Industry must embrace innovation to remain internationally competitive.

Renato Hyuda de Luna Pedrosa and **Hernan Chaimovich**

This laboratory uses desalination to convert ocean water into drinking water. It is situated in Bertioga, in the State of São Paulo.

Photo: © Paulo Whitaker/Reuters

8 · Brazil

Renato Hyuda de Luna Pedrosa and Hernan Chaimovich

INTRODUCTION

Economic downturn could jeopardize recent gains

Brazil's economy has experienced a severe downturn since 2011, after almost a decade of growth and a short-lived recovery from the 2008–2009 global financial crisis in 2010 (Figure 8.1). This economic slowdown has been triggered by weaker international commodities markets, on which Brazil is highly dependent, coupled with the perverse effects of economic policies designed to fuel consumption. The latter eventually caused government spending to overtake revenue by a large margin: in 2014, Brazil had a primary deficit of over 0.5% of GDP for the first time in 16 years; this deficit has helped to push annual inflation rates to over 6% since 2013. Brazil's economy stagnated in 2014 (0.1% of GDP growth) and the outlook is even worse for 2015, with the Ministry of Finance forecasting in April this year that the economy would contract by 0.9%.

Since her re-election in November 2014, President Dilma Roussef has overhauled national macro-economic policies. The new Minister of Finance, Joaquim Levy, has put in place, or proposed, a series of measures to cut spending and increase tax revenue, with the aim of obtaining a primary surplus of 1.2% in 2015.[1] Interest rates have been raised twice since the November election (to 12.75%) to try to curb inflation, which hit 8.1% for the 12-month period ending in March 2015. To make matters worse, the giant state-controlled oil company, Petrobrás, is currently fighting a crisis tied to poor management and a kick-back corruption scandal. The latter has taken a political turn, with the implication of several prominent political figures. At the end of April 2015, Petrobrás finally published its annual report for 2014, in which it acknowledged losses of over 50 billion reals (R$, *circa* US$ 15.7 billion), R$ 6 billion of which were related to the corruption scandal.

It is against this economic and political backdrop that Brazil is striving to maintain the momentum of reforms to its national innovation system, including innovation in social policies.

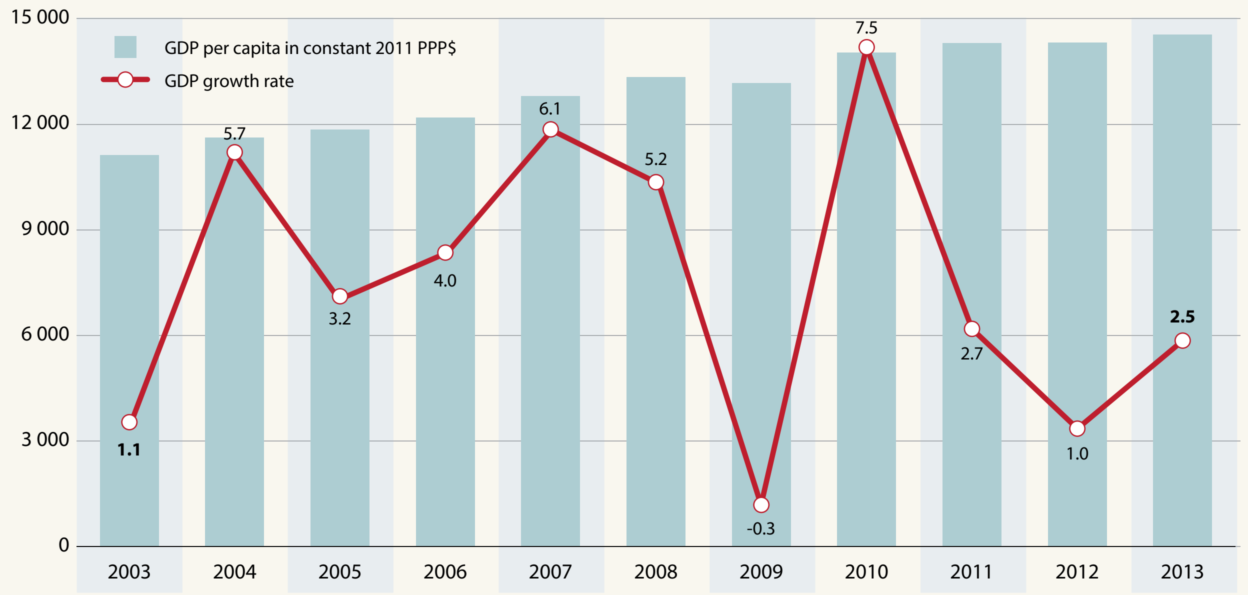
Social inclusion progressing more slowly

The downturn in the economy is starting to rub off on social inclusion, which had been one of Brazil's success stories, especially during the commodities boom up to 2010 when Brazil essentially managed to eliminate hunger and extreme poverty and, thereby, narrow the income gap. Between 2005 and 2013, unemployment rates fell from 9.3% to 5.9% of the population.

More recent data suggest that this growth cycle may already be at an end. According to the Social Panorama on Latin America published by the United Nations' Economic Commission for Latin America and the Caribbean (ECLAC, 2014a), Brazil reduced poverty rates by one-third between 2003 and 2008 but progress slowed from 2008 to 2012 and stagnated in 2013. Preliminary data even suggest that extreme poverty may

1. Given the difficulties in getting support from Congress for the fiscal policies proposed by Minister Levy, the target for primary surplus was reduced to 0.15% of GDP in July 2015. Recent forecasts put the contraction in GDP at 1.5% or more for 2015.

Figure 8.1: **GDP per capita and GDP growth rate for Brazil, 2003–2013**



Source: World Bank's World Development Indicators, May 2015 have regained some ground, since it affected 5.9% of the population in 2013, compared to 5.4% a year earlier. Despite having managed to reduce poverty rates faster than the rest of Latin America, Brazil still trails the region's leaders for this indicator, namely Uruguay, Argentina and Chile (ECLAC, 2014a).

Brazilian labour productivity stagnating

Another recent study (ECLAC, 2014b) indicates that greater social spending by governments in Latin America has failed to translate into better labour productivity, contrary to what has been observed in high-income countries. The notable exception is Chile, which saw its labour productivity almost double between 1980 and 2010.

If we compare Brazil with other emerging economies, the Brazilian experience is akin to that of Russia and South Africa, where labour productivity has stagnated since 1980. China and India, on the other hand, have improved their own labour productivity remarkably over the past decade, in particular, albeit from a low starting point (Heston *et al.*, 2012).

Even the commodities boom between 2004 and 2010 did not make a difference. Part of the explanation for Brazil's poor performance even during this growth cycle lies in the fact that the bulk of economic growth over these years came from service industries; as this sector requires less skill, the average productivity of the employed actually dropped.

The government has enacted a range of policies which seek, indirectly, to raise labour productivity. The 2011–2020 *National Education Plan* provides incentives for developing basic and vocational education: new programmes established in 2011 finance the vocational training of low-skilled workers and offer scholarships for tertiary education. The dual reforms of the public pension and unemployment insurance systems in 2012, coupled with a reduction in the labour tax wedge, have been designed to encourage people to work in the formal economic sector, which is more amenable to innovation than the informal sector (OECD, 2014). However, there seem to be few, if any, substantial public policies designed specifically to help Brazilian enterprises catch up to their competitors on the frontier of technology. Since productivity levels are an indication of the rate of absorption and generation of innovation, Brazil's own low productivity levels suggest that it has not managed to harness innovation to economic growth.[2]

TRENDS IN STI GOVERNANCE

More flexible social organizations cutting the red tape

Brazil's public research institutes and universities follow rigid rules that tend to make them very difficult to manage. States may opt to develop their own research institutes and university systems but, as all laws and regulations are adopted at federal level, they all have to follow the same rules and regulations. Thus, they all come up against the same hurdles. These include extensive bureaucratic structures, an obligation to recruit staff, academic or otherwise, from among public servants, analogous career ladders and salary systems, an irregular flow of funds, overly complex procurement procedures and powerful unions in the civil service.

A structural alternative was developed in 1998, with the creation of social organizations. These private, non-profit entities manage public research facilities under contract to federal agencies. They have the autonomy to hire (or fire) staff, contract services, buy equipment, choose the topics and objectives of scientific or technological research and sign

2. The relationship between innovation and economic development, including productivity, has been at the centre of modern development economic theory and empirical studies. A good discussion may be found in Aghion and Howitt (1998).

Box 8.1: The Brazilian Institute for Pure and Applied Mathematics

The Institute for Pure and Applied Mathematics (IMPA) in Rio de Janeiro was set up in 1952 as part of Brazil's National Research Council (CNPq). From the outset, IMPA's mission was to carry out high-level mathematical research, train young researchers and disseminate mathematical knowledge in Brazilian society.

Since 1962, IMPA's graduate programme has awarded over 400 PhDs and twice as many master's degrees. About half of its student body comes from abroad, mainly other Latin American countries. The 50 faculty also include citizens of 14 different countries.

In 2000, IMPA obtained the status of social organization to allow for a more flexible and agile management of resources and to give greater autonomy in hiring researchers and in career development.

IMPA has since become involved in organizing the Brazilian Mathematics Olympiad for public schools and in training secondary school teachers.

In 2014, IMPA joined the exclusive group of institutions with a Fields Medallist on their staff, Ártur Avila, who had obtained his PhD from IMPA in 2001 and has been a permanent faculty member since 2009. Avila is the only Fields Medallist to date to have had been entirely educated in a developing country.

IMPA and the Brazilian Mathematical Society are organizing the International Congress of Mathematicians in 2018.

Source: www.icm2018.org

Box 8.2: The Brazilian Centre for Research in Energy and Materials

The National Centre for Research in Energy and Materials (CNPEM) is the oldest social organization in Brazil. It runs national laboratories in the areas of biosciences, nanotechnology and bioethanol.

It also runs the only Latin American synchrotron light source, which has been operational since the late 1990s. The light source and beamline were designed and installed using technology developed at the centre itself (see photo, p. 210).

CNPEM is currently engaged in the development and construction of a new internationally competitive synchrotron called Sirius. It will have up to 40 beamlines and will be one of the world's first fourth-generation synchrotrons. This US$ 585 million project will be the largest infrastructure for science and technology ever built in Brazil. It will be used for Latin American R&D projects stemming from academia, research institutes and private and public companies.

Typical industrial applications of this equipment will include developing ways to break down asphaltenes to allow the pumping of high viscosity oil; explaining the elementary process of catalysis in the production of hydrogen from ethanol; understanding the interaction between plants and pathogens to control citrus diseases; and analysing the molecular process that catalyses cellulose hydrolysis in the production of second-generation ethanol.

This endeavour has been made possible by CNPEM's structure as a social organization, a status that confers autonomy in project management.

Source: authors

R&D contracts with private companies. The flexibility accorded to these social organizations and their management style have made them a success story in Brazilian science. Today, there are six such organizations:

- the Institute for Pure and Applied Mathematics (IMPA, Box 8.1);
- the Institute for the Sustainable Development of the Amazon Forest (IDSM);
- the National Centre for Research in Energy and Materials (CNPEM, Box 8.2);
- the Centre for Management and Strategic Studies (CGEE);
- the National Teaching and Research Network (RNP); and
- the most recent addition, the Brazilian Research and Industrial Innovation Enterprise (Embrapii), established by the federal government in late 2013 to stimulate innovation through a system of calls for proposals; only institutions and enterprises deemed eligible may respond to these calls, thus speeding up the whole process and offering applicants a greater chance of success; Embrapii is due to be assessed in late 2015.

In the late 1990s, as economic reforms took hold, legislation was adopted to stimulate private R&D. Arguably the most important milestone was the National Law on Innovation. Soon after its approval in 2006, the Ministry of Science, Technology and Innovation published a *Plan of Action for Science, Technology and Innovation* (MoSTI, 2007) establishing four main targets to be attained by 2010, as described in the *UNESCO Science Report 2010*:

- Raise gross domestic expenditure on R&D (GERD) from 1.02% to 1.50% of GDP;
- Raise business expenditure on R&D from 0.51% to 0.65% of GDP;
- Increase the number of scholarships (all levels) granted by the two federal agencies, the National Research Council (CNPq) and the Foundation for Co-ordinating Capacity-building of Personnel in Higher Education (Capes), from 100 000 to 150 000; and
- Foster S&T for social development by establishing 400 vocational and 600 new distance-learning centres, by expanding the Mathematics Olympiad to 21 million participants and by granting 10 000 scholarships at the secondary level.

By 2012, GERD stood at 1.15% of GDP and business expenditure on R&D at 0.52% of GDP. Neither of these targets has thus been reached. Concerning tertiary scholarships, CNPq and Capes easily reached the target for PhDs (31 000 by 2010 and 42 000 by 2013) but fell short of reaching the target for tertiary scholarships as a whole (141 000 by 2010). The target of the *National Plan for Graduate Education 2005–2010* was for 16 000 PhDs to be granted by the end of the plan period. Since the actual number of PhDs granted stood at 11 300 in 2010 and less than 14 000 in 2013, this target has not been reached either, despite the fact that almost 42 000 federal PhD scholarships were granted in 2013.

On the other hand, the targets related to fostering a popular science culture have been partly reached. For instance, in 2010, over 19 million students took part in the Brazilian Mathematics Olympiad for Public Schools, up from 14 million in 2006. However, since then, the number of participants has tended to stagnate. Up until 2011, it was looking as if the targets for distance learning and vocational education might be reached but there has been little progress since.

The Fourth[3] National Conference on Science and Technology (2010) laid the groundwork for the *National Plan for Graduate Education 2010–2015* and established guidelines orienting R&D towards reducing regional and social inequalities; exploiting the country's natural capital in a sustainable manner; raising the added value in manufacturing and exports through innovation; and strengthening the international role of Brazil.

The proposals put forward at the Fourth Conference on Science and Technology were presented in a *Blue Book* which served as the basis for the elaboration of targets within a four-year plan dubbed *Brasil Maior* (Larger Brazil). The launch of this plan coincided with the arrival of the Roussef administration in January 2011. Targets of *Brasil Maior* to 2014 include:

- increasing the level of fixed capital investment from 19.5% in 2010 to 22.4% of GDP;
- raising business expenditure on R&D from 0.57% in 2010 to 0.90% of GDP;
- augmenting the share of the labour force that has completed secondary education from 54% to 65%;
- raising the share of knowledge-intensive businesses from 30.1% to 31.5% of the total;
- increasing the number of innovative small and medium-sized enterprises (SMEs) from 37 000 to 58 000;
- diversifying exports and increasing the country's share in world trade from 1.36% to 1.60%; and
- expanding access to fixed broadband internet from 14 million to 40 million households.

The only tangible progress so far concerns the last target. By December 2014, almost 24 million households (36.5%) had fixed broadband internet access. Investment in fixed capital has actually declined to 17.2% of GDP (2014), business expenditure has fallen back to 0.52% of GDP (2012) and the Brazilian share of world exports has receded to 1.2% (2014); in parallel, Brazil has dropped three places to 25th worldwide for the absolute amount of exports. The number of young adults completing secondary education has not risen, nor has their participation in the job market. We shall be examining the reasons for these trends in the following pages.

Another programme that has nothing to do with *Brasil Maior* has been attracting the most attention from the authorities and receiving a generous portion of federal funds for R&D. Science Without Borders was launched in 2011 with the aim of sending 100 000 university students abroad by the end of 2015 (Box 8.3).

3. The first was held in 1985 after the return to civilian government, in order to establish the mandate of the new Ministry of Science and Technology. The second conference took place in 2001. The third, in 2005, laid the groundwork for the *Plan of Action for Science, Technology and Innovation* (2007).

TRENDS IN HIGHER EDUCATION

Private enrolment slowing after years of rapid growth

Higher education has experienced very fast growth rates since the launch of the economic stabilization programme in the second half of the 1990s. Growth has been most visible in undergraduate enrolment, where the student body has swelled by an extra 1.5 million students since 2008. About three-quarters of undergraduates (7.3 million in 2013) are enrolled in private institutions. The latter tend to be mostly teaching institutions, with a few exceptions, such as the network of Catholic universities and a handful of non-profit institutions teaching economics and administration like the Getulio Vargas Foundation. About half of the growth in private tertiary education can be attributed to distance learning programmes, a new trend in Brazilian higher education.

Federal subsidies financed some two million student loans in 2014. Despite this assistance, growth in enrolment in private tertiary institutions appears to be tailing off, perhaps as consequence of the economic slowdown and a lesser willingness to contract debt. Only 1.2 million loans had been renewed up to March 2015, a month after the start of the new academic year. Whereas students took out 730 000 new loans in 2014, the Ministry of Education expects this figure to drop to 250 000 in 2015.

In the public sector, the Restructuring and Expansion of Federal Universities Programme (Reuni)[4] resulted in the number of public universities and polytechnics growing by about 25% and student numbers by 80% (from 640 000 to 1 140 000) between 2007 and 2013. Graduate education also flourished in public universities, where the number of PhD degrees granted between 2008 and 2012 rose by 30% (Figure 8.2).

The quality of education matters more than the duration

Raising labour productivity requires increasing capital investment and/or the adoption of new technologies. Creating, developing and incorporating new technologies requires a skilled labour force, including training in the sciences for those more closely involved in the innovation process. Even in the case of the services sector, which now generates about 70% of Brazilian GDP, a better-educated labour force will result in significant productivity gains.

It is thus of strategic importance for Brazil to raise the educational level of the average adult. The quality of education seems to be very low, judging from the OECD's Programme for International Student Assessment (PISA). In the 2012 PISA exams, the average 15-year old Brazilian scored roughly one standard deviation (100 points) below the OECD

4. See: http://reuni.mec.gov.br/

Box 8.3: **Science without Borders**

Science without Borders is a joint initiative of the Ministry of Science, Technology and Innovation and the Ministry of Education, through their respective funding agencies, the CNPq and Capes.

The programme was announced in early 2011 and began sending its first students abroad in August the same year.

By the end of 2014, it had sent more than 70 000 students abroad, mainly to Europe, the USA and Canada. More than 80% of these students are undergraduates who stay for up to a year at a foreign university.

Students enrolled in PhD programmes in Brazil are also entitled to spend up to a year furthering their research at an institution abroad.

Other target groups include students enrolled in full PhD programmes abroad and postdocs, as well as small numbers of visiting faculty and young faculty members. Researchers employed by private companies may also apply for specialized training abroad.

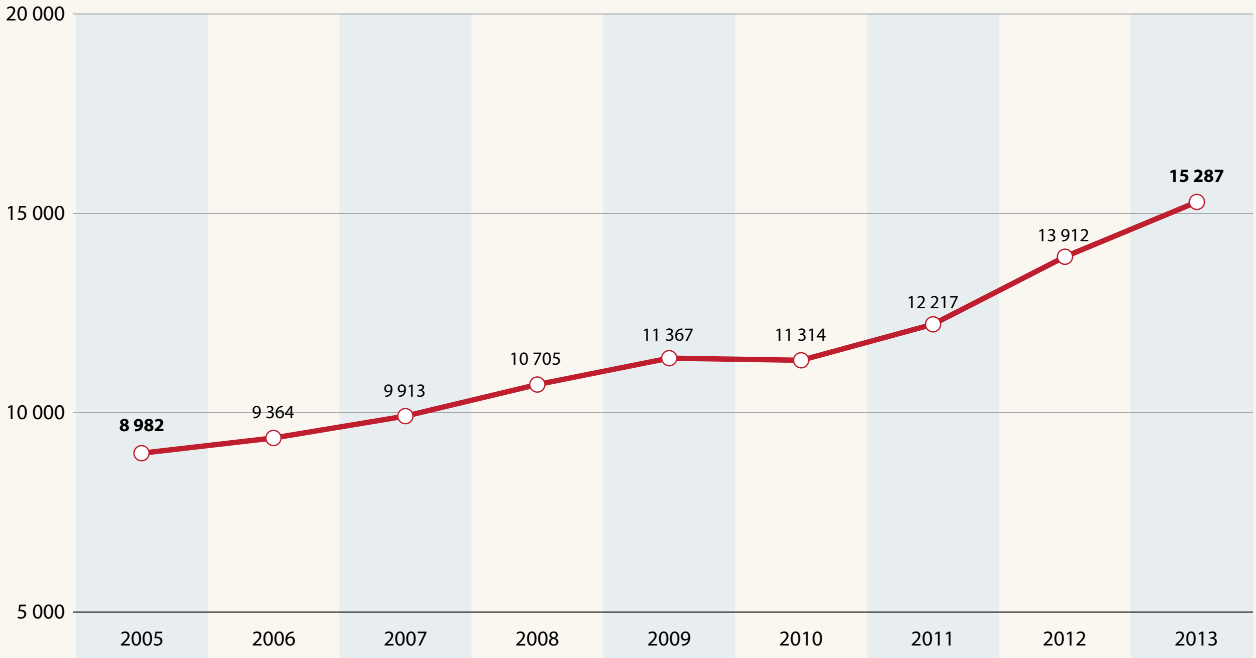
The programme also seeks to attract young researchers from abroad who might wish to settle in Brazil or establish partnerships with Brazilian researchers in the programme's priority areas, namely:

- Engineering;
- Pure and natural sciences;
- Health and biomedical sciences;
- ICTs;
- Aerospace;
- Pharmaceuticals;
- Sustainable agricultural production;
- Oil, gas and coal;
- Renewable energy;
- Biotechnology;
- Nanotechnology and new materials;
- Technology for the prevention and mitigation of natural disasters;
- Biodiversity and bioprospection;
- Marine sciences;
- Minerals;
- New technologies for constructive engineering; and
- Training of technical personnel.

The impact of this experience on the Brazilian higher education and research systems has not yet been evaluated. In September 2015, it was decided not to extend Science without Borders beyond 2015.

Source: authors

Figure 8.2: **PhD degrees obtained in Brazil, 2005–2013**



Source: Capes; Ministry of Education; InCites average in mathematics, despite Brazilian youth having recorded the biggest gains in mathematics of any country between 2003 and 2012.[5] Brazilian teenagers also scored relatively poorly in reading and science.

A recent study which used international learning outcome assessments and economic data for a large sample of countries over four decades (1960–2000) has concluded that it is not the number of years of formal education that matters for economic growth but how well that education has developed the requisite skills (Hanusheck and Woessmann, 2012). Using the PISA score as a proxy for the skills of the young adult population, the authors conclude that, for each 100 points, the average yearly rate of economic growth per capita increases by about 2 percentage points.

Brazil has just enacted a new National Law on Education establishing targets to 2024. One of these is to attain a PISA score of 473 points by 2024. If the recent past is any indication, that target may remain elusive: from 2000 to 2012, the score of Brazilian participants rose by about two points a year, on average, for mathematics, science and reading; at this rate, Brazil will not attain 473 points until 2050.

Quality is not the only aspect of basic education that should be attracting the attention of policy-makers: the number of secondary-school graduates has stagnated since the early 2000s at about 1.8 million a year, despite efforts to expand access. This means that only half of the target population is graduating from secondary school, a trend which limits the further expansion of higher education. Many of the 2.7 million students admitted to university in 2013 were older people coming back to study for a degree, a source of demand that is unlikely to evolve much further. Even the relatively small fraction of the population that is able to complete a university degree (currently about 15% of the young adult population) is not developing high-level skills and content-related knowledge, as evidenced by the results of the National System of Assessment of Higher Education (Pedrosa *et al,* 2013).

One federal initiative to expand qualified labour is Pronatec, a programme launched in 2011 for technical and vocational secondary-level education. According to government data, over 8 million people have already benefitted from the programme. This impressive picture is somewhat clouded by the growing claims from independent observers that most of the teenagers trained under the programme have not acquired many new skills and that much of the money might have been better spent elsewhere. A major criticism has been that most of the money went to private schools that had very little experience of vocational education.

5. See: www.oecd.org/pisa/keyfindings/PISA-2012-results-brazil.pdf

TRENDS IN R&D

R&D expenditure targets remain elusive

Brazil's economic boom between 2004 and 2012 translated into higher government and business spending on R&D. Gross domestic expenditure on R&D (GERD) almost doubled to PPP$ 35.5 billion (in 2011 dollars, Figure 8.3). Most of this growth occurred between 2004 and 2010, when GERD climbed from 0.97% to 1.16% of GDP. Since 2010, the government sector alone has been driving up R&D intensity, since the non-government contribution has actually declined from 0.57% to 0.52% of GDP (2012). Preliminary figures for 2013 indicate slight growth in government spending and a constant contribution from the business sector (relative to GDP). Business R&D expenditure is likely to contract from 2015 onwards until the economy shows signs of recovery. Even the most optimistic analysts do not expect this to happen before 2016. Fixed capital investment in Brazil is expected to decline further in 2015, especially in the manufacturing sector. This trend will certainly affect R&D expenditure by industry. The Petrobrás crisis is expected to have a major impact on investment in R&D, since it alone has accounted for about 10% of the country's annual fixed capital investment in recent years. The recently announced cuts to the federal budget and other austerity measures should also affect government spending on R&D.

Brazil's GERD/GDP ratio remains well below that of both advanced economies and such dynamic emerging market economies as China and, especially, the Republic of Korea (see Chapters 23 and 25). At the same time, it is quite comparable to the more stagnant developed economies such as Italy or Spain and other major emerging markets like the Russian Federation (see Chapter 13). It is also well ahead of most other Latin American countries (Figure 8.4).

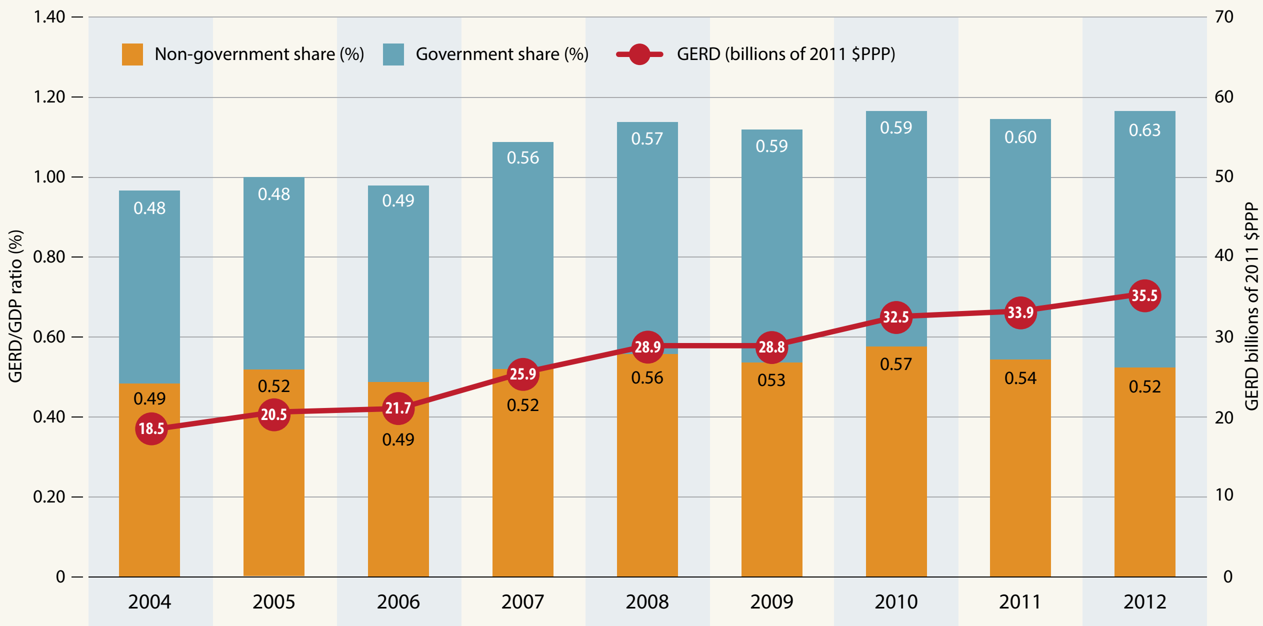
The gap between Brazil and advanced economies is much greater when it comes to human resources in R&D (Figure 8.5). Also striking is the sharp decline in the share of research personnel employed by the business sector in recent years (Figure 8.6). This is contrary to the trend observed in most developed and major emerging countries; it partly reflects the expansion of R&D in higher education and partly the anaemic growth of business sector R&D highlighted above.

Private firms are spending less on R&D

Almost all of non-government expenditure on R&D comes from private firms (private universities performing only a fraction of it). Since 2010, this expenditure has been declining as share of GDP (Figure 8.3); it has shrunk from 49% to 45% (2012) of total expenditure and even to 42% in 2013, according to preliminary government data. This trend is likely to last for some time. The business sector will, thus, have no chance of devoting 0.90% of GDP to R&D by 2014.

Figure 8.3: **GERD in Brazil by funding sector, 2004–2012**

In 2011 PPP$ billions and percentage share of GDP

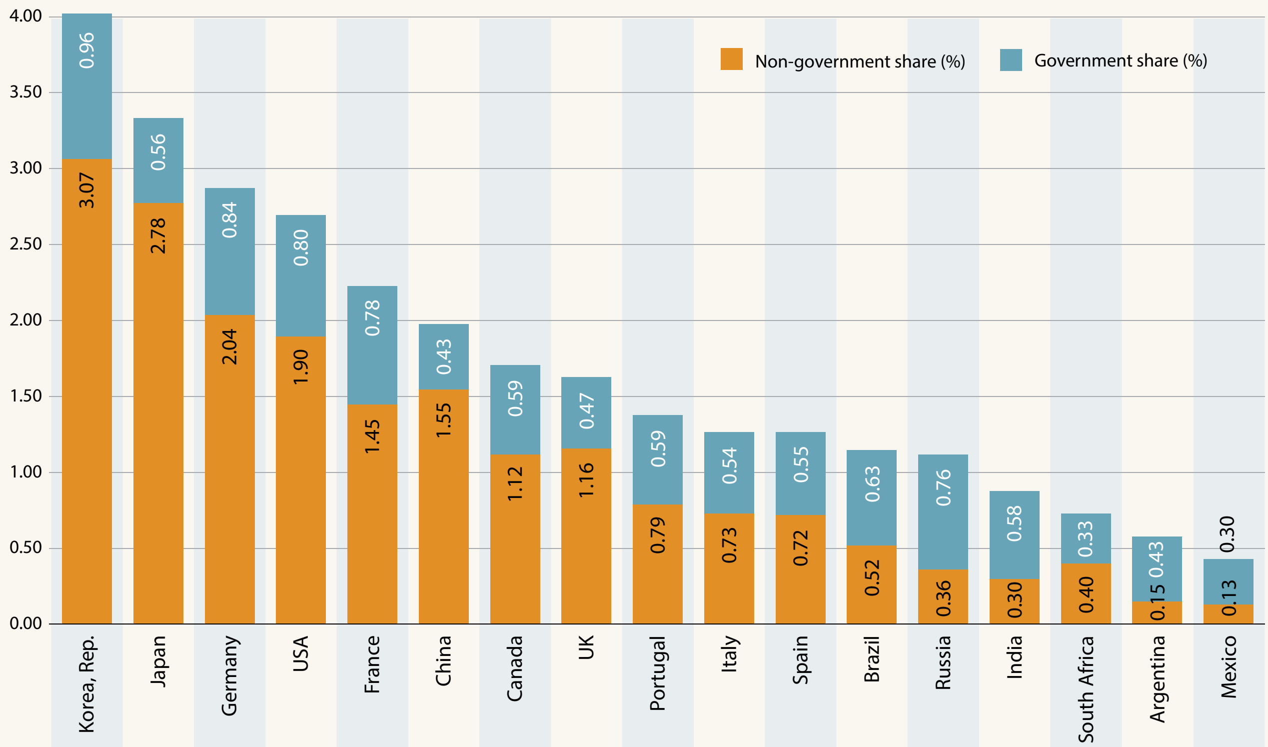


Note: The great majority of non-government funding comes from business enterprises. Private universities accounted for just 0.02–0.03% of GERD between 2004 and 2012. Figures 8.3 and 8.4 are based on updated GDP data for Brazil available as of September 2015 and may thus not match other indicators indexed on GDP reported elsewhere in the present report.

Source: Brazilian Ministry of Science, Technology and Innovation

Figure 8.4: **Brazilian business sector's contribution to GERD as a share of GDP, 2012 (%)**

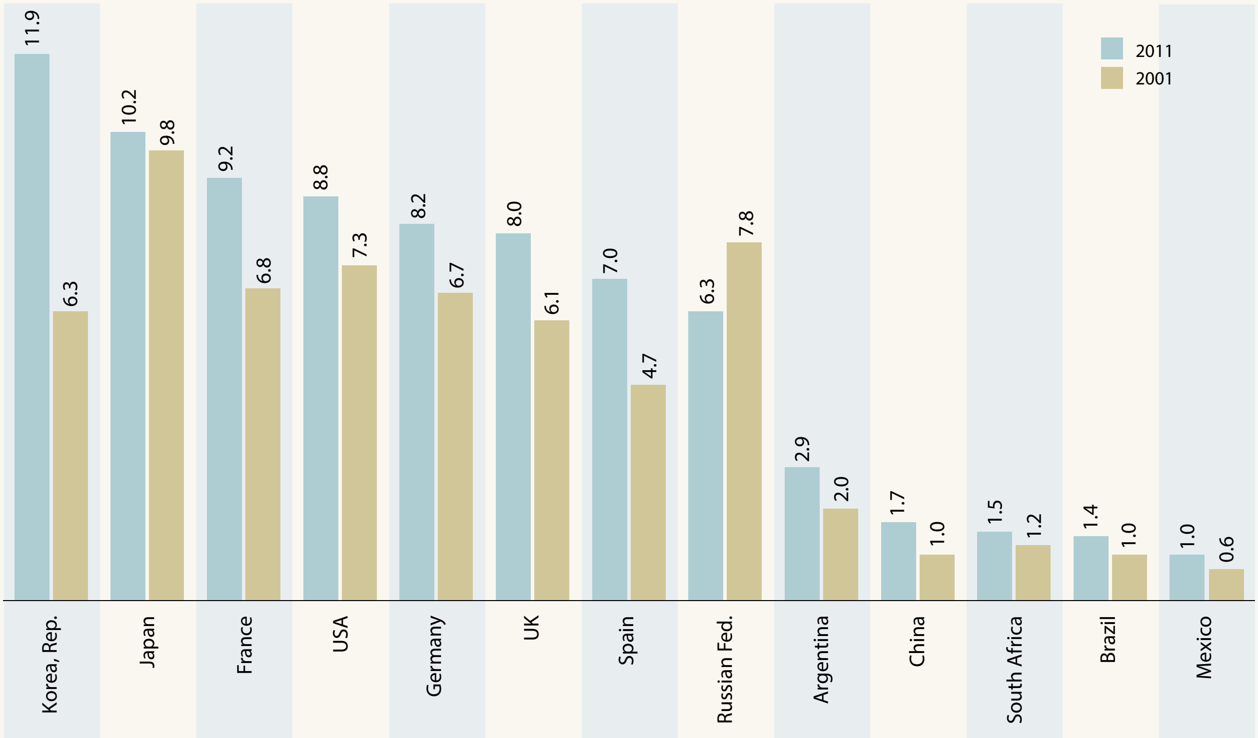
Other countries are given for comparison



Source: OECD's Main Science and Technology Indicators, January 2015; Brazilian Ministry of Science, Technology and Innovation

Figure 8.5: **Share of Brazilian FTE researchers per 1 000 labour force, 2001 and 2011 (%)**

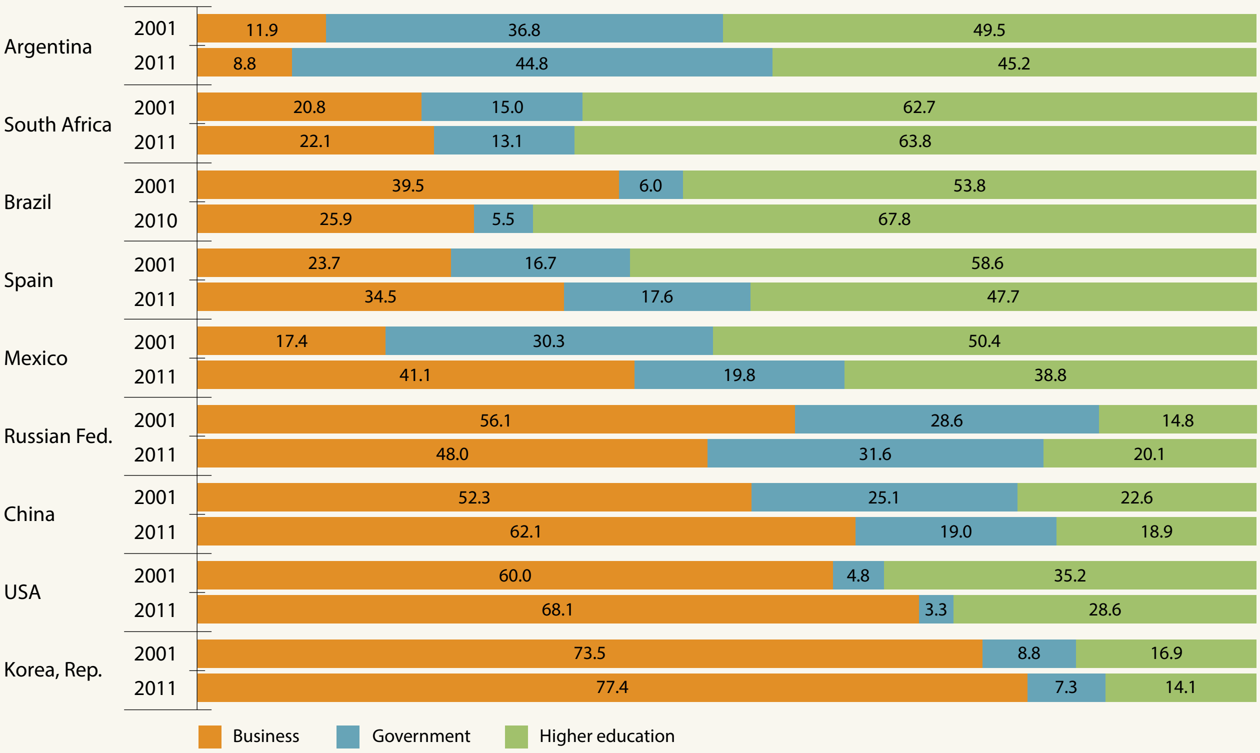
Other countries are given for comparison



Source: OECD's Main Science and Technology Indicators, January 2015

Figure 8.6: **FTE researchers in Brazil by sector, 2001 and 2011 (%)**

Other countries are given for comparison



Source: OECD's Main Science and Technology Indicators, January 2015

The main reasons for Brazil's low levels of private-sector R&D lie in the general population's low level of scientific and technical skills and the lack of incentives for businesses to develop new technology, new products and new processes. As we saw in the previous section, all available indicators show that Brazil's education system has not equipped the population to function properly in a technologically advanced society, nor to contribute effectively to technological progress.

As for Brazil's low level of innovation, this phenomenon is rooted in the deeply ingrained indifference of businesses and industry towards developing new technologies. There are fields where technological innovation sparks interest, of course: Embraer, the Brazilian aircraft manufacturer, Petrobrás, the state oil company and Vale, the large mining conglomerate, are all very competitive in their respective fields, with highly trained personnel and technologies and processes and products that are both innovative and competitive. These innovative companies share a common characteristic: their staple products are either commodities or used by the services industry, as in the case of commercial aeroplanes. Another area where Brazil has shown itself to be innovative and internationally competitive is agriculture, also a commodities sector. However, Brazil does not have a single company that is competing at the forefront of information and communications technologies (ICTs), in electronics or in biotechnology. Why is that so? In our view, the long-standing Brazilian industrial policy of protecting internal markets for locally produced goods (in various guises) has played a central role in this process. Only now are we coming to realize just how destructive this import substitution policy can be for the development of an innovative environment. Why would a local business invest heavily in R&D, if it is only competing with similar non-innovative companies operating within the same protectionist system? The consequence of this policy has been a gradual decline in Brazil's share of global trade in recent decades, especially when it comes to exports of industrial goods, a trend that has even accelerated in the past few years (Pedrosa and Queiroz, 2013).[6]

The situation is likely to deteriorate in the short term, as the most recent data indicate that 2014–2015 may turn out to be the worst years in decades for industry, especially for the transformation subsector of the manufacturing industry.

The current slowdown in the economy is already affecting the ability of the government's sectorial funds to collect revenue, since profits are down in many quarters. Created in the late 1990s, Brazil's sectorial funds have been one of the main sources of government funding for R&D. Each sectorial fund[7] receives money via taxes levied on specific industrial or service sectors, such as energy utility companies.

The 'Brazil cost' is holding companies back

Modern industrial development in Brazil is constrained by a lack of modern infrastructure, especially in logistics and electric power generation, along with cumbersome regulations relating to business registration, taxation or bankruptcy, all resulting in a high cost of doing business. This latter phenomenon has been described as the 'Brazil cost' (*Custo Brasil*).

The 'Brazil cost' is affecting the ability of Brazilian businesses to compete internationally and hindering innovation. Brazil has a relatively low level of exports. Their share of GDP even dropped from 14.6% to 10.8% between 2004 and 2013, despite the commodities boom. This trend cannot be explained solely by the unfavourable exchange rate.

Most Brazilian exports are basic commodities. These peaked at 50.8% of all exports in the first half of 2014, up from 29.3% in 2005. Soybean and other grains represented 18.3% of total exports, iron ore, meats and coffee making up another 32.5%. Just one-third of goods (34.5%) were manufactured, a sharp drop from 55.1% in 2005. Within manufactured exports, only 6.8% could be considered high technology, compared to 41.0% with a low-tech content (up from 36.8% in 2012).

The most recent figures paint a bleak picture. Industrial output declined by 2.8% between November and December 2014 and by 3.2% over the entire year. The decline was even more marked for capital (-9.6%) and durable goods (-9.2%) on an annual basis, indicating a drop in fixed capital investment.

Most government R&D expenditure goes to universities

The lion's share of government expenditure on R&D goes to universities, as in most countries (Figure 8.7). This level of spending increased slightly from 58% to 61% of total government funding of R&D between 2008 and 2012.

Among specific sectors, agriculture comes next, in a reflection of the sector's relevance for Brazil, the second-largest food-producing country in the world after the USA. Brazilian agricultural productivity has risen constantly since the 1970s, due to the greater use of innovative technology and processes. Industrial R&D comes third, followed by health and infrastructure, other sectors having shares of 1% or lower of government expenditure.

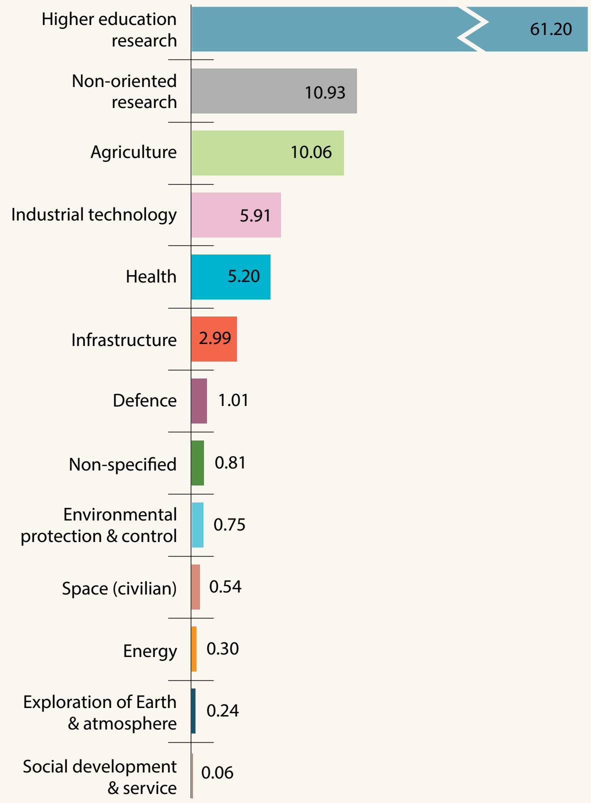
With some exceptions, the distribution of government spending on R&D in 2012 is similar[8] to that in 2000. After a sharp increase in industrial technology from 1.4% to 6.8%

6. Pedrosa and Queiroz (2013) present a detailed analysis of recent Brazilian industrial policies and their consequences in various areas, from the oil and wider energy sector to the auto-industry and other consumer goods.

7. For a detailed analysis of Brazilian sectorial funds, see the *UNESCO Science Report 2010*.

8. See t*he UNESCO Science Report 2010 for* a comparison with the years 2000 and 2008, p. 105.

Figure 8.7: **Government expenditure on R&D in Brazil by socio-economic objective, 2012 (%)**



Source: Ministry of Science, Technology and Innovation

between 2000 and 2008, its share of government expenditure declined to 5.9% in 2012. The share of space R&D (civilian) has been pursuing a downward spiral from a high of 2.3% in 2000. Defence research spending had been curtailed from 1.6% to 0.6% between 2000 and 2008 but has since rebounded to 1.0%. Research into energy has also declined from 2.1% (2000) to just 0.3% (2012). Overall, though, the allocation of government R&D spending seems to be relatively stable.

In May 2013, the Brazilian administrative body Redetec contracted the Argentine company INVAP to build a multipurpose nuclear reactor in Brazil for research and the production of radioisotopes employed in nuclear medicine, agriculture and environmental management. INVAP has already built a similar reactor for Australia. The multipurpose reactor is expected to be operational by 2018. It will be based at the Marine Technology Centre in São Paulo, with the Brazilian company Intertechne building some of the infrastructure.

Firms report a drop in innovative activity

In the latest innovation survey conducted by the Brazilian Institute of Geography and Statistics, all firms reported a drop in innovation activity since 2008 (IBGE, 2013). This survey covers all public and private firms in the extractive and transformative sectors, as well as firms in the services sector involving technology, such as telecommunications and internet providers, or electric power and gas utilities. For example, the proportion of companies undertaking innovative activities decreased from 38.1% to 35.6% between 2008 and 2011. The drop was most noticeable in telecommunications, both as regards the production of goods (-18.2%) and services (-16.9%). The larger companies seemed to have reduced their innovative activities by the biggest margin between 2008 and 2011. For example, among those with 500 or more employees, the share that were involved in developing new products declined from 54.9% to 43.0% over this period. A comparison of IBGE's innovation surveys over the periods 2004–2008 and 2009–2011 reveals that the 2008 crisis has had a negative impact on the innovative activities of most Brazilian firms. Since 2011, the economic situation in Brazil has further deteriorated, especially in the industrial sector. It can be expected that the next innovation survey will show even lower levels of innovative activity in Brazil.

Cutbacks in spending on renewable energy

Brazil's ambitions for biodiesel may have caught the headlines in the late 2000s when global energy and food prices spiked but energy-related industries have always had a high profile in Brazil. The state-controlled oil giant Petrobrás registers more patents than any other individual company in Brazil. Moreover, electricity-producing companies are directed by law to invest a given percentage of their revenue in R&D (Box 8.4).

The fact that energy is a key economic sector did not prevent the government from cutting back its spending on energy research from 2.1% to 1.1% of the total between 2000 and 2008 and again to 0.3% in 2012. Renewable energy sources have been the primary victim of these cuts, as public investment has increasingly turned towards deep-sea oil and gas exploration off Brazil's southeast coast. One area that has been directly affected by this is trend is the ethanol industry, which has had to close plants and cut back its own investment in R&D. Part of the ethanol industry's woes have resulted from Petrobrás' pricing policies. Under the influence of the government, its major stockholder, Petrobrás artificially depressed petrol prices between 2011 and 2014 to control inflation. This in turn depressed ethanol prices, making ethanol uneconomic to produce. This policy ended up eating into Petrobrás' own revenue, forcing it to cut back its investment in oil and gas exploration. As Petrobrás alone is responsible for about 10% of all fixed capital investment in Brazil, this trend, along with the corruption scandal currently shaking the company, will certainly have ramifications for Brazil's overall investment in R&D.

Brazil generates nearly three-quarters (73%) of its electricity from hydropower (Figure 8.8). This contribution was even as high as four-fifths in 2010 but the share of hydropower has been eroded by a combination of declining rainfall and ageing hydroelectric plants, many of which date back to the 1960s and 1970s.

Box 8.4: Company investment in energy efficiency – a legal obligation in Brazil

By law, Brazilian electricity companies must invest a share of their revenue in energy efficiency programmes and contribute to the National Science and Technology Development Fund (FNDCT).The law covers both public and private firms working in electricity generation, transmission and distribution. The FNDCT funds R&D conducted by universities, research institutes and industrial R&D centres.

The first such law was enacted in 2000 and the most recent one in in 2010.

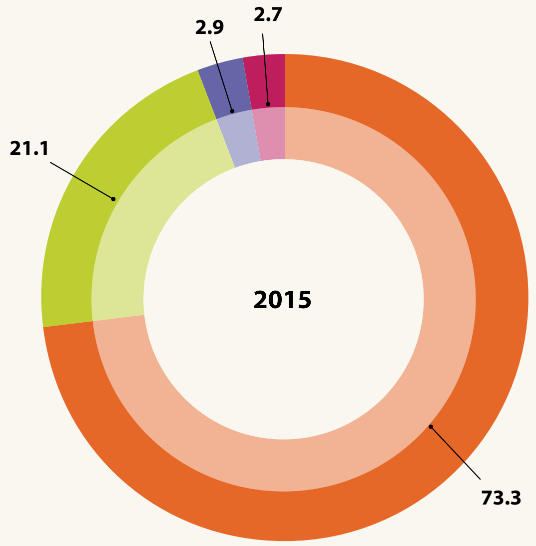
The law requires distribution companies to invest 0.20% of their net operating revenue (NOR) in R&D and 0.50% in energy efficiency programmes; a further 0.20% goes to FNDCT. For their part, generation and transmission companies must invest 0.40% of NOR in R&D and contribute 0.40% to FNDCT. The investment in energy efficiency programmes is considered business R&D expenditure, whereas the funds transferred to FNDCT are considered government funding. The law will remain in force until the end of 2015, when it is expected to be renewed or reviewed.

According to the National Agency of Electrical Energy, the energy efficiency programmes supported by this initiative helped to save 3.6 GWh between 2008 and 2014, a fairly modest amount. In 2014, R$ 342 million was spent on such projects, representing a drop of more than 50% before inflation from the R$ 712 million spent in 2011.

Source: authors
See also: www.aneel.gov.br

Intensive use of thermoelectric power plants operating on fossil fuels has compensated for much of the loss, since the share of new sources of renewable energy, such as solar and wind, in the energy mix remains small. Moreover, although Brazil has made great strides in the use of bioethanol in transportation, there has been little focus on research and innovation in energy generation, be it in terms of developing new sources of energy or improving energy efficiency. In light of the foregoing, there is little reason to expect public investment in energy R&D to rebound to the levels seen at the turn of the century that would rebuild Brazil's international competitiveness in this field.

Figure 8.8: Electricity generation by type in Brazil, 2015
Share of total electric power generation (%)



Source: National System Operator data: www.ons.org.br/home/

Technology transfer to private sector key to innovation

Despite the generally low level of innovation by Brazilian companies, there are exceptions like Embraer. Another example is Natura, a home-grown company dedicated to cosmetics (Box 8.5).

Technology transfer from public research institutions to the private sector is a major component of innovation in Brazil in fields ranging from medicine to ceramics and from agriculture to deep-sea oil drilling. Two key centres have been set up in recent years to foster the development of nanotechnology, the National Nanotechnology Laboratory for Agriculture (LNNA, est. 2008) and the Brazilian Nanotechnology National Laboratory (LNNano, est. 2011). This strategic investment, combined with federal and state funding of specific research projects in related fields, has led to considerable growth in the number of researchers working in materials science with the corollary of high-impact research and technology transfer. A report published by the Brazilian Materials Research Society (2014)[9] cites researcher Rubén Sinisterra from the Federal University of Minas Gerais, who has been developing drugs to alleviate hypertension. Sinisterra is confident that Brazilian universities now have the capacity to develop nanoscale materials for drug delivery but also observes that 'our domestic pharmaceutical companies don't have internal R&D capabilities, so we have to work with them to push new products and processes out to market'. According to Statnano, which crunches Thomson Reuters' data, the number of articles on nanoscience in Brazil rose from 5.5 to 9.2 per million inhabitants between 2009 and 2013 (see Figure 15.5). The average number of citations per article dropped, though, over the same period, from 11.7 to 2.6, according to the same source. In 2013, Brazilian output in nanoscience represented 1.6% of the world total, compared to 2.9% for scientific articles, in general.

9. See: http://ioppublishing.org/newsDetails/brazil-shows-that-materials-matter

Box 8.5: **Innovation made in Brazil: the case of Natura**

Founded in 1986, Natura Cosméticos is Brazil's market leader for personal hygiene products, cosmetics and perfumes. Today a multinational corporation, it is present in many Latin American countries and in France, with net revenue of R$ 7 billion in 2013 (*circa* US$ 2.2 billion). Natura's stated mission is to create and commercialize products and services that promote well-being. It operates mainly through direct sales, with about 1.7 million mainly female consultants selling directly to their network of regular customers rather than through stores. Two-thirds of these consultants (1.2 million) are based in Brazil.

The company's philosophy is to turn socio-environmental issues into business opportunities through innovation and sustainability. In 2012, the Corporate Knights considered Natura the second-most sustainable company in the world (according to economic criteria) and the Forbes List ranked it the eighth-most innovative company in the world. As a result of its corporate behaviour, Natura became the largest enterprise in the world to obtain the B-Corp certification in 2014.

Natura employs a team of 260 people who are directly involved in innovation, over half of them with graduate degrees. It ploughs about 3% of its revenue back into R&D; in 2013, this represented an investment of R$ 180 million (*circa* US$ 56 million). As a result, two-thirds (63.4%) of revenue from sales in 2013 involved innovative products released in the previous two years. Overall growth has been very intense, the size of Natura having quadrupled in the past ten years.

Brazilian biodiversity is a key ingredient in Natura's innovation process, which uses plant extracts in new products. The incorporation of active biological principles derived from Brazilian flora requires interaction with Amazonian communities and partnerships with research institutes like the Brazilian Agricultural Research Company (Embrapa). One example is the Chronos line, which uses active principles from *Passiflora alata* (passion fruit), developed in partnership with the Federal University of Santa Catarina using federal funds (FINEP); the Chronos line has generated new patents and collaborative research.

Natura has also developed research centres in Cajamar (São Paulo), within the Ecoparque Natura in Benevides Pará. Its Manaus Innovation Centre in the capital city of the State of the Amazon establishes partnerships with the region's institutions and companies to turn locally developed knowledge and technology into new products and processes; this has incited other businesses to invest in the region.

Natura also participates in innovation hubs abroad like the Global Hub of Innovation in New York. It has also developed international partnerships with the Massachusetts Institute of Technology's Media Lab (USA), the Massachusetts General Hospital (USA) and Lyon University in France, among others.

Today, Natura interacts with over 300 organizations – companies, scientific institutions, funding agencies, specialists, NGOs and regulatory agencies – in implementing more than 350 projects related to innovation. In 2013, these partnerships accounted for more than 60% of all the projects undertaken by Natura. One highlight has been the inauguration of the Applied Research Centre in Wellbeing and Human Behaviour in 2015, in partnership with the São Paulo Research Foundation (FAPESP). The new centre includes research facilities based at the state's public universities.

Source: compiled by authors

Patents have grown at a slower pace than publications

Scientific publications by Brazil have more than doubled since 2005, primarily as a result of the jump in the number of Brazilian journals being tracked by the Thomson Reuters database between 2006 and 2008. Despite this artificial boost, the pace of growth has slowed since 2011 (Figure 8.9). Moreover, in terms of publications per capita, the country trails both the more dynamic emerging market economies and advanced economies, even if it is ahead of most of its neighbours (see Figure 7.8). In fact, when it comes to impact, Brazil has lost a lot of ground in the past decade. One possible cause may be the speed with which enrolment in higher education has expanded since the mid-1990s, especially as concerns students passing through the federal system of universities, some of which have resorted to hiring inexperienced faculty, including candidates without doctorates.

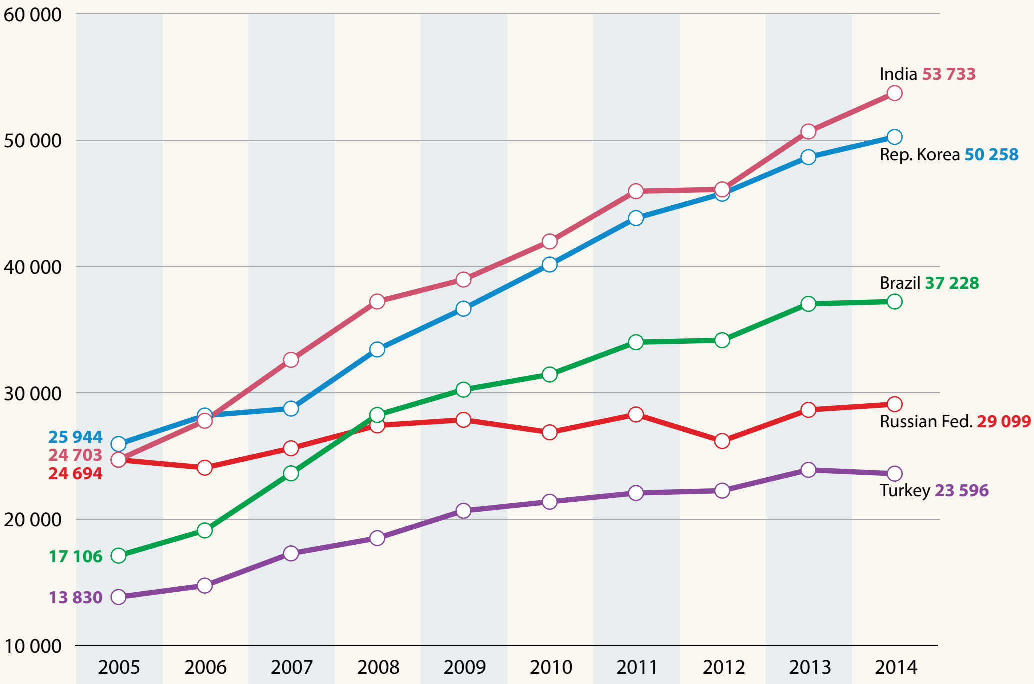
Patent applications to the Brazilian Patent Office (INPI) increased from 20 639 in 2000 to 33 395 in 2012, progressing by 62%. This rate pales in comparison with that of scientific publications over the same period (308%). Moreover, if one considers only patent applications by residents, the growth rate over this period was even lower (21%).

International comparisons using the number of patents granted by the US Patent and Trademarks Office (USPTO) provide an indirect measure of the extent to which an economy may be seeking international competitiveness on the basis of technology-driven innovation. Although Brazil has registered strong growth in this field, it trails its biggest competitors for the intensity of patenting relative to its size (Table 8.1). Compared to other emerging economies, Brazil also seems to be relatively less focused on international patenting than on publications (Figure 8.10).

Figure 8.9: **Scientific publication trends in Brazil, 2005–2014**

Growth in Brazilian publications has slowed slightly since 2008

Other countries are given for comparison



147

Publications per million inhabitants in 2008

184

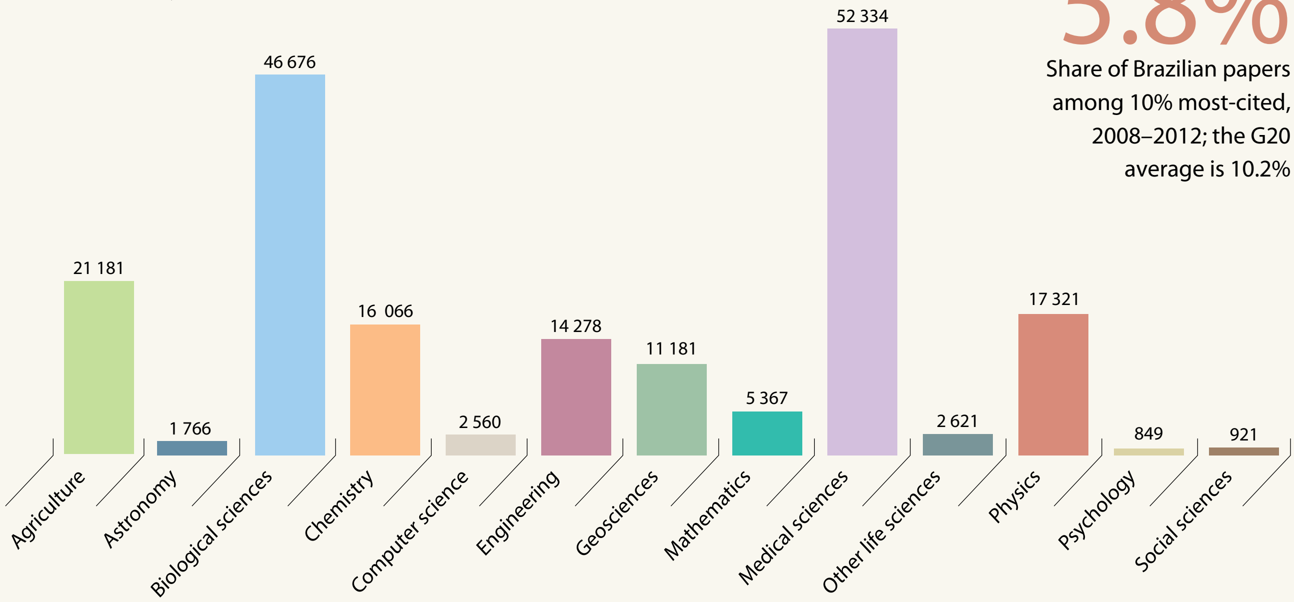
Publications per million inhabitants in 2014

0.74

Average citation rate for Brazilian publications, 2008–2012; the G20 average is 1.02

Life sciences dominate Brazilian publications

Cumulative totals by field, 2008–2014



5.8%

Share of Brazilian papers among 10% most-cited, 2008–2012; the G20 average is 10.2%

Note: Unclassified articles (7 190) are excluded from the totals.

The USA is Brazil's closest partner

Main foreign partners, 2008–2014

	1st collaborator	2nd collaborator	3rd collaborator	4th collaborator	5th collaborator
Brazil	USA (24 964)	France (8 938)	UK (8 784)	Germany (8 054)	Spain (7 268)

Source: Thomson Reuters' Web of Science, Science Citation Index Expanded; data treatment by Science–Metrix

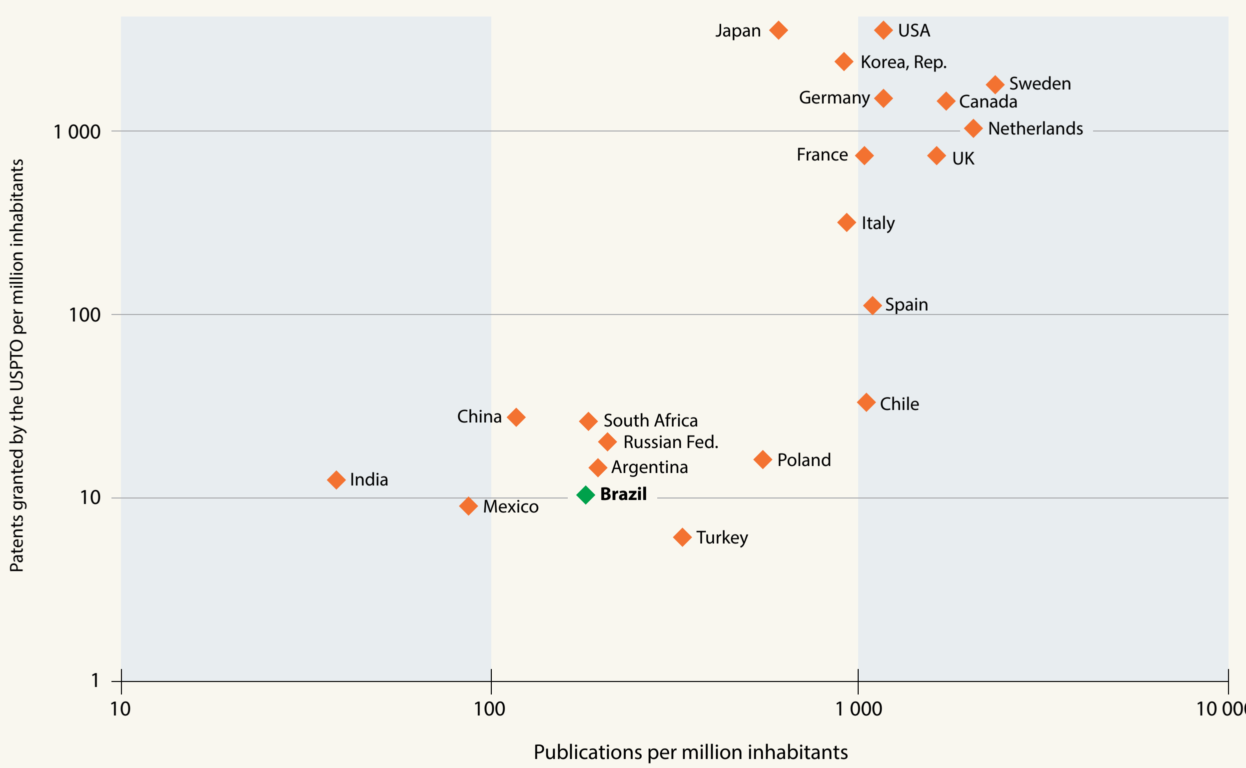
Table 8.1: **Invention patents granted to Brazilians by USPTO, 2004–2008 and 2009–2013**

	No. of patents, 2004–2008	No. of patents, 2009–2013	Cumulative growth (%)	Per 10 million inhabitants, 2009–2013
Global average	**164 835**	**228 492**	**38.6**	**328**
Japan	34 048	45 810	34.5	3 592
USA	86 360	110 683	28.2	3 553
Korea, Rep.	3 802	12 095	218.1	2 433
Sweden	1 561	1 702	9.0	1 802
Germany	11 000	12 523	13.8	1 535
Canada	3 451	5 169	49.8	1 499
Netherlands	1 312	1 760	34.1	1 055
UK	3 701	4 556	23.1	725
France	3 829	4 718	23.2	722
Italy	1 696	1 930	13.8	319
Spain	283	511	80.4	111
Chile	13	34	160.0	33
China	261	3 610	1 285.3	27
South Africa	111	127	14.2	25
Russian Fed.	198	303	53.1	21
Poland	15	60	313.7	16
Argentina	54	55	3.4	14
India	253	1 425	464.2	12
Brazil	**108**	**189**	**74.6**	**10**
Mexico	84	106	25.1	9
Turkey	14	42	200.0	6

Source: USPTO

Figure 8.10: **Relative intensity of publications versus patenting in Brazil, 2009–2013**

Other countries are given for comparison. Logarithmic axes



Source: for patents: USPTO; for publications: Thomson Reuters; for population: World Bank's World Development Indicators

REGIONAL TRENDS

STI still dominated by the State of São Paulo

Brazil is a country of continental dimensions, with highly diverse levels of development across its 27 states. The southern and southeastern regions show a much higher level of industrialization and scientific development than the northern ones, some of which encroach on the Amazonian forest and river basin. The centre-west is Brazil's agricultural and cattle-raising powerhouse and has been developing rapidly recently.

The starkest example of this contrast is the southeastern State of São Paulo. Home to 22% (44 million) of the country's 202 million inhabitants, it generates about 32% of GDP and a similar share of the nation's industrial output. It also has a very strong state system of public research universities that is lacking in most other states and hosts the well-established São Paulo Research Foundation (Box 8.6). The State of São Paulo is responsible for 46% of GERD (public and private expenditure) and 66% of business R&D.

All indicators paint the same picture. Some 41% of Brazilian PhDs were granted by universities in the State of São Paulo in 2012 and 44% of all papers with Brazilian authors have at least one author from an institution based in São Paulo. São Paulo's scientific productivity (390 papers per million inhabitants over 2009–2013) is twice the national average (184), a differential which has been widening in recent years. The relative impact of publications by scientists from the State of São Paulo has also been systematically higher than for Brazil as a whole over the past decade (Figure 8.11).

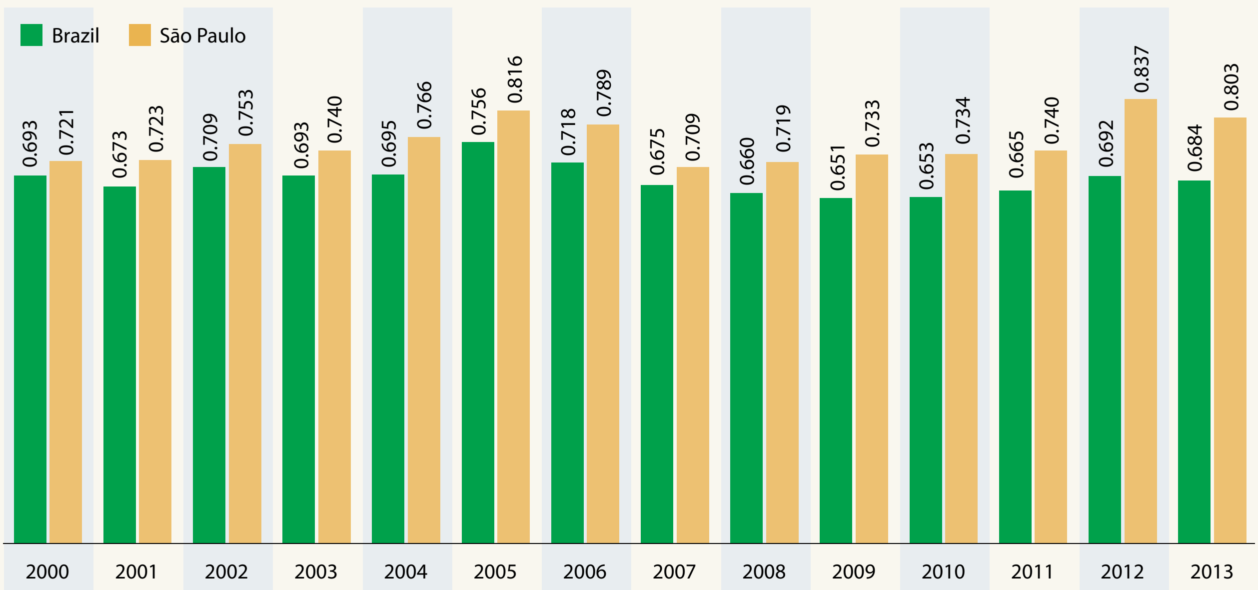
Two key factors explain São Paulo's success in scientific output: firstly, a well-funded system of state universities, including the University of São Paulo, University of Campinas (Unicamp) and the State University of São Paulo (Figure 8.12), all of which have been included in international university rankings;[10] secondly, the role played by the São Paulo Research Foundation (FAPESP, Box 8.6). Both the university system and FAPESP are allocated a fixed share of the state's sales tax revenue as their annual budgets and have full autonomy as to the use they make of this revenue.

Between 2006 and 2014, the share of Brazilian researchers hosted by southeastern institutions dropped steadily from 50% to 44%. Over the same period, the share of northeastern states rose from 16% to 20%. It is still too early to see the effect of these changes on scientific output, or in the number of PhD degrees being awarded but these indicators should logically also progress.

Despite these positive trends, regional inequalities persist in terms of R&D expenditure, the number of research institutions and scientific productivity. Extending the scope of research projects to other states and beyond Brazil would certainly help scientists from these regions catch up to their southern neighbours.

10. In the Times Higher Education 2015 ranking of universities in BRICS and other emerging economies, the University of São Paulo came 10th, Unicamp 27th and the Universidade Estadual Paulista (Unesp) 97th. Among the top 100, only one other Brazilian university features, the Federal University of Rio de Janeiro (UFRJ, 67th). In the 2015 QS Latin America ranking, the University of São Paulo comes first, Unicamp second, UFRJ fifth and Unesp eighth.

Figure 8.11: **Relative impact of scientific publications from São Paulo and Brazil, 2000–2013**



Source: InCites/Thomson Reuters, October 2014

Figure 8.12: **Relative shares of Brazilian states for investment in science and technology**

R$ 69.50

National average for expenditure on science and technology per capita

The State of São Paulo concentrates the most expenditure on science and technology per capita

R$ 183.80

Expenditure on science and technology per capita in São Paolo

- Above national average expenditure on S&T
- 50–100% of national average expenditure on S&T
- 25–50% of national average expenditure on S&T
- Below 25% of national average expenditure on S&T

Ten of Brazil's research universities are found in Rio de Janeiro and São Paulo

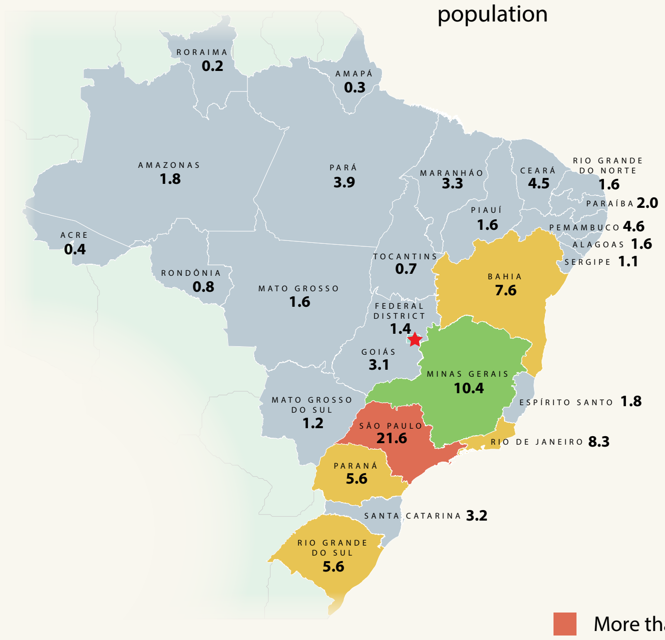
Research universities in Brazil

Region/ Federative unit	Research universities	Region/ Federative unit	Research universities
Ceará	Federal University of Ceará	**São Paulo**	University of São Paulo
Pernambuco	Federal University of Pernambuco		University of Campinas (Unicamp)
Minas Gerais	Federal University of Minas Gerais		State University of São Paulo
Rio de Janeiro	Federal University of Rio de Janeiro		Federal University of São Paulo
	Oswaldo Cruz Foundation		Federal University of São Carlos
	Pontifical Catholic University	**Rio Grande do Sul**	Federal University of Rio Grande do Sul
	University of Rio de Janeiro		Pontifical University of Rio Grande do Sul
	State University of Rio de Janeiro	**Santa Catarina**	Federal University of Santa Catarina
Paraná	Federal University of Paraná	**Distrito Federal**	University of Brasília

Six states account for 59% of the population

22%

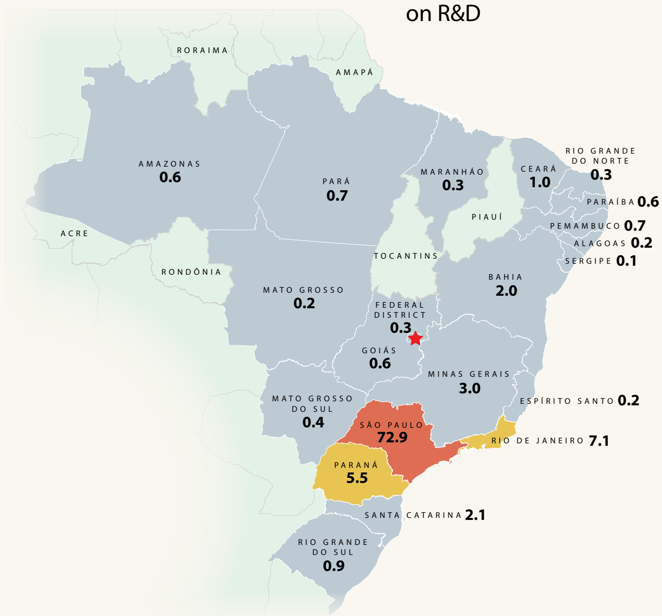
State of São Paulo's share of Brazilian population



The State of São Paulo concentrates three-quarters of public expenditure on R&D

73%

State of São Paulo's share of public expenditure on R&D

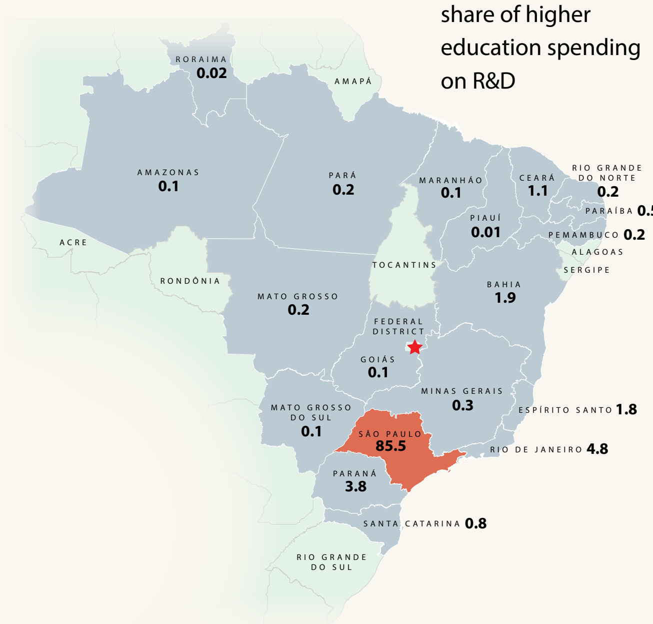


- More than 15% of total
- 10–14.9% of total
- 5–9.9% of total
- Less than 5% of total
- Data unavailable
- Number of research universities

São Paulo dominates higher education spending on R&D

86%

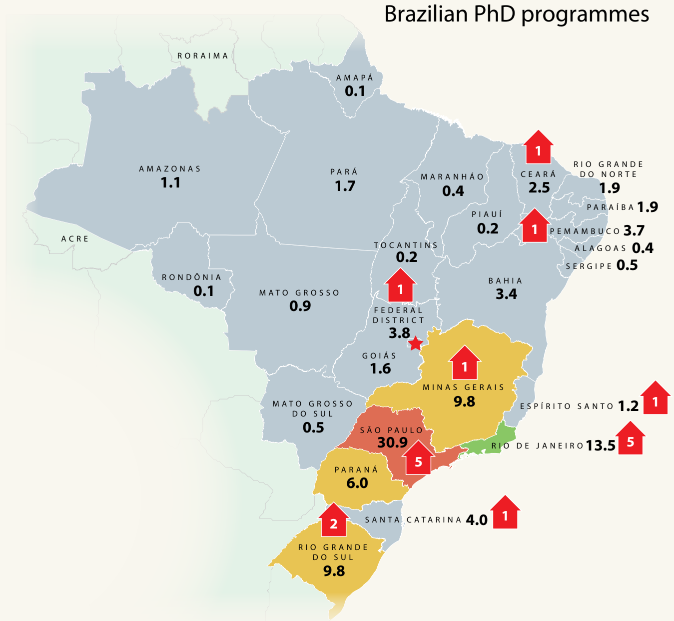
State of São Paulo's share of higher education spending on R&D



Five states concentrate more than half of Brazilian PhD programmes

31%

State of São Paulo's share of Brazilian PhD programmes



Source: Instituto Brasileiro de Geografia e Estatística (IBGE)

Box 8.6: **The São Paulo Research Foundation: a sustainable funding model**

The São Paulo Research Foundation (FAPESP) is the State of São Paulo's public research foundation. It receives sustainable funding in the form of an annual 1% share of state sales taxes, under a provision inscribed in the State Constitution. The Constitution also stipulates that only 5% of the Foundation's budget may be used for administrative purposes, thereby limiting misuse. The foundation thus enjoys stable funding and operational autonomy.

FAPESP operates through a peer-review system with the help of panels composed of active researchers and arranged by research theme. Besides funding research across the full spectrum of science, FAPESP supports four large research programmes covering biodiversity, bio-energy, global climate change and neurosciences.

In 2013, FAPESP's expenditure amounted to R$ 1.085 billion (*circa* US$ 330 million). The foundation maintains co-operation agreements with national and international research funding agencies, universities, research institutes and business enterprises. International partners include the Centre nationale de recherche scientifique in France, the Deutsche Forschungsgemeinschaft in Germany and the National Science Foundation in the USA.

FAPESP also offers a wide range of programmes to support foreign scientists wishing to work in São Paulo. These include postdoctoral fellowships, young investigator awards and visiting researcher grants.

Source: compiled by authors

CONCLUSION

Industry must embrace innovation to remain internationally competititve

In recent decades, Brazil has basked in the global recognition of its achievement in reducing poverty and inequality by means of active social policies. Since economic growth began to falter in 2011, however, progress towards social inclusion has also slowed. With much of the active population holding down a job these days (unemployment was down to 5.9% by 2013), the only way to kickstart economic growth once more will be to raise productivity. That will take two essential ingredients: STI and a well-educated labour force.

The volume of Brazilian publications has grown considerably in recent years. A number of individual researchers have also been recognized for the quality of their work, as in the case of Ártur Avila, who became the first-ever Latin American mathematician to receive the prestigious Fields Medal in 2014.

Nevertheless, there has been a general lack of progress in the overall impact of Brazilian science. Citations of Brazilian publications still fall well beneath the G20 average; to some extent, this may be due to the fact that many Brazilian articles are still published in Portuguese in Brazilian journals of limited circulation, thereby passing under the international radar. If so, this lack of visibility is a temporary price to pay for the surge in access to higher education in recent years. However, the fact remains that other emerging economies such as India, the Republic of Korea or Turkey have performed much better than Brazil in the past five years or so. Raising the quality and visibility of Brazilian science will require a concerted effort to expand and intensify international collaboration.

Education has become a central topic of national political debate. The new Minister of Education is promising to overhaul the secondary education system, which has been one of the main bottlenecks to improving the education level of the labour force, as the PISA results so eloquently illustrated. The new National Law of Education proposes some very ambitious goals to 2024, including those of broadening access to higher education further and raising the quality of basic education.

Another bottleneck is to be found in the low number of patents granted by USPTO to Brazilian applicants. This trend shows that Brazilian businesses are not yet internationally competitive when it comes to innovation. Private expenditure on R&D remains relatively low, in comparison with other emerging economies. More worryingly, there has been almost no progress in this area since the modest growth registered during the commodities boom between 2004 and 2010. Investment, in general, is declining, as is the share of industrial output in GDP and Brazil's participation in foreign trade, especially as regards exports of manufactured goods. These are all indicators of an innovative economy and they are all in the red.

The new Minister of Finance seems to be aware of the many bottlenecks and distortions that have undermined the economy in recent years, including misguided protectionism and favouritism in relation to some large economic groups.[11] He has proposed a series of measures to regain fiscal control as a means of preparing the terrain for a new growth cycle. Notwithstanding this, Brazilian industry is in such a dire state that the country's entire approach to industrial and trade policies needs to be overhauled. The national industrial sector must be exposed to international competition and encouraged to consider technological innovation as an essential part of its mission.

11. The investigation into the recent scandal involving the giant oil company, Petrobrás, has shed light on the large amount of subsidized funds received by some construction companies via the National Bank of Economic and Social Development (BNDES) for some international projects implemented with little oversight from Brazilian regulatory agencies.

KEY TARGETS FOR BRAZIL

- Brazilian 15-year-olds to attain a mathematics score of 473 by 2024 in the OECD's Programme for International Student Assessment (PISA);
- Raise the level of fixed capital investment from 19.5% in 2010 to 22.4% of GDP by 2014;
- Raise business expenditure on R&D from 0.57% in 2010 to 0.90% of GDP by 2014;
- Augment the share of the labour force having completed secondary education from 54% to 65%;
- Raise the share of knowledge-intensive businesses from 30.1% to 31.5% of the total by 2014;
- Increase the number of innovative SMEs from 37 000 to 58 000 by 2014;
- Diversify exports and increase the country's share in world trade from 1.36% to 1.60% by 2014; and
- Expand access to fixed broadband internet from 14 million to 40 million households by 2014.

REFERENCES

Aghion, P. and P. Howitt (1998) *Endogenous Growth Theory*. Massachusetts Institute of Technology Press: Boston (USA).

Balbachevsky, E. and S. Schwartzman (2010) The graduate foundations of Brazilian research. *Higher Education Forum,* 7: 85-100. Research Institute for Higher Education, Hiroshima University. Hiroshima University Press: Hiroshima.

Brito Cruz, C.H. and R. H. L. Pedrosa (2013) Past and present trends in the Brazilian research university. In: C.G. Amrhein and B. Baron (eds) *Building Success in a Global University*. Lemmens Medien: Bonn and Berlin.

ECLAC (2014a) *Social Panorama of Latin America 2013, 2014*. United Nations Economic Commission for Latin America and the Caribbean: Santiago (Chile).

ECLAC (2014b) *Compacts for Equality: Towards a Sustainable Future*. United Nations Economic Commission for Latin America and the Caribbean, 35th Session, Lima.

FAPESP (2015) *Boletim de Indicadores em Ciência e Tecnologia n. 5*. Fundação de Amparo à Pesquisa do Estado de São Paulo (São Paulo Research Foundation, FAPESP).

Hanushek, E. A. and L. Woessmann (2012) Schooling, educational achievement and the Latin American growth puzzle. *Journal of Development Economics,* 99: 497–512.

Heston, A.; Summers, R. and B. Aten (2012) *Penn World Table Version 7.1*. Center for International Comparisons of Production, Income and Prices. Penn University (USA). July. See: https://pwt.sas.upenn.edu

IBGE (2013) *Pesquisa de Inovação (PINTEC) 2011*. Brazilian Institute of Geography and Statistics: Rio de Janeiro. See: www.pintec.ibge.gov.br

MoSTI (2007) *Plano de Ação 2007–2010, Ciência, Tecnologia e Inovação para o Desenvolvimento Nacional*. (*Plan of Action 2007–2010: Science, Technology and Innovation for National Development*.) Ministry of Science, Technology and Innovation.
See: www.mct.gov.br/upd_blob/0203/203406.pdf

OECD (2014) *Going for Growth*. Country Note on Brazil. Organisation for Economic Co-operation and Development: Paris.

Pedrosa, R.H.L and S.R.R. Queiroz (2013) *Brazil: Democracy and the 'Innovation Dividend'*. Centre for Development and Enterprise: South Africa; Legatum Institute: London.

Pedrosa, R. H. L.; Amaral, E. and M. Knobel (2013) Assessing higher education learning outcomes in Brazil. *Higher Education Management and Policy*, 11 (24): 55–71. Organisation for Economic Co-operation and Development: Paris.

PISA (2012) *Results, Programme for International Student Assessment*. Organisation for Economic Co-operation and Development: Paris. See: www.oecd.org/pisa/keyfindings/PISA-2012-results-brazil.pdf

Renato Hyuda de Luna Pedrosa (b. 1956: Brazil) is an Associate Professor in the Department of Science and Technology Policy at the University of Campinas in Brazil. He holds a PhD in Mathematics from the University of California in Berkeley (USA).

Hernan Chaimovich (b. 1939: Chile) is a biochemist and Special Advisor to the Scientific Directorate of the São Paulo Research Foundation (FAPESP). He regularly publishes scientific articles in journals, magazines and newspapers related to higher education, science and technology policy.

ACKNOWLEDGMENTS

The authors wish to thank Joana Santa-Cruz from the team in charge of STI indicators at the São Paulo Research Foundation (FAPESP) for her help in collecting and organizing the data used in the present chapter.