brazil
the natural knowledge economy

Kirsten Bound

THE ATLAS OF IDEAS

DEMOS

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Kirsten Bound
July 2008

Introduction

If you grew up in Europe or North America you will no doubt have been taught in school that the Wright Brothers from Ohio invented and flew the first aeroplane – the *Kitty Hawk* – in 1903. But if you grew up in Brazil you will have been taught that the real inventor was in fact a Brazilian from Minas Gerais called Alberto Santos Dumont, whose *-bis* aeroplane took to the skies in 1906. This fierce historical debate, which turns on definitions of 'practical airplanes', the ability to launch unaided, length of time spent in the air and the credibility of witnesses, will not be resolved here. Yet it is a striking example of the lack of global recognition for Brazil's achievements in innovation.

Almost a century later, in 2005, Santos Dumont's intellectual heirs, the company Empresa Brasileira de Aeronáutica (EMBRAER), made aviation history of a different kind when they unveiled the *Ipanema*, the world's first commercially produced aircraft to run solely on biofuels. This time, the world was watching. *Scientific American* credited it as one of the most important inventions of the year.

The attention paid to the *Ipanema* reflects the growing interest in biofuels as a potential solution to climate change and rising energy demand. To their advocates, biofuels – most commonly bioethanol or biodiesel – offer a more secure, sustainable energy supply that can reduce carbon emissions by 50–60 per cent compared to fossil fuels.

From learning to fly to learning to cope with the environmental costs of flight, biofuel innovations like the *Ipanema* reflect some of the tensions of modern science, in which expanding the frontiers of human ingenuity goes hand-in-hand with managing the consequences. The recent backlash against biofuels, which has seen them blamed for global food shortages as land is reportedly diverted from food crops, points to a growing interdependence between the science and innovation systems of different countries, and between innovation, economics and environmental sustainability.

The debates now raging over biofuels reflect some of the wider dynamics in Brazil's innovation system. They remind us that Brazil's current strengths and achievements have deeper historical roots than is sometimes imagined. They reflect the fact that Brazil's natural resources and assets are a key area of opportunity for science and innovation – a focus that leads us to characterise Brazil as a 'natural knowledge-economy'. Most importantly, they highlight the propitious timing of Brazil's growing strength in these areas at a time when climate change, the environment, food scarcity and rising worldwide energy demand are at the forefront of global consciousness. What changed between the maiden flight of the *-bis* and the maiden flight of the *Ipanema* is not just Brazil's capacity for technological and scientific innovation, but the rest of the world's appreciation of the potential of that innovation to address some of the pressing challenges that confront us all.

It was in 1975, in response to the 1973 oil crisis, that the government set up the *PróAlcool* bioethanol policy for the purpose of energy security.[1] A combination of effective regulation, subsidies, tax breaks, expanded distilleries and technological developments such as the 'flex fuel' engine meant that, by 2006, 83 per cent of cars sold in Brazil could run on biofuels. Today, Brazil is the world leader in biofuels production, and accounts for almost 43 per cent of the global supply of ethanol.

Of course, Brazil's achievements in biofuels are not the only remarkable thing about science and innovation in the country. Broader changes are afoot. The number of postgraduate students in Brazil's universities has risen tenfold in the past 20 years. The number of PhDs in science has grown by roughly 12 per cent a year for the past decade. And Brazil is now one of the top fastest-growing countries in the world in terms of scientific publications.[2]

Brazil is making waves in areas from software to stem cell technology. Top companies like Petrobras are investing upwards of US$1 billion a year in research and development

(R&D). The agricultural research organisation Embrapa has helped Brazil to become one of the most productive agricultural nations in the world. Economic reform and a raft of new legislation designed to stimulate investment in innovation are starting to have an effect. Yet biofuels provide a spotlight with which to illuminate some of the tensions that will confront Brazil as it strives for greater innovation.

First is the challenge of *competition*. How effectively can Brazil compete in the changing global landscape of science, technology and innovation? What new strengths are likely to emerge? Can it produce the volume of skilled science and engineering graduates needed to galvanise future growth? Following five years of 'ethanol diplomacy', as Brazil has built up its reputation for innovation on the back of biofuels, how will it cope with the current backlash? Can Brazil convince the world that it has excellence to offer in other areas?

Second, the challenge of *inequality*. The strikingly unequal land ownership in Brazil that is a feature of the agribusiness behind ethanol is representative of serious social and geographical inequality. This is reflected in approaches to science and innovation as much as in other areas of the country's economic life. Near the University of Campinas, a major player in Brazil's unfolding story of innovation, the Ministry of Science and Technology plans to open a new centre for bioethanol science and technology, as part of the ultra high-tech National Synchrotron Laboratory. But only a short distance away, a team of young entrepreneurs from the start-up Agricef are plugging away at their designs for a new sugar cane harvesting device that has an inbuilt requirement for manpower, in an effort to improve efficiency, while maintaining sorely-needed employment. Elite science is being developed side-by-side with appropriate technology to benefit the poor.

Third, the challenge of balancing innovation in economic terms with *environmental sustainability*. The Amazon rainforest, most of which lies within Brazil's borders, is home to a third of all plant species and contributes 15 per cent of the world's oxygen. The Amazon is a crucial factor in the global climate equilibrium, and its biodiversity is regarded as one of the most significant resources for the active ingredients for new medicines and cures. How can it ensure that economic growth and innovation are not achieved at the expense of its most important assets?

A natural knowledge-economy?

While a fine-grained picture of science and innovation in Brazil is inevitably diverse, this report argues that is helpful to think of Brazil as a 'natural knowledge-economy'. By this we mean that its innovation system is in large part built upon its natural and environmental resources, endowments and assets. We are used to thinking of knowledge economies and natural resource economies as being at two ends of a continuum of economic development. In reality the distinction is fuzzy, since all economies are based on a mix of knowledge and natural asssets of some kind. Yet we tend to regard a comparative advantage based on natural resources as indicative of an economy at a relatively immature stage in its development, one that must be outgrown if it is to reach and start expanding the frontiers of technological possibility.

The Brazilian case, we suggest, challenges this linear view. The alternative trajectory it offers is one in which growing scientific and technological capability is not separate from, or in opposition to, natural resources and endowments, but integrally linked to them. From oil and hydropower to biofuels and agriculture, from biodiversity development to the climate change properties of the Amazon rainforest, Brazilian innovation is at its best when applying the ingenuity of its people to its natural assets.

The report builds on the first phase of the *Atlas of Ideas* project, which included studies of developments in China, India and South Korea.[3] As with those earlier reports, the focus here is on the *scientific and technological* dimensions of innovation, rather than a comprehensive effort to address all aspects of Brazil's innovation system. Of course, there is much more to innovation than simply science and technology (S&T),[4] and there are clearly links between progress in S&T

and wider developments in Brazil's education system and its capabilities for creativity, invention and entrepreneurship. Where helpful, we have highlighted these linkages and suggested areas for further research, but for reasons of manageability our detailed analysis is restricted to S&T.

The structure of the report is as follows. Chapter 1 is an attempt at *mapping* the inputs and outputs of science and innovation in Brazil, while unpicking some of the trends and policy choices which explain these patterns. Chapter 2 looks at the *people* behind Brazilian science and innovation and examines progress in developing human capital. Chapter 3 turns to the *places* where science and innovation happens in Brazil: both the established hotspots and 'rising stars' that deserve our attention. Chapter 4 focuses on the *business* of R&D, revealing where research and development efforts are concentrated in the private sector, and assessing the environment for entrepreneurship. In Chapter 5, we explore how Brazil's *culture* is an important source of innovative potential. Chapters 6 identifies new alliances and barriers to scientific collaboration. And the final chapter assesses overall strengths and weaknesses, and offers a *prognosis* for Brazil's future as a 'natural knowledge-economy'.

A note on methods

This study was conducted by Demos in collaboration with the Centre for Strategic Studies and Management (CGEE) in Brazil. It is based on a review of relevant literature and web sources, supplemented by over 100 interviews with policy makers, entrepreneurs, scientists and economists in seven Brazilian cities: Brasília, Curitiba, Florianópolis, Manaus, Recife, Rio de Janeiro and São Paulo. The interviews took place on two field trips between November 2007 and March 2008. A list of the organisations interviewed is available in Appendix 1.

1 Mapping

People used to say that Brazil is the country of the future. I wouldn't say that the future has arrived, but the future is arriving, and fast.[5]

When the Austrian novelist Stefan Zweig wrote *Brazil: the Country of the Future* in the 1930s, he probably had no idea that the book would be transformed in the popular imagination from a promise to a curse. *Brazil is the country of the future* wrote Zweig – *and it always will be* add the cynics.

As Brazil has risen in prominence on the global stage, some of that cynicism has begun to recede. There's a conviction amongst Brazilian policy makers, scientists and business leaders alike that its story in global innovation is only just beginning. This is not breathless enthusiasm or self-publicising hype. It is a cautious, modest optimism, often tinged with a note of regret that the country didn't get here sooner. And as the optimism begins to displace the cynicism of an earlier time, Zweig's maxim is being reclaimed. Rather than a eulogy to unfulfilled potential, it is coming to symbolise rising expectations of what Brazil can achieve.

To glean a few insights into what that future might hold, this chapter maps the current state of Brazil's science and innovation system, describes how it works, who are the key players and areas of strength and weakness. It examines the trends that have brought Brazil to this point, and explores some of the key sectors and industries that will shape its future direction. We begin by examining the macroeconomic environment for science and innovation that has emerged in recent years.

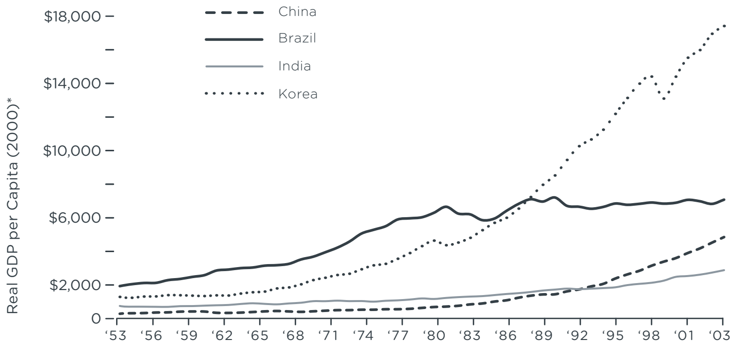
A new era of economic predictability

The introduction of the *Real* during the government of President Fernando Henrique Cardoso in 1994 contributed to the end of a decade of crippling high inflation and economic crisis in Brazil. Despite fears that Workers Party President Luis Inacio 'Lula' da Silva would retreat from the global economy when he was elected in 2002, he has instead managed to entrench stability.[6] In 2008, Brazil, a former debt defaulter, was awarded an 'investment grade' rating of creditworthiness for the first time. This is likely to strengthen the already dramatic increases in foreign direct investment (FDI) the country has received over the past five years. Explosive growth in China and India is further fuelling Brazil's economy through increased demand for commodities, from iron ore to soy beans.

In 2003 Goldman Sachs grouped these three countries, along with Russia, into an elite club it termed the 'BRICs' (the initials of Brazil, Russia, India and China). However, based on economic growth rates, some questioned whether Brazil really belonged in such exalted company. Compared to India's GDP growth of 8.7 per cent in 2007, and China's of 11.9 per cent,[7] Brazil's GDP rate of 4.6 per cent is more modest (although it is more than double the 2 per cent average of the 1980s).[8] The reality is that Brazil's slower growth is largely down to the fact that it is already more developed and urban than China and India. Figure 1 shows Brazil's economic boom happened much earlier than that of China and India.

Although there may not be as much untempered excitement about Brazil's growth as that of its BRIC cousins, growth is now steady and democracy is stable. Compared to the high inflation days when the only sensible thing to do with your money in Brazil was spend it as fast as possible, investment in the long-term and often risky process of innovation and research is starting to make sense. A summary of economic and social data can be seen in Table 1.

Figure 1 **Economic growth in Brazil and selected comparison countries, 1953–2003**



Source: Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.[9] *GDP per capita at constant prices (chain series) and purchasing power parity (PPP).

Table 1 **Summary of economic and social data in Brazil**

	Figure	Year	Source
GDP growth (%)	4.6 average annual growth	2006-2010 (projected)	World Bank[10]
Foreign Direct Investment (FDI) (net inflows BoP current US$)	US$33.4 billion US$72.7 billion	2006 2007	Central Bank and IBGE[11]
GNI per capita US$PPP	8,700	2006	World Bank[12]
Population	187 million (85% urban)	2007	IBGE[13]
% pop. living below the poverty line	22	Latest yr available 2000–2006	World Bank[14]
Internet users (per 1,000)	156	2005	World Bank[15]
Mobile phone subscribers (per 1,000)	462	2005	World Bank[16]
% of households with a TV	93	2005	PNAD[17]
Literacy rate (% pop. aged 15+)	89	2005	World Bank[18]

Science and innovation in Brazil: a brief history

As the story of Santos Dumont in the last chapter shows, excellence in Brazilian science and innovation is not only a recent phenomenon. Yet in comparison to some of Brazil's peers, it is *relatively* recent. Unlike China and India, Brazilian science and technology does not have ancient roots. Before European settlement, Brazil's Indian tribes were primarily nomadic and had not erected the great civilisations that emerged in other parts of South America.[19]

Colonial rule left a thin legacy in terms of education and schooling. Literacy only began to exceed 30 per cent after 1925. A comparison with Finland is instructive. In the mid-1890s, the ratio of students in school to the population aged 5 to 19 has been estimated at 0.08 in Brazil and 0.12 in Finland – in other words, in both countries there were about nine children out of school for every one in school. But by about 1920, this ratio had almost trebled to 0.29 in Finland, while it increased only slightly to 0.10 in Brazil. By the 1940s, the ratio had reached 0.53 in Finland and only 0.22 in Brazil.[20]

The slow development of basic education was matched in higher education. While Spanish colonisers set up universities in other Latin American countries as early as the 16th century, in Brazil the Portuguese were less interested in such long-term investments. A formal university system did not emerge until the 1930s, although some engineering and medical schools – like the Butantan Institute in São Paulo or the Oswaldo Cruz Institute in Rio de Janeiro – were founded in the early 20th century.[21]

The systematic national funding of science began in 1951 with the creation of two national agencies, the National Research Council, CNPq – now called the National Council for Scientific and Technological Development – and CAPES, which was given the responsibility for postgraduate education. The system was consolidated in the late 1960s, 70s and 80s in the period of military rule (despite significant conflicts between the government and the scientific community) with the inauguration of FINEP, Brazil's innovation agency, and the creation of FUNTEC, later FNDCT, the Brazilian national fund for science and technology.

Timeline of key science and innovation milestones

1951	**CNPq** — The National Council for Scientific and Technological Development – A federal agency dedicated to the promotion of scientific and technological research and to the formation of human resources for research in the country
1951	**CAPES** — Coordenação de Aperfeiçaomento de Pessoal de Nivel Superior - Division of the Ministry of Education that manages Masters and Doctoral level academic standards and support. Manages international partnerships between Brazil and foreign universities
1962	**FAPESP** — the State of São Paulo Funding Agency inaugurated in 1962
1971	**FINEP** — Financiadora de Estudos e Projetos - Founded 1967, this is the Agency for Research and Projects Financing, also known as the Brazilian Innovation Agency. Since 1971 it is the Executive Secretary for the National Fund for Science and Technology (FNDCT)
1985	**MCT** — Ministry of Science and Technology founded 1985
1988	**1988 Constitution** — legislates that each state should create its own science funding agency along the lines of that of São Paulo – hence the birth of the other FAPs
1998	**Sectoral Funds** — Creation of the first sectoral fund (Petroleum) in 1998 designed to focus sector specific research collaborations between enterprise, universities and research institutions. (By 2008 there were 16 sectoral funds)
2004	**The Innovation Law** — 2004

The modern Brazilian innovation system

1 Key actors

CNPq, CAPES and FINEP remain key actors in Brazilian science and innovation. They work under the auspices of the Ministry of Science and Technology, which coordinates national science and technology policy, although several other ministries coordinate science budgets, most notably the Ministry of Agriculture and its research arm, EMBRAPA. The states also play a significant role in science and technology funding in many places. The 1988 constitution set out the requirement for a science funding agency in every state, following the path setting example of São Paulo in 1962. The State of São Paulo research foundation (FAPESP) remains a key player, with a budget comparable to that of CNPq. A National Science and Technology Council is designed to oversee the relationships between the different organisations.

2 Policy and governance

In the last ten years, a number of policies and regulations have been put in place to strengthen Brazil's science and innovation potential, particularly by linking up actors in the innovation system and stimulating private sector investment. These include the:

Innovation Law ( ): This is designed to strengthen the university–industry research relationship, promote shared use of science and technology infrastructure by research institutions and firms, allow direct government grants for innovation in firms and increase the mobility of researchers within the system.

Good Law ( ): As well as providing fiscal incentives for private R&D investment, this provides funding for firms who hire employees with Masters degrees and PhDs. The subsidy can reach up to 60 per cent of the salary in the North East and Amazon regions and 40 per cent in the rest of the country for up to three years.

Programme of Accelerated Growth in Science, Technology and Innovation (PAC da Ciência) (November): This national action plan for science and technology, part of the wider PAC growth programme, sets out a R$41 billion (US$20 billion) programme of investment until 2010 and a target of raising the percentage of GDP invested in R&D from 1 per cent to 1.5 per cent by 2010. It entails expansion and consolidation of the national innovation system, promotion of industrial technologies, strategic priorities for R&D, and S&T for development and social inclusion.

Productive Development Policy (PDP) (May): This new industrial policy includes spending targets and tax breaks for key sectors like IT, biotechnology and energy as well as ambitious plans to increase international trade from 1.18 per cent in 2007 to 1.25 per cent by 2010, and in particular high tech exports (see Table 2). Targets include boosting the number of micro and small businesses that export goods and services by more than 10 per cent by 2010.

Table 2 **Composition of country exports by technological intensity, 2005 (%)**

	Chile	Argentina	Brazil	EU-25	Japan	USA
High technological intensity	5.6	9.2	12.8	30.6	31.6	37.6
Medium technological intensity	1.9	12.5	20.7	20.7	45.5	29.4
Low technological intensity	2.2	3.4	9.8	6.9	9.6	4.2
Labour and natural resource intensive products	3.5	5.3	9.5	10.8	3.5	6.7
Primary products	81.5	50.8	40.4	8.1	2.8	11.8
Unclassified	5.4	18.8	6.9	11.4	7	10.4

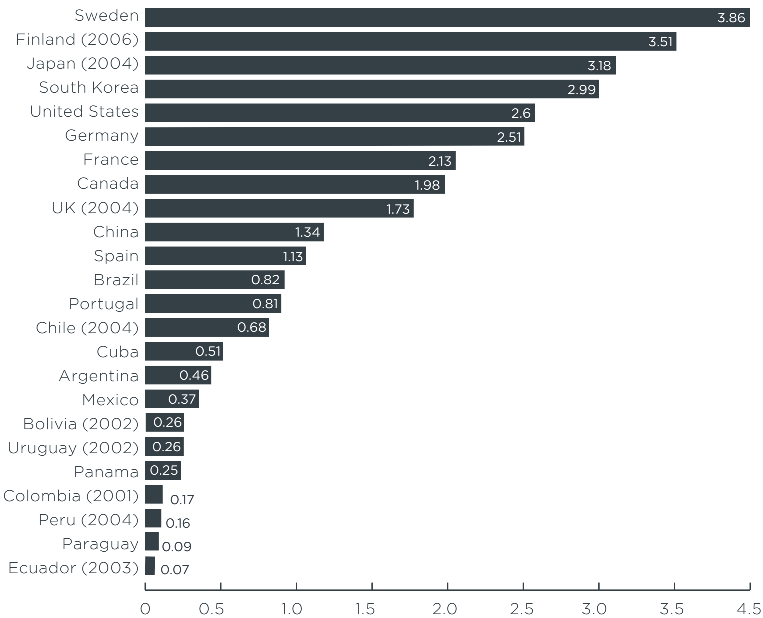
Source: Presentation to CGEE by Mariano Laplane, University of Campinas, 2007.

Key inputs to the science and innovation system

Human capital

The talent pool for science and innovation has greatly expanded over the last 20 years. However, Brazil's stock of tertiary educated people is still only equivalent to that of France or the UK, despite having a population three times the size of those countries. Chapter 3 explores the issue of Brazil's human capital in some detail.

Figure 2 **R&D intensity, Brazil and selected OECD and Latin American comparison countries, 2005**



R&D Expenditure as % of GDP, 2005 unless otherwise stated

Sources: Network on Science and Technology Indicators (RICYT). National Science Foundation, National Science and Engineering Indicators 2008.[23]

Funding

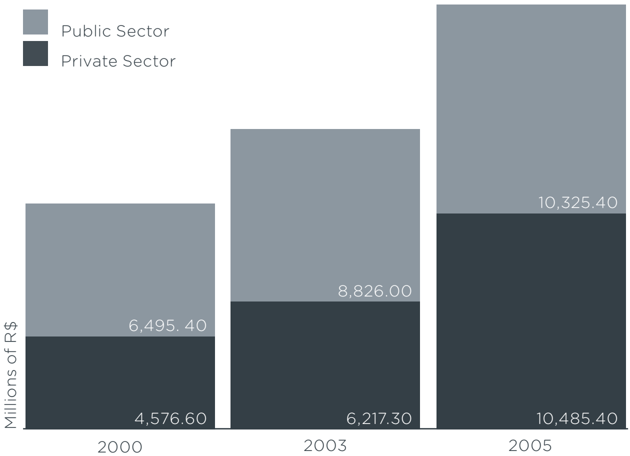
Brazil has invested around 1 per cent of its GDP in R&D for the last five years, with minor fluctuations. Although this is a small proportion compared to the OECD global average (2.2 per cent), Brazil is the unquestionable leader in Latin America (see Figure 2). As one economist said to us: *e federal budget is very decent for a country like Brazil. is is remarkable when you consider that to years ago there was almost no infrastructure for scientific research.*[22]

The public sector has historically been the dominant source of funding for science and technology,[24] although the share of private sector investment has been rising and the balance is now approximately 50-50 (see Figure 3). In November 2007, Science Minister Sergio Rezende launched the National Action Plan for Science and Technology 2007–2010. This aims to raise spending on R&D to 1.5 per cent of GDP by 2010. Just under half the money will come from the Ministry of Science and the national science fund (FNDCT), while the rest will be drawn from other ministries and the Brazilian development bank. After 2010 there is a commitment to maintain spending at GB£4.5 billion a year, more than double what was spent in 2006. This ambitious plan entails a 'step-change' in private investment in science from 0.5 per cent to 0.65 per cent of GDP; Brazilian companies will have to outlay an extra US$3.4 billion by 2010.[25] This marks the continuation of a trend in increasing science spending since 2000 as shown in Figure 3.[26]

State vs federal funding

Brazil is a Federal Republic with 27 states divided into five regions: North, North East, Centre West, South East and South. Although federal sources account for most science funding, state-funded programmes play a significant role in some states, contributing over a third of public investment in science and innovation.[32] In São Paulo, the wealthiest state, which contributes almost 40 per cent of Brazil's GDP, the state contribution accounts for a high proportion of public spending in addition to the federal science budget.[33]

Figure 3 **Public and private sector spending on R&D, 2000–2005**



Source: Ministry of Science and Technology
(Indicadores nacionais de ciência e tecnologia).[27]

Table 3 **Summary of key science and innovation inputs**

	Figure	Year	Source
Investment in R&D (% GDP)	0.97% (0.51% private)	2005	OECD[28]
Annual investment in R&D	US$ 13 billion ppp	2005	OECD[29]
Annual human capital production	UG – 626,617 M – 32,370 PhD – 9,336	2006	ASCAV/SEXEC Ministerio da Ciencia e Tecnologia[30]
Researchers per 1,000 people in the labour force	0.92	2004 (up from 0.79 in 2001)	RICYT[31]

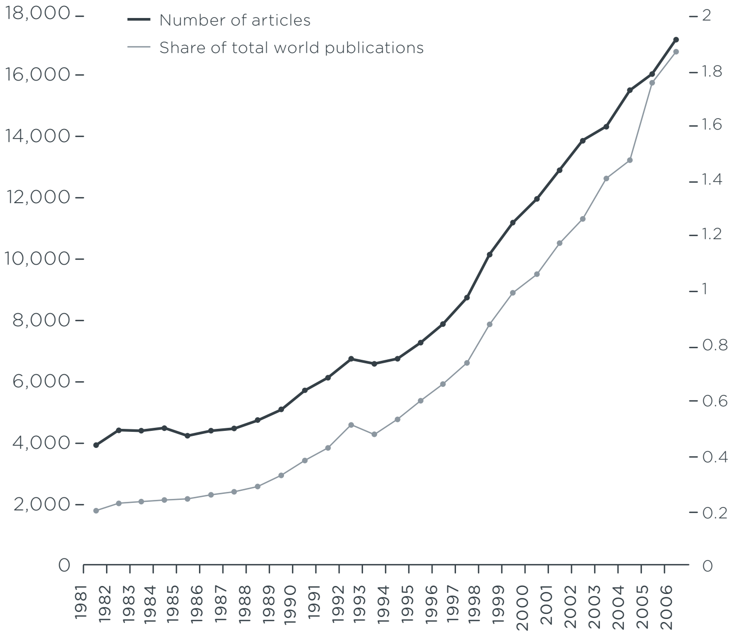
The most recent government action plan for science and technology highlights 11 areas for strategic investment: biotechnology and nanotechnology; ICT; health; biofuels; energy (electrical, hydrogen and renewables); oil, gas and minerals; agri-science; biodiversity; the Amazon; climate change;and space, nuclear and defence. Since 1999, there has been a policy shift from funding purely academic research to public–private collaboration and industrial R&D. The policy with arguably the greatest impact on the current state of Brazilian R&D is the creation of the Sectoral Funds. First established in 1998, there are now 16 Sectoral Funds in strategic areas such as energy, telecoms and IT. They direct a fraction of the taxation of key industries to R&D projects selected by public committee.[34] The funds not only intensified the R&D activities of former state-owned companies after privatisation, but have also redistributed resources for R&D throughout Brazil. At least one-third of each Sectoral Fund must be spent in the less-developed North, North East and Central West of the country. Approximately two-thirds of these funds are used for joint ventures between the public and private sector. While they have contributed an estimated R$1.1 billion (US$690 million) a year to the FNDCT science fund between 2000 and 2005, it is important to note that the 'contingency' required by the government has in the past significantly detracted from the amount of earmarked Sectoral Fund money that can actually be spent. With increased economic stability, this contingency is decreasing all the time.

Key outputs from the science and innovation system

Publications

One way to measure Brazil's progress in science and innovation is to look at bibliometrics: the analysis of scientific publications and citations. According to the Thompson ISI database, Brazil is the 15th largest producer of scientific publications in the world.[35] It rose from 23rd place in 1999, growing at around 8 per cent per year (see Figure 4), dramatically outstripping other Latin American countries and overtaking countries with significant science bases such as Belgium and Israel in the process.[36]

Figure 4 **Brazilian SCIE-indexed publications, total and share of world output, 1981–2006**



Source: ISI Science Citation Index Expanded.[37]

And this doesn't show the whole picture, as there are a number of other databases not included in this figure. One of the most interesting is SciELO (Scientific Electronic Library Online).[38] This open access science resource was created in 1997, and is maintained by FAPESP and the Latin American & Caribbean Health Sciences Information Centre (BIREME). Over 37,000 articles are freely available to download in Portuguese, Spanish and English; Brazil accounts for 69 per cent of articles.[39]

We can get an idea about where Brazil's strengths lie by looking at the areas of science that produce the most publications. The largest concentrations of publications are in agriculture, biology and earth and space sciences – a clustering that some analysts have called a 'bioenvironmental model', also found elsewhere in Latin America.[40] It is worth noting that biomedical sciences and biotechnology tend to produce more publications the world over, so the high number of publications in these fields is not by itself surprising. However, the relative weight of agricultural science is three times higher, and of biology 2.6 times higher, in Brazil's publications than the average for the world as a whole, underlining Brazil's comparative advantages in these 'natural knowledge-economy' areas. That said, there are also a number of high impact contributions (as measured by the number of times subsequent articles have cited these publications) in neurosciences, cardiovascular surgery, and human genetics and genetic sequencing.[41]

Eighty per cent of research projects are developed in public universities and research institutes.[42] The production of scientific publications is not evenly distributed throughout the country, and there is a strong concentration in the South East region. The University of São Paulo accounts for almost a quarter of Brazil's scientific publications alone.[43]

Patents

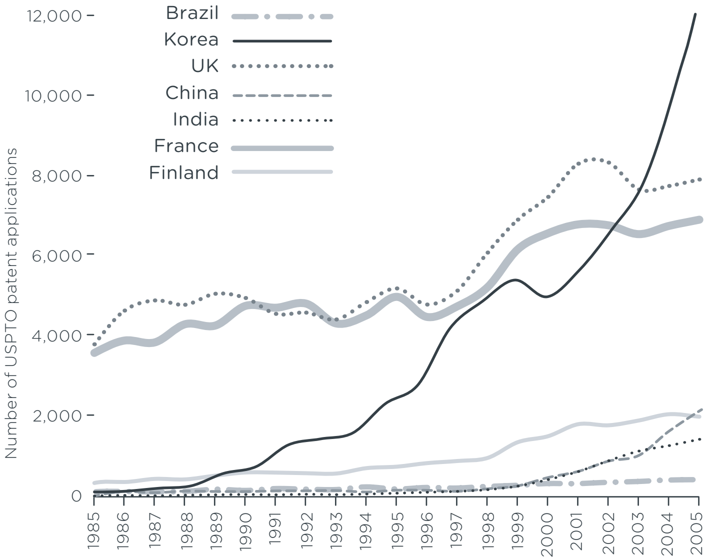
Another key output of the science and innovation system is patents. The rise in patents has failed to keep pace with the rise in publications, pointing to potential weaknesses in the commercialisation of knowledge. In 2005, Brazil accounted for about 1.8 per cent of SCIE-indexed publications but only 0.08 per cent of USPTO patent applications. Brazilian patenting activity trebled between 1985 and 2005, a faster rate of growth than its Latin American neighbours, Mexico and Argentina. But its competitors in other regions have been growing much faster. The starkest illustration of this is South Korea: in 1985, the number of Brazilian applications to the USPTO was 60 per cent of the Korean total; by 2005, it was just 2 per cent. In 1985, Brazil had almost twice as many USPTO patent applications as Singapore and India combined. By 2005, Singapore was producing more than three times as many as Brazil, and India almost five times as many. As late as 1997, Brazil was producing more USPTO patent applications than China. Yet, as Figure 5 shows, less than 10 years later China was producing seven times as many.

Table 4 **Top 25 most prolific Brazilian research institutions, 1991–2003**

Institution	% Share of publications	Rank
Univ. São Paulo	23.89	1
Campinas State Univ.	9.69	2
Fed. Univ. Rio Janeiro	9.28	3
State University São Paulo	6.34	4
Fed. Univ. Rio Grande do Sul	5.47	5
Fed. Univ. Minas Gerais	5.19	6
Fed. Univ. São Paulo	3.54	7
Braz. Agr. Res. Corp.	3.01	8
Fed. Univ. São Carlos	2.88	9
Oswaldo Cruz Fdn.	2.77	10
Fed. Univ. Santa Catarina	2.35	11
Fed. Univ. Pernambuco	2.34	12
Fed. Univ. Paraná	2.11	13
Fed. Univ. Fluminense	2.07	14
Univ. Brasilia	2.03	15
State Univ. Rio Janeiro	1.94	16
Braz. Centre Res. Phys.	1.78	17
Cath. Univ. Rio Janeiro	1.6	18
Fed. Univ. Vicosa	1.56	19
Fed. Univ. Céara	1.48	20
Natl. Inst. For Space Res	1.45	21
Natl. Com. Nuclear Energy	1.28	22
Fed. Univ. Paraiba	1.2	23
Fed. Univ. Bahia	1.19	24
State Univ. Maringa	1.11	25

Source: 'Science in Brazil', Scientometrics.[44]

Figure 5 **Trend in USPTO patent applications, Brazil and selected comparison countries, 1985–2005**



Source: OECD Compendium of Patent Statistics 2007.[45]

Table 5 **Summary of key science and innovation outputs**

	Figure	Year	Source
Number of SCIE indexed scientific publications	18,765 (1.6% global production)	2005	RIYCT[46]
Growth in number of SCIE indexed publications	587%	1985-2005	Glanzel, W. et al[47]
Number of USPTO patent applications	295	2005	OECD Compendium of Patent Statistics 2007
Growth in number of USPTO patent applications	278%	1985-2005	OECD Compendium of Patent Statistics 2007

Mapping the frontiers: portraits of science

Having reviewed the overall character of the Brazilian science and innovation system, it is helpful to examine some of its frontier fields in more detail.

Biofuels

As discussed earlier, a great deal of political and scientific debate now surrounds the development of biofuels. The Centre for Strategic Management and Studies (CGEE), which has just completed a major study on the future of ethanol in Brazil, estimates that in the past 30 years, US$207 million has so far been invested in biofuels research in Brazil. In the most recent national industrial policy (published in May 2008) the government pledged to raise bioethanol production to 23.3 billion litres by 2010.[48] Apart from the size of its production, Brazil is set apart from other biofuel producing countries by its use of sugar cane to produce ethanol, and for the sugar cane biotechnology required. In 2003, Brazilian scientists completed the identification of 40,000 sugar cane genes. Compared to US bioethanol, produced from corn, sugar cane ethanol has an energy balance up to five times higher.[49] Brazil has a more recent history in biodiesel than ethanol. The first national programme on biodiesel production and usage, PNPB, was launched in 2005; 2 per cent of petrol-based diesel must be replaced by animal or plant biodiesel, rising to 5 per cent by 2013.[50]

How sustainable are biofuels? The social and environmental dilemmas raised by biofuels are manifold. It will be disastrous if crops end up being grown to fuel the cars of the rich while the poor starve, as some campaigners are suggesting. At the same time this is a complex situation, and one in which the debate is often oversimplified, neglecting other political and trade reasons for food insecurity.

In some situations, subsidies for biofuel production could impact on food availability. Yet globally, only 1 per cent of arable land is used now for biofuel production, with a prospective coverage of 3 or 4 per cent by 2030. In Brazil, sugar cane for bioethanol is produced on only 5 per cent of the country's cultivated land.[51] Twenty billion litres of bioethanol are produced from 3.5 million hectares. Based on the Brazilian experience, to achieve a blend of 10 per cent of bioethanol from sugar cane in the global gasoline consumption today, less than 25 million hectares of land would be required. But not all biofuels cultivation will be based on the Brazilian model. There are also additional environmental concerns relating to water and fertilizer use.

Cultivating its leadership position in biofuels, particularly the advisory role it is assuming in the developing world, brings huge responsibility for Brazil. It needs to ensure that the biofuels industry can be truly sustainable, and lead by example in the way it balances competing priorities.

Stopclock on science: There is a point at which current biofuel production cannot be increased without threatening biodiversity and land availability for food production. This is why people are so interested in 'second generation biofuels' – those that can produce more fuel without increasing the area of land or using food crops. There are two main scientific challenges in the case of ethanol. First, reducing the requirement of land area, nitrogen fertilizer and water. Second, finding ways of using the entire plant including the cellulose and lignin – which are waste products under current production methods – to produce fuel. In addition there is research under way in several countries to find new sources of biofuel such as algae – often referred to as 'third generation'.

Meeting these challenges is likely to require a mix of genetic improvement and genetic engineering, as well as advancements in hydrolysis (a chemical reaction that involves water to break down a compound). Brazil is sometimes mistakenly thought to be focusing only on improving the efficiency of first generation biofuels, when it also boasts a considerable body of research and a strong cluster of cutting-edge research expertise in São Paulo and Rio de Janeiro states. Key institutions include the Universities of São Paulo (USP), Campinas (Unicamp) and the State of São Paulo

(UNESP), the Agronomics Institute of Campinas, Embrapa and the sugar cane technology centre (CTC), which in 2008 announced the opening of a pilot plant for ‘bagasse’, the cellulose waste product of ethanol production from sugar cane. The FAPESP programme, SUCEST, involving a network of 50 laboratories has been active since 1999, and is to date the world’s largest initiative on sugar cane genomics in the world. In the private sector, Petrobras spend 5 per cent of their US$1 billion R&D budget on biofuels research.

In addition to FAPESP’s BIOEN initiative, a major public-private partnership research programme on bioenergy involving almost one hundred São Paulo scientists and the world’s largest manufacturer of ethanol mills, other recent developments include the planned inauguration in August 2008 of the Centre for Bioethanol Science and Technology (*Centro de Ciência e Tecnologia do Bioetanol – CTBE*). The Centre will be co-located with the National Synchrotron Light Laboratory in Campinas (São Paulo state), which, in addition to its light source, houses a structural molecular biology lab and a nanotechnology centre. With an initial research budget of R$130 million (US$80 million), the centre’s studies will range from finding new ways to produce ethanol to basic research on nano and biotechnology. The centre is designed as a national hub for capacity building, to speed up sustainable solutions to biofuels production.

Biodiversity research

Despite the advances of synthetic chemistry, scientists continue to be excited by micro-organisms and plants as a source for new drugs. Brazil’s incredible store of biodiversity comprises nearly one-fourth of all the plants, animals and micro-organisms found in natural habitats over the world. Several programs and projects for the use of biodiversity components have been put in place in the last two decades, led by federal or state agencies. In 1994 the Brazilian government created the National Programme for Biological Diversity, Pronabio,[52] which in turn led to the development of state programmes such as FAPESP’s Biota.[53] INPA, the National Research Institute of the Amazon, has also been cataloguing biodiversity for decades.

The Centre for Strategic Management and Studies (CGEE) was recently appointed by the Ministry of Science and Technology to supply technical and organizational guidance to support the creation of innovation networks based on Amazonian biodiversity in the area of cosmetics, phyto-pharmaceuticals and non-alcoholic beverages. Yet establishing a legal framework for the successful commercialisation of these products has been fraught with difficulty, putting strain on international collaboration as we explore in chapter 7.

Nanotechnology

Concerted government support for nanotechnology in Brazil began in 2001 with the creation of four national nanotechnology and nanoscience networks that today link almost 40 research institutes across Brazil. A recent study by COCEX-CNPq identifies more than 2,200 members of these nanotechnology networks. The focus of much of this research is materials, devices (including electronics and optics) and nanobiotechnology.[54] By 2004 Brazilian efforts in nanoscience and nanotechnology were classified as 'Middle Ground' amongst developing countries.[55] A 2006 Nature article placed Brazil 20th out of 33 countries in nanoscience publications production between 1999 and 2004. In the last four years, there has been strong support from MCT, MEC and the State Foundations for this area of research.[56]

Table 6 illustrates MCT investments in nanotechnology from 2001 to 2007. The leap in 2005 reflects the considerable investment by strategic and regional laboratories (LNLS, INMETRO and EMBAPA CBPF), totalling close to US $32 million. In 2008 Petrobras set up its own nanotechnology network, which is likely to have a positive effect.[57]

The main sectors to benefit from nano research in Brazil are aerospace, materials manufacturing, catalysis, chemicals, textiles, pharmaceuticals and cosmetics. However, the physical, legal and political infrastructure for nanoscience and technology is still quite new, and there remain concerns that it will be some time before nano has widespread industrial applications.

Table 6

Brazilian government investment in nanotechnology research, 2001–2006

Funding Action	Budget
Nanotechnology networks 2001-2003	R$3 million
Millennium Institutes 2001-2004	R$22.5 million
Nanotechnology networks 2003-2004	R$5 million
Sectoral funds 2003-2005	R$6.7 millon
Development of Nanoscience and Nanotechnology Programme (PPA 2004-7)	R$8.4 million
Sectoral funds 2004-2006	R$9.1 million
RHAE Innovation 2004-2006	R$7.1 millon
National Nanotechnology Programme 2005-2009	R$58.6 million
Millennium Institutes and microelectronics call 2005-2008	R$21.5 million
National Nanotechnology Programme call 2006	R$28.4 million
Total 2001-2006	**R$170.2 million (US$ 105 million)**

Source: NanoforumEULA.[58]

Stem cell research – firm foundations

In 2003, collaboration between the Federal University of Rio de Janeiro and the University of Texas found that stem cells could be useful in treating end-stage heart failure. It was a considerable milestone for stem cells, and although the Brazilian end of the partnership had mainly been focused on clinical trials, it caught the imagination of the government, and alerted them to the potential of stem cells in Brazil.[59] In 2004, the Brazilian government launched a US$4.3 million network programme to fund research into the use of stem cells to treat heart disease, and there is now a significant stem cell programme in cardiology.[60] Dr Professor José Krieger, who runs a prolific research group at Incor, a heart research hospital with over 3000 beds in São Paulo, is receiving so much interest in his stem cell work that a Singaporean government institution recently called him up to offer him a grant. 'Funding is reasonable here,' he said, 'but that just doesn't happen – and it wasn't even in my area of expertise! It shows we are on the radar.'

And this expertise is now extending beyond cardiology. In 2007, Brazilian scientists at the University of São Paulo, working in partnership with a US team, held the first successful trial of a stem cell therapy cure for diabetes.

While adult stem cell research is advancing at a considerable pace, there has been controversy regarding embryonic stem cell research since the 'Biosafety Law', which was principally concerned with genetically modified crops, permitted embryonic stem cell research in 2005. The attorney general took the health ministry to appeal on the decision, claiming the ruling was unconstitutional and an infringement of the right to life. But in May 2008 that appeal was overturned and the Supreme Court ruled in favour of embryonic stem cell research. How quickly this field develops in Brazil now remains to be seen.

2 People

The smoke from Professor Bertha Becker's cigarette drifts lazily across the breathtaking view of Copacabana beach from her apartment. In her zebra print dress and matching sandals, she looks every bit the retired academic. But a huge pile of papers and books on the table behind her tell a different story. Bertha is hard at work preparing a report for Roberto Mangabeira Unger, Long Term Planning Minister, on the future development of the Amazon region. Having worked in this complex area of research and policy for many years, Bertha now calls herself an 'autodidact'. Her academic career grew with the system. When she graduated in the early 1950s, Brazilian higher education was still in its adolescence. When she did her doctoral studies in 1970 she was amongst only a handful of peers. Like many of her contemporaries, she did her post-doctoral work overseas, at MIT, in the 1980s but returned after her studies to become a professor. The university system in which she now works is unrecognisable from the one she left a few decades ago. Next year it will graduate over 10,000 PhD students and 30,000 Masters students.

This chapter is about human capital in Brazil. In it, we assess the critical importance to the innovation system of the increase in highly skilled people over the last 30 years. But as well as mapping the trends among the highly educated elite, the chapter examines efforts to unlock the potential of all Brazil's people. As a natural knowledge-economy, Brazil recognises the need to broaden its understanding of a 'national innovation system' to one which truly encompasses the whole nation.

Critical mass, not en masse

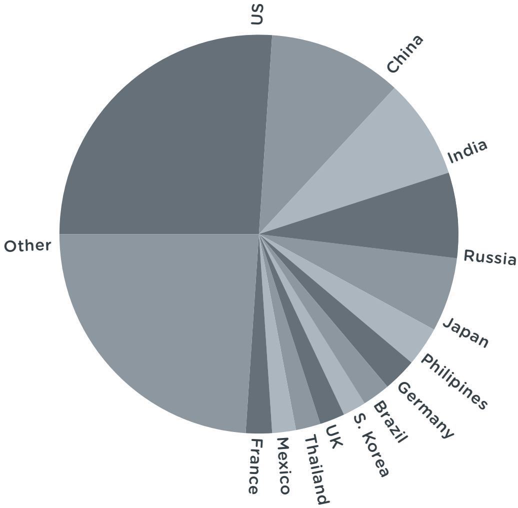
As we saw in the mapping chapter, Brazil's higher education system got off to a slow start thanks to historical circumstances.[61] Yet there has been a transformation over the last two decades. The number of PhD and Masters students produced today in Brazil is ten times as many as 20 years ago. Compared to 1960, when only one postgraduate course was available, there were over 1900 Masters courses available in 2004 and 988 PhD courses.[62] The number of PhDs in science has grown by over 12 per cent every year for the last decade.[63]

Brazilian higher education has expanded dramatically in the last two decades. In 2004, Brazilian universities enrolled over 4 million students. The federal government maintains 44 universities (at least one in each of Brazil's 27 states, but up to 11 in more developed states such as Minas Gerais) and 39 Centres for Technical Education. There are 2165 universities in Brazil – yet 89 per cent of them are private and not usually oriented towards technical courses.[64] Private higher education has seen enormous expansion over the last decade, with enrolments in this sector rising 50 per cent in São Paulo and 84 per cent in Brazil as a whole from 1998 to 2002.[65]

Graduate programmes are stringently assessed by the organisation in the Ministry of Education that coordinates postgraduate education – CAPES[66] – and at least two thirds of courses are rated as 'international standard'. However, the quality of undergraduate education is more variable.

Despite being one of the world's largest countries in geographical terms, Brazil's comparative advantage in science does not lie in sheer weight of numbers. Its 190 million population is overshadowed by that of India and China. In fact, as Figure 6 shows, Brazil has a comparable number of tertiary educated people to Britain or France.[67]

Figure 6 **Tertiary-educated population aged 15 and over, Brazil and selected comparison countries, 2000**



Source: US National Science Foundation Science and Engineering Indicators 2008.[68]

Paulo Figueiredo, a professor at the Fundação Getúlio Vargas in Rio de Janeiro, the oldest Public and Business Administration School in Brazil, is currently working with colleagues to model human capital supplies. They are looking not just at increases in numbers, but also suitability for the Brazilian system. There is a clear pattern in the supply and demand relationship emerging; one that is very different to Asian economies.

Asian countries are very good at high volume, high scale production, Brazil just can't compete with that. So we need a di erent vision. Our vision for is one of high end research in natural resource industries such as biotechnology, biofuels, food processing and steel – a very sophisticated model of R&D for natural resources… We can't compete with Asia on micro-electronics – so we need to jump to a new technological paradigm.[69]

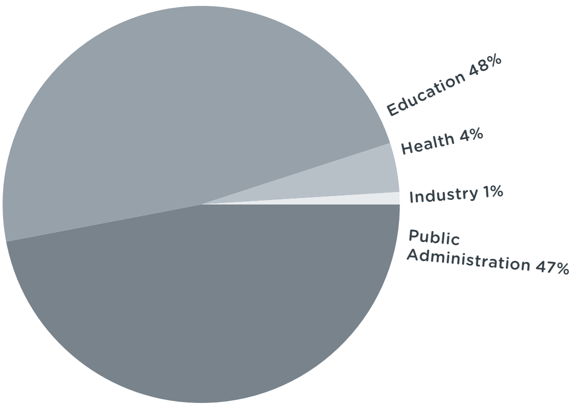
This will require a large supply of highly skilled technical manpower – of which there is still a significant shortage.[70] In order to optimise the impact of increasing supplies of human capital there are two challenges which Brazil must face.

The first is *absorbing* this human capital into the areas of the system where it can have most impact and attract the potential Brazilian scientific diaspora. The second is *deepening* the supply of human capital through continued emphasis on basic education and tackling inequality.

Absorbing graduates, attracting the diaspora

In most advanced scientific nations, the vast majority of R&D personnel work in the business sector. In Brazil, the vast majority of them work in higher education and public administration, as Figure 7 below shows.

Figure 7 **Sectoral distribution of doctorates in the Brazilian labour market**



Source: Viotti and Baessa 2008[71]

Brazil needs to change this balance and raise the number of scientists working in industry. There are considerable new subsidies available for companies who hire those with Masters and Doctorate qualifications, as discussed in the previous chapter, but no significant evidence yet to suggest changes to the hiring patterns of companies.

As well as absorbing new stocks of homegrown graduates, Brazil could be making more of its disaspora flows of graduates and entrepreneurs. The crucial role of the Indian and Chinese diaspora in their recent scientific, technological and entrepreneurial success is well documented.[72] India has a dedicated government ministry – the Ministry of Overseas Indians – to organise policy relating to remittances and investment flows. The Indus Entrepreneurs (TiE) is a diaspora entrepreneurship organisation founded by Indians in Silicon Valley that now has a global membership of 12,000 people, spread over 49 chapters in 11 countries. It has assisted the creation of businesses worth over US$200 billion. China has extensive policies to attract returnee scientists, known in Mandarin as 'sea turtles', including dedicated schemes and generous financial packages. But Brazil doesn't appear to use any of these sweeteners.

According to one recent study, every year between 140,000 and 160,000 Brazilians with degrees leave the country looking for professional opportunities elsewhere.[73] Yet brain drain is not yet a major concern. This is partly because a high proportion of Brazilians who study abroad return home after graduation. Funding patterns appear to be changing, with CAPES covering the costs of fewer overseas graduate students. Some suggest that this reduced funding will lessen the obligation on graduates to return. But this may not be such a bad thing, as long as they stay connected. Director of the molecular genetics and cardiology lab at INCOR, Dr José Krieger, himself a graduate of Stanford and Harvard, felt the diaspora had a mixed impact on Brazilian science: 'In some ways I wish more scientists would stay abroad longer – they are crucial collaborators for us.'

Some diaspora scientists have already been making waves in the Brazilian scientific academy. In January 2008, *Scientific American* reported the plans of Brazilian neuroscientist Miguel AL Nicolelis, based at Duke University, to build a 'proof-of-concept' neuroscience institute in Natal, in North Eastern Brazil – the hub of a cluster of neuroscience projects that will form a 'campus of the brain'.[74] By last August Nicolelis had already raised US$25 million for his non-profit foundation, including a considerable endowment from the widow of one of Brazil's biggest banking magnates, Edmond Safra. Nicolelis' long term plans involve the creation of a network of 'science cities' throughout Brazil's poorest regions, each with a different world-class specialism. The success of diaspora scientists almost always generates some kind of friction with local scientists, who feel, sometimes with justification, that their achievements are being overshadowed, but there are undoubtedly huge benefits to embracing the opportunities presented by the diaspora community.

Higher education indicators tell us an important story about the top of the tree. But while national and global elites represent an important part of the spectrum of science and technology in Brazil, the long-term foundations for future growth are reflected in the quality of basic education. Here, despite enormous improvement, there is still some way to go. The four million enrolments to higher education each year are just a fraction, around 10 per cent, of the potential student population aged 18 to 24 across Brazil. Deepening and widening access to quality education remains crucial.

Deepening

Brazil has made huge strides in ensuring universal provision of primary school education. Whereas a fifth of children aged between seven and ten were not enrolled in school in 1980, by 2002 that had fallen to 3 per cent.[75] Income of the poor has risen at 'Chinese rates' according to some analysts,[76] and massive social transfer programmes such as the *Bolsa Familia* seem to be proving successful.[77] Yet inequality remains stark. Just take the case of São Paulo: it is the city with the highest number of helicopters after New York, allowing highly-paid executives to dodge the rush hour traffic, while 1.7 million Paulistas still live in slums.

While Brazil's favelas have been made infamous by films like Mereilles and Lund's *City of God*, Brazil is not the only country with this problem of extreme inequality. According to recent estimates, both China and India have greater numbers of slum dwellers as a proportion of the population.[78] But inequality matters to science and innovation – and it affects Brazil particularly adversely. A recent report from the OECD compared the effect of inequality on performance in science education across a range of countries. While all countries displayed some degree of class bias, the study found that inequality contributed significantly to aggregate underperformance in Brazil. Brazil's per pupil spending on science education is comparatively high. But this investment is not producing the returns that it should because of inequalities in provision. If Brazil was as equal as the average OECD country, overall performance in science education would increase by over 30 points.[79] It is somewhat depressing to notice that despite the expansion of Brazil's education system and recent improvements, rates of inequality remain similar today to when Bertha Becker was a student.[80]

3 Places

You can't talk about Brazil as an innovation system.
You need to understand the di erences within.

José Cassiolato, Institute of Economics, Federal University of Rio de Janeiro

You don't expect to find a city in the middle of a jungle. Yet after flying over nothing but dense forest and rivers for hours, visitors to Manaus in Amazonia land in a cosmopolitan city of 1.6 million people. If you are not expecting civilisation, you certainly don't expect microelectronics, but Sony, LG and Samsung all have large plants in the city's successful free trade zone. In INPA, the National Amazon Research Centre, the city also boasts one of the country's top scientific insitutions.

Nonetheless, the scientific production *from* Amazonas cannot match the volume of scientific research produced internationally *about* the region. The Amazon basin is probably one of the most studied places in the world. And it can still yield surprises, as recent press reports of a previously undiscovered tribe living in the state of Acre near the Peruvian border in May 2008 bring home to us, even if it turned out the tribe had already been documented by experts.[81]

Brazil is still exploring the frontiers of its own territory even as it explores the frontiers of science. The fifth largest country in the world by geography. Brazil has seven and half thousand kilometres of coastline and borders ten countries. It is home to almost 190 million people who live mostly in the Atlantic coastal regions of the South Eastern and North Eastern States. The densely forested Northern region that contains the Amazon basin is one of five regions that include the arid scrubland of the North East, the mountains and plains of the Central West and South and the coastal strip of the South East.

Brazilian science and innovation is strongly concentrated in the South East of the country: in São Paulo, Rio de Janeiro and Minas Gerais. But change is afoot. The rich south of the country, where states like Paraná, Santa Catarina and Rio Grande do Sul offer some of the highest living standards in Brazil, is revealing its innovation promise. At the same time, one of the biggest projects of diffusion of national research and innovation funding in the world is under way. The map of human capital creation, for so long so concentrated in the South, is beginning to shift, while swathes of funding are being dedicated to 'underdeveloped regions' like the North and North East, where some striking clusters are emerging, not least in Manaus. This chapter explores these patterns and concentrations, highlighting existing hotspots for science and innovation and future 'rising stars'.

Source: Digital Vector Maps

The physical differences between regions are matched by profound social and economic differences, as Table 7 illustrates. The South East is not just more populous than the other regions: it is richer, more urbanized and better educated. By contrast, the North and North East regions are poorer and more rural, with per capita incomes approximately half of those in the South East. Poverty rates are also higher, with between one-quarter and one-third of households receiving social assistance, and illiteracy rates between two and four times as high.

Table 7 **Regional variation in socio-economic indicators**

	Total Population, 2006 (000s people)	GDP per capita, 2004 (R$)	Urbanization Rate, 2006 (%)	Illiteracy Rate, people 15+, 2006 (%)	Households benefiting from social assistance programs, 2006 (%)
North		6,500	75.6	31.6	37.6
North-East	15,080	4,927	71.4	45.5	29.4
Central-West	51,713	10,324	86.3	9.6	4.2
South-East	13,313	12,540	92	3.5	6.7
South	79,753	8326	82.9	2.8	11.8
BRAZIL	27,368	9,729	83.3	7	10.4

Source: IBGE.[82]

As well as the variation *between* regions, there is also a great deal of social and economic diversity *within* regions, as Table 8 shows. Although Brazil is linguistically homogenous, it is ethnically heterogeneous, a legacy of late 19th-century and early 20th-century migration from Europe, Japan and the Middle East, and before that of colonialism and the African slave trade.

Income and wealth in Brazil are unequally distributed. Brazil's Gini coefficient – a standard measure of inequality that takes values between 0 (perfect equality) and 1 (perfect inequality) – consistently ranks among the highest in the world, and as Table 8 shows there is relatively little variation in levels of inequality across Brazilian regions.

Table 8 **Regional variation in inequality and ethnic diversity**

	Income inequality Gini co-efficient 2005	Ethnic composition				Ethnic diversity Approximate ethnic fractionaliza-tion index[83]
		White	Black	Mixed	Asian/ Indig-enous	
North	0.509	0.239	0.062	0.692	0.007	0.460
North East	0.551	0.292	0.078	0.625	0.005	0.518
Central-West	0.564	0.430	0.057	0.505	0.008	0.557
South East	0.534	0.588	0.077	0.325	0.010	0.543
South	0.519	0.796	0.036	0.160	0.007	0.339
BRAZIL	**0.552**	**0.497**	**0.069**	**0.426**	**0.008**	**0.567**

Source: IBGE.[84]

Concentration and diffusion in S&I

These patterns of social and economic diversity within and between regions are reflected in the distribution of inputs to science and innovation and in the intensity of outputs. As Table 9 shows, the South East region attracts the lion's share of human and financial capital for science and innovation. It accounts for about half the total enrolment of students in higher education, a third of the total number of incubators, and about 70 per cent of government spending on S&T.

Table 9 **Regional variation in science and technology**

Region	**Innov-ative activity** (Patents per million people)	**Techno-logical penetration** (Internet users per 1,000 people)	**Human Capital** Enrolments in higher education per 1,000 people	Share of total number of higher education students	**Financing** Number of incu-bators, 2006	Share of govern-ment S&T spending
North	2.45	90.5	16.6	5.7	14.0	1.99
North-East	2.98	95.0	13.2	15.7	63.0	10.08
Central-West	2.85	188.6	28.9	9.7	28.0	0.89
South-East	31.08	219.3	25.8	49.7	127.0	70.32
South	48.27	213.0	29.0	19.0	127.0	16.72

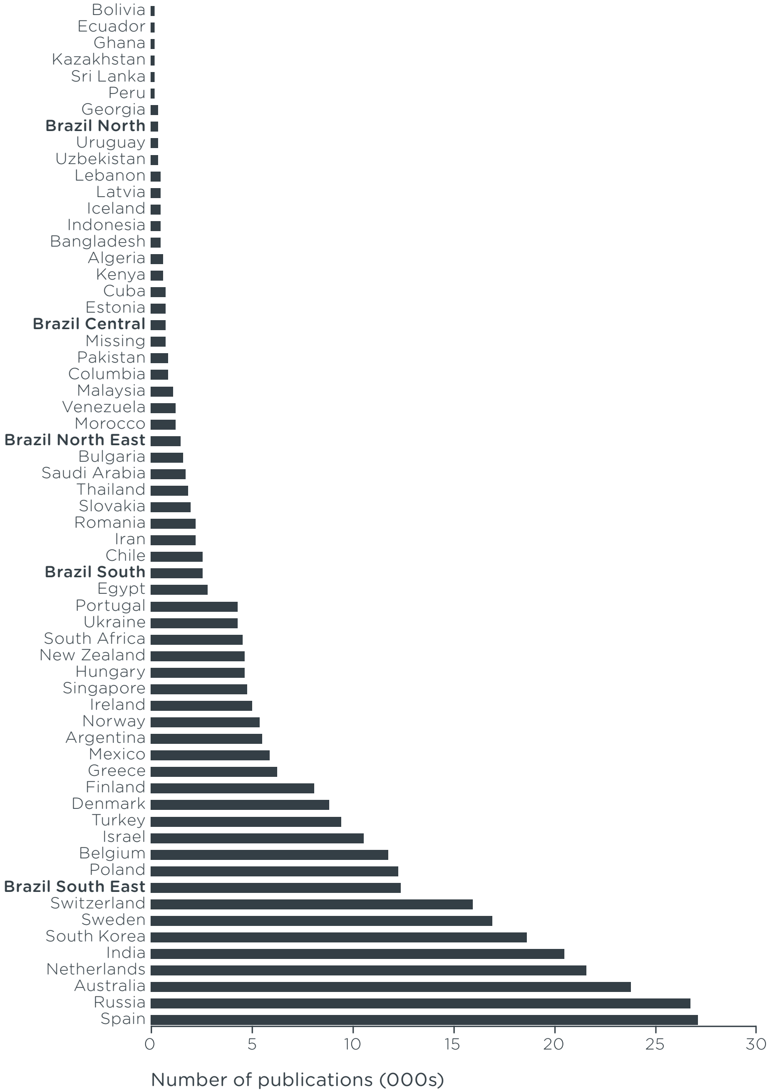
Sources: INEP[85]; MCT[86]; IBGE.[87]

Another way to examine the concentration of science and innovation capacity in the South and South East is through an international comparison. Figure 8 benchmarks the performance of each of Brazil's regions on one common measure of scientific activity – SCIE-indexed publications – against a number of comparison countries. The results are stark.

The South East region alone produces more publications than many of Brazil's South American neighbours like Mexico, Argentina and Chile. Its scientific output is greater than or comparable to that of several (smaller) OECD countries including New Zealand, Ireland, Norway, Denmark, Finland and Switzerland.

By contrast, the North region produces less than Uruguay, despite having almost five times the population, while the North East produces less than 60 per cent of the publications produced by Chile, despite having more than three times its population.

Figure 8 **SCIE-indexed publications, Brazilian regions and selected comparison countries, 2002**



Source: ISI Science Citation Index Expanded.[88]

Overcoming the South East's dominance, and ensuring that the opportunities for scientific discovery are more equally shared among Brazil's regions, is a daunting task. Yet the government has embarked on one of the biggest efforts to decentralise knowledge production in the world. Key elements of this include the ring-fencing of at least a third of national science fund (FNDCT) finances from the sectoral funds for investment in the less developed North, North East and Central West regions of the country.

The evidence suggests that decentralisation is beginning to happen. Since 1995, all 27 of Brazil's states have had secretariats for science and technology. This has generated real momentum over the past few years.[89] As Table 10 shows, the higher education system has grown faster outside São Paulo. Undergraduate enrolments in the North grew by 124 per cent between 1998 and 2002 compared to 46 per cent for São Paulo state as shown in Table 10.

For a more comprehensive picture, Table 11 shows that on a number of indicators – the number of incubators, the amount of government spending, and the number of patents and publications – the South East is growing more slowly than any of the other regions. The only problem is that the region that is catching up fastest is the South, which had less ground to make up in the first place, and second, that the South East is so far ahead to begin with that these differential growth rates will have to be sustained for some time if the gap is to be narrowed.

Having examined the variation across Brazil's regions at a macro-level, we now turn to a more fine-grained exploration of some of the innovation hotspots around the country.

Table 10 **Numbers and growth of undergraduate enrolments: São Paulo state, Brazil and regions, 1998 & 2002**

	1998		2002		Change 1998-2002 (%)
São Paulo	678,706	31.90%	988,696	28.40%	46
South East (except São Paulo)	449,298	22.10%	757,581	21.70%	69
North	85,077	4%	190,111	5.50%	124
North East	310,159	14.60%	542,409	15.60%	75
South	419,133	19.70%	677,655	19.40%	62
Centre West	163,585	7.70%	323,461	9.30%	98
Brazil	**2,125,958**	**100%**	**3,479,913**	**100%**	**64**

Source: FAPESP Science, Technology and Innovation Indicators in the State of São Paulo, 2004.

Table 11 **Trends in deconcentration of scientific activity**

	Number of			Patents			Publications			Spending		
	1999	2006	Growth	1990	2001	Growth	1998	2002	Growth	2000	2004	Growth
North	2	14.0	600.0%	14	34	142.9%	220	340	54.5%	26,288	40,349	53.5%
North East	13	63.0	384.6%	92	242	163.0%	850	1,405	65.3%	137,031	294,564	115.0%
Centre West	1	28.0	2,700.0%	82	192	134.1%	412	654	58.7%	864,581	1,297,943	50.1%
South East	55	127.0	130.9%	1,774	3,733	110.4%	7,937	1,2216	53.9%	244,807	361,281	47.6%
South	29	127.0	337.9%	391	1,300	232.5%	1,465	2,508	71.2%	37,196	56,666	52.3%

Sources: Anprotec;[90] MCT;[91] FAPESP.[92]

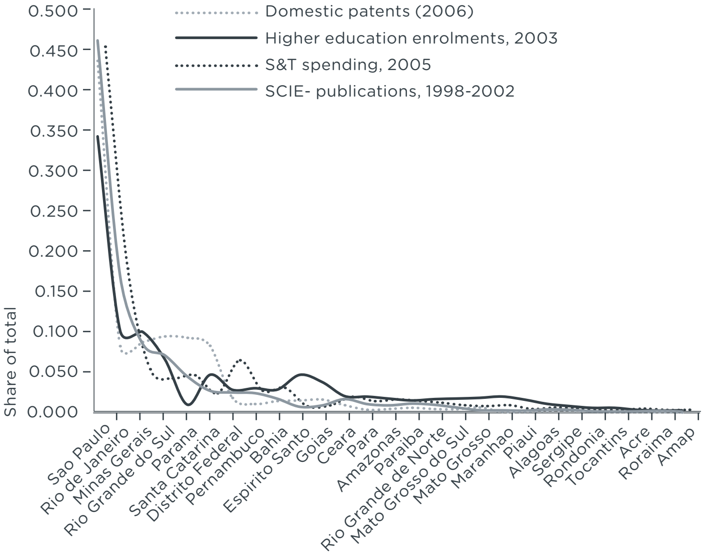
'São Paulo is another country'[93]

The state of São Paulo in South Eastern Brazil is home to over 20 per cent of the country's population. Almost 11 million of these people live in metropolitan Sao Pãulo, one of the world's five largest cities.[94] The state contributes over a third of Brazil's GDP. As a result of its demographic and economic power, São Paulo dominates Brazilian science and innovation. The state spends more on research and development than any Latin American country apart from Brazil. Of the eight best Brazilian universities, five are in São Paulo. One university, USP, accounts for more than a quarter of the scientific publications produced by the country, and the state has the highest number of innovative companies.

To gauge the full extent of São Paulo's dominance, we took a series of measures of science and innovation activity – domestic patents, higher education enrolments, total public (federal plus state) spending on science and technology, and number of SCIE-indexed publications – and calculated the share of the total accounted for by each state.

Figure 9 displays the results. States are ordered along the horizontal axis according to their average share of these four measures of science and innovation activity. The vertical axis displays their share. What is striking about this chart is that it shows a classic 'power law' or 'long tail' distribution. The 'normal' distribution known to characterise many phenomena – for example, IQ or height – is centred around a typical or average value, and both small and large occurrences are very rare. It is this property that gives it its familiar 'bell shape'. Power law distributions are different. Popularised originally by the Pareto Principle or '80-20 rule' (named after the economist Vilfredo Pareto, who formulated it after discovering that 80 per cent of wealth was owned by 20 per cent of people) and more recently by books like Chris Anderson's *e Long Tail*,[95] power law distributions describe phenomena which are *not* centred around a typical value: instead, small occurrences are very common, large occurrences are very rare, and 'average' occurrences are therefore not very meaningful. Figure 9 shows very clearly that science and innovation activity in Brazil is characterised by a power law distribution: São Paulo does not just spend and produce more, it spends and produces *exponentially* more.

Figure 9 **The 'Power Law' distribution of Brazilian science and innovation activity**



Sources: Patents - INPI; Higher education enrolments and S&T spending - MCT; SCIE publications – ISI.[96]

Clearly this partly reflects other concentrations, notably of population: São Paulo is a lot bigger. But this is not the full extent of the story. With 20 per cent of Brazil's population, São Paulo accounts for 44 per cent of its domestic patents, 45 per cent of total public spending on science and technology, and 46 per cent of SCIE-indexed publications.

The main implication of this for understanding Brazilian science and innovation is to reinforce statistically the point we made earlier: *averages are profoundly misleading*. São Paulo really is another country.

There are several reasons for São Paulo's scientific success. Through coffee plantations and later through industry, São Paulo has been one of Brazil's richest states since the end of the 19th century. In the early 1880s, the literacy rate in the state was 42 per cent compared to 15.3 per cent in the country as a whole.[97] The immigrants who flocked to São Paulo in the early 20th century populated USP and galvanized the local elite, making it a world class institution from the start.[98] But it is the long-term commitment to science funding at the state level that sets São Paulo apart from the pack. The sState funding agency for science and technology, FAPESP, was set up in 1962 with a US$2.6 million endowment – a considerable amount at the time. Even before this, the state government had agreed to set aside 1 per cent of state GDP to invest in science and technology. As Figure 9 shows, this volume of funding is at a scale that no other state approaches even today, and it was delivered with a stability year on year that was not matched by federal funds that used to suffer from fluctuation.

Across the state, science and innovation activities are further concentrated into a number of metropolitan hubs.

Campinas

In July 2000, *Wired* magazine anointed the University of Campinas, or Unicamp, as Brazil's answer to MIT.[99] Founded in 1966, it contributes 17 per cent of Brazil's indexed publications and 10 per cent of the country's PhDs. It stands out from other universities in Brazil for having almost as many graduate students (circa 15,000) as undergraduates (circa 17,000). Unicamp makes more patent requests than any other university in Brazil, 40 per cent of which spring from the chemistry institute. Its *Inova* incubator has been active since 2003, and can already claim credit for a string of successful graduate companies, such as *Allelyx*.

Box 1

Allelyx

Founded in February by a small group of molecular biologists, Allelyx today employs over people in Campinas. It is a wholly Brazilian owned company that works with a number of international partners. Leaders in plant genomics, the founders were partly responsible for the sequencing of a bacteria called Xylella fastidiosa *– which causes millions of dollars of damage to citrus fruit crops each year – research which earned them the front page of the journal 'Nature' in July* .[100]

Despite these advances, Campinas is still best known for its telecommunications and IT clusters, and has attracted a swarm of high tech electronics multinationals like IBM, Lucent, Samsung, Motorola, Dell, Huawei, 3M and Texas Instruments.

Another prized asset is the National Synchrotron Light Laboratory (LNLS), until recently the only synchrotron light source (a type of particle accelerator) in the southern hemisphere. The Laboratory also boasts a centre for electron microscopy with the most powerful microscope in Latin America and will house the new Centre for Ethanol Science and Technology.

São Paulo city

The University of São Paulo (USP) caters for around 75,000 students on 11 campuses, four of which are in the city. The university produces a quarter of Brazil's research publications. Both the Times Higher and the Shanghai Jiao Tong indexes rank USP among the top 20 universities in the world. Its faculty includes molecular biologist and geneticist Mayana Zatz, working in the area of neuromuscular disorders – one of Brazil's most highly cited scientists. The city is a hub for medical schools and health research with top institutes like the Instituto do Coração, INCOR, a centre for excellence in cardiovascular medicine. There are a number of other important institutes on the USP campus: the prestigious Institute of Technological Research (IPT) and the Nuclear Energy Research Centre IPEN to name but two.

São Jose dos Campos

A medium-sized city about an hour from São Paulo, this is home to the country's most important cluster for aeronautical engineering and space sciences. As well as the CTA, the Brazilian General Command for Aerospace Technology, São José dos Campos is the premier centre for civilian aerospace engineering education at ITA – the Aerospace Technology Institute.

Box 2

Embraer

If you have been lucky enough to get a ride in a corporate jet, or spend any time on city hoppers, it is likely that you have travelled on an Embraer plane. Whilst Boeing and Airbus are household names, Embraer is less widely known, despite being the world's fourth largest aeroplane maker. With , employees, of which over per cent work in research and development, it is one of Brazil's most significant industrial innovators. Originally developed from the military research centre, CTA, Embraer was privatised in and, unusually for a Brazilian company of its era, has run like a multinational from the start.

Since the early 1960s São José dos Campos has also been the primary location for space research in Brazil – formalised with the creation of INPE, the Brazilian National Centre for Space Research in 1971. One of the major players in science and innovation in Brazil, INPE has one of only eight supercomputers for advanced climate forecasting worldwide, and been instrumental in climate change observation and research. The centre is involved in a great deal of international collaboration with Asia, Europe and the USA.

The other two points most clearly marked on Brazil's map of science and innovation are the states of Rio de Janeiro and Minas Gerais.

Rio de Janeiro

Science and innovation activity is strongly centred on the state capital, also called Rio de Janeiro. The former capital may be most well known for its beaches, dental floss bikinis, carnival and football stadium, but it is also one of the country's strongest centres for science and innovation. Its main attractions include Fiocruz, the Oswaldo Cruz Foundation, which produces over 60 per cent of Brazil's vaccines, and is an important centre for new drug development.

The Federal University of Rio de Janeiro (UFRJ – formerly the University of Brazil) is responsible for 9 per cent of scientific output. Although there are important institutions throughout the city such as IMPA, the National Institute of Pure and Applied Maths, the Brazilian Academy of Sciences and numerous other universities such as PUC-Rio, there is a strong cluster around UFRJ on the Ilha do Fundão, forged from longstanding collaboration on engineering and energy between the CENPES Petrobras research centre and COPPE, UFRJ's high ranking postgraduate engineering school.

Minas Gerais

The second most populous state, Minas Gerais grew wealthy through mining thanks to its rich mineral deposits. Minas has a high concentration of education institutions, concentrated around the capital, Belo Horizonte. In addition to its strong automotive cluster, Minas Gerais has become well known for its biotechnology industry. At least 60 biotech companies are based in or around Belo Horizonte. Several of these work on human diagnostics and pharmaceuticals, but there are a growing number in other areas, including phytotherapeutics (medicine from plant products), applied IT and fine chemistry. In 2007 the successful incubator, Fundação Biominas, which has graduated over 20 companies in its ten-year life span, rebranded itself as 'Habitat'.[101]

Box 3 **Santa Rita do Sapucaí – 'community innovation' in telecoms**

When Sinhá Moreira, the well-connected wife of a US diplomat, le him and his Japanese posting and returned to Santa Rita do Sapucaí in she was alarmed at the rate at which young men were leaving the city. e city needed a

> *future, and Sinha believed that in Japan she had seen it: the future was electronics.*
>
> *Using her own money, Sinha set up the first electronics graduate school in Latin America, the Technical School of Electronics (ETE). e new buzz around the electronics industry rapidly caught the imagination of the population. Six years later the National Institute of Communications was established (INATEL) – this was the first institution teaching electronics in the hinterland.*
>
> *Sometimes called 'Electronics Valley', since then Santa Rita do Sapucaí has given rise to over high tech enterprises, said to employ half the active population. In , the city's telecoms industry had a revenue of US$ million.*[102]

The South

The Southern region of Brazil is the country's 'little Europe', and the states of Paraná, Santa Catarina and Rio Grande do Sul are renowned throughout the country for the high numbers of Italian, German and Portuguese descendants. This region has the highest rankings on the human development index and some of the best quality of life indicators in Brazil. Innovation activity is concentrated around the state capitals of Curitiba (Paraná), Florianópolis (Santa Catarina) and Porto Alegre (Rio Grande do Sul). But there are important secondary centres such as Londrina in Paraná and Joinville in Santa Catarina.

Curitiba

Curitiba in the state of Paraná is well known for its environmental policy and urban planning. This city banned plastic bags before most European cities had even considered the option, and its recycling scheme has been running since the late 1980s. Not a blade of grass seems out of place in its pristine city centre. Its iconic glass-tube bus stops are part of an integrated transport system that has been so successful that 75 per cent of commuters use public transport, despite high rates of private car ownership. The city established a Free University of the Environment (*Universidade Livre do Meio Ambiente*)[103] in 1992, which provides courses on environmental sustainability to everyone from public sector workers to students.

The Federal University of Paraná is one of the oldest universities in Brazil (some claim the oldest). One of the most famous Paranaense success stories of recent years is Bematech, an electronics company dealing in commercial automation equipment that grew from the university incubator to be a global company with a turnover of more than R$89 million in 2003.[104] Other success stories include Positivo – a company well known for its lucrative private higher education business, and also making waves in personal computing. Although the top global computer brands are widespread in Brazil, Positivo has cornered the market for the household PC with a machine that can be bought on credit for as little as US$30 a month. Their success is based on low-cost technology with a business model that is adapted to the Brazilian lifestyle. For example its Media Centre TV combines a PC with a TV function that suits low-income households. As demand increases, the company is setting its sights on the laptop market. Some analysts attribute its success to a deep understanding of the changes under way in Brazil: *e success of Positivo, it's simple. Dell saw the country as static, whereas Positivo sees it as dynamic.*[105]

Florianópolis

With 40 beaches and a reputation as one of the top tourist spots in Brazil, Florianópolis, or Floripa as it is popularly known, may seem an unlikely innovation hotspot. Known more for surfing than science, Florianópolis is an island joined by a causeway to the mainland, where a large proportion of its 400,000 inhabitants live. More than 60 per cent of the city region is nature reserve. Yet Florianópolis is a centre of excellence for engineering in Brazil. The city region boasts 16 universities and five technical universities. The Federal University of Santa Catarina (UFSC) in the city is one of the top five universities for technology and engineering in Brazil, with 2,000 PhDs enrolled in 2007 – 1,000 of which are in science and engineering.[106] This human resource helps to support 250 tech companies in Florianópolis and around 2,000 in the state of Santa Catarina as a whole.

The close links between academia and industry in Florianópolis are one factor contributing to the success of its incubators. The ALFA technology park, founded in 1993, houses 60 high tech enterprises with a revenue of over US$150 million. And the CERTI incubator on the UFSC university campus has graduated some of the country's most influential tech companies. One example is Nano (Endoluminal), which designs and produces tiny (although not nanoscale) titanium medical devices for treating aneurisms, which can be introduced in a minimally invasive procedure via the femoral artery. Today they have a turnover of R$4 million (US$2.5 million) and are one of only 12 companies in the world making this kind of device.

Despite restrictions on manufacturing due to anti-pollution laws in Florianópolis, and a limited local market, nothing can tempt Nano away from Florianópolis. And you can't blame them. Quality of life in Florianópolis is one of the highest in Brazil, a factor which the new Sapiens Park initiative is banking on. Science parks usually conjure up images of windowless labs on affordable land on the outskirts of cities. Sapiens Park will turn this idea on its head. By 2020, this will become the first 'urban biosphere reserve' in the world on Florianópolis Island. Integrating new science facilities with high tech business, sustainable tourism, education and business services, it expects to generate US$600 million in funding, and to attract 400 innovative companies.

The North East

A new map of Brazil is being drawn – and on this new map, the biggest computer park in Brazil is in Recife, not in São Paulo or even in Rio. Silvio Meira, Chief Scientist, CESAR, Recife

In the early 1990s, the computer science department in the Federal University of Pernambuco in Brazil's less developed North East region was one of the best in the country. Yet this was a problem. The vast majority of the graduates would leave for lucrative job opportunities in the South or overseas following graduation, draining valuable brains from a region desperately in need of them. The North East needed to create an incentive for these people to stay, so a small group of professors from the university created CESAR (The Recife Centre for Advanced Studies and Systems). From five people and R$12,000 in 1996, the private, non-profit incubator and services centre posted an income in 2007 of R$50 million, with over 600 employees. In 2001, on the site of the dilapidated former sugar port, the IT park Porto Digital was created with an initial state government grant of R$33 million. This brought CESAR's efforts to scale. From three ICT companies in 2001, the Recife cluster now boasts 207, 90 per cent of which are graduates of the CESAR incubator. ITC accounts for 1.8 per cent of the State GDP, compared to a 0.8 per cent average for Brazil.

CESAR is currently testing a new graduate programme for 800 students, 200 of whom were drawn from outside Recife – coming from as far away as Finland, USA, Switzerland and India. Recife now has world class talent in Java, open software, electronic security and mobile applications. Why has its IT cluster proved so successful? Chief Scientist Silvio Meira puts it down to the sheer scale of collaborative activity they have developed between the university, CESAR and Porto Digital, along with a 'willingness to be global'. While other Brazilian incubators are often focused toward the domestic market, CESAR was international from the start. The three biggest clients for R&D are Motorola, Samsung and Sony-Ericsson. Its international partnerships include those with IIT Guwahati in India, the IAS in Germany and the ICDC in UK.

Pernambuco has developed an international reputation for IT and this is only the beginning. Receiving a sizeable portion of Sectoral Funds for research and development, and some advantages from the fact that the last two science ministers have been from Pernambuco, the state is now expanding its focus. There is a US$65 million federal government commitment to create a pharmaceutical pole with emphasis on blood related products for domestic supply, while in the Western part of the state, a high-tech 'tropical' wine industry has grown in the San Francisco valley around Petrolina.[107]

The North

When the Fraunhofer Institute, one of Europe's most successful research institutes, picked Manaus for the site of their only Brazilian joint research centre in 2006, Hernan Valenzuela admits that many of his Southern colleagues couldn't believe it:

they couldn't understand why Fraunhofer hadn't chosen somewhere in the South of the country instead for their microelectronics research. It's something we come up against a lot – there is little understanding in the South of the country of the growth in science and technology in Manaus. That's why it is sometimes easier to collaborate with international partners rather than Brazilian ones – then there are no mindset issues to overcome.[108]

A port 900 miles from the coast, Manaus grew in the late 19th century with the rubber boom. The wealth and success of Manaus during its rubber years is symbolized by the grand opera house at the heart of the city. Painstakingly created by materials shipped thousands of miles from Europe, then hundreds of miles upriver – Italian crystal, wrought iron from Glasgow, ceramics from England – it is a monument to the city's colonial past. The city's modern story began with the creation of the Manaus Free Trade Zone in 1967, a geographical zone of subsidies and tax exemptions designed to encourage industrial growth. Today there are over 450 companies (including the main producers of analogue and digital TV sets) receiving tax incentives in the Manaus Industrial Pole, which contributes around 1.4 per cent of the GNP of Brazil.

Manaus is in a race against time since these tax incentives are due to be phased out by 2023. But since the introduction of the informatics law in the early 1990s, which legislated for mandatory minimum R&D efforts for ITC companies, Manaus has benefited from considerable investment. One of the private, non-profit institutions that have thrived since the introduction of the informatics law is the Genesis research centre. The vanguard for a number of technology research and development centres in Manaus, Genesis specialises in embedded electronics and signals interpretation. Its R&D ranges from the creation of new pacemakers to military intelligence devices, and advanced software for competitive karaoke.

The other great hope for this region is biotechnology. The research base of the region to date is small, yet high quality. The National Research Institute for the Amazon (INPA) was inaugurated in 1954 and is today a world leader in tropical biology. Some 200 scientists and up to 500 graduate students work to constantly update the institute's biodiversity catalogue of over 599 primary types and 200,000 species. For Adalberto Val, director of INPA, if there is one barrier to the future scientific development of the region it is human capital – they need more local brain power: 'The Amazon is singular. We have a wealth of scientific demands and questions, yet no scientists! In the whole of the Amazon there are only 3,000 scientists.'

In 2002, the Amazon Biotechnology Centre (CBA) was inaugurated. This enormous white building, adorned with giant cut-outs of native species, was set up as a part of the National Programme of Molecular Ecology for the Sustainable Use of the Amazon Biodiversity Resources (PROBEM) at a cost of US$5 million. The centre hosts 26 labs and is the hub for a growing cosmetics and functional foods pole in Manaus. The centre has attracted scientists from all over Brazil, but if the Amazon region is to achieve its ambitions it has to grow, attract and retain the best. This challenge is at the heart of a new strategy launched in May 2008 by the Brazilian Academy of Science (ABC) for the scientific development of the Amazon, which calls for a 'scientific and technological revolution for the Amazon'. It will include the creation of centres of applied science to cover areas such as water, degraded areas, biodiversity, biotechnology and renewable energy, working directly with enterprises. The goal is the integrated development of productive chains for a number of products, from pharmaceuticals to environmental services.

Box 4

Brasília: conquering the interior?

Brazil's e orts at 'deconcentration' of knowledge and resources are not new. In , the country inaugurated a brand new capital city, Brasília, built in 'the wilderness' in the state of Goias, , kilometres from the previous capital of Rio de Janeiro. With the country's population concentrated on the south east coast, it was seen as a way to 'interiorize' Brazil. It took just five years to build, with the then president, Juscelino Kubitschek, promising 'fi y years of progress in five'. A modernist dream, Brasília was built to Le Corbusier's ideals on a blank canvas (an empty, flattened site belonging entirely to the federal government). Street life and the bustle and corruption it represented was a thing of the past, with roads designed only for cars. All addresses are acronyms, abbreviations and numbers. Public spaces are o cial and symbolic, and Oscar Niemeyer's incredible modernist administrative and cultural buildings populate the oversized 'Plaza of the ree Powers'. For James C. Scott, it is 'almost as if the founders of Brasília, rather than having planned a city, actually planned to prevent a city'. E orts to control the development of this utopian city stalled, and by over three-quarters of Brasília's inhabitants were living in unplanned settlements.

Today Brasília is a thriving, if unusual capital, with a population of just under . million, amongst the highest GDP per capita in Brazil, and top-tier higher education institutions. With Brasília, the country managed to conquer the interior and begin to shi focus from the populated coast, but it did it in a way that could be considered totally at odds with the rest of Brazil.[109]

As the story of Brasília exemplifies, the desire amongst policy makers to diffuse wealth and knowledge throughout the country is not a new one. Focus on the average in Brazil, overlooking the specific, and you will miss many of the places emerging on the map of Brazilian science and innovation. Significant changes in funding and grand redistribution programmes will no doubt galvanize new centres. But at the same time, sharp regional variations and Brazil's map of inequality remain slow to change.

4 Business

Being met at the office door by men dressed as angels, carrying cloud shaped leaflets about how to have a nice day, is all in a day's work for employees at the HQ of Petrobras in Rio de Janeiro. It's a little more unusual for visitors, who may be also be surprised to find suited executives gathering around a fitness instructor in the hallway for their mid-morning exercises. Petrobras have absorbed innovations from around the world in their quest to improve company performance. President Lula recently joked that Petrobras has become so successful that maybe it would be better for Brazil if they started picking the country's president.

With net profits of R$21.5bn in 2007 (over US$13 billion), Petrobras made headlines in early 2008 when it announced new oil discoveries that could mean Brazil has amongst the largest oil reserves in the world.[110] Its success has been based, at least in part, on pioneering approaches to deep sea drilling and some of the most advanced engineering techniques in the world. To generate these innovations, the company invests between 1 and 2 per cent of profits in R&D – some R$1.7bn (US$1 billion) annually – ranking it amongst the top companies in R&D spending in the world and resulting in the highest number of triadic patents[111] in the country.[112] CENPES, its already large research centre in Rio de Janeiro, is in the process of doubling in size. Another 180,000m^2 will be added to the existing area to house over 500 R&D projects and 2000 researchers.

While much of Petrobras' research remains focused on oil and gas, this is beginning to change. According to Ricardo Castello-Branco, Energy and Sustainable Development R&D manager, biofuels research accounts for 5 per cent of the R&D budget today, with a goal to double this over the next five years. Much of the newly expanded R&D facility will house research on hydrogen, wind and solar energy. Petrobras has been listed on the Dow Jones Sustainability index since 2006, and in 2008 one international index ranked it as the most sustainable oil company in the world.[113] According to one senior chemist: 'Sustainability is the ambient thing now, crossing all over – every new thing, new process has to be sustainable… Before, five years ago, we had the rules, but not the consciousness.'

How typical is Petrobras of the wider Brazilian private sector? This chapter provides an assessment of the scale and character of private sector R&D, and the wider environment for entrepreneurship in Brazil. With a raft of new government policies recently introduced and a rapidly changing external environment, it also asks how these trends will develop in future years and what Brazil's specific advantages and challenges are in private sector R&D.

Homegrown heroes

Petrobras is one of a number of successful, increasingly multinational Brazilian companies whose businesses are built on natural resources and assets. These account for the bulk of Brazil's private sector R&D. Others include mining company Vale do Rio Doce and steel enterprise Gerdau. A number of the other big R&D investors in Brazil are former state-owned companies, like Embraco, which makes some of the most energy-efficient compressors in the business. And it's not just Petrobras that has a focus on environmental technologies. Over 85 per cent of electricity is provided by hydro-power, and there are considerable opportunities in clean tech being explored by groups such as the climate centre at COPPE in Rio de Janeiro.

Farming might seem a strange inclusion in a chapter on business innovation, but Brazil's agribusiness contributes almost a third of GNP and much of it is built on science and technology. With agricultural exports of around US$30 billion in 2004, Brazil is the largest producer of oranges and coffee in the world, holds the biggest stocks of beef and chicken, and produces over 20 per cent of soy beans. Yet it still has the largest remaining stocks of cultivable land in the world. When Michael Shearn of the US Foreign Agricultural Service visited Brazil in 2003 he reported that *the future of farming in Brazil has enormous potential, and… previous estimates of the scope for possible agricultural expansion have been grossly underestimated*.[114]

Much of this success is attributed to Embrapa, the Brazilian Agricultural Research Corporation. Created in 1973, Embrapa has a network of 37 research centres and 2,221 researchers, over half of whom have a doctorate. It receives over 13 per cent of federal R&D funding, and is credited with revolutionising the production of soy beans, helping to make Brazil one of the most efficient producers in the world. The science behind agribusiness is increasingly high tech, and so is the process of large scale cultivation. As one professor explained: 'Here tractors have dashboards like the control centre of a jumbo jet – linked to satellites that give information about soil humidity.'[115]

The natural assets of the Amazon are also fostering innovation. The Campinas headquarters of Natura, Brazil's largest cosmetics company, feels more like a sculpture than a factory.[116] Its sweeping concrete curves and huge glass facades form a building designed on green principles. Natura's annual growth was 11 per cent last year, and the company now launches well over 200 new products a year. When Daniel Gonzaga, Head of Research and Technology, was appointed in 2003, the company had 90 researchers. Now they have 210 and spend between 2.5 per cent and 3 per cent of their revenue on R&D. Natura operates in an extremely competitive sector and its brand and mission is heavily based on the unique biodiversity of Brazil and particularly the Amazon, where they have a satellite lab working on naturally derived oil and soaps. They have close links with Brazilian universities, notably in Campinas, where they are constructing a new research centre as part of a diversification plan into functional foods – or 'nutriceuticals' – another expanding market.

Natura has made a systematic effort to learn from other innovative companies like Proctor and Gamble and Nokia and has designed a 'triple helix model of economic, environmental and social sustainability'. It is basing its future moves on the principles of 'open innovation' with a target of 50 per cent of research carried out externally. It even has a section on its website where it posts research problems and challenges academics and others to respond, rather like the Innocentive model.[117] And this open approach appears to be working. Gonzaga reveals 'we've had eight great ideas through the website in the past year alone.'

Underlying weaknesses

However, in Brazil, companies like these are still the exception rather than the rule. While Brazil hosts outposts of many of the world's biggest multinational companies, they carry out little of their R&D activity there, even compared to India and China. As former Motorola boss Flavio Grynzspan points out: '[innovation offshoring] is primarily a search for talent, but Brazil's talent is not so unique as to make this a compelling argument.'

Certainly the size of the talent pool is much smaller. Once they are embedded in the country however, there is a legal requirement on multinationals to spend a proportion of sales on R&D, an amount which varies by sector according to sectoral fund. This is why Motorola has to invest 3 per cent of sales in R&D and has around 400 R&D engineers carrying out global-facing research. The role this is playing in capacity building is smaller than one might think, since according to Grynzspan, most firms are not fully integrated into the innovation system. 'Motorola can do a lot more for Brazil, but Brazil needs to know what to ask for. Often the country doesn't make the most if its MNCs – it sees them as "foreign" rather than an asset for Brazil.'

The intensity of R&D among the wider domestic private sector as a whole remains very weak. A recent survey of innovation in Brazilian firms found that only a third of companies employing more than ten people are active in innovation. Much of this innovation is focused on processes, rather than products. Process innovations are typically aimed at lowering production costs by adopting existing technologies, rather than creating genuinely new technological possibilities.[118] Only about 7 per cent of Brazilian firms focus solely on product innovation, while twice as many, 14 per cent, focus solely on process innovations. A further 14 per cent focus on a mixture of product and process innovation.[119] Only a quarter of Brazil's scientists work in the private sector – compared to four-fifths of scientists in Korea or the USA – and of these fewer than one in ten have more than an undergraduate degree.[120]

A number of historical factors help account for the disappointing innovation performance of the Brazilian private sector. First, the firm structure of the Brazilian economy has been dominated by relatively small, family-owned businesses, when innovation rates tend to be higher in larger firms, as Table 12 illustrates.[121]

Table 12 **Relationship between firm size and innovative activity**

Firm Size (number of employees)	Proportion of all firms over 10 employees	Innovation rate 2003-2005 (product and process)
10–29	65.6%	29.8%
30–49	14.1%	31.9%
50–99	10.9%	41.0%
100–249	5.8%	55.9%
250–499	2.0%	65.3%
500+	1.7%	79.6%

Source: IBGE.[122]

Second, Brazil pursued a closed, inwardly oriented growth strategy of 'import substitution industrialisation' until well into the 1980s. As a result, many firms have not had been exposed to competition from foreign companies. Rates of innovation are highest for firms operating in markets where the market share of foreign businesses is also high, suggesting that international competition is an important driver of innovation.[123]

Third, economic and political instability, including high inflation and Brazil's poor credit rating, depressed investment in private sector innovation. This left a legacy of relatively low private sector investment, and a heavy reliance on government intervention. In 2004, almost 60 per cent of R&D spending came from government sources, with most of it spent indirectly through public universities or directly through government institutions. Only a small fraction went to businesses.

Policy responses

The government has been conscious that this poor private sector performance needs to improve for some time, and a raft of new measures have emerged in the last decade. One of the most important is the Innovation Law, which was conceived in the late 1990s. After years of debate it was finally approved in December 2004, the first of its kind in Latin America. It is designed to promote innovation in private companies, and incentivise partnerships between universities, research institutes and firms.

As a result of the innovation law, companies can now hire university researchers. This was previously forbidden by law on the grounds that it was misusing public funds for private profit. In a considerable break from the past, for the first time it allows the government to give direct grants for innovation to companies.

Brazil is growing a strong system of support and incentives for innovation that is arousing interest the world over. Senator Kim Carr, Australia's new Minister for Innovation, recently pleaded in a speech entitled 'New Agenda for Prosperity':

Brazil has legislated to provide incentives for research co-operation between universities, research institutes and private companies… If Brazil can get the public and private sectors sharing research staff, funding and facilities, why can't we? [124]

As many plaudits as the legislation has received, implementing the system remains a considerable challenge. According to Olivio Avila, the Executive Director for ANPEI,[125] the National Association for Research, Development and Engineering in Innovative Companies:

Ten years ago we had no mechanisms to incentivise innovation in the private sector. Now we have a new agenda, we have a new regulatory framework – we've got a full menu of tools, but the challenge is to put this on the street…

While some believe direct subsidies for companies will rapidly breed results in innovation in the private sector, others remain unconvinced that incentives are sharp enough to change behaviour, meaning companies that wouldn't normally invest in R&D will not be persuaded to take them up.[126]

We have good strategies and policies now – the problem is implementation, and this is down to the institutional and legal environment. The 'systemic risk' of innovation makes things very difficult… If companies invest in innovation in one way to access the available subsidies, there is a considerable risk that they will be audited by a different system.[127]

There are clearly regulatory issues to iron out surrounding the implementation of recent regulations, yet this is unsurprising considering the scale of the project in Brazil. Take the example of companies working in Sectoral Fund areas of the economy. Current legislation means that after the maths is done, due to the size of its sales, Petrobras is required to spend around US$300 million a year on joint research with universities, 30 per cent of which must be carried out in the less developed areas of the country. There is an important proliferation of scientific infrastructure, but an exposure of the shortage of skills in some areas. As Ricardo Castello Branco, Energy and Sustainable Development R&D Manager at Petrobras, explained: 'In some areas we really need the university system to grow up, and fast.'

Pressure for growth and cohesion in the national innovation system is coming from several angles. But as we saw in chapter 2, Brazil is not yet achieving the results in terms of patents that it hopes for. What are the long term prospects for more success stories like Petrobras and Natura emerging in the future?

The environment for entrepreneurship

Our current entrepreneurs were educated in a time of crisis – a time of per cent inflation a month… ey look only to survival… is makes long term planning very di cult.[128]

Dating from the fall of the military regime in the mid-1980s, the incubator movement was a reaction to the large scale top-down technology projects of the 1960s. Funded by a variety of federal and state agencies, and supported by an influential networking association, ANPROTEC, since 1996 Brazil has increased its number of incubators at a rate of 30 per cent a year.[129] Brazil now has over 375 incubators, over 200 of which were created in the last five years or less.[130] According to some critics, only a small proportion provides high quality, comprehensive services and achieves significant success.

Notable incubators include that of the Paraná Institute of technology, home to Bematech, whose fiscal printers earned the company revenue of over a US$100 million in 2007; the CELTA incubator of the CERTI foundation in Santa Catarina, winner of the ANPROTEC prize for best incubator in 2006, INOVA – the innovation agency of the University of Campinas which has the largest number of domestic patents in Brazil, and the biggest incubator in Latin America, Genesis at PUC Rio, CIETEC, situated in a golden research triangle between USP (University of São Paulo), IPEN (The Nuclear and Energy Research Institute) and IPT (The Institute of Technology Research of the State of São Paulo).

Although infrastructure is supportive, there remain significant challenges in persuading some scientists of the merits and potential of linking the pursuit of knowledge with the pursuit of wealth. Silvio Meira, Chief Scientist of CESAR, observes that:

We are still at the point when a number of professors think they should be Franciscan monks, that they should be poor, and they don't have to have any economic or political or institutional relevance. But in my group at the university at least that is no longer true – you aren't condemned to death, or hell, because you drive a BMW like I do!

Indicators suggest that Brazil is not an easy place to start a business, ranking 122 out of 178 countries.[131] Yet two transformative trends could revolutionise the environment for entrepreneurship. First, at the macro-economic level, the Brazilian economy has been placed on a much more solid financial footing in recent years. In May 2008, Brazil was reclassified as 'investment grade' by a number of ratings agencies. A country that was a one-time foreign debt defaulter is now flush with foreign reserves.[132] Net Foreign Direct Investment into Brazil more than doubled between 2006 and 2007 from US$33.4 billion to US$72.7 billion.[133]

Second at the micro-economic level, there has been a surge of venture capital in Brazil. As Professor Pimenta at PUC Rio notes, 'a few years ago, Brazil was a capital market desert… but over the last 2-3 years the concept of VC in Brazil has undergone an enormous transition – from an intellectual delight to a practical reality'. The majority of venture capital remains late stage – concerned with scaling up business rather than getting it off the ground – and a relatively small percentage is focused on science and technology. Yet private players are making inroads, whether it is multinationals like Intel, who set up a US$50 million Brazilian venture fund in

2006, VC funds like UK-based Imprimatur, which recently set up an office on the Unicamp campus, or Brazilian players like Votorantim and Fir Capital. Expectations are clearly high and rising. A new government supported seed fund, privately managed by development bank BNDES, opened in 2008 and will make its first investments of R$80 million (US$50 million) this year. The Brazilian innovation agency, FINEP, is also set to fund a series of local seed funds at state level.[134]

For Cortex Intelligence, a newly graduated startup from the Genesis Incubator at PUC Rio, the major issue for start-ups is not access to financial capital, but access to human capital. The company's success came from its development of the first Brazilian system for Competitive Intelligence. Its platforms for text and data mining have made it a leader in the Portuguese language, and faced with competitors like IBM, middle and rising in the English language. But it hasn't been easy to find the right kind of staff to scale up the company. According to General Manager, Eduardo: 'We need a very specific profile of person and its hard to find them – they have to "buy the dream." But here young people still want to go to work for big companies: Petrobras, Shell, that's the dream. They don't know this world exists.'

The culture for enterprise shows signs of improvement, because of success stories, incubator opportunities and above all a macro-economic environment that is allowing Brazilians to plan ahead. There are a strong and diverse set of laws to improve Brazil's low level of investment in private sector R&D. But these are complex, and measuring the true impact of these initiatives may take years. Cultural changes are required as well as policy instruments, and these are often harder to predict or enforce. Science and innovation, research and development, whether in academia or industry, do not take place in a vacuum. They are subject to a number of socio-economic, political and cultural forces. It is these we turn to in the next chapter.

5 Culture

Revellers at Rio de Janeiro's world-famous Carnival are used to seeing some pretty unusual things. So when, in 2004, they were treated to the sight of a team of Samba dancers recreating notable scientific achievements – from Santos Dumont to Dolly the Sheep – they probably didn't raise an eyebrow. The inspiration for this unusual performance was a team of researchers from the Federal University of Rio de Janeiro, who joined forces with Carnival organisers to give public engagement with science a novel twist. It may not have been enough to win – they finished runner-up to reigning champions *Beija Flor* – but it caught the attention of policy makers keen to build links between science and popular culture. 'In order to stimulate innovation one needs to create a favourable mindset among the wider public,' argues Ildeu de Castro Moreira of the Science and Social Inclusion Secretariat at the Ministry of Science and Technology.[135]

It's a truth all too often overlooked. From Galileo to GMOs (genetically modified organisms), science and innovation are always influenced by their cultural context. And this often reflects distinctive, country-specific confluences of religion, history, values and politics. For all the talk of 'national innovation systems', we also need to pay attention to the national cultures that surround those systems, and the degree to which they enhance or impair their effectiveness.

This chapter offers a brief and inevitably imperfect portrait of aspects of Brazilian culture that are pertinent to science and innovation: values, democracy, diversity and creativity.

The Brazilian value system

We can obtain a snapshot of the social values that underpin Brazilian science and innovation by examining some evidence from public opinion surveys.

Tradition and openness

Brazil reflects an unusual mixture of tradition and openness. On the one hand, Brazil remains a highly religious, socially conservative country. For example, the 1997 World Values Survey asked respondents to rate how important God was in their life on a scale from 1 to 10. Fully 87 per cent of Brazilian respondents chose the maximum figure of 10.[136] Ronald Inglehart's measure of traditional versus secular-rational values, a composite index based on several items in the World Values Survey, places Brazil firmly at the traditional pole.[137] More recently, the Pew Global Attitudes Survey asked respondents whether they agreed that 'it is necessary to believe in God to be moral and have good values'. 83 per cent of Brazilians agreed, one of the highest figures for any country outside the Islamic world.[138]

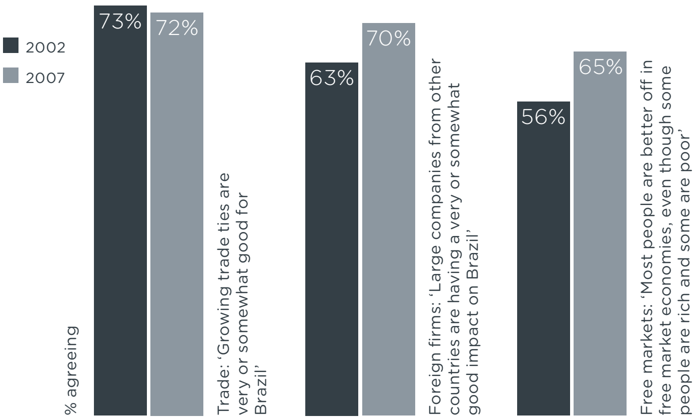
On the other hand – as Carnival itself demonstrates – Brazilian culture is much more outgoing, open and tolerant than this description might suggest. For example, 65 per cent of Brazilians say homosexuality should be accepted,[139] while in a Gallup poll last year 61 per cent of Brazilians – more than any other Latin American country – agreed that 'women in politics have done a better job than men'. Finally, Brazil was a surprise star performer in Gallup's 2007 Subjective Well Being Index. The index ranked 130 countries according to the self-reported well-being of their citizens as defined by a range of measures, such as whether in the previous day respondents felt they had been treated with respect, or had laughed and smiled a lot. Although overall there was a strong correlation between affluence and subjective well-being, Brazil came in 7th out of 130, far higher than its per capita income would predict.[140]

Globalisation

As the original host of the World Social Forum, the annual anti-capitalist gathering set up in opposition to the World

Economic Forum which meets every year at Davos, Brazil has sometimes been seen as a hotbed of anti-globalisation sentiment. The survey evidence suggests this may be overstated. As Figure 10 shows, there is solid (and in some cases, growing) support for the basic tenets of globalisation.

Figure 10 **Public support for globalisation, 2002-2007**



Source:Pew Global Attitudes Survey (2007) 'World Publics Welcome Global Trade – But Not Immigration' [141]

Environmentalism

Perhaps reflecting the burgeoning 'natural knowledge-economy' described in this report, Brazilians are increasingly green in their outlook. In a Pew Global Attitudes survey of 47 countries published last year, Brazilians emerged as the most concerned about global warming, with 88 per cent describing it as a 'very serious problem'.[142] The proportion of Brazilians identifying environmental degradation as the first or second greatest danger facing the world climbed from 20 per cent in 2002 to 49 per cent in 2007, the largest increase of any of the 47 countries surveyed.[143] When asked in a 2004 poll to identify the three major areas of research where science and technology should invest, respondents said medicines, agricultural technologies and solar energy.[144]

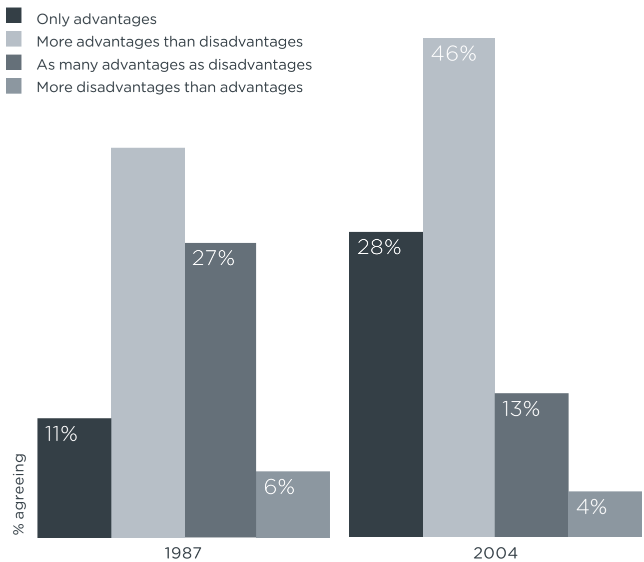
Politics and government

Brazilian attitudes towards government are somewhat ambiguous. On the one hand, trust in politics is rather low,[145] and that extends to government's role in science and technology. In a 2004 poll that asked Brazilians which institutions they would have most confidence in as a source of information, only 4 per cent identified politicians as their first or second choice. When the question was reversed to ask about the institutions they would have least confidence in, 84 per cent identified politicians.[146] Brazilians also want a less interventionist government: in a 2007 Pew Global Attitudes Survey, three-quarters of Brazilians agreed that 'the state controls too much of our daily lives', more than almost any of the other 46 countries in the study bar Pakistan and Bangladesh. On the other hand, large majorities think that the environment should be protected even at the expense of some jobs, the national way of life should be protected against foreign influence, the state should have a responsibility to look after the poor, tighter restrictions should be placed on immigration, and military force may sometimes be necessary to promote world order – positions which implicitly or explicitly suggest a significant role for government.

Science and technology

On the whole, Brazilians seem to have positive attitudes towards innovation. A 2004 poll found that a large proportion of Brazilians believed the benefits of science and technology outweighed the disadvantages – a proportion that has grown considerably over the last 20 years (see Figure 11). Interestingly, Brazilians are also highly supportive of the idea of public engagement in science. 89 per cent think that the public should be involved in taking key decisions about science and technology.[147]

Figure 11 **Increasingly positive public opinion towards science, 1987–2004**



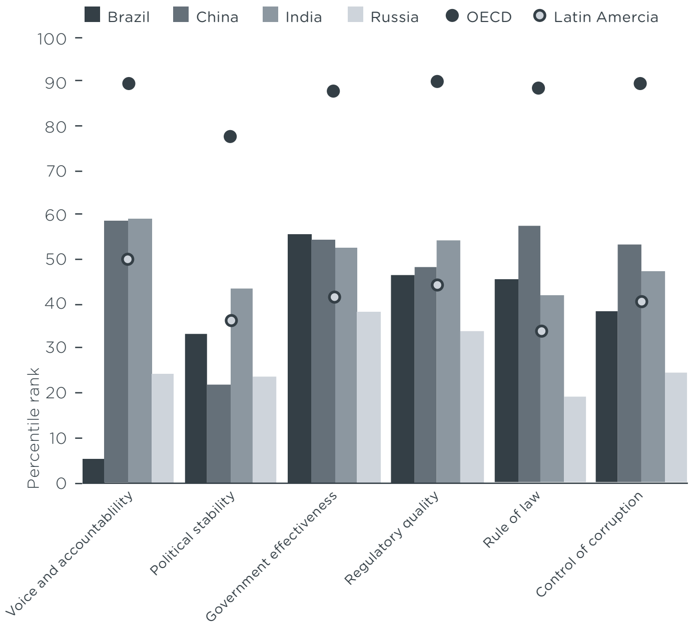
Question: *'Has science and technology given more advantages or disadvantages to humanity?'*

Source: Departamento de Popularização e Difusão da C&T, Secretaria de Ciência e Tecnologia para Inclusão Social, Ministério da Ciência e Tecnologia.[148]

Democracy

Brazil is a relatively young democracy. The country returned to civilian rule in 1985 after 21 years of military dictatorship and is now one of the world's biggest democracies, with over 120 million voters. Although Brazil is classed as a full electoral democracy by organisations like Freedom House, Brazilian politics is frequently tainted by corruption, with international rankings placing Brazil only at the 47th percentile worldwide for its control of corruption. Its relative performance actually deteriorated between 1996 and 2006.[149] Other indicators of governance paint a similar picture (see Figure 12): while Brazil's performance is comparable to the other BRICs, it falls well short of OECD standards.

Figure 12 **Comparative performance on World Bank Governance Indicators, Brazil and selected comparison countries, 2006**



Source: World Bank.[150]

Brazil has a vibrant civil society. Galvanised under the dictatorship (when for example, the majority of today's Brazilian human rights organisations were founded), non-governmental organisations have undergone a transformation over the last 15 years.[151] Under the influence of some of these groups, Brazil has become famous worldwide for its democratic innovations, such as the participatory budgeting process pioneered in Porto Alegre in 1989, or the World Social Forum that began in the same city in 2001.

It is not just process-driven innovations in democracy that Brazil has led; technology has also played a role. In 1996 a team working in the CELTA incubator in the grounds of the Federal University of Santa Catarina developed an electronic voting machine. In 2000 Brazil held the first completely automated national election. Whereas in 1989 the election results between Fernando Collor de Mello and Luis Inácio da Silva took nine days to call, in the 2002 elections the result from Brazil's 100 million voters was announced in a matter of hours. Amidst fears of electoral fraud (despite a high security system) the Electoral Tribunal in Santa Catarina is currently testing a biometric version for fingerprint voting in the near future.

But more important than the process of democracy in Brazil is the substance of it. Demos has argued elsewhere that involving wider society in setting the *directions* for science and innovation can be just as important as the *speed* of improvements in innovation capabilities, as measured by conventional indicators such as R&D investment, publications and patents.[152] Ary Plonski describes the 'directional' challenges for Brazilian science as follows:

Will Brazil be able to incorporate knowledge and innovation into the national e ort to raise the level of environmental, social and economic performance? Will the Brazilian innovation system be sensitive and responsive to the complex challenge of reconciling economic growth objectives and income distribution?[153]

While the polling data cited above demonstrates the public commitment to engaging with these directional challenges, the experience with GMOs constitutes a cautionary tale that illustrates both the vibrancy of Brazil's social movements in scientific decision making, and the challenges of growing an institutional system that can respond adequately to it.

Designs on nature

As the world's second largest producer of soybeans and third largest producer of corn, Brazil has always been seen by the biotechnology industry as key to its worldwide expansion. But the path to commercialisation of GMOs in Brazil has been far from smooth.

Back in 1998, Monsanto first applied to the National Technical Biosafety Commission (CTNBio), Brazil's appropriate regulatory body, for permission to sell its Roundup Ready soybeans. This move was challenged by Greenpeace Brazil and the Brazilian Consumer Defense Institute, sparking a debate that has now run for a decade. Initially, the Brazilian government attempted to defend the biotechnology industry, but President Lula then campaigned against GMOs in the run-up to his 2002 election, declaring at one point: 'I am totally against [the release of transgenic products] and I think it is a backward step for the government to do this.'[154]

On taking office, the President softened his stance, but the composition of his Cabinet reflected wider divisions in the country on the GM issue, with the ministers of agriculture and industry and commerce strongly in favour, and the minister of the environment opposed. With the legal position still hotly contested, a large number of farmers went ahead and planted GM soybeans (with financial support from the biotech industry), and by the end of 2003, around 10 per cent of Brazil's harvest was transgenic. On one side, pro-GM farmers' associations and a number of prominent scientists and the biotech industry lined up in favour of a further loosening of restrictions, while on the other, NGOs such as Greenpeace, the Movement for Landless Rural Workers, the environment ministry and consumer groups insisted that a tighter moratorium should be enforced.

In the end, a compromise was brokered whereby those farmers who had broken the law by planting GM crops in 2003 were excused, provided they destroyed any extra stock and did not plant it again as seed. In 2005, a new Biosafety Law was passed, which strengthened the hand of those who advocated a precautionary approach. The CTNBio was reformed to include additional civil society members, but pro-GM voices were still in the majority, and tensions persisted between the two camps. One commentator argues that the CTNBio 'muzzled divergent opinions from within the academic community, while preserving its own public image as the legitimate vehicle of what tries to come across as neutral, homogenous and progressive scientific knowledge'.[155]

Despite continued regulatory tussles, the unlicensed commercialisation of GM continues apace. It is estimated that 15 million hectares in Brazil are now planted with GM soybeans and cotton, making it the third largest market in the world. The current rise in global food prices is likely to increase the pressure from industry to use GM to boost yields, and earlier this year, the Brazilian government approved the commercialisation of two varieties of GM corn. But arguments over GM's environmental and health consequences continue to rage, and a 2004 poll showed that 74 per cent of Brazilians would prefer not to eat GM foods.

GMOs remain a highly contentious issue in Brazil, and the polarising way they have been introduced, regulated and debated amongst wider society leaves a lot to be desired. The question that now confronts policy makers is whether other new and emerging technologies, such as nanotechnology, will prove similarly divisive, or whether lessons from GM can be applied to ensure that future advances in science enjoy more widespread support from Brazilian society.

Diversity, creativity and social innovation

In a knowledge economy, more jobs require creative input, analysis and variation.[156] Creative processes in the arts or science are not that different, which explains why some have questioned whether China – a prospective innovation superpower, but with a relatively closed political, artistic and literary culture – will achieve its full potential.[157] By contrast, there are several reasons why Brazil is seen as a highly creative nation.[158] Many begin with one of the defining characteristics of Brazil's population: its diversity.

He remembered nothing at all about Syria, so thoroughly had he blended into his new environment and so completely had he become both a Brazilian and an Ilhéan. It was as if he had been born at the moment of the arrival of the ship in Bahia when he was being kissed by his weeping father. Nacib 'the arab' in 'Gabriela, Cinnamon and Clove' by Jorge Amado [159]

There is no such thing as a typical Brazilian. The diversity of the country's geography is matched by the diversity of its people. In the most recent census,[160] 54 per cent of people describe themselves as white, 40 per cent as brown or mixed race, 5 per cent as black, and 1 per cent as Asian or indigenous Indian. Brazil is home to the largest Italian restaurant in the world, a 300,000-strong ethnic Ukrainian community in the Southern state of Paraná and the largest Japanese population in São Paulo outside Japan itself. In Brazil, difference is the norm.

The source of this diversity dates back to the end of the 19th century. The Brazilian slave trade brought between three and five million African slaves to the country. When the trade was finally abolished in the mid-19th century, huge numbers of plantation workers were needed to fuel the country's booming coffee industry. Between 1884 and 1959 over 1.5 million Italians, 1.3 million Portuguese, 680,000 Spanish, 335,000 Germans and 70,000 Arabs settled in Brazil.[161] When the Italian government restricted migration flows to Brazil in 1902, Brazilian authorities designed policies aimed at attracting Japanese migrants. In the first seven years, 4,434 families (14,983 people) arrived. With the beginning of the First World War, the number of immigrants grew rapidly: between 1917 and 1940, around 164,000 Japanese made their home in Brazil.

Diversity is not without challenges. It is wrong to say there is no racial discrimination in Brazil, despite the country's aspirations for a 'racial democracy'.[162] On average, black and mixed race Brazilians earn half the income of the white population and the 'melting pot' of races exists primarily amongst the poor.[163] But segregation has never existed in the way it did in North America.

Cannibals of culture

Brazil seems to thrive on this difference, in part thanks to its unusual knack for absorbing new cultural influences and adapting them to be part of a distinctively Brazilian culture. This issue is explored in a pivotal art and literature movement of the 1920s in Brazil: *antropofagismo*. Anthropophagism is another word for cannibalism. But this wasn't a metaphor for violence. Instead the works explore the digestion, absorption and reinvention of many cultures by Brazil in an effort to solve the tensions and contradictions of indigenous African, and European cultures. Nacib the Arab may have adopted Brazilian identity in its entirety in Jorge Amado's novel but he remained a proud Syrian, and Brazilians today celebrate their varied ancestry.

One of the most striking examples of this is the Brazilian carnival, when millions of Brazilians and foreign revellers take to the streets for four days before Lent. This exuberant national festival is said to have its origins in the late 19th century when the Rio de Janeiro bourgeoisie imported the practice of holding Parisian style balls from Europe. Yet nothing could be more quintessentially Brazilian.

Brazil became an exporter of its *antropofagismo* culture in the late 1950s with *bossa nova*, followed in the 1960s by the *Tropicalismo* – a musical movement derived from a combination of *bossa nova*, rock and roll, Bahia folk music, African music and Portuguese *fado*. Contemporary exiles from the dictatorship, Caetano Veloso and Gilberto Gil, are the leading musicians of the movement. The latter was appointed Brazilian Minister for Culture in 2003.

This rich, vibrant patchwork of influences has helped to ensure that Brazil's culture is well known throughout the world. And it is big business. Two hundred and ninety thousand firms operate in the cultural market in Brazil, with recent estimates suggesting cultural activities provided revenues of up to R$156 billion (US$97 billion) a year.[164] Gaming hubs are growing in Recife, Curitiba and the São Paulo–Rio axis, and Brazil's film industry now accounts for almost a quarter of the national market.[165] Brazilian design, from Havianas flip flops to the 'Favela chair', is taking the world by storm and Oscar Niemeyer leads an international architecture movement at the ripe old age of 101. The Brazilian music industry is ranked by the International Federation of Phonography as one of the world's most profitable – while a recent poll showed that two-thirds of Brazilians claim it to be their biggest source of national pride.[166]

Even outside the formal creative sector, there are grounds for thinking that Brazil's diversity could nurture the creative impulse that lies behind successful science and innovation. Some scholars argue that diversity within particular organisational settings aids problem solving and provides a context for people to think in new ways about new issues.[167] Others, such as Richard Florida, have claimed that difference is a fundamental element of creativity, and that it is diversity among the 'creative class' that helps generate the new ideas to power regional economic growth.[168]

Brazil actually fared poorly in Florida's Global Creativity Index.[169] However, many of the indicators used to construct this index – which include HRST, patents, investment in R&D – are measures on which Brazil punches below its weight. The more novel indicators include a measure of tolerance towards minorities, a measure of self-expression values, and the Inglehart measure of traditional versus secular values mentioned above – precisely the kinds of measures on which, as we noted earlier, Brazil presents a mixed picture.

One powerful element that Florida's Index is missing are the number of pioneering examples of 'social innovation' now emanating from Brazil. Despite much theoretical advance, conventional thinking about innovation remains dominated by the simplistic model of a 'pipeline' from idea to market, as Charles Leadbeater describes:

Ideas get created in special places by special people: the boffins in the lab, the designers in their studio. Those ideas are embedded in physical products, which are then engineered, manufactured and distributed to consumers waiting at the other end of the pipeline.[170]

But as Leadbeater explains, while this is an important part of innovation, it is also an extremely limited understanding of what innovation is. It implies that innovation is the preserve of the few. Not only does this understate the value of innovation in non R&D-intensive sectors, such as retailing and services, it also fails to recognise the value of social innovation. This is innovation with a social purpose, whether poverty alleviation or distance-learning. Or it can be used to describe innovation using social processes like the 'open source' model of software development. Brazil has been in the vanguard of both types.

Social processes: 'open source' software

Brazil made waves in the global software developer community when in 2005 it switched all its government IT systems from Windows to open source, Linux-based operating systems. Some developers are fairly ambivalent about this mass experiment and political statement in an international environment of anxiety over protection of intellectual property, yet it could have significant consequences for Brazil's approach to innovation. As one expert put it: 'Open source is shades of blue… there are degrees of openness… The discussion of open source is mainly important for the discussion of whether "open" is better for innovation.'[171]

Brazil has been an active player in the debate over alternative forms of intellectual property – ones that balance the interests of the owners of intellectual property with those of society as a whole. This is reflected in the 'Development Agenda' for IP, which Brazil presented to the World Intellectual Property Organisation in collaboration with Argentina in 2004. Brazil's music industry has also been experimenting with open source models for some time now. It's *Canto Livre* (Free song) project aims to create an open environment for sharing Brazilian music, while various musical movements like the 'Techno-brega' of the Northern state of Pará have been operating outside the 'normal' market for years.[172]

Social purposes
AmazonLife[173] manufactures chic handbags, bicycle courier bags, briefcases and other leather-like products using the sap of Amazonian rubber trees. The origins of the company lie in EcoMercado, a store selling eco-friendly goods founded in Rio de Janeiro by Maria Beatriz Saldanha and her partner Joao Augusto Fortes. On a trip to Amazonas in search of products for her store, Saldanha met a group of rubber tappers who had traditionally used wild rubber to make simple bags. Following their lead, she ordered a number of sheets of rubber, which she used to make a range of bags and cases. Having ironed out some initial difficulties in the production process, she now sells the raw rubber and finished bags to a number of clients including leading European fashion designers. The company shifts the equivalent of about 30,000 sheets of wild rubber per year. Among the major beneficiaries of the company's success have been the rubber tappers; formerly earning about $0.30 a sheet, they can now charge about ten times that. As well as their share of sales, the tappers share ownership of the trademark on the products with AmazonLife.

Stories of social innovations like this are not unusual, from *Sociedade do Sol* [174] – which developed and distribute DIY cheap solar energy kits through schools – to local cooperatives for small scale hydropower generation projects like *Cooperativa Regional de Eletrificação Rural do Alto Uruguai Ltda* (CRERAL) in Erechim, South Brazil, that are winning plaudits from international green energy campaigners.[175] Sometimes it is easy to miss the fact that Brazil's drive for green energy is as much from the grass roots as from the national authorities.

Likewise in health services and citizenship education, Brazil has a huge number of fascinating projects. In Curitiba, South Brazil, tyre manufacturer BS Colway has reproduced an entire town – *Vila Cidadania* – to mini scale on a 3km squared site.[176] With the support of local government and around 25 small businesses, the aim is to teach children aged from 7 to 10 how to live together as citizens, respect differences and negotiate disagreements, whilst also teaching them about entrepreneurship.

It is hard to estimate the scale of social and grass roots innovation happening in Brazil, since it is only recently that efforts have been made to try and build a large scale database of this kind of initiative with the creation of the social technology network Rede de Tecnologia Social.[177] In contrast, in India, the 'Honey Bee network', a project that has so far collected well over 10,000 grassroots innovations from all over the country and assembled them in an open access database for all to see, has been running for over 15 years.[178] If Brazil can harness the potential of this disparate force of innovators, it could have a powerful effect. One sign of this potential is the creation of the *Bovespa Social* – a parallel organisation to the *Bovespa*, Brazil's stock exchange.[179] Founded in 2003 and regarded as a world first, rather than selling shares in companies, this sells social shares in third sector and not-for-profit organisations. Investors can track the progress of their social shares just like they would in any other stock exchange, witnessing just how much 'social profit' their investment has created.

If Brazil's assets in terms of culture, diversity and creativity can be combined with the other elements of its 'natural knowledge economy', then the country is well placed to prosper, not only in S&T-based forms of innovation, but also the wider aspects of a successful and thriving innovation system. Ultimately, Brazil's goal should be to forge a common agenda for what Charles Leadbeater describes as 'mass innovation' – a wider culture of 'citizen innovation', in which the vast majority of people see themselves as contributing to a more innovative, prosperous and sustainable future.[180] In many countries, this would seem improbably or idealistic. In Brazil, it could just happen.

6 Collaboration

Brazilians know it as the first case of biopiracy. When an English botanist called Sir Henry Wickham collected 70,000 rubber tree seeds in Brazil in 1876, it probably didn't cross his mind that he might one day be considered responsible for the downfall of the Brazilian rubber industry. Yet those seeds (some of which are now on display at the London Science Museum) were dispatched to the Royal Botanical Gardens at Kew and subsequently to Malaysia, which soon became the world's largest rubber producer. The Brazilian industry quickly found it could not compete with the better growing conditions in Malaysia, and even today Brazil imports most of its rubber from Malaysia.

While Brazil may have got a raw deal from this early scientific partnership, today collaboration is firmly back on the agenda. This chapter tracks Brazil's scientific collaboration with the world and how it is changing. It explores regional patterns of collaboration as well as identifying areas of strategic importance in Brazil. As well as looking at Brazil's collaboration with the major science centres, including the UK, it will also assess the new wave of Brazilian collaboration with the southern hemisphere. And because, as the Wickham case infamously proves, legal frameworks are crucial in shaping who actually benefits of collaboration, it will begin by examining the current struggle to create an effective legal regime for biodiversity collaboration.

Biodiversity barriers

Despite the signing of the UN Convention on Biological Diversity in Rio de Janeiro in 1992, Brazil is still struggling to develop the legal framework that would allow access to biological and genetic resources for research and benefit sharing. There have been numerous high profile cases of Brazil failing to receive adequate compensation for the use of active ingredients extracted from its biodiversity. The situation is even more uncertain when indigenous knowledge is brought into the equation.

Take the case of Captopril, the billion dollar blood pressure drug developed by pharmaceutical company Squibb (now Bristol Myers Squibb) from the venom of the Amazonian viper *Bothrops jararaca* in the 1970s. Because of a lack of effective legislation, Brazil did not profit in any way from Captopril. More recently, there has been controversy over a Japanese company's patenting of an Amazonian fruit called cupuaçú, used by indigenous peoples for everything from facilitating easy births to making a kind of chocolate called 'cupulate', and now widely used as a common ingredient in Brazilian desserts. Despite provisional legislation, international collaboration is suffering, since attempting to get permission for research is punitively difficult. The number of genetic resource samples sent from Brazil to countries abroad is diminishing and this is impacting the acquisition by Brazilian institutions of similar materials, since relationships are based on the principle of reciprocity. This is happening at the same time as other countries like China and Singapore are surging ahead with similar legal frameworks and research agreements.

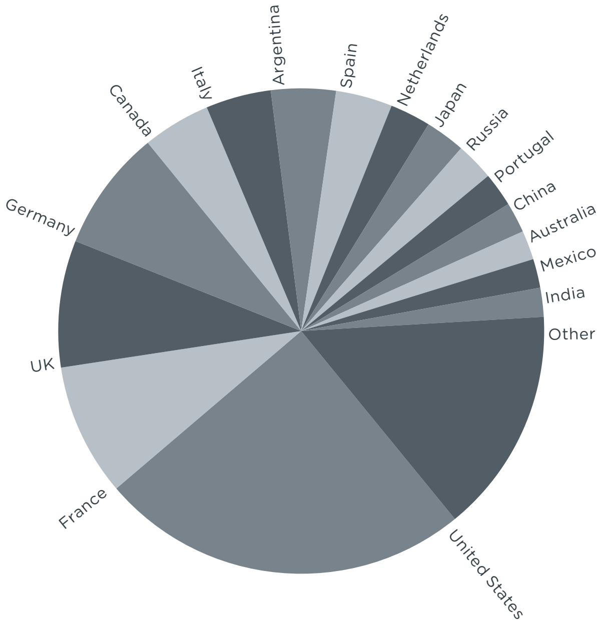
Although Brazilian research in this area is making progress (see chapter 2), and the country has been successful in the process of developing innovative products and processes derived from exotic biological resources, considerable difficulties with IP and commercialization have hampered collaboration. The 1999 collaboration between Rio-based Extracta and the UK-based GlaxoSmithKline was affected by these complexities and is no longer operational.

Patterns of collaboration

Despite the specific challenges of collaborating on biodiversity research, overall international collaboration is growing at a healthy rate. Brazil's international collaboration grew 43 per cent from 1998 to 2002, particularly with the US, UK, Germany, Spain, Canada and Argentina. Collaboration with Australia has also seen significant growth, albeit from a low starting level. But as a proportion of overall publications, the share of articles based on international collaborations actually redcuced slightly over this period – perhaps a sign, some suggest, of the increasing capacity and improving infrastructure within Brazilan science. At the state level, collaboration between São Paulo state and China grew 206 per cent, and collaboration with Chile and Mexico also increased considerably.[181]

As Figure 13 shows, the US remains Brazil's single largest bilateral scientific partner, although taken together the European Union countries account for a greater proportion of collaborative activity.

Figure 13 **Patterns of Brazil's international collaboration in scientific publications, 2005**



Source: NSF Science and Engineering Indicators, 2008.[182]

Snapshot of Brazil's international collaboration in scientific publications, 2005[183]

The USA

Bilateral collaboration in science and technology between Brazil and the US is coordinated largely by the Environment, Science, Technology and Health Section (ESTH Section) at the US Embassy in Brasília, and has four main strands:

- Health (mainly HIV/AIDS)
- Environment (a notable collaboration being that between the National Amazon Research Institute – INPA – and the Smithsonian, which has been active since the 1970s)
- Energy (for example a virtual EMBRAPA laboratory in the US, and a joint renewable energy laboratory) The US and Brazil signed a technology sharing agreement on biofuels in 2007
- Space

The USA is the top destination for Brazilian students studying abroad, with 7,244 at university in the US in 2006.[184] Examples of scholarships include the Fulbright Commission, operating in Brazil for over 50 years.[185] It runs 12 different programs, offering a specific program on science and technology for doctoral level students and granting several other scholarships to students and professors in Brazil (in collaboration with CAPES).[186]

France

The bilateral relationship in science with France dates all the way back to 1913. The agreement was consolidated in 1967, the date of a special accord relating to solar and non-traditional forms of energy. Areas of cooperation include:

- Biomedicine (for example in July 2008 the Institut Pasteur is co-funding a course on bioinformatics and comparative genome analysis at the Federal University of Santa Catarina in Florianópolis)
- Space (including micro-satellites)
- Environment, sustainable development and climate change
- Aerospace and military
- Biofuels

There has been an agreement on education cooperation since 1978.[187] Over the last 25 years the Capes COFECUB agreement has graduated 1000 doctoral students. It has a budget of €735,000 (US$1.3 million). There are 137 doctoral courses in projects as wide-ranging as industrial/urban management, photonics and nanotechnology.[188]

Germany

Since bilateral cooperation agreements began in 1963, the total volume of technical and financial cooperation amounts to €1,273,140,221 (US$2 billion) – but it is notable that this includes loans. For 2007–8 the programme covers areas such as:

- Forestry preservation and management
- Health (particularly HIV)
- Renewable energy (in partnership with Eletrobras)[189]

The DAAD (German Academic Exchange Service) has been active in Brazil for more than 50 years and it is estimated that over 900 Brazilians have benefited from the scholarships it offers jointly with CNPq, Capes and FAPESP.[190]

Japan

The Brazil–Japan technical and scientific cooperation programme aims at strengthening mechanisms of technology and knowledge transfer from Japan to Brazilian institutions. The programme consists mainly of consultancy (with the visit of Japanese technical teams) offered to Brazilian institutions whose projects are selected by Brazilian and Japanese Technical Cooperation agencies. The programmes cover the following areas:

- Environment
- Industry
- Social development
- Agriculture
- Health
- Transportation
- Energy[191]

Through the Ministry of Education Sports and Science and Technology, Japan offers a total of 28 scholarships in several areas to undergraduate, masters and PhD level students who wish to pursue their studies in Japanese public universities.[192]

UK

The British have a surprisingly long history with Brazil. After the Royal Navy protected the Portuguese Royal Family on their voyage to Brazil in 1808, they were granted a (one way) preferential trading agreement that lasted until 1944. Today Brazil remains Britain's largest trading partner in Latin America. In 2006, a Joint Economic Trade Committee (JETCO) was created between the UKTI and Brazil to help promote and develop trade, address barriers and to create a better business climate, while the year 2007–8 was dedicated as the Year of UK–Brazil science and innovation. The latter, administrated by the Foreign Office's Science and Innovation Network in Brazil, included 40 joint workshops and events on subjects as varied as bioenergy, stem cell research, neurodegenerative medicine and nanotechnology. It also stimulated eight cooperation agreements on research. For example a memorandum of understanding was signed between the Brazilian Agricultural Research Corporation (Embrapa) and the UK Cereals and arable farming research institute at Rothamsted. Key areas of strategic collaboration include energy, agriculture, space and climate change.

Since 1945, the British Council, with regional offices in Brasília, Curitiba, Recife, Rio de Janeiro and São Paulo, has acted as a link between Brazil and the UK in culture and education. In recent years its science work has focused on building networks of young scientists and the shared challenge of climate change.[193] The Council estimates that there are over 100 link schemes with Brazil, ranging from simple student exchanges to joint curriculum projects. Its project *De Olho no Clima* (An Eye on Climate) is an impressive awareness-raising initiative about climate change.

Whilst the last British Census in 2001 suggested that there are only 8,000 Brazilians living in the UK, UK-based

Brazilian organisations and analysts estimate that the Brazilian community is around 200,000, up to 160,000 of them based in London.[194] There are around 1200 Brazilian students studying at UK universities, and thousands more in English language schools.

The European Union

A Cooperation Agreement between the European Union and Brazil dates from 1992, while a specific science and technology agreement was inaugurated in 2004. The EU–Brazil strategy for the 2007–13 period has an attached budget of €61 million (US$95 million). The main objective is to stimulate exchanges, contacts and knowledge transfer between regions. It supports several initiatives to strengthen sectoral dialogue and links between academic institutions (at €30.5 million/US$48 million, the EU's higher education program corresponds to half of its total budget) and also foresees the creation of a European Studies Institute in Brazil.[195] This approach is complemented by projects of scientific cooperation in key areas such as health, bio and nanotechnology, agriculture, IT, energy, environment (including climate change), space and security.[196]

During the sixth Framework-Program, running from 2002 to 2006, nine cooperation projects were approved in domains such as digital video broadcasting (Instinct Project), health (Allostem), biotechnology and genomics (Elan2Life project) and environment (INREP, Borassus and Biomercury projects).[197] Collaborative projects in the field alternative energy and aerospace are also being developed. In 2008 the EU funded NanuforumEULA, a project mapping the activities of the nanoscience research community in Brazil.[198]

Although mapping these bilateral strategic priorities tells an interesting story about Brazil's strengths in global science, 'bottom up' links are likely to be distributed across a broader range of subject areas, with significant collaborations in physics, one of the most international sciences, as well as medicine, neuroscience and microbiology.

South–South collaboration

At the same time as bilateral cooperation with established science powers continues to develop, there is also a new wave of scientific collaboration emerging in Brazil. It is only in the last decade that 'South–South' collaboration has really begun to take-off. There are many reasons for this: increased scientific spending around the world, the facilitation of research relationships by the internet and the fact that less developed countries can collaborate on issues like tropical diseases that are not high priorities for more developed nations. For Brazil, South–South collaboration is becoming increasingly important, particularly as a new kind of scientific hierarchy is taking shape that allows it to play a growing leadership role. As Jerson Lima, the scientific director of the Rio de Janeiro state funding agency FAPERJ, says:

ere didn't used to be very many transversal links, all the collaboration was with the 'traditional science countries' – but this is changing – Argentina, Uruguay and Chile are becoming major collaborators and there is a growing programme of work with Africa.

So long the giant of the 'forgotten continent', as Michael Reid dubbed Latin America in a recent book, Brazil's geo-strategic position as both a developed and a developing country is creating an interesting niche for it in global science. Among Latin American countries, Brazil's most well-established scientific scheme is with Argentina, where collaboration dates back to the creation of a bi-lateral Biotechnology Centre in 1986 (CBAB/CABBIO). Focusing in areas such as health sciences, agriculture and food industry, it is estimated that roughly 3,200 Brazilian and Argentinean students have benefited from the 227 short term courses the Centre has offered in both countries and that over 100 projects have been financed through it. The success of the CBAB also served to propel the creation of the Argentinean–Brazilian Centre for Nanotechnology (CABNN), which coordinates courses, workshops and joint projects in nanoscience and nanotechnology simultaneously in the two countries.

Africa

In Accra, Ghana, the Brazilian Agricultural Research Corporation, Embrapa, recently inaugurated a new research centre. Brazil, a country that doubled its agricultural output in ten years while expanding the cultivated area by only 20 per cent, will work with African countries to improve the productivity of small farms and large scale commercial agriculture. One of the areas receiving most interest from African countries is, unsurprisingly, biofuels. A significant development in this field was the 2007 agreement between Brazil and Africa's largest oil producing nation, Nigeria, to build a US$200 million ethanol plant on the Niger delta to help the region introduce a 10 per cent ethanol baseline into their petrol supply.[199] Included in the agreement is the creation of a 'Biofuel Town' (at a cost of US$100 million in a first phase) near Lagos that will house 1000 people who will be trained to become bioenergy experts.[200]

In 2003, an agreement was signed to formalise the creation of the India–Brazil–South Africa trilateral development initiative to promote cooperation and exchange. Areas of collaboration include malaria, TB, HIV/AIDS, climate change, nanotechnology and biotechnology.[201] In addition Brazil has nurtured major collaborations with China on space and agricultural research.

Where next?

Despite log jams in some areas like biodiversity research, Brazil's international collaboration in science is intensifying and diversifying. Although basic science plays a big role in its international co-authorships, high level strategic partnerships are predominently focused around Brazil's natural knowledge economy pillars of energy, agriculture and climate change.[202] There appears to be a tendency towards applied research that may not figure so prominently in bibliometric analysis, and we should be mindful of this when we assess Brazil's global role in science and innovation.

Another feature that sets Brazil apart from India and China is the perceived balance of threat and opportunity. Much of the media coverage of China and India views the emergence of these countries' scientific strength as a source of competitive threat. This attitude is also reflected in the tone of the 2005 US National Academy of Science report *Rising Above the Gathering Storm*. But collaboration and competition with Brazil is rarely couched in those terms. In contrast to fears of a potentially 'techno-nationalist' China, or of European industries hollowed out by armies of Indian graduates, Brazil is seen as a more 'Western' power, whose political allegiances and multilateral tendencies are clear.[203] This is despite the fact that Brazil is also increasingly a 'Southern' power, as that hemisphere's capacity for scientific research and collaboration continues to develop.

What will all this mean for Brazil's future in global science? And what challenges lie ahead? It is to these questions that we turn in the final chapter.

7 Prognosis

In a November 2007 speech at the Santa Adélia factory in Jaboticabal, São Paulo, UN Secretary General Ban Ki-moon went out of his way to praise the efforts Brazil was making to tackle climate change – efforts, he suggested, that had gone unappreciated elsewhere in the world. Brazil, he said, is 'the quiet green giant' of the fight against global warming. The phrase seemed to perfectly capture the way Brazil has emerged onto the global map of science and innovation: discreetly, without a great deal of fanfare, and without stoking a sense of threat among existing science powers. While the global media has raved and bayed in equal measure about China's enormous investments in science, or India's huge potential stock of science graduates, there has been relatively little discussion about Brazil and its science prospects.

But in the months following Ban's visit, things have been anything but quiet, and the sheen on Brazil's green reputation has been tarnished. After three years of declining deforestation in the Amazon, figures for last year show a sharp rise. And a series of riots worldwide over high food prices have ignited a furious debate about biofuels policy, thrusting Brazil, as a leading proponent of biofuels, into the limelight. Brazil may be a green giant, but as policy makers struggle to understand the environmental implications of different innovation trajectories, it seems there is a fine line between hero and villain. Brazil's quiet programme of 'ethanol diplomacy' [204] has turned into a vigorous international campaign to defend its environmental credentials and its domestic biofuels industry.

These developments have led some commentators to link Brazil's geopolitical prospects with the future of its environmental technologies.[205] But above all, they have exposed just how little the rest of the world knows about Brazilian science and innovation.

This report has sought to remedy this, and provide some insights into the role Brazil is likely to play in the newly emerging geography of science and innovation. In this chapter, we review our main findings, and pinpoint the key strengths and weaknesses of Brazilian science and innovation. We conclude with some recommendations about what Brazil and its international partners can do to best address the challenges the Brazil's emergence as a centre for science and innovation is bringing into sharp relief.

The argument restated

First, we have tried to explain what we think is most distinctive about Brazilian science and innovation. Since the focus of much of Brazil's scientific excellence and innovation success is related to natural resources, energy and agriculture, and since some of its biggest challenges and opportunities are related to developing, while not destroying, its natural endowments like biodiversity and water resources, Brazil can best be characterised as a 'natural knowledge-economy'. Its development as a knowledge economy and a science power will be closely intertwined with its natural resources, endowments and geography.

Second, at the same time, we have also tried to highlight the variation that exists *within* Brazilian science and innovation. From high impact research in biomedical sciences in the South East of the country to the development of advanced digital TV platforms in the North and North East, different places offer contrasting environments for science and innovation.

Third, while this variation can be positive, we have also highlighted its downside. We have seen how the distribution of population, resources, knowledge and commercial opportunities in Brazil is highly unbalanced, weighted strongly towards the South East, and making any assessment of scientific capabilities based on the 'average' particularly unhelpful.

Fourth, we have examined both levels of and change in science and innovation activity and achievement. We have mapped the rapid increase in postgraduate students and publications in Brazil – all the more impressive considering that the country has only had a national university system since the 1930s and concerted government promotion of scientific research only began in the 1950s. Today, Brazil's top tier of universities would not look out of place next to those of Europe, and a select few feature amongst the world's top institutions. We have also highlighted the considerable growth in funding for science and innovation in Brazil since the late 1990s and the profusion of policy measures designed to improve Brazil's mediocre performance in translating this accumulated knowledge into commercial innovation. We have seen that science and innovation is strongly concentrated in the public sector, and that the private sector as a whole still lags in science terms, despite the achievements of Brazil's largest and best companies like Petrobras.

Strengths and weaknesses of Brazilian science and innovation

Strengths

1 **Economic and political stability:** GDP growth may not be spectacular, but it is predictable. A former foreign debt defaulter, the country now has an investment grade credit rating with booming foreign direct investment. Unlike China and Russia, it is a full democracy with an active civil society. On the widely cited Freedom House rankings, which measure countries' protection of civil liberties and political rights, it scores far higher than China and Russia, and above India on civil liberties. This is not to say it is devoid of corruption. Brazil ranks 70th out of 163 countries in Transparency International's Corruption Perceptions Index for 2006. But the trends in both political and economic risk seem to be going in the right direction, and this augurs well for the future.

2 **Growing base of knowledge and human capital:** On a number of the conventional metrics of scientific output and potential, Brazil is improving fast. Brazil is now the 15th largest producer of scientific publications in the world, up from 23rd place in 1999, and its output is growing at around 8 per cent per year. The number of PhD and Masters students produced today in Brazil is ten times as many as 20 years ago.

3 **Well-organised federal support, both financial and regulatory, for S&I:** Brazil has introduced a raft of national laws and regulations since the late 1990s to raise scientific production, encourage greater and more productive partnerships between industry and academia and stimulate innovation in the private sector. Implementation of this complex policy system remains a challenge, but the basic ingredients are all now in place.

4 **Challenging position on global intellectual property:** Brazil adopted the 1995 WTO Trade Related aspects of Intellectual Property (TRIPS) agreement in 1996, whereas it took India around a decade to accede. Combined with the advantages of an occidental legal system, this creates a good baseline for intellectual property in Brazil, yet the country has also challenged the status quo in the ownership of knowledge. Its compulsory licensing of HIV/AIDS drugs has been widely praised, and in 2004 it created with Argentina the 'Group of Friends for Development', an initiative designed to make the WIPO agenda more transparent and effective in the poorest countries. Its widespread experiments with open source have been an inspiration to many countries.

5 **Rich in environmental capital:** Policy makers, economists and businessmen increasingly recognise, particularly in relation to climate change, that there is an economic value to protecting the environment. In Brazil's case it's not just about the value of the country's forests, water reserves and biodiversity, but also about the long-term security of an energy mix that is based on 45 per cent renewable energy and the most significant biofuels programme in the world.

6 **Culture that nurtures creativity:** With globally renowned cultural industries and a diverse population, Brazil benefits from a culture that excels at adaptation and absorption of ideas and ways of life. This is a benefit for business as well as for scientific collaboration. Creativity can also be interpreted as a type of innovation through necessity, a catalyst for Brazil to become a leading source of social innovation.

7 **Home-grown heroes:** Brazil may not have one of the most outward-looking private sectors, but its home-grown multinationals such as Petrobras, Vale, Gerdau and Embraer have become international success stories. Jobs in these companies are highly sought after, raising the prestige of engineering careers. These can be a huge influence on building capabilities in the system of innovation thanks to the Sectoral Funds' emphasis on R&D partnerships with universities.

Weaknesses

1 **Social and geographical inequalities:** Wealth is highly unevenly distributed in Brazil: the income of the richest 10 per cent corresponds to 45 per cent of Brazilian GDP. If you include assets in the equation this rises to 75.4 per cent of total Brazilian wealth.[206] The same goes for science: although there are around one thousand universities and colleges in the country, one university in São Paulo accounts for almost a quarter of all of Brazil's scientific publications.

2 **Low conversion rate of knowledge base to innovation:** Brazil has failed to match its increase in publications with a commensurate increase in patents. There is clear recognition of the need to boost the role of the private sector in Brazil's innovation system, and many policy initiatives to incentivise this shift. But these are still relatively new and the consequences are not yet visible. There are significant challenges implementing the new policies, particularly in less developed regions where the supporting environment for companies may be weaker.

3 **Inward looking system**: Despite notable exceptions like Petrobras, innovation in enterprise remains largely focused on the domestic market. This has led to a low level of high-tech exports – a fact addressed in a serious way for the first time in the 2008 PDP industrial policy. Although there is a strong multinational presence in Brazil, there are no strong fiscal incentives to attract them to do R&D, so the focus remains on manufacturing.

4 **Tax burden**: Businesses in Brazil face a high tax burden known colloquially as the 'custo Brazil' or 'Brazil penalty'. In the 2008 World Bank 'Doing Business' rankings, Brazil ranks 137 out of 178 countries for paying taxes. This is slightly better than India and China in terms of total tax as a percentage of profit, but companies spend an average of 2600 hours a year processing tax returns in Brazil compared to 871 in China and 271 in India.[207] The government has introduced a number of measures since 2005 to diminish the punitive effect of tax on R&D in companies.

5 **The burden of environmental capital**: Despite wide recognition of the value of environmental capital, it remains very hard to 'cash in'. Global experience with environmental services and mechanisms such as carbon credits is still limited, and there are considerable regulatory challenges to develop the economy and tackle poverty, while conserving the environment. This is exemplified by the debate over biodiversity research in Brazil, and the understandably slow progress in achieving a consensus on rules for its sustainable exploitation.

6 **Education system below its potential**: Only 9.8 per cent of 18 to 24 year olds are in university in Brazil. Progress has been made in basic education, and social transfer programmes like the *Bolsa Familia* are incentivising young people to stay in education longer. Yet significant challenges remain. Private higher education is increasing rapidly but there is concern about the variable quality and a lack of industry-ready graduates. The World Bank's 'Difficulty of hiring' index puts

Brazil in position 78 out of 178 countries, compared to 11 for China and 33 for both Russia and Mexico.[208]

7 **Failure to fully exploit attractiveness to talent**: With growing fears about an ageing population shrinking the workforce in many countries, and acknowledgement that highly skilled human capital is one of the main drivers of competitiveness, governments around the world are increasingly concerned with their ability to attract and retain skilled workers. Brazil has important historical immigration links – creating modern channels for mobility with the possibility of dual citizenship since 1996 – and yet neither has extensive programmes to attract skilled immigrants nor any concerted effort to attract back the significant global diaspora of skilled Brazilians. This is in sharp contrast to China and India, whose international diasporas have played a considerable role in the transformation of their science and innovation systems over the last decade.

Recommendations

Recommendations for Brazil

Engaging the public: In the introduction to this report we suggest that there are tensions at the heart of Brazil's model of science and innovation: between stimulating development and protecting the environment, and between achieving excellence while striving for equity in a rapidly changing global environment. There are real trade-offs, for example, between investing in cutting edge science that allows Brazil's most scientifically advanced states, companies and research institutions to compete on a global stage, and investing in basic science capacity that levels the playing field within Brazil but risks sacrificing its global leadership. Tensions like these cannot be resolved, they can only be managed. The best way to manage them is democratically, by engaging the Brazilian people in making the difficult choices and trade-offs that lie ahead.

Tell a new innovation story: Part of this process of engagement needs to be focused on creating a new national conversation about innovation. Brazil needs the confidence to write a new chapter in its innovation story, and be the first country to place the environment at the heart of this. We heard earlier about the cynicism that still lingers from earlier attempts to write such a story – the techno-optimism of earlier periods giving way to a cynicism that 'Brazil is the country of the future and always will be'. Policy makers, NGOs, business leaders and academics need to confront that cynicism head on. As the quote from Ban Ki-moon at the beginning of this chapter illustrates, many people are now taking Brazilian science and innovation seriously, and that has everything to do with its potential as a natural knowledge-economy.

Make the most of the global limelight: Brazil needs a stronger national 'elevator pitch' to potential collaborators in science and innovation. In an increasingly competitive environment, it needs to be able to communicate its distinctive strengths to the world. But it must showcase a reality that is broader than biofuels. Brazil must leverage the international attention biofuels has garnered to tell a more comprehensive story about its scientific strengths.

Make common cause with other potential 'natural knowledge-economies': We have emphasised Brazil's impressive ability to absorb influences from abroad. It should capitalize on that ability by reaching out to other countries with substantial natural resource and environmental services sectors, which share a common interest in increasing the knowledge intensity and value added of those sectors. An international forum of natural knowledge-economies – including, for example, Finland, Australia and Canada alongside Brazil – could help to share good practices and promote scientific collaborations and commercial partnerships.

Galvanise the diaspora: In China and India, the diaspora of scientists and entrepreneurs around the globe have played a critical role in the accelerated growth of science and innovation in these countries. While the scale of its diaspora is smaller, Brazil could galvanise this resource far more effectively, for example by reaching out to Brazilians and Brazilophiles around the globe with an Overseas Brazilians Day, stimulating diaspora networks of entrepreneurs and financiers like The Indus Entrepreneurs (TiE) did for India, or creating a prize for Brazilian scientific achievement overseas.

Go the last mile: Following a raft of legislation for stimulating innovation that has received international plaudits, Brazil should ensure it does not fall short at the implementation stage. As we have seen, there have been real issues in absorbing certain funds. Further research may be needed to identify the key barriers to absorption, and to identify interventions that might help overcome them. For example, it may be necessary to rethink the way the funds are allocated to some states, perhaps by spreading them out over a longer period and backloading them to give time for the necessary capacity to develop in states which have historically been rather weak. After the drive for new policies, Brazil should now concentrate on building the links between them through cross-sectoral programmes, building on the recognition that much cutting edge science and innovation lies at the intersection of previously distinct sectors or disciplines.

Recommendations for international collaborators

Look beyond the stereotypes: The focus of the international community's interest in Brazil often revolves around the Amazon rainforest. While this is a key issue, international governments and collaborators must understand the breadth and diversity of science and innovation in Brazil and be prepared for the contrasting strategies and contexts for collaboration that might be required.

Recognize Brazil as a source of 'new science': Whether we consider its facility for large scale electronic experiments, its successes with open source science publishing or its push for models of knowledge ownership more appropriate to a changing global environment, Brazil has shown leadership in *new ways of doing science*. Collaboration in these areas could contribute important insights to wider processes of global knowledge sharing.

UK: capitalise on the Year of Science: The UK has just completed a successful Year of Science with Brazil which included over 40 events and workshops. The task is now to maintain the momentum that this has helped to generate in UK–Brazil science relationships. One way would be to set up a joint higher education scholarship fund, since the UK system is seen as very expensive for Brazilian students. Many areas of science and innovation could benefit, but one option might be to focus the scholarship on 'bright green' science and innovation – with a research component linked to environmental solutions.

Conclusion

Despite Brazil's natural resources and endowments, and despite its propensity for creativity and new ideas, being a successful natural knowledge-economy will not come naturally. Much will depend on Brazil's ability to convert these natural assets into a new national story about innovation – to be told to the world and inside Brazil – and to make good on the promise that that story offers.

Brazilians know that such promises have been made before and not been kept. But this time the prospects look unusually bright. One of the reasons Ban Ki-moon's 'quiet green giant' tag may strike such a particular chord with Brazilians is that, intentionally or not, it finds an echo in Brazil's own national anthem, a hymn laden with references to Brazil's extraordinary natural endowments. Brazil, according to one particularly apt lyric, is 'a giant by thine own nature'. A better way of summarising the aspirations of this emerging natural knowledge-economy would be hard to find. But whether the next line – 'and thy future mirrors thy greatness' – turns out to be equally fitting, only time will tell.

Appendix 1

List of organisations interviewed

Acumuladores Moura
Agência Brasileira de Desenvolvimento Industrial (ABDI)
Agricef
APEX Brasil
Assembléia Legislativa do Estado do Rio de Janeiro
Associação Nacional de Pesquisa e Desenvolvimento das Empresas Inovadoras (ANPEI)
Biologicus
British Consulates, São Paulo, Manaus
British Council, Rio de Janeiro, Recife
Centro de Biotecnologia da Amazonia (CBA)
Centro de Convergência Digital
Centro de Estudos e Sistemas Avancados do Recife (CESAR)
Centro de Gestão e Estudos Estratégicos (CGEE)
Centro de Incubação de Empresas Tecnologicas - Universidade do Estado de São Paulo (CIETEC)
Centro de Pesquisa e Desenvolvimento Leopoldo A Miguez de Mello (CENPES)
Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)
Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)
Departamento de Antibioticos - Universidade da California
Departamento de Difusão de Cinecia e Tecnologia - Ministerio da Ciência e Tecnologia
Embraco
Empresa Brasileira de Aeronáutica (EMBRAER)
Empresa Brasileira de Pesquisas Agropecuárias (EMBRAPA)
Faculdade de Tecnologia - Universidade de Manaus
Financiadora de Estudos e Projetos (FINEP)

Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ)
Fundacao Certi
Fundação de Amparo a Ciência e Tecnologia do Estado de Pernambuco (FACEPE)
Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP)
Fundação Getúlio Vargas (FGV)
Fundação Joaquim Nabuco (FUNDAJ)
Grynszpan Projetos e Servicos Empresariais
Inova - Universidade de Campinas
Insituto Químico - Universidade de Campinas
Instituto Alberto Luiz Coimbra de pós-graduação e Pesquisa de Engenharia (COPPE)
Instituto Brasileiro de Qualidade e Produtividade (IBQP)
Instituto de Pesquisa de Economia Aplicada (IPEA)
Instituto de Pesquisas Energeticas e Nucleares (IPEN)
Instituto de Pesquisas Tecnológicas (IPT)
Instituto do Coração - Universidade de São Paulo (INCOR)
Instituto Genesis, PUC Rio
Instituto Nacional de Pesquisa da Amazonia - Ministério da Ciência e Tecnologia (INPA)
Instituto Nacional de Tecnologia (INT)
Instituto Oswaldo Cruz (FIOCRUZ)
Intituto de Tecnologia Genius
Laboratório de Materiais - Universidade Federal de Santa Catarina (UFSC)
Laboratório de Química Solida - Universidade de Campinas (UNICAMP)
Ministerio de Ciência e Tecnologia (MCT)
Ministerio de Planejamento de Longo Prazo
Ministério do Desenvolvimento
Nano Endoluminal
Natura Cosmetics
Nutrimental
ORBIS Indicadores de Sustentabilidade
Panorama Rural
Petrobras

Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio)
QualiHouse
Sapiens Parque
Secretaria de Desenvolvimento do Estado de São Paulo
Serttel
Sistema Federação de Indústria do Estado do Parana (FIEP)
Superintendência da Zona Livre de Manaus (SUFRAMA)
TechnOkena
Tribunal Regional Eleitoral
UK Trade and Investment (UKTI)
Unidade de Competitividade Industrial - Confederção Nacional da Industria (CNI)
Universidade de Campinas (UNICAMP)
Universidade do Estado do Amazonas
Universidade do São Paulo (USP)
Universidade Federal de Santa Catarina (UFSC)
Universidade Federal de Santa Catarina (UFSC)
Universidade Federal do Amazonas (UFAM)
Universidade Federal do Parana (UFPR)
Universidade Federal do Rio de Janeiro (UFRJ)
Valee S. A.

Appendix 2

Sectoral funds, regulation data and funding sources

Fund	Date of Regulation	Source of Funds
Petroleum	30 November 1998	25% of the royalties that exceed 5% of the petrol and natural gas production
IT	20 April 2001	Minimum of 0.5% of companies' turnover benefited by the TI Law
Infrastructure	26 April 2001	20% of the resources of each sectoral fund
Energy	16 July 2001	0.75% to 1% gross income from concessions
Mineral	16 July 2001	2% of financial compensation (Cfem) pays for firms with access to minerals
Water	19 July 2001	4% of the financial compensation used for power generators
Space	12 September 2001	25% of income used for orbital positions; total income from licenses e authorizations from the
Health	25 February 2002	17.5% from CIDE*
Biotechnology	07 March 2002	7.5% from CIDE
Agribusiness	12 March 2002	17.5% from CIDE
Aeronautic	02 April 2002	7.5% from CIDE
Yellow Green Fund	11 April 2002	50% from CIDE, 43% from the income from IPI stemming from products benefited by the TI Law
Transportation	06 August 2002	10% of the income from the National Transport Infrastructure Department (contracts for the use
Amazon	01 October 2002	Minimum of 0.5% computer firms' turnover in the Manaus Duty-free Zone
Telecommunications	30 January 2001	0.5% of the net income of telecommunications companies and 1% of gross income related to
Naval	22 October 2004	3% of tax collection for the renewal of Merchant Navy (AFRMM)

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The landscape for innovation in Brazil is changing fast. Research budgets are rising. Brazilian scientists and innovators are at the forefront of developments from biofuels to genomics and software. And Brazil is now the fifteenth largest producer of scientific publications, up eight places in under a decade. This report argues that Brazil is a 'natural knowledge-economy' where the intertwining of knowledge, skills and innovation with environmental and other natural assets holds the key to competitive advantage.

But in Europe, Brazil's innovation capabilities are even less well understood than those of its 'BRIC' counterparts, China and India. This report assesses the prospects for science and technology-based innovation in Brazil over the next ten years. And it suggests how the UK and Europe can scale up collaboration with its new centres of excellence.

This report forms part of The Atlas of Ideas, a research programme on the new geography of science and innovation (www.atlasofideas.org). The project was conducted in partnership with the Centro de Gestão e Estudos Estratégicos (CGEE) in Brazil, and was generously funded by a consortium of partners listed on the inside cover.

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