in 2010. Federal and state government fiscal revenues are up again, as is R&D expenditure.

Like other Latin American countries, Brazil enjoyed strong economic growth between 2002 and 2008, thanks largely to a favourable global commodities market. The election of a new president, Luiz Inácio Lula da Silva (known as Lula), slowed the momentum somewhat during the federal government's transition period in 2003 but, after 2004, the Brazilian economy embarked on what seems to be a sustainable path of economic growth, with rates averaging 4.7% per year. In parallel, both the business sector and the federal and state governments began increasing R&D expenditure. This did not reflect a change in priorities on the part of the federal government, however, as witnessed by the constant ratio between R&D expenditure and federal fiscal revenue between 2001 and 2008 (2.1%). Between 2002 and 2008, the intensity of gross domestic expenditure on R&D (GERD) increased by just 10%, from 0.98% to 1.09% of GDP. Over the same period, GDP grew by as much as 27%, from R$ 2.4 trillion to R$ 3.0 trillion[1]. In other words, Brazil's R&D intensity progressed more slowly than the economy as a whole. President Lula promised to raise the GERD/GDP ratio to 2.0% by the end of his first mandate in 2006 when he presided the first meeting of the Science and Technology Council in 2003 and in his message to Congress the same year. In 2007, when R&D expenditure stood at 1.07% of GDP, the federal government announced plans to raise the GERD/GDP ratio to 1.5% by 2010. This target features in the *Plan of Action in Science, Technology and Innovation for Brazilian Development,* adopted in 2007.

Thanks to sustained economic growth in recent years, the US$ 23 billion[2] spent on R&D in 2008 compares well with investment levels in Spain (US$20 billion) and Italy (US$ 22 billion) in absolute value. We shall see later, however, that Brazil nevertheless lags behind both countries when it comes to translating R&D investment into results.

One important feature of GERD in Brazil is that the public sector shoulders most of the burden (55%), a phenomenon common to almost all developing countries. Approximately three-quarters of scientists continue to work in the academic sector. Brazilian scientists published 26 482 scientific articles in journals indexed in Thomson Reuter's Science Citation Index in 2008, making the country the 13th largest producer of science in the world. More than 90% of these articles were generated by public universities.

The business sector is also dynamic, however, and in recent years has developed some world-class industries. Brazil is self-sufficient in oil and can boast of having developed the world's most efficient systems for growing soybean and producing ethanol from sugarcane. It manufactures competitive commuter jet planes and the world's best flex-fuel cars. The business sector has also developed a national system of electronic voting that is capable of totalizing more than 100 million votes on election day. Despite these achievements, the Brazilian business sector registered only 103 patents at the United States Patents and Trademark Office (USPTO) in 2009. We shall see why in the following pages.

Although business leaders have long recognized the importance of creating knowledge to drive competitiveness, it is only in the past ten years that effective policies have been put in place to foster industrial and service-sector R&D. It was in 1999, after a long period during which the focus was almost exclusively on academic research, that Brazilian science and technology (S&T) policy started including business R&D as a progressively relevant target not only for the use of knowledge but also for its creation. This was followed by a series of milestones, beginning with the creation of the first sectoral funds in 1999 then the validation of the entire strategy in 2001 by the Second National Conference on Science, Technology and Innovation and culminating

1. In constant Brazilian reais (R$) for 2008 in the present chapter.

2. All dollar amounts in the present chapter are in purchasing power parity dollars.

Image taken by the CBERS-2 satellite on 10 April 2005 showing Florianópolis, the capital of the State of Santa Catarina in southern Brazil. Visible is the continental part of the city, the island of Santa Catarina and a few small surrounding islands.

Photo: CBERS/INPE

in the Innovation Bill prepared for Parliament in 2002 and approved in 2004. In 2003, there was an important development with the announcement of the national Innovation, Technology and Trade Policy (PITCE). PITCE connected innovation policy to the objectives for exports and established priority areas for government action, namely: semiconductors and microelectronics; software; capital goods; pharmaceuticals and medication; biotechnology; nanotechnology; and biomass. Four years later, the federal government announced its *Plan of Action in Science, Technology and Innovation for Brazilian Development* to 2010.

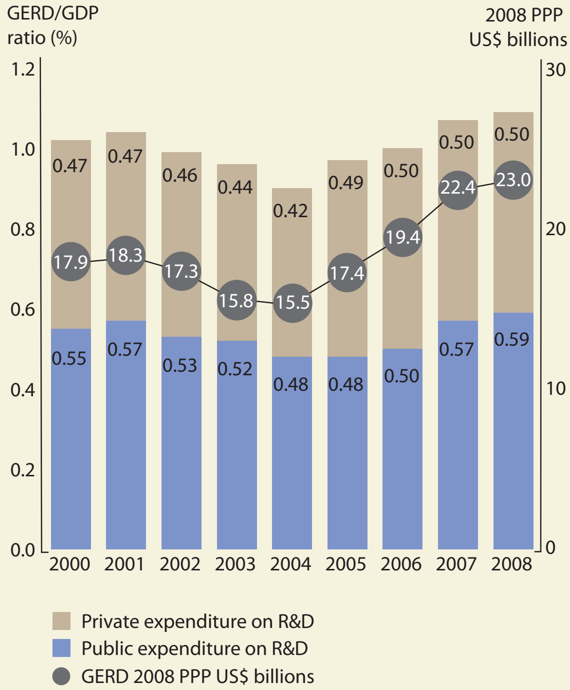
The booming economy has been conducive to business investment in R&D. However, despite a much more clement environment for R&D since 2004, some barriers remain in place. These include the difficult access to capital owing to high interest rates, poor logistics which hamper exports and an inadequate education system which penalizes not only social development but also the availability of qualified workers for almost all positions, especially those related to engineering.

Brazil's S&T capacity has come a long way, however, since the National Research Council (CNPq) and a second federal agency, Co-ordination for Training Higher Education Personnel (CAPES), were set up in the 1950s, followed by the São Paulo Research Foundation (FAPESP) in 1962. The early 1960s also saw the State of São Paulo make the landmark decision to step up academic research by creating the Full-time Regime for faculty to give professors ample time to do research. Scientific endeavour is less than a century old in Brazil. Even today, development tends to be concentrated in the country's south and southeast regions, home to the seven main universities, those of São Paulo (USP), Campinas (Unicamp), the State of São Paulo (UNESP), Minas Gerais (UFMG), Rio Grande do Sul (UFRGS), Rio de Janeiro (UFRJ) and the Federal University of São Paulo, all just half a century old.

Brazil thus faces three major challenges. *Firstly*, it needs to intensify business R&D, in order to drive innovation and competitivity. This requires creating an environment conducive to business R&D, including by encouraging greater interaction between the public and business research communities. *Secondly*, it needs to develop and internationalize its best universities to turn them into world-class centres of excellence. *Thirdly*, it needs to spread scientific excellence beyond São Paulo, Rio de Janeiro and other major urban centres to less privileged regions, such as the Amazon and the Northeast.

In the following pages, we shall analyse the shift in government S&T policy since 1999 from a quasi-exclusive orientation towards academic research to a policy of strengthening the role of business R&D. We shall describe the institutions that make up Brazil's innovation system, its demographics and investment pattern, heavily weighted towards the public sector. We shall then analyse Brazil's scientific productivity in terms of publications, patents, products and trade balance before concluding with a study of recent trends in international collaboration, including the emergence of new partners. We shall leave for last the discussion of the current policy environment, as most of the effects of the *Plan of Action in Science, Technology and Innovation for Brazilian Development* are yet to be reflected in the data.

Figure 1: Trends in GERD in Brazil, 2000–2008



Note: Private R&D includes private non-profit R&D, such as the share spent on research by private universities (0.02% of GERD).

Source: Ministry of Science and Technology, S&T Indicators, June 2010

R&D INPUT

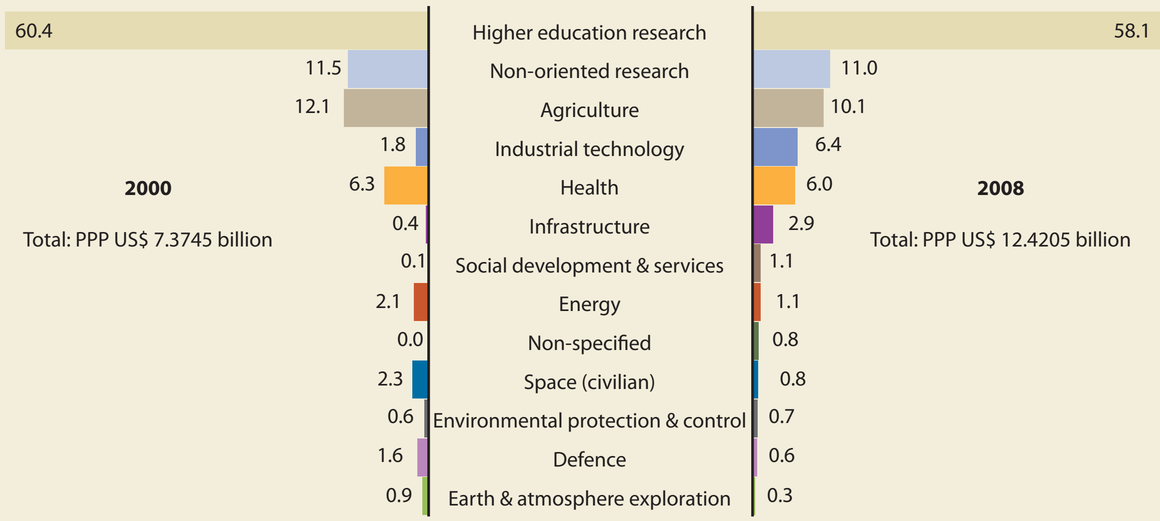
Trends in R&D expenditure

Between 2000 and 2008, GERD in Brasil grew, in constant 2008 values, by 28% from R$ 25.5 billion to R$ 32.8 billion. The GERD/GDP ratio progressed more modestly, from 1.02 to 1.09% of GDP (Figure 1).

Public R&D expenditure increased for almost every socio-economic objective between 2000 and 2008 (Figure 2). The exceptions were defence, energy, space and the exploration of Earth and the atmosphere. However, even some of those sectors which benefited from a monetary increase saw their 'priority status' diminish over this period. This was notably the case of agriculture, which represented 12% of the total public budget in 2000 but just 10% eight years later, a drop of 17%. Energy also saw its share whittled down by 41%, from 2% to 1% of the total budget. Although social development and services received a boost, this remained a fairly low R&D priority in 2008. Greater priority was also accorded in 2008 to infrastructure. In the case of industrial technology, the observed increase is in line with the stated objectives of S&T policies adopted since 1999, including the *Plan of Action in Science, Technology and Innovation for Brazilian Development* (2007–2010) discussed on page 118. However, the statistics for energy and space are at odds with the declared priorities of the Plan. The lower priority accorded agriculture should be especially troubling, considering the economic relevance of this sector for Brazil.

Public R&D expenditure is mostly directed towards academic R&D in Brazil, where it funds graduate school-related research and public research institutions to a large extent (Table 1).

Figure 2: Government expenditure on R&D by socio-economic objective, 2000 and 2008 (%)



Source: Ministry of Science and Technology, S&T Indicators, June 2010

Table 1: GERD in Brazil by source of funds, 2008
In PPP US$ millions

	Federal	State	Private	Total	%
Higher education	3 535.7	2529.2	497.6	6 562.5	29
Institutes and agencies	4 942.7	1 413.0	6 355.6	–	28
Business	155.0	–	9 946.3	10 101.3	44
Total	8 633.3	3 942.2	10 443.9	23 019.4	100
Share of total (%)	38	17	45	100	

Source: Ministry of Science and Technology, S&T Indicators, June 2010

At 1.09% of GDP (2008), Brazil's R&D intensity exceeds Latin American standards but lags well behind the average (2.28%) for the Organisation for Economic Co-operation and Development (OECD) and European Union (1.77%). In 2008, 55% of GERD was provided by the public sector, either through direct government spending or through expenditure on higher education. This puts the level of public investment in R&D at 0.59% of GDP. Some 45% of GERD thus comes from the private sector, a share that has remained stable over the past decade, compared to 69% for OECD countries and 65% for the European Union (Figure 3).

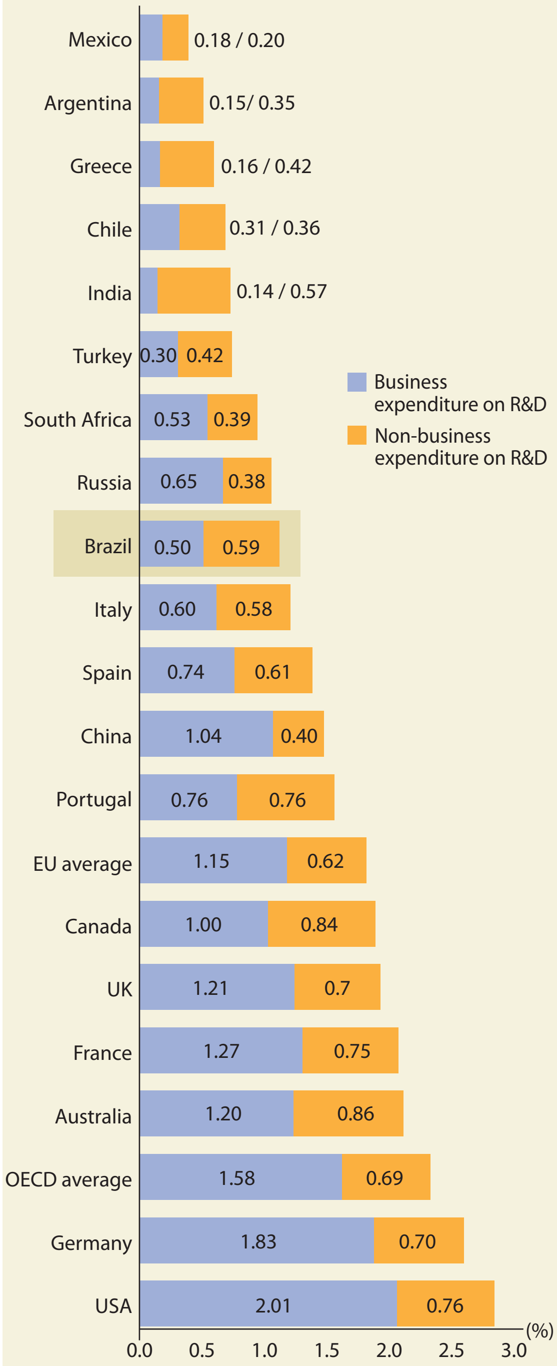
The difference in the share of GERD contributed by the business sector in Brazil and OECD countries is striking. Whereas non-business R&D expenditure in Brazil (0.59% of GDP) is only 15% less intense than the average for OECD countries, the Brazilian share of business R&D expenditure (0.48% of GDP) amounts to just 32% of the OECD average. This gap exposes one of the main challenges for the Brazilian national innovation system: creating the requisite conditions for the share of business R&D expenditure to increase by a factor of at least three to reach an intensity comparable to the OECD average and thereby maintain an adequate level of technical competitiveness for industry.

The creation of sectoral funds

The most important innovation in federal R&D funding in Brazil in the past 20 years has been the creation of the so-called sectoral funds, enacted by law during 2000–2002 (InterAcademy Council, 2006, p.79). These sectoral funds introduced targets for government-selected R&D projects of benefit to industry and cut back taxation to a fraction of the revenue of certain industries earmarked for privatization over this period.

The concept of sectoral funds sprang from the recognition that many of the state-owned companies due to be privatized were strong in R&D, mostly in the fields of telecommunications and energy, and that these activities deserved not only to be protected but also intensified. The sectoral fund model was created for Ronaldo Sardenberg, Minister of Science and Technology at the time, by the ministry's Executive Secretary, Carlos Pacheco. The sectoral funds would turn out to be a great success. Rather than creating any new tax, they redirected existing taxation and related contributions which were already part of the country's privatization strategy.

Figure 3: GERD/GDP ratio in Brazil, 2008 (%)
Other countries and regions are given for comparison



Source: Ministry of Science and Technology S&T Indicators accessed June 2010

In recognition of the heterogeneity of Brazil and its R&D system, the legislation passed between 1999 and 2002 specified that no less than 30% of the value of each sectoral fund was to be used to develop those regions with weaker R&D activities, namely the North, Northeast and Central West of Brazil.

The first sectoral fund was that created for oil and natural gas in 1999 (Table 2). Thirteen others followed over the next three years. Two of these 15 sectoral funds are unrelated to specific industries, namely:

- the R&D Infrastructure Fund is financed by a 20% contribution from each of the other funds and focuses on developing academic R&D infrastructure;
- the Green–Yellow Fund – a reference to the national colours of Brazil – is funded via 33% of the taxes paid by corporations that send funds abroad for technical assistance, royalties and specialized technical and professional services, plus (nominally) 43% of the recovered taxes from a progressively decreasing tax exemption awarded to the information technology (IT) industry to foster its development.

Each fund has a steering committee composed of members from academia, government and industry. This committee makes all decisions regarding expenditure, usually keeping a portfolio of projects that are expected to blend research proposals in the basic and applied sciences. It also oversees investment to make sure the funds are spent on projects related to the respective industry.

The sectoral funds injected new money into R&D funding in Brazil, even though the federal government continued to confiscate a fraction of the industrial revenue due to the funds in order to meet and exceed its fiscal surplus target. After this practice ceased in 2008, the National Fund for Scientific and Technological Development (FNDCT) reached an all-time high the same year, with expenditure tipping PPP US$ 1.4 billion. Figure 4 shows the steep rise in FNDCT expenditure after the creation of the first Sectoral Fund for Oil and Natural Gas in 1999 and another 13 sectoral funds in the next three years.

State-level R&D expenditure

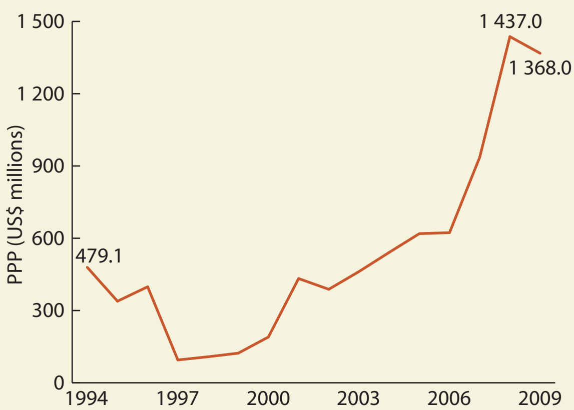
A substantial slice of government R&D funding comes from state governments, via foundations they fund, mission-oriented, state-owned institutes and state-owned

Table 2: Brazilian state industries targeted by sectoral funds, 1999–2002

CT-Aero	Aeronautics
CT-Agro	Agribusiness Sectoral Fund
CT-Amazônia	Amazon
CT-Aquaviário	Waterways and Naval Industry
CT-Biotec	Biotechnology
CT-Energ	Energy
CT-Espacial	Space
CT-Hidro	Hydroresources
CT-Info	Information Technology
CT-Infra	R&D Infrastructure
CT-Mineral	Mining
CT-Petro	Oil and Natural Gás
CT-Saúde	Health
CT-Transpo	Ground Transportation
CT-FVA	Green–Yellow Fund (industry–university cooperation)

Source: Brazilian Innovation Agency: www.finep.gov.br/fundos_setoriais/fundos_setoriais_ini.asp

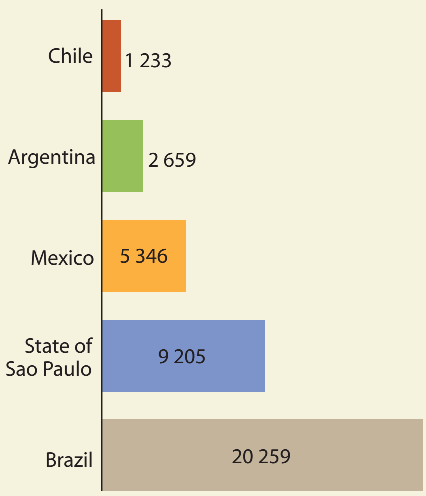
Figure 4: Evolution in Brazilian National Fund for Scientific and Technological Development (FNDCT), 1994–2009



Source: Ministry of Science and Technology; for the conversion of monetary amounts to PPP $US: Melo, L.M. (2009) *Revista Brasileira de Inovação 8* (1), pp. 87–120 institutions of higher education. In 2008, about 32% of public R&D expenditure originated from state funds. Some states have strong R&D systems, the main one being São Paulo where 64% of public R&D funding comes from the state (Figure 5).

The State of São Paulo generates 34% of Brazilian GDP and it has a long tradition of supporting higher education and research: the University of São Paulo dates from 1934 and the São Paulo Research Foundation was written into the State Constitution in 1947. Of all the states in Brazil, it is São Paulo which receives the most funding from federal agencies, normally 30–35% of the total. This is essentially because the state supports three world-class public universities which are among the 500 best in the world, according to the Institute of Higher Education at Shanghai Jiao Tong University, as well as the state-funded Foundation for the Support of Research in São Paulo (FAPESP) which has been operating since 1962. The state government's strong support makes São Paulo the second-biggest spender on R&D in Latin America. This underscores the relevance of regional R&D funding in a large federal system like that of Brazil.

Figure 5: The Brazilian State of São Paulo's contribution to GERD, 2007
In PPP US$ billions



Source: for Brazil: FAPESP (2010) *Indicadores de C&T&I em SP e Brasil 2010;* for other countries: RICYT database, June 2010

A sizeable portion of state investment in R&D comes from state foundations whose mission is to support research. These exist in almost all Brazilian states. Besides FAPESP, the main ones are FAPEMIG in Minas Gerais, FAPERJ in Rio de Janeiro, FAPERGS in Rio Grande do Sul, FACEPE in Pernambuco, FAPECE in Ceará and FAPESB in Bahia.

Business R&D expenditure

Of 95 301 companies polled in the Technological Innovation Survey (PINTEC) conducted by the Brazilian Institute for Geography and Statistics (IBGE) in 2005, only 6 168 reported having any type of R&D activities, permanent or otherwise. The full sample corresponded to a total revenue of US$1 097 billion. Of this, total R&D expenditure was reported of US$ 9 368 billion. The biggest spenders were the motor vehicle, trailers and semi-trailers industry (16% of total expenditure) and oil refining, ethanol and nuclear fuel (9 % of the total).

An interesting feature of business spending on R&D relates to the opportunities for attracting foreign direct investment. In 2006, US majority-owned corporations invested US$ 571 million in R&D operations in Brazil, 185% more than in 2001, according to the US Bureau of Economic Analysis.

Tax incentives for business R&D

Four federal laws provide tax incentives for business R&D (Table 3). Altogether, taxes waived in 2008 corresponded to US$ 3 643 billion, or 37% of business R&D expenditure.

Two other laws benefit academic institutions mostly. These laws have established an import tax waiver for scientific equipment and materials. The 2005 law on tax incentives for business R&D (Law 11196/05)[3] is considered by company representatives as being an improvement on previous legislation, since it simplifies the formalities required to benefit from these incentive measures. Although the 1991 law on tax incentives for information technology R&D (Law 8248/91) is used intensely by firms in the IT sector, non-IT companies use Law 11196/05 to a limited degree.

An important criticism by the business sector of this regime of incentives and subsidies is that there is an over-emphasis on the IT sector because of Law 8248/91.

3. In Brazil, laws do not bear names, only numerical references that include the year of adoption.

This regime is comparable in size to that of OECD countries but, in point of fact, few sectors are entitled to benefit from it. The difficulty stems from the fact that the IT incentive law is actually an internal equalization law to compensate for non-R&D incentives offered to IT companies to encourage them to locate in Manaus, in the Amazon (IEDI, 2010). Once the IT incentives are set aside, the incentives cum subsidies regime corresponds to just 13% of business expenditure on R&D.

In addition to tax incentives, government purchasing power through procurement is used in many countries to foster innovation, especially in defense- and health-related industries. This type of support for industrial R&D is still very limited in Brazil even in defense and health spending. The law on innovation of 2004 includes articles designed to foster more intense use of procurement. The government has come under unrelenting pressure from representatives of industry to adopt a more pro-active attitude in its procurement policies (Box 1).

Venture capital

The venture capital industry has grown in Brazil since the economy stabilized in the mid-1990s. The National Bank for Economic and Social Development (BNDES) has been active in this market since 1995, whereas relevant government initiatives date back to 1999. In 2000, the Ministry of Science and Technology launched an initiative called Inovar, led by the Brazilian Innovation Agency (FINEP), a federal agency with some investment bank-like attributes. The market responded well to this initiative and several venture fora were subsequently organized to present companies to potential investors. In 2005, BNDES announced the bank's return to venture operations, via a fund of approximately U$ 150 million for investment in partnerships to capitalize private funds. Legislation enacted on 15 February 2006 in a provisional decree known as Executive MP, or Executive Order, substantially reduced the tax burden on revenue from venture funds for foreign investors. However, most investment in venture funds tends to target 'non-technology-based' industries. A 2003 report concluded that 86% of venture operations in Brazil targeted these 'non-technology' sector industries (ABCR and Thomson Venture Economics, 2003).

Trends in R&D personnel

A shortage of PhDs

Although Brazil has managed to increase the number of doctorates granted each year to 10 711 in 2008, the country still faces a shortage, especially in engineering. The number of graduates may seem high but this translates into just 4.6 doctorates per 100 000 inhabitants,

Table 3: R&D tax laws and subsidies for business R&D in Brazil, 1991-2005

Focus of law	Year of adoption	Reference	PPP US$	Type of advantage
Tax incentive				
Tax incentives for the IT sector	1991	Law 8248/91	2 236.4	Tax incentives for IT sectors
Tax incentives for business R&D	2005	Law 11196/05	1 085.0	Tax incentives for all sectors
Subsidy				
Subsidies for business R&D in the form of government loans	2002	Law 10332/02	62.9	Interest rate equalization
		and Industrial Technology Development Plan (PDTI)	34.8	Other subsidy
Subsidies for business R&D	2004	Law 10973/04	224.1	General subsidy
Total (Incentives + subsidies)			3 643.3	
Business expenditure on R&D			9 946.3	
Share of incentives and subsidies in business expenditure on R&D			37%	

Source: IEDI (2010) *Desafios da Inovação - Incentivos para Inovação: O que Falta ao Brasil*

Box 1: Procurement policies to develop essential vaccines

Public buying policies are one of the mechanisms used globally to promote both science and the social appropriation of knowledge. The Brazilian vaccination and procurement policies have had a major impact over the last decade on both basic research and vaccine production. These policies promote immunobiological self-sufficiency and universal access to vaccines that are provided free of charge. Two centennial public institutions, the Butantan Institute and Oswaldo Cruz Institute, have built parallel research, development and vaccine production facilities that allow Brazil to be competitive both scientifically and technologically in the field.

The legal framework responsible for stimulating vaccine production by these twin institutions is based on Article 24 of Law 8666 of June 1993. This article regulates Article 37, Item XXI, of the Federal Constitution and institutes norms for the bidding process and award of contracts by the public administration, among other measures. Article 24 states that bidding in the procurement process may be dispensed with if a public entity acquires goods or services from another entity or body belonging to the public administration, as long as these goods or services were created for this specific purpose prior to the enactment of Law 8666 and providing that the contract price is compatible with the market price. This decision incited both the Butantan and Oswaldo Cruz Institutes to develop pilot plants for vaccine production, with the Ministry of Health as their key partner. The ministry played a vital role, as it guaranteed the institutes a main buyer and minimal threshold for production. It was evident, however, that these facilities would need to be accompanied by a parallel expansion of vaccine-related basic science.

Making a full scientometric analysis of progress in this area of basic science is a tricky exercise, since many biological fields are vaccine-related. Notwithstanding this, a search for publications produced in Brazil using 'vaccine' as a topic reveals that, over the past five years, the contribution of related basic sciences in Brazil has jumped from a 2% share of world literature to a 3% share. More importantly, the two vaccine producers, Butantan and Oswaldo Cruz, have been responsible for about 30% of all scientific output in Brazil in the field of vaccine development since 2004. In 2009, the Butantan Institute produced more than 200 million doses of vaccines using in-house technology, including those for diptheria, tetanus and pertussis (DTP), also known as whooping cough, and for Hepatitis B. The same year, Biomanguinhos, a manufacturing facility associated with the Oswaldo Cruz Institute, produced more than 170 million doses of vaccines for yellow fever, *Hemophilus influenza* type B and oral poliomielytis Sabin, among others.

Both the Butantan and Oswaldo Cruz Institutes are developing technology derived from in-house basic science and actively pursuing the launch of new state-of-the-art vaccines for the Brazilian and export markets via technology transfer agreements with private companies. Products in the pipeline from the Butantan Institute include vaccines for cell-culture rabies, dengue, rotavirus and influenza.

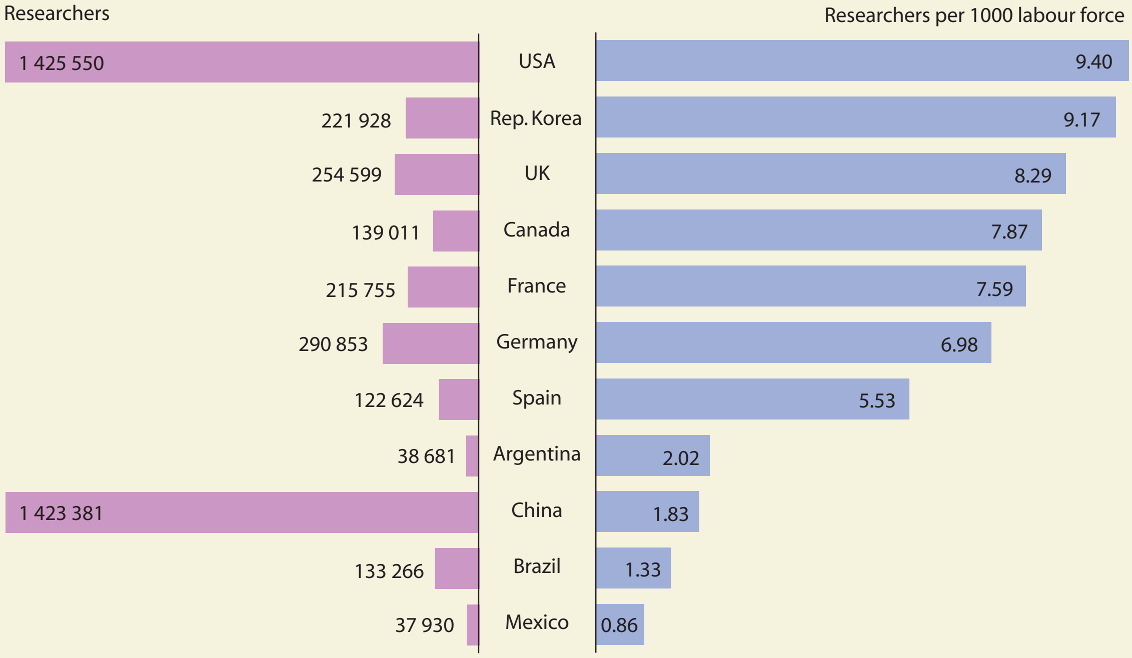
Source: authors

a ratio 15% lower than in Germany and roughly one-third that of the Republic of Korea (CAPES, 2005). At undergraduate level, Brazil faces an enormous challenge, since only 16% of youth aged 18–24 years were enrolled in higher education in 2008. This percentage will have to treble, if Brazil wishes to be on a par with the low end of the scale for OECD countries. The country's strategy so far has been to expand the number of private institutions offering 4–5 year courses, in tandem with fostering greater enrollment at public universities offering courses of the same duration. This strategy has not sufficed, however, to raise the enrollment rate to an internationally competitive level.

Most Brazilian researchers are academics

The lion's share of R&D is conducted by academic institutions in Brazil, as confirmed by the demographics (Figures 6 and 7). In most cases, it is easier to obtain precise information about the number of employees than about R&D expenditure, especially in the private sector. Researchers in Brazil occupy primarily full-time academic positions: 57% are employed by universities and another 6% by research institutes. That leaves just 37% in the business sector, which is consistent with the smaller portion of private R&D expenditure compared to public disbursements. The low number of scientists in the private sector is not without repercussions, as witnessed by the

Figure 6: Researchers in Brazil, 2008
Other countries are given for comparison



Source: Ministry of Science and Technology database, May 2010

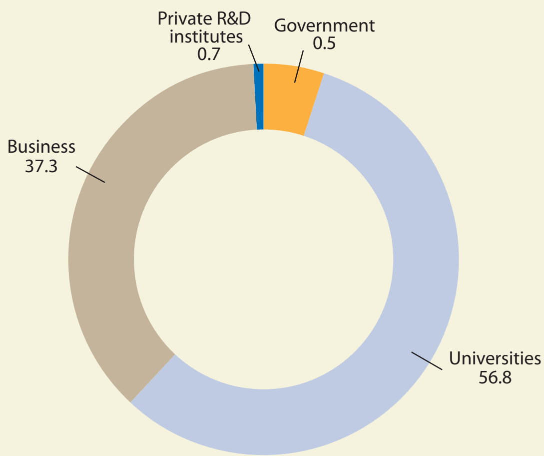
deficiency in patents generated by Brazilian industry. It is also one of the main obstacles to the development of stronger university–industry ties. Moreover, only 15% of Brazilian researchers in the business sector hold an MSc or PhD. In the Republic of Korea, this percentage is 39%: 6% hold a PhD and 33% an MSc. Government R&D funding agencies like CNPq, FINEP, FAPESP and others have created fellowship programmes for doctoral researchers in industry but these have shown limited results.

R&D OUTPUT

Scientific publications

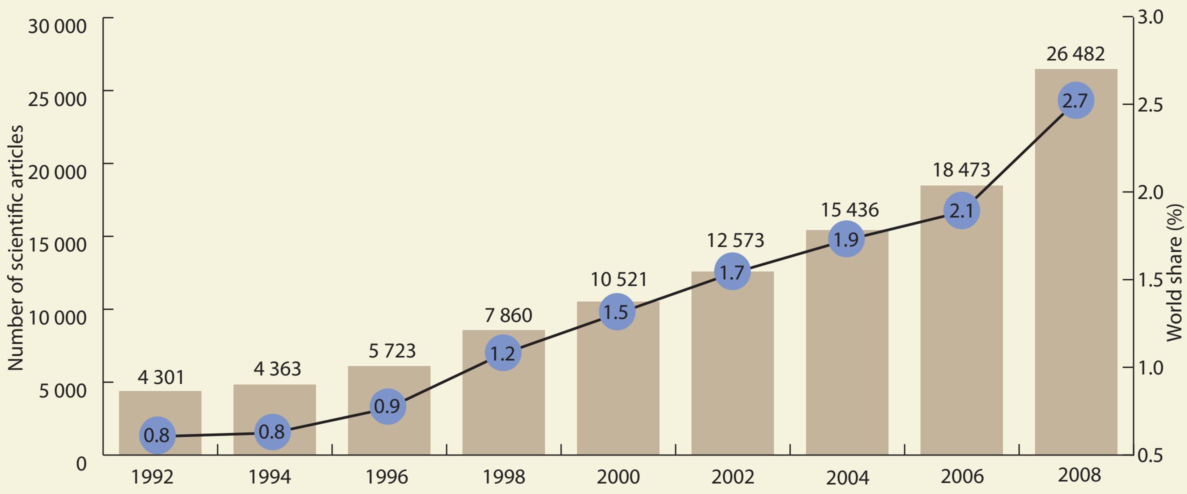
The number of scientific publications originating from Brazil has grown steadily over the past 26 years, culminating in 26 482 in 2008 (Figure 8). In parallel, Brazil's world share of articles has climbed from 0.8% in 1992 to 2.7% in 2008. There is a correlation between this increase and the growing number of PhDs awarded annually. Thanks to a consistently favourable policy for graduate education over the past 50 years or more, the number of PhD-holders has gone from 554 in 1981 to 10 711 in 2008.

Figure 7: Researchers in Brazil by performing sector, 2008 (%)
Full-time equivalent



Source: Ministry of Science and Technology database, June 2010

Figure 8: Scientific articles written by authors affiliated to Brazilian institutions, 1992–2008



Note: The evolution in scientific publications should inspire caution because the Thomson Reuters Web of Science changes the selection of journals over time. Some growth may thus be due to the inclusion of new journals, especially in 2008.

Source: Thomson Reuters (Scientific) Inc. Web of Science, (Science Citation Index Expanded), compiled for UNESCO by Canadian Observatoire des sciences et des technologies, May 2010

The impact of articles originating from Brazil has also grown: in 2000, there were 1.45 citations per article two years after publication,[4] compared to 2.05 citations for articles published in 2007. Brazil's presence has grown in all the major fields of science but articles are most common in agronomy and veterinary sciences (3.07% of the world total), physics (2.04%), astronomy and space science (1.89%), microbiology (1,89%) and plant and animal sciences (1.87%)[5].

The existence of a burgeoning scientific community has allowed special research programmes requiring a large pool of researchers to develop. A good example is the Genome Project implemented in São Paulo, which was the first to sequence the DNA of a phyopathogenic bacterium, *Xylella fastidiosa*. This programme was run in partnership with Fundecitrus (Citrus Producers Association).

4. Data collected by the authors using the Thomson Reuters Web of Science and counting those articles restricted to the category of 'articles' and citations recorded in the two years following publication

5. For a comparison with China and Índia, see Figure 8 on page 375.

In addition to producing advanced science, the Genome Project contributed knowledge that enabled researchers at Fundecitrus to devise ways of controlling a disease which attacked orange trees, Citrus Variegated Chlorosis. It also generated at least two spin-off companies in the fields of genomics and bioinformatics. Another example is the Biota Research Programme, one of the largest in the world in the field of biodiversity science (Box 2).

The data recorded in the Thomson Reuters database do not tell the whole story about Brazilian productivity, however. In developing countries, new knowledge frequently finds its way into local journals that often pass under the radar of Thomson Reuters' Science Citation Index, unless the journal has international circulation, which is rarely the case. Moreover, the language of most Brazilian scientific journals is Portuguese rather than English, especially as concerns articles in the humanities and applied social sciences. In order to enhance the visibility of Brazilian scientific production, FAPESP and the Latin American and Caribbean Center on Health Sciences Information

Box 2: Mapping biodiversity in São Paulo

Since 1998, a 'virtual institute of biodiversity' by the name of Biota has been mapping the biodiversity of the State of São Paulo and defining mechanisms for its conservation and sustainable use.

Being a virtual institute, it has no physical premises – participating researchers work in their own departments anywhere in the State of São Paulo. The 200 researchers and 500 graduate students who work for the institute are employed as faculty at 16 institutions offering higher education and research. FAPESP has thus avoided the risk of a major 'turf war' between rival institutions plaguing the programme. The virtual institute also employs about 80 collaborators from other Brazilian states and approximately 50 from abroad. Participation is open to anyone with a sound project that has survived the peer-review process managed by FAPESP.

In 11 years, the programme has supported 87 major research projects with an annual budget of approximately US$ 7.1 million. During that time, the programme has also trained 150 MSc and 90 PhD students, uncovered and stored information about approximately 10 000 species and managed to make data available from 35 major biological collections. This has translated into 464 published articles published in 161 scientific journals, 16 books and two atlases.

In 2001, the programme launched an open-access electronic peer-reviewed journal, *Biota Neotropica*, to communicate original research results on biodiversity in the Neotropical region. The journal is quickly becoming an international reference in its field.

In 2002, the programme launched a new venture called BIOprospecTA, in order to search for new compounds of economic interest for pharmaceutical or cosmetic applications. As a result, three new drugs have been submitted for patenting.

The programme has also had a considerable impact on public policy. The government of the State of São Paulo has drawn on the results of the programme to issue four Governor decrees and 11 resolutions concerning conservation of areas in the state. In January 2009, for example, the state government designated three large coastal Areas for Environmental Protection (APA Litoral Norte, APA Litoral Centro, APA Litoral Sul). Over the next ten years, the Biota–FAPESP Programme may produce data to improve management of these protected areas.

The international Scientific Advisory Board responsible for evaluating the programme has stated that 'science in most Biota projects is of a high quality that is either equivalent or exceeds that in other countries and, in several projects, it is of outstanding quality and on the cutting edge of international efforts'.

In 2009, the Biota programme began preparing a draft *Science Plan and Strategies for the Next Decade*, based on the recommendations of a workshop held in June the same year on Establishing Goals and Priorities to 2020.

Source: www.biota.org.br/; www.bioprospecta.org.br; www.biotaneotropica.org.br

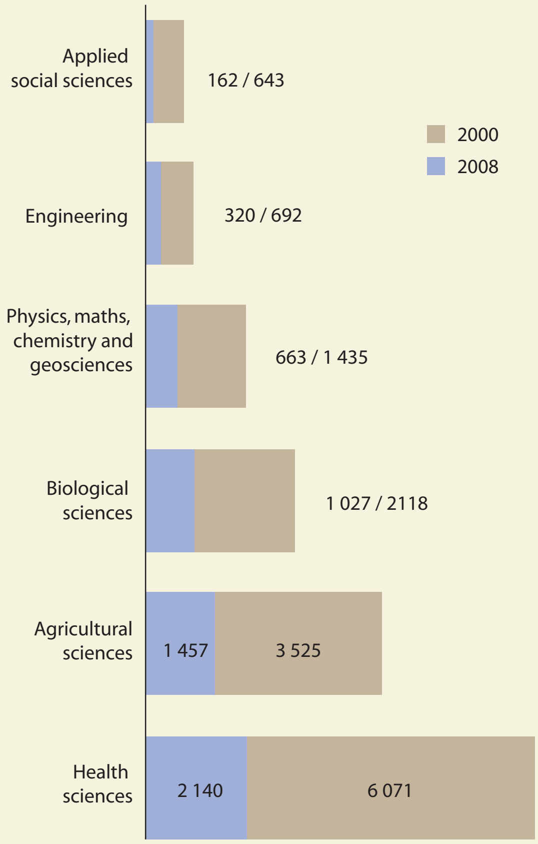
created an open access web portal in 1999, the Scientific Electronic Library Online (Scielo). In 2009, Scielo offered access to 203 peer-reviewed journals, including titles from Argentina, Brazil, Chile, Colombia, Cuba, Spain, Portugal and Venezuela. The same year, the Scielo website received 119 million visitors, who downloaded 15 759 articles. See Figure 9 for a comparison of the number of articles published in national journals in 2000 and 2008.

Most scientific production comes from public universities. Just seven universities accounted for 60% of articles published in international journals in 2009 (Table 4). Their share of the total increased from 60% in 2000 to 71% in 2007 before falling back to 60% in 2009. The University of São Paulo, with a full-time faculty of 4 670, produced 23% of the country's science in 2009, followed by the University of the State of São Paulo (2 889 full-time faculty) and Unicamp (1 538 full-time faculty), both with 8%.

Industrial and academic patents

In 2009, 103 utility patents for Brazilian inventions were issued by the United States Patents and Trademark Office (USPTO), almost the same number as five years previously (106). This is a dismal count, given the size of the Brazilian economy and its scientific infrastructure. Even if Brazil

Figure 9: Scientific articles published in Brazilian journals, 2000 and 2008



Source: Scielo Brazil database

outshines its Latin American neighbours for this indicator, it is dwarfed by India (Figure 10).

The small number of scientists working in the business sector directly affects the number of patents originating from Brazil, in the same way that dominant industrial sectors and export coefficients do. There may be a correlation between these low patent figures and the level of qualification of researchers employed in the business sector, given the small fraction with an advanced graduate degree (*see page* 109). Another factor may be a lack of audacity in the R&D objectives of most Brazilian industries, stemming from decades of operating in a closed market and an erratic economy. Changes in the economic climate since the 1990s have created a more open market, stronger competition and a stable economy. In turn, this is changing attitudes in many companies but the impact has not yet made itself felt in terms of the quantity and quality of business R&D.

Academic patenting has been gaining momentum in Brazil, especially since the feats of some institutions gained country-wide visibility, such as those of Unicamp and the Federal University of Minas Gerais. Unicamp has been strong in patents for more than two decades and has the largest stock of any Brazilian academic institution. In the period 2000–2005, it was awarded the most patents after Petrobrás, the Brazilian state-owned oil company. In 2002, the university founded the Unicamp Agency for Innovation encompassing a Technology Transfer Office, thereby demonstrating a strong penchant for licensing and the generation of revenue from its intellectual

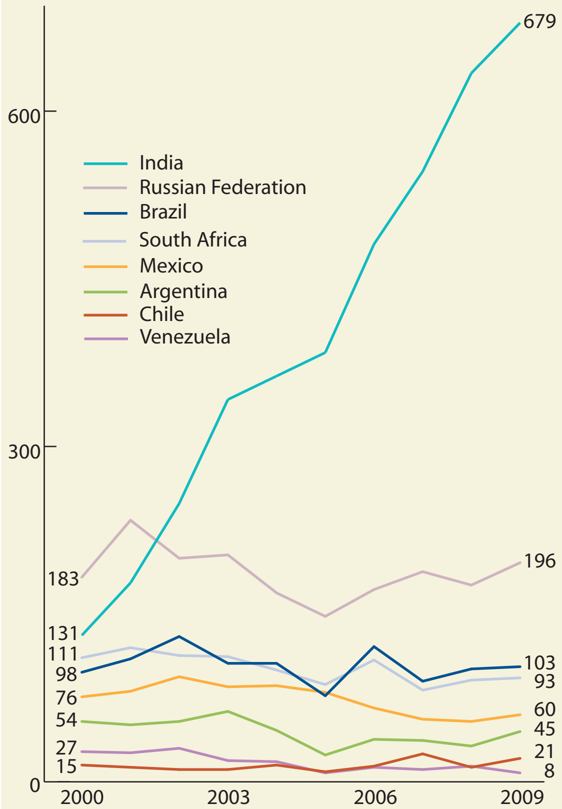
Table 4: Scientific articles published by Brazil's main research universities, 2000–2009

University	2000	2003	2006	2009
University of São Paulo (USP)	2 762	3 888	6 068	7 739
University of the State of São Paulo (UNESP)	772	1 104	2 065	2 782
University of Campinas (Unicamp)	1 190	1 498	2 386	2 582
Federal University of Rio de Janeiro (UFRJ)	1 080	1 253	1 778	2 357
Federal University of Rio Grande do Sul (UFRGS)	557	792	1 374	1 797
Federal University of Minas Gerais (UFMG)	597	810	1 392	1 685
Federal University of São Paulo (Unifesp)	433	659	1 251	1 561
Total for seven universities above	7 391	10 004	16 314	20 503
Total for Brazil	11 978	15 125	23 061	34 172
Share of seven universities above in total (%)	62	66	71	60

Source: SCOPUS, search restricted to articles, notes and reviews, August 2010

Figure 10: USPTO patents awarded to Brazilian inventors, 2000–2009

Other countries are given for comparison



Source: USPTO (Utility Patents)

property. Moreover, most of these licenses are exclusive, as in this case the licensee takes part in the development of the intellectual property through a co-operative R&D agreement.

Of the top 10 awardees of patents by the Brazilian Patent Office (INPI) in the period 2000–2005, three were academic institutions: Unicamp, FAPESP and the Federal University of Minas Gerais. This seems to indicate two things: *firstly,* that academic institutions have embraced the idea of protecting their intellectual property and are seeking opportunities to generate businesses with it; and, *secondly,* that efforts by industry to generate intellectual property remain ineffectual, since it is rare to find situations in which academic institutions generate more patents than industry among industrialized economies.

This said, very few research universities have, so far, been able to make more money out of licensing than they spend in the process (Mowery *et al.* 1999). The real motivation for a university to license its intellectual property should be in order to fulfill its mandate of diffusing knowledge throughout society and creating opportunities for its students. An exclusive fixation on financial benefits has thwarted many attempts by Brazilian universities to transfer technology and purchase it via licensing fees — and even attempts by R&D public agencies. There is still a lot to be learned in Brazil about the benefits to society of generating new businesses via excellent higher education, a sector in which Brazil has already obtained some important successes. One example is the Aeronautics Technology Institute, one of the best engineering schools in Latin America, which gave rise to the Brazilian Aeronautics Company (EMBRAER).

SUCCESS STORIES IN INNOVATION

Brazil can boast of some extremely successful cases of knowledge-based innovation. Take the example of jet aircraft, a highly competitive product of Brazilian R&D. Since being privatized in 1994 at a time of economic crisis, EMBRAER has gone on to become the third-largest aircraft manufacturer in the world. The first units of the 90-seater ERJ–190 have been flying commercially since early 2006 (*see page* 94). Moreover, a subsidiary of EMBRAER, the Neiva Aeronautics Industry, has produced the world's first alcohol-powered aircraft, the EMB 202 Ipanema. By 2006, Neiva had delivered more than 3 700 units, making the EMB 202 the most common agricultural aircraft in Brazil.

The agribusiness sector has also obtained outstanding results in both production and productivity. This sector benefits from public R&D investment via the Brazilian Agricultural Research Corporation (EMBRAPA) and other organizations within the national system of agricultural R&D. Soybeans, oranges and coffee are important export products, largely due to years of continual R&D.

Energy obtained from ethanol is another demonstration of the country's ability to create and use knowledge to generate opportunities. The ProAlcool National Programme (Alcohol Programme) launched in the 1970s is the world's most ambitious scheme today for using ethanol fuel in automobiles (Box 3). In 2005, 50% of

Box 3: Bioenergy R&D in Brazil

Since the launch of the ProAlcool National Programme in 1975, industrial, government and academic R&D have been making a considerable contribution to the development of the ethanol business in Brazil. A group of well- established research organizations like the Center for Sugarcane Technology (CTC), the Agronomical Institute of Campinas (IAC) and the Network for Sugarcane Improvement (Ridesa) have developed a large number of new varieties that have raised the average yield from 50 to 85 tons per hectare. Industrial R&D, often in association with universities, has improved industrial productivity from 55 to 80 litres of ethanol per ton of sugarcane. It has also obtained important results in the treatment of industrial residues.

The recent surge in international interest in bioenergy has intensified research in this field in many countries, causing Brazil to align its own strategy on competing in global markets. This strategy requires not only more R&D but above all cutting-edge R&D. Together with CTC and Central Alcool, FAPESP embarked on a project in 1999 to identify expressed genes in sugarcane and in functional genomics (SUCEST and SUCEST-Fun) and train human resources in this field. This effort contributed to an increase in the number of scientific articles about sugarcane in Brazil.

Given the potential for a massive scaling-up of production and the competitivity of Brazilian sugarcane ethanol, sustainability came to be an essential element of increasing productivity. In the past three years, a number of initiatives have been launched in Brazil to harness advanced science to sustainability and productivity targets. For instance, EMBRAPA, the state-owned company for agricultural research, has opened a division on agro-energy.

In addition, a new research centre was inaugurated in 2009, the Brazilian Bioethanol Science and Technology Laboratory (CTBE), in Campinas in the State of São Paulo. CTBE has three objectives: to perform competitive R&D to improve crops and conversion paths for bioethanol production from sugarcane; to partner other research organizations working in related areas, through a network of associated laboratories in universities and research institutes and; to act as a supplier of technology for the industry, providing strategic information of mutual concern.

A third initiative is the FAPESP Programme for Research on Bioenergy (BIOEN). BIOEN aims to create linkages between public and private R&D by using academic and industrial laboratories to advance and apply knowledge in fields related to ethanol production in Brazil. The BIOEN programme has five divisions:

- Sugarcane Plant Technologies, including plant improvement and sugarcane farming;
- Ethanol Industrial Technologies;
- Bio-refinery Technologies and alcohol chemistry;
- Otto Cycle Engines and Fuel Cells, ethanol applications for motor vehicles;
- Social and Economic Impact, Environmental Studies, Land Use and Intellectual Property.

The BIOEN Programme is well-equipped to support exploratory academic research on these topics and train scientists and professionals in essential areas for advancing the ethanol industry's capacities.

On top of this, BIOEN establishes partnerships co-funded by FAPESP and industry for co-operative R&D between industrial and academic laboratories at universities and research institutes. Other research agencies from the federal government and other state governments participate in the programme. They include CNPq and FAPEMIG. In 2009, BIOEN contracted its first round of 60 research projects.

A fourth initiative in progress in mid-2010 is the establishment of the São Paulo Bioenergy Research Center, with hubs in the three São Paulo State research universities (University of São Paulo, Unicamp and UNESP). The centre will set out to attract a greater number of scientists in the field of bioenergy to the three participating universities and will receive funding from FAPESP, the state government and the universities themselves to the tune of US$100 million over the next ten years.

In addition to these state or federal initiatives, companies have also stepped up their R&D efforts in bioenergy. Petrobrás has a programme on second-generation biofuels, which use waste from crops, and large companies such as Vale, Braskem and Oxiteno are also conducting a lot of bioenergy-related R&D.

Source: authors; www.cnpae.embrapa.br/; www.bioetanol.org.br/english/index.php; www.fapesp.br/en/bioen automobiles sold in Brazil were of the flex-fuel type and, by January 2006, as much as 74%. On top of that, the country adds 25% ethanol to gasoline to reduce carbon emissions and import costs. Automakers in Brazil have developed flex-fuel systems that can use from 0 to 100% of ethanol or gasoline. This technology is the brainchild of Brazilian R&D teams working in the country for foreign-owned auto-parts and automobile manufacturers who have developed a technology superior to that used anywhere else in the world (Bueno, 2006; Lovins *et al*., 2009). In 2008, Brazil was the world's second-largest ethanol producer (24.5 billion litres) after the USA, at a cost of US$ 0.19 per gallon, less than half the world average (US$ 0.40). Industry, government institutes and universities have developed better varieties of sugarcane and more efficient planting and harvesting methods, in tandem with more sophisticated ethanol refineries.

In each case, the main asset has been a stock of well-educated personnel trained in institutions which meet the world's best academic standards. All of these industries share another common feature: at some point, each has depended on policies which harnessed the government's purchasing power to stimulating technological development. The last ingredient in this recipe for success has been a fruitful public–private partnership to get the ideas to market.

One challenge the country has yet to overcome is that of diffusing this experience and skill in innovation through all sectors of industry. Years of a closed market and economic instability have taken their toll on attitudes towards innovation in the business sector. The sector has, however, responded quite well to incentive measures; during the 1990s when the Brazilian economy began opening up to the outside world, the federal government developed a country-wide programme for improving the quality of industrial products and processes that proved highly successful. More recently, both the government and leaders of industry have turned their attention to technological innovation. As a result, momentum has been building to develop this important area. For example, the National Confederation of Industry (CNI) initiated a Movement for Business Innovation (MEI) in 2009 to woo business leaders, a scheme that is already picking up speed.

INTERNATIONAL COLLABORATION

Brazilian international scientific collaboration has been steady for the past five years, according to Vanz (2009). However, at 30%, the share of internationally co-authored articles is substantially lower than the figure of 42% reported by Glanzel (2001) for the period 1995–1996.

US scientists are the main partners for Brazilians. A study by Adams and King (2009) found that 11% of scientific articles written by Brazilians between 2003 and 2007 had at least one co-author in the USA and 3.5% a co-author from the UK. Argentina, Mexico and Chile combined represented just 3.2% of co-authors of Brazilian articles.

International scientific collaboration is supported by both federal and state agencies via initiatives ranging from individual scholarships to multilateral programmes. CAPES, the main body responsible for supporting and evaluating graduate programmes, has a diverse portfolio of measures for financing international collaboration. In 2008, CAPES granted 4 000 scholarships to Brazilian graduate students abroad. CAPES also maintains bilateral collaboration programmes with Argentina, Cuba, France, Germany, the Netherlands, Portugal, Uruguay and the USA. In 2009, more than 500 joint research projects were financed under these agreements.

Through the Department of International Collaboration (ASCIN), the CNPq runs programmes ranging from individual scholarships for foreigners to regional programmes for scientific collaboration. Latin America and Africa, one of Brazil's priorities for regional collaboration, benefit from specific programmes: ProSul and ProAfrica. Other CNPq programmes focus on specific fields within a wider region. One example is the InterAmerican Collaboration in Materials involving Argentina, Canada, Chile, Colombia, Jamaica, Mexico, Trinidad and Tobago, Peru and the USA.

FAPESP itself has agreements for co-funding research with agencies in Canada, France, Germany, Portugal, the UK and USA. In fact, all the main Brazilian universities and research organizations offer services fostering international collaboration in research[6].

6. See page 96 for more information on Pan-American scientific collaboration.

Brazilian scientists and organizations serve on the governing bodies of the InterAcademy Panel, InterAcademy Council, InterAmerican Network of Academies of Science, International Council for Science, Academy of Science for the Developing World and several international disciplinary unions. Participation in these decision-making bodies has helped to integrate Brazilian science into global and local collaborative and large-scale projects, while offering Brazil's scientific community greater international exposure.

One example of a large-scale collaborative programme is that for the Southern Astrophysical Research (SOAR) Telescope commissioned in 2003. This 4.1-m aperture telescope has been designed to produce the best-quality images of any observatory in its class in the world. Funded within a partnership involving primarily Brazil, Chile and three US institutions, the National Optical Astronomy Observatory, Michigan State University and the University of North Carolina at Chapel Hill, SOAR is situated on Cerro Pachón at an altitude of 2 700 m, on the western edge of the peaks of the Chilean Andes. Brazilian participation in this project has contributed significantly to the growth of the scientific community and resulted in a rise in Brazilian publications in astronomy from 274 in 2000 to 404 in 2009. World-class instruments, such as an integral field spectrograph, have been designed and built in Brazil for installation in the SOAR facility.

Brazilian scientists are also collaborating with their Chinese counterparts on an ambitious project to develop and operate remote–sensing satellites for Earth observation (Box 4).

Another important programme for international S&T collaboration is led by the Brazilian Agricultural Research Corporation (EMBRAPA). EMBRAPA has set up laboratories in the USA, Netherlands, UK and Republic of Korea to throw bridges to the most advanced research in the world. EMBRAPA also has offices in Senegal, Mozambique, Mali and Ghana. These offices are part of the EMBRAPA Africa Programme, which strives to develop projects for scientific co-operation. The offices in Africa also interact with governments and local bodies to offer assistance in defining priorities, so that EMBRAPA laboratories in Brazil can propose contributions that address local needs.

AN ACTION PLAN FOR S&T

In 2007, the government presented a *Plan of Action in Science, Technology and Innovation for Brazilian Development* for the period 2007–2010.

Box 4: China and Brazil developing space technology together

The China–Brazil Earth Resources Satellites (CBERS) programme embraces a family of remote-sensing satellites built jointly by Brazil and China. This example of successful South–South co-operation in high technology currently includes five satellites which provide coverage of the world´s land areas. CBERS-1 functioned from October 1999 to July 2003, CBERS-2 from October 2003 to June 2008 and CBERS-2B from September 2007 to May 2010. CBERS-3 will be launched in 2011 and CBERS-4 in 2014. CBERS-3 and CBERS-4 are each equipped with four cameras with bands in visible, near-infrared, middle and thermal infrared (*see image page* 102).

Brazil and China share the responsibility for, and cost of, building the satellites. In Brazil, the National Institute for Space Research (INPE) designs half of the subsystems and contracts them to the Brazilian space industry. The Brazilian participation in the programme amounts to a total cost of about US$ 500 million, with 60% of investment taking the form of industrial contracts.

Data obtained from the CBERS satellites are released within a free and open data policy. From 2004 to 2010, more than 1.5 million images were delivered to users in Brazil, Latin America and China. These images have applications in forestry and agriculture assessment, urban management and geological mapping. Brazil uses the images to survey deforestation in Amazonia and to assess land use associated with cash crops such as sugarcane and soybeans and with large-scale cattle ranching.

China and Brazil have agreed on a joint strategy for facilitating international access to remote-sensing data in Africa. From 2012 onwards, African ground stations in South Africa, the Canary Islands, Egypt, and Gabon will receive and freely share CBERS data. The CBERS programme thus enables Brazil and China to contribute to global environmental policy-making.

Source: www.cbers.inpe.br/

The *Plan* is an important advance in that it groups most of the federal initiatives in S&T in a single document. This allows for a much better understanding and monitoring of the federal S&T system and, hypothetically, for an evaluation of the Plan's implementation. The *Plan* has been welcomed by the scientific community.

The Plan does have its shortcomings, however. For one thing, it fails to to integrate the various federal ministries that should be involved in fostering science, technology and innovation (STI). Federal initiatives are also poorly articulated with those at state level. Moreover, in many cases, those sectors defined as being strategic actually received a smaller share of funding in 2008 than in 2000, as we have seen in Figure 2. This is the case of agriculture, energy and defence, for example. Nor has the goal of raising GERD to 1.5% of GDP by 2010 been attained. These shortcomings do not invalidate the usefulness of the *Plan*, however. Overall, it has been a positive initiative with most of its proposals being implemented to some extent. These shortcomings will need to be rectified, however, in future action plans.

The *Plan* has four thrusts:

- To expand, integrate, modernize and consolidate the national innovation system by improving co-ordination at the federal, state and municipal levels, as well as between these public entities and private enterprises. The focus is on strategic areas for national development and both the renewal and consolidation of international co-operation. Another important goal is to increase the number of scholarships and fellowships for under-graduates, master's and PhD students, postdoctoral students and senior researchers from 102 000 in 2007 to 170 000 by 2011.

- To improve and promote technological innovation in companies by nurturing an innovation-friendly environment within firms and by strengthening industrial, technological and export policies. The aim is to generate employment, raise income and add value to each stage of the production process. One priority is to increase the number of active researchers in the private sector while, in parallel, training human resources and developing a 'knowledge creation culture' in enterprises. Another goal is to create a structure for the Brazilian Technology System (SIBRATEC). SIBRATEC is a group of entities that helps companies across Brazil develop their businesses by providing services that include technology transfer and assistance. These services relate in particular to the Basic Industrial Technology (TIB) programme[7]. One goal is to increase the number of business incubators and technological parks. Another is to permit the creation of self-governing innovative enterprises.

- To strengthen R&D in strategic areas that include biotechnology, nanotechnology, agribusiness, biodiversity and renewable sources of energy. Specific goals are included for the nuclear, space, metrology, national security and defence sectors.

- To promote science popularization and improve science teaching, as well as technology diffusion for social inclusion and development. Social development is a major objective of current state policies. Key tools are the Mathematics Olympiads for Public Schools launched in 2005, which attracted 18 million participants in 2008; the promotion of National Science and Technology Week in October each year; support for the establishment of TeleCenters in rural areas to narrow the digital divide and fight poverty, a programme launched by the Ministry of Communication in 2007, and; the programme offering Research and Development Support for Nutritional and Food Security. The latter was launched in 2008 by networking Research and Technological Institutes of Food Sciences and now offers information and consultancy services to small and medium-sized enterprises, as well as to individual farmers and food producers.

CONCLUSION

It is evident from the foregoing that Brazil has developed a competitive academic base in science. Academia still faces a number of challenges, however. Although the number of scientific articles and doctorates granted annually has been rising, there remains a lack of homogeneity in the regional distribution of academic staff and the country's knowledge base: 60% of all scientific articles originate from just seven universities, four of which are in the State of São Paulo. There is also a lack of homogeneity in disciplinary fields. Efforts will be required in engineering and computer science, for example, to train more undergraduates and PhD-holders and expand Brazil's international presence. At the same time, the advancement of knowledge in Brazil might benefit from

7. This programme includes metrology, technical norms and standards, conformity to standards, intellectual property and design.

a more balanced governmental approach between directed and unfettered research. Recently, there has been a seemingly excessive tendency to direct calls for projects towards specific objectives. This penalizes curiosity-driven research, the cornerstone of a strong academic system.

Industrial R&D is in need of even greater attention than academic research. It still suffers from a lack of government support, even though the situation has improved radically over the past eight years. Recent measures like the law on innovation (2004) and its consequences, such as the refurbishing of tax-incentive legislation and the introduction of a policy of subsidies, are expected to have a big impact on industrial R&D. These measures fall within the framework of the national Industry, Technology and Trade Policy (PITCE) adopted in 2003. The emergence of the National Bank for Economic and Social Development (BNDES) as a funding source for technological development and industrial R&D is, possibly, the most important boost for industrial R&D in the country for many years.

As we have seen, research funding comes mainly from the public purse (55%). Brazil falls below the OECD average for both its GERD/GDP ratio (1.09%) and the share of GERD contributed by government (0.59%). To meet the OECD average for public funding of R&D, Brazil would have to invest an additional R$3.3 billion (PPP US$ 2.3 billion). This amount corresponds to roughly three times the budget of CNPq.

The largest gap of all with the OECD countries concerns business spending on R&D. Here, the OECD average (1.58% of GDP) is three times that of Brazil (0.48% of GDP). Catching up to the OECD would entail the Herculean task of raising private R&D expenditure from US$ 9.95 billion in 2008 to US$ 33 billion. This challenge calls for much more effective policy instruments than those employed thus far by the Brazilian state. Moreover, these must not be confined to financial instruments, such as government subsidies, tax breaks and procurement policies, but should also encompass the legal and political instruments necessary to create an environment conducive to private investment in R&D.

A final note is in order here to address a question that comes up frequently in political circles in Brazil, namely, 'Why should taxpayer money pay for R&D?' As a tentative answer, we would say that there are at least two equally valid justifications for this. One is that contributing to the universal pool of knowledge makes Brazilians more capable of determining their own destiny. Like people everywhere, Brazilians ask themselves, 'How did the Universe begin?' 'How does it work?' 'Why does society behave the way it does?' 'What drives human beings towards good or evil?' Understanding the classics of literature and appreciating nature and art are part of what makes us human. Studying these and an infinite number of other questions enriches us. This alone would be reason enough to use taxpayer money to find science-based answers – even incomplete ones – to fundamental questions and thereby improve our knowledge of the Universe and humankind. This endeavour is obviously much more the sphere of universities than industry or the private sector.

The other reason why taxpayer money should finance R&D seems far more popular nowadays than the first reason evoked above: the more knowledge a society obtains by employing the scientific method, the richer it becomes. This utilitarian view has strong appeal, especially since the discovery of the genome and atomic energy, and the invention of the transistor and Internet.

In our view, both reasons are complementary rather than antagonistic, since both perceive science as a productive force. This line of reasoning depends strongly on the capacity of industry and other enterprises to improve Brazilians' standard of living to make its case.

The challenge for Brazil will be to turn these dual reasons into a functioning tandem by creating conditions under which universities and private companies can, in the words of Francis Bacon[8], through 'good and sound research', make the country a better place and a full member in the concert of nations.

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