CHAPTER 13

Science and Technology in Brazil[1]

Carlos H. Brito Cruz

INTRODUCTION

Scientists in Brazil published 16,950 scientific articles in indexed journals in 2005. The country is the 17th-largest producer of science in the world. Nine out of ten of these articles were generated in public university laboratories. Scientists and engineers in business sector R&D activities created several cases of world-class competitive innovation. These include oil self-sufficiency, the most efficient ethanol in the world, commuter jet planes, the most productive soybean production, a national system for electronic elections that can count more than 100 million votes in hundreds of candidates by midnight on election day and the best flex-fuel cars. Still, the Brazilian business sector registered only 283 patents at the USPTO in 2005. While Brazil invests 1% of its GNP in R&D, most of the scientists in Brazil — 75% of them — work in academic institutions. Although business-sector leaders have recently recognized the importance of creating knowledge to warrant not only some degree of competitiveness, but even for being followers in the global technology race, only in the last eight years have effective policies for fostering industrial and service sector R&D been put into operation.

This paper describes some characteristics of the Brazilian Innovation System in terms of its institutions — universities, government laboratories, institutes and funding agencies and business sector R&D facilities.

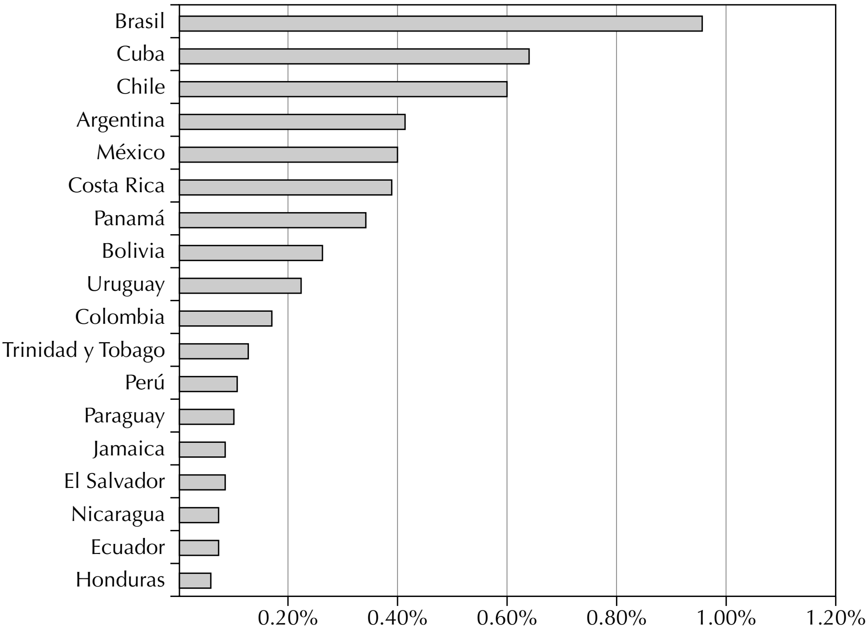
THE BRAZILIAN INVESTMENT IN R&D

Brazil has been investing around 1% of its GNP in R&D for the last five years (MCT, 2007), roughly 60% of it being invested by the public sector, and 40%

1 This article was prepared from previous reports on the subject by the author.

from the private sector. At a level of 1% GNP invested in R&D, while Brazil exceeds Latin American standards (Figure 1), it lags well behind the index practised by OECD countries (Figure 2). The average level for R&D investment for the 17 OECD countries is at 2.24% of the GNP, a percentage that has been steady for the past decade.

Figure 2: R&D investment by Latin American countries, measured as a percentage of their GDP's. Data is for 2004 or most recent year



Source: http://www.ricyt.org/indicadores/comparativos/05.xls on 25 Feb 2006.

In absolute value invested in R&D, Brazil's 13 billion PPP dollars compares to the investment practiced by Spain (9 billion PPP dollars) or Italy (17 billion PPP dollars).

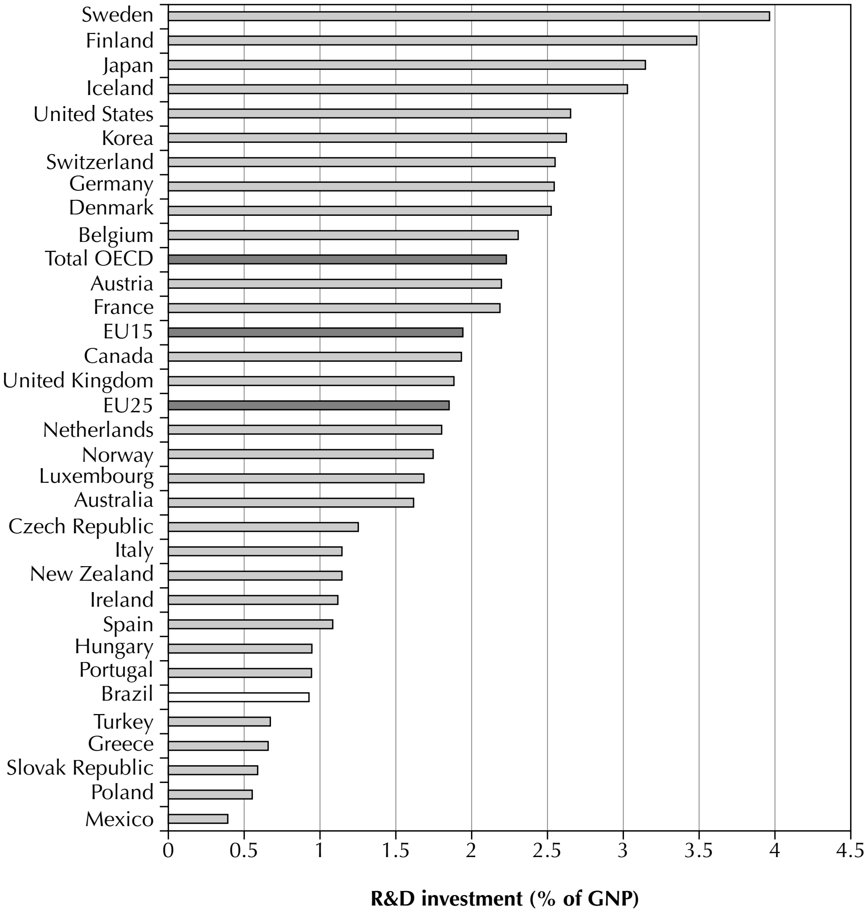
An important feature of the Brazilian investment is that, as happens in most developing countries, most of the burden (60%) is carried by the public sector.

THE INSTITUTIONS AND THEIR DEMOGRAPHY

The funding data presented in Section 2 reflects the fact that most of the R&D activities in Brazil are carried out in academic institutions. The demographics of the R&D institutions and companies in Brazil is consistent with this observation.

Researchers in Brazil work mostly in full-time academic positions, 74% of them in universities and another 10% in research institutes. Only 16% of the

Figure 3: A comparison of the Brazilian investment in R&D (in 2004) with that of OECD countries (2003 or most recent year)



Source: Brazil: http://www.ricyt.org/indicadores/comparativos/05.xls on 25 Feb 2006; OECD countries: S&T & Industry Outlook 2005 (OECD, 2005), Table A.2.1.

researchers work in business sector R&D, which is consistent with the smaller portion of private R&D expenditures, as compared to the public one. The small number of private sector scientists has a strong effect on Brazil's industry deficiency to generate patents. It is also one of the main restrictions to the development of stronger university-industry scientific linkages.

International comparisons underline the weakness of business-sector R&D in Brazil as compared to OECD countries: in Korea and the US, close to 80% of the nation's scientists work for the business sector, and in Australia or Spain this percentage is close to 60%, almost twice as much as that observed in Brazil.

Table 1: Number of scientists in R&D positions in universities (year 2002), research institutes (year 2002) and business sector (year 2003), in Brazil

Institution	Quantity	%
Full-time university faculty (1) – Federal universities – State universities – Private universities	90.631 43.494 25.299 21.838	73%
Researchers in public R&D institutes (2)	9.422	8%
Researchers in private R&D institutes (3)	2.500	2%
Researchers in business sector R&D (4)	21.795	18%
Total	124.348	100%

Sources:
(1) C.H. Brito Cruz, "A universidade, a empresa e a pesquisa", in "Brasil em Desenvolvimento" (UFRJ, 2004).
(2) Fapesp, "Indicadores de C&T&I em SP e no Brasil", Tabela 4.12 (Fapesp, 2004). Available at http://www.fapesp.br/materia.php?data[id_materia]=2060.
(3) http://www.cgee.org.br/cncti3/Documentos/Seminariosartigos/Geracaoriqueza/DrMarcel%20Bergerman.pdf
(4) IBGE, PINTEC 2003, Tab. 1.1.12.

THE BRAZILIAN UNIVERSITY SYSTEM

Most of the higher education enrolment in Brazil is composed of students attending university type (4 years or longer) courses. Institutions are federal, state or privately owned and managed.

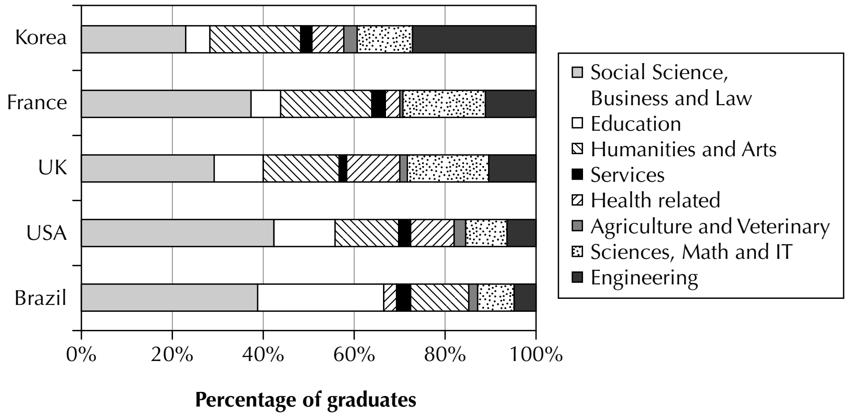
As of 2005 there were 4,453,156 students enrolled in undergraduate courses in Brazil. This translates to a gross enrolment rate of 19% of the age cohort (between 18 and 24 years old) and a net enrolment rate slightly above 12%.

73% of the enrolment is in private higher education institutions, which have very little research and courses of limited quality, with a few exceptions of course.

There are 2,165 higher education institutions, 231 of them public. These institutions graduated 717,858 students in 2005, out of which 36,918 (5%) are engineers and 56,436 (8%) are in science, mathematics and computer science. The distribution of graduates among the fields of knowledge is shown in Figure 3, in comparison to the proportions in some OECD countries.

There are 176 universities, 90 of which are public. Most of the scientific research is carried in these public universities, although with a heterogeneous distribution — six universities respond for 60% of the scientific papers that originate from Brazil. Universities are a recent institution in Brazil: the first Brazilian university was the University of São Paulo (USP), a state university, created in 1934.

Figure 4: Percentage of graduates classified by fields of knowledge



The public university system has been the basis for a successful policy which started in the early 1950s for the development of a system of graduate courses associated with research universities. Two federal agencies were created in 1951 to foster research and graduate studies: the Brazilian National Research Council (CNPq in the Portuguese language abbreviation) and the Coordination for the Training of Higher Education Faculty (CAPES). These were joined by the State of São Paulo Research Foundation in 1962 and the federally owned Fund for Research Projects (FINEP) in 1967. These four organizations are the main funding agencies for research in Brazil.

While Brazil has been able to increase the number of doctorates granted every year, reaching close to 10,000 doctorates concluded in 2006, the country still faces a shortage of higher education graduates, especially in engineering.

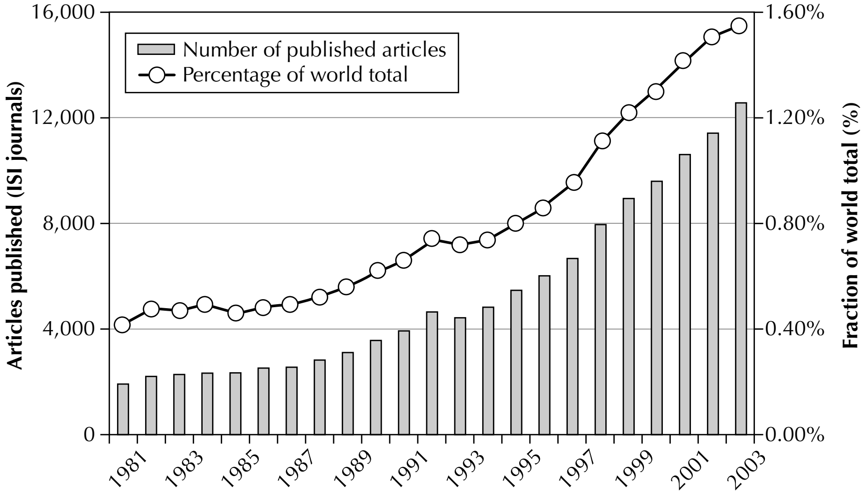
At the undergraduate level, there is an enormous challenge: in 2004 only 12% of the youth at age 18 to 24 years old were enrolled in higher education courses. This percentage must be tripled so that Brazil reaches a level on a par with the low end of OECD countries. The country's strategy so far, based on the expansion of private institutions offering 4-5 year courses together with an expansion in the enrolment at public universities which also offer 4-5 year courses, was not successful enough to dramatically raise the enrolment rate.

SCIENCE, TECHNOLOGY AND INNOVATION OUTPUTS

Scientific publications

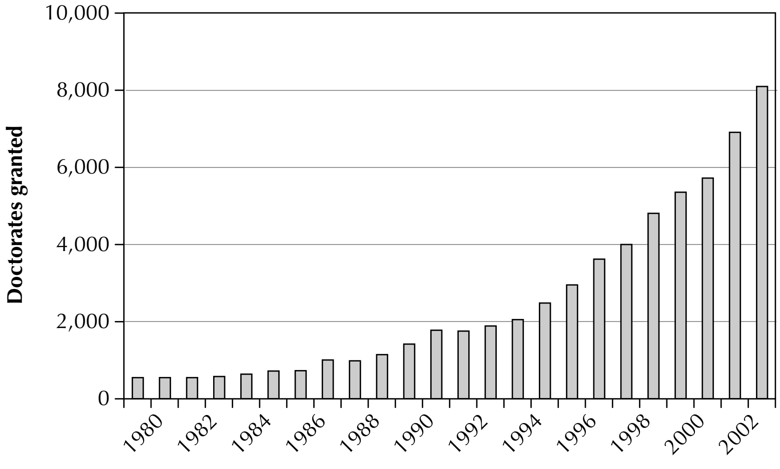
The number of scientific publications originated in Brazil has been growing steadily for the past 26 years (Figure 4), reaching a number of 12,627 in 2003 and 16,950 in 2005. The growth rate has been larger than that of the world total number of publications, so that there was also an increase in the percentage of theses articles that were originated in Brazil, climbing from 0.4% in 1981 to 1.6% of the world total in 2003. This growth in the number of scientific publications is closely related to the growth in the number of Ph.D.s graduated yearly, which, due to a steady policy, which now lasts for 50+ years, regarding graduate education, expanded from 554 in 1981 to 8,094 in 2003.

Figure 5: Evolution of the number of scientific articles originated in Brazil (bars) and its percentage over the world total (circles)



Source: National Science Indicators, Institute for Scientific Information, Philadelphia.

Figure 6: Number of doctorates granted yearly in Brazil



Source: CAPES, Plano Nacional de Pós-graduação, 2005.

The impact of articles originated in Brazil has grown, from 1.056 citations per article, for those published in 1981, to 1.862 citations per article, for those published in 1998 (Leta & Brito Cruz, 2003). For all fields the presence in terms of the fraction of world publications has grown in the same period, and the fields at which the scientific articles originating from Brazil have the largest presence are Agronomy and Veterinary (3.07% of world total publications), Physics (2.04%), Astronomy and Space Science (1.89%), Microbiology (1.89%) and Plant and Animal Sciences (1.87%).

Data from 2000 shows that 50% of the publications were in the field of Life Sciences, 33% in the Physical Sciences, 13% in Engineering, Technology and Mathematics, and 3% in Social and Behavioral Sciences. This is a distribution similar to the average for OECD countries (OECD, 2003). The participation of Engineering, Technology and Mathematics has been growing steadily, from a fraction of 10% in 1991.

The existence of a growing scientific community has allowed for the development of special research programmes that require a large number of researchers; a good example was the Genome Project, organized in São Paulo, which sequenced for the first time the DNA of a phytopatogenic bacterium, the Xylella Fastidiosa. This Program, organized in partnership with the Citrus Producer Association (Fundecitrus), generated advanced science, while at the same time contributing knowledge that allowed the researchers at Fundecitrus to devise ways to control a disease of the orange trees (citrus variegated clorosis, CVC) and generating at least two spin-off companies in the field of genomics and bioinformatics (Simpson, 2000).

Another example is the Biota Research Program, one of the largest biodiversity research efforts in the world, which groups more than 500 doctoral level scientists to study and map the biodiversity in the State of São Paulo. Since 1999 BIOTA, a “Virtual Institute for Biodiversity”, has been studying the biodiversity in the state of São Paulo, Brazil. The mission of the institute is to inventory and characterize the biodiversity of the State of São Paulo, and define the mechanisms for its conservation and sustainable use. In six years, with an annual budget of approximately US$2,500,000, the Biota/Fapesp Program supported 75 major research projects — which trained successfully 150 MSc and 90 PhD students, produced and stored information about approximately 10,000 species and managed to link and make available data from 35 major biological collections. This effort is summarized in 464 articles published, in 161 scientific journals. Furthermore, the programme has published, so far, 16 books and two atlases.

The articles published in ISI journals do not tell the whole story about Brazilian scientific production. For developing countries, many times a relevant part of the generated knowledge is published in local journals, some of which have international circulation. In order to enhance the visibility of Brazilian science production Fapesp and the Latin American and Caribbean Center on Health Sciences Information organized since 1999 an open access web portal, Scielo (Alonso, 2002) (Scientific Electronic Library Online — www.scielo.org). Scielo offers access to 148 peer reviewed journals and has mirrors in Chile, Uruguay, Venezuela and Cuba.

Table 2: Number of journals, articles published per year and number of downloads from the Scientific Electronic Library Online, Scielo

	Journals	Articles, by year	Downloads, by year
1996	0	2,707	
1997	9	1,738	
1998	25	2,723	4,896
1999	35	3,646	67,725
2000	54	4,629	392,576
2001	66	5,570	1,070,988
2002	96	6,929	1,982,009
2003	115	8,101	4,071,871
2004	131	9,122	12,607,965
2005	148	10,048	27,921,378

Source: Scielo management.

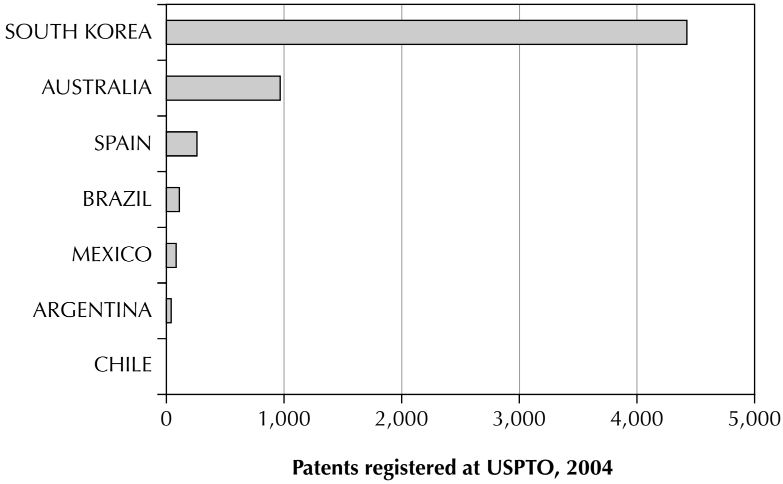
Patents — industrial and academic

In 2004 there were 106 utility patents originated in Brazil issued by the United States Patents and Trademark Office (USPTO). This is a dismal quantity, considering the size of Brazilian economy and its scientific infrastructure described above, and although it compares well with the patenting activity of Brazil's Latin American neighbours, it is dwarfed by the numbers from Korea, Australia or Spain (Figure 6).

The number of scientists working in the business sector affects directly the number of patents that originate in the country. Other factors, such as the dominant industry sectors and export coefficients, affect the number of patents too.

Academic patenting has been gaining momentum in Brazil, especially since the examples of some institutions, such as the State University of Campinas (Unicamp) and Federal University of Minas Gerais (UFMG), gained countrywide visibility. Unicamp has had a strong patenting effort going on for more than two decades, and is the Brazilian academic institution which bears the largest patent stock, being the largest patent holder in Brazil for the period

Figure 7: Number of USPTO patents registered in 2004 by South Korea, Australia, Spain, Brazil, Mexico, Argentina and Chile



Source: USPTO, at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utlh.htm, on 26 February, 2006.

1999-2003 (Figure 7). The university created, in 2002, a Unicamp Agency for Innovation, a Technology Transfer Office, which demonstrated a strong licensing effort generating revenues from its intellectual property. Most of the licences were exclusive, since the licensee takes part in the development of the IP through a cooperative R&D agreement.

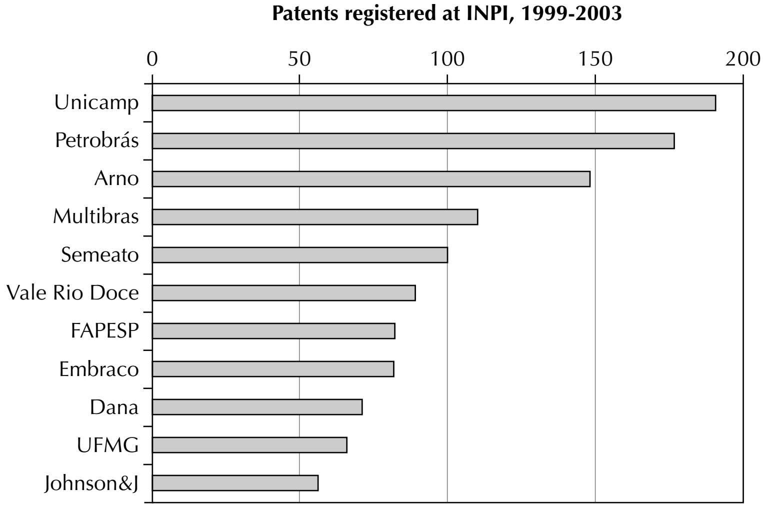
The Unicamp Agency for Innovation, Inova, was created in 2003, with the mission of fostering university industry linkages through cooperative R&D, consulting and intellectual property licensing. With a staff of 49, the Agency has licensed 40 patents and three non-proprietary technologies in 21 contracts. Prior to Inova's foundation the university had as few as eight licensed patents.

In 2004-2005, 87 cooperative R&D contracts with private companies dealt by Inova increased by 60% university revenues from this source. Patents applied at the Brazilian Instituto Nacional de Propriedade Industrial (INPI) in 2005 were 66, a one-third rise from 50 in 2004, making 2005 the best year for IP generation in Unicamp's 39-year existence. Licensing contracts include mainly pharmaceuticals and phytotherapeutic agents, food processing and nanotechnology-incorporated products. The first licensed technology (May 2004) originated Aglycon Soy, a soy-derived phytotherapeutic agent for menopausal women, which reached the market in 2007. Inova executives estimate the product will generate R$12 million per year royalties from 2008 on.

The BiphorTM licensing-contract, with Bunge Alimentos, has been Inova's most significant achievement when IP issues are involved. It is a nanotechnology-based, environmental-friendly new white pigment for paint, coatings and allied products, jointly developed by Bunge Alimentos and Unicamp's Chemistry Institute. According to Bunge, its white pigment will have a 10% world market-share by 2010. Expectations confirmed, royalty payments to Unicamp can reach US$45 million over the next decade.

Inova also works closely with the 100 companies that spun-off from Unicamp in the last 20 years, coordinating the studies for the implementation of a Technology Park in a 7 million sq. meters area adjoining the University.

Figure 8: Main patent originators in Brazil, in the perios 1999-2003, for patents registered at the Brazilian Patent Office (INPI)



Source: FONTE: Pedidos de Patente BR publicados, BANCO DE DADOS EPOQUE

The fact that three academic institutions (Unicamp, Fapesp, the State of São Paulo Foundation for the Support of Research and UFMG, the Federal University of Minas Gerais) appear among the 10 largest patent generators in Brazil seems to indicate two things: first, that the academic institutions embraced the idea of protecting their intellectual property and looking for opportunities to generate businesses with it; and, second, that industry efforts to generate intellectual property are still weak since it is rare to find, among industrialized economies, situations in which academic institutions generate more patents than industry.

Universities must bear in mind that very few research universities have been, so far, able to make more money out of licensing than they spend doing it (Mowery, 1999). The actual motivation for a university to license its IP should be to fulfil its mandate to diffuse knowledge through society and to create opportunities for its students. An exclusive focusing on financial results has undone many efforts in technology transfer and licensing in Brazilian universities and even R&D public agencies, as it might have done worldwide. There is still a lot to be learned in Brazil about the benefits to society of generating new businesses through excellent higher education, an activity at which Brazil has already obtained some important successes, as for example, the case of the Aeronautics Technology Institute, one of the best engineering schools, which gave rise to Embraer.

Products and success cases in business-sector innovation

Brazil has some very successful cases of knowledge-based innovation. The agribusiness sector, benefiting from the public R&D investments at Embrapa and other organizations in the National System of Agricultural R&D, obtained outstanding results in both production and productivity. Soybeans, oranges, coffee are important items in the export balance due, in good part, to years of continuous R&D.

Energy from ethanol is another demonstration of the country's capability to generate and use knowledge to generate opportunities. The "Proalcool" (Alcohol Program), devised in the 70s, is the world's largest operation for the use of ethanol as fuel for automobiles. In 2005, 50% of the automobiles sold in Brazil were of the flex-fuel type, while in January 2006 this percentage went up to 74%. On top of that, the country adds 25% of ethanol to the gasoline to reduce emissions and also import costs. In 2005 Brazil was the largest ethanol producer in the world — at 15.4 billion litres — at a cost of US$0.19 per gallon, less than half of the world average of US$0.40. Industry, government institutes and universities R&D developed better sugarcane and more efficient planting and harvesting methods, together with developments in the ethanol refineries and their associated costs.

Jet aircraft is another case for which Brazil has used and produced knowledge to obtain a very competitive product and develop the 4th-largest aircraft manufacturer in the world. Following the 50-seat ERJ-145, Embraer has developed the 90-seat ERJ–190, of which the first unities have been flying commercially since the beginning of 2006.

In all these cases the main asset has been well educated human resources, formed in higher education institutions built to conform to the best world academic standards. Besides the human resources, all the cases have, at some point, depended on government policies for using its purchasing power to stimulate the technology development. Finally, a successful public-private partnership got the ideas to the market.

The challenge that the country has not yet overcome is that of diffusing the practice and the value of innovation through all sectors of industry. Years of a closed market and economical instability took their toll on the adoption of an innovative attitude in the business sector. With both government and industry leaders' attention directed to technology innovation, momentum has been building to develop this important area.

CONCLUSION

Brazil has developed a competitive academic science base, and the country must address important challenges to increase its industrial R&D sector. Important challenges exist for academia too.

In the academic sector, while the number of scientific articles and the number of doctorates granted yearly have been climbing, the country must find sensible ways to foster the development of the homogeneity of the academic base, both in regional and in terms of fields of knowledge perspective. Engineering and Computer Science stand as two fields in which an effort is required to form more graduates and doctorates and to increase the international insertion. However, the advancement of knowledge in Brazil might benefit from a more balanced government approach between directed and unfettered research. Recently there is a seemingly excessive tendency to direct the calls for projects to specific objectives, hurting curiosity-driven research which is the base of a strong academic system.

Industrial R&D suffers from a lack of government support, a situation which has been changing markedly for the last eight years. Recent measures such as the Law for Innovation and its consequences, as the refurbishing of the Tax Incentive legislation and the introduction of a subvention policy are expected to have an important effect in fostering industrial R&D. These measures are in the framework of the National Industrial, Technology and Exports Policy (PITCE in the Portuguese acronym), which also established areas of focus for the government actions.

The public portion of the R&D investment amounts to 0.56% of Brazil's GNP. This percentage is below the average OCED country by 0.12 percentage points, or 18%. In absolute values, raising the fraction of public R&D investment to the level of the average observed for OECD countries amounts to an additional 1.7 billion PPP dollars or R$2 billion (Reais from 2004) in additional money from public sources.

On the side of private R&D investment, it is clear that, when compared with the values practiced by developed countries, that is where the largest gap occurs. The private sector R&D investment in Brazil is close to 0.37% of the GNP, while the OECD average is 1.38% of the GNP, or 3.7 times higher. In absolute values this translates into the Herculean challenge of raising the private R&D investment to 13 billion PPP dollars, from the 3.8 billion PPP dollars practiced in 2000. This will require policy instruments much more effective than the ones used so far to this end.

A final note is in order here, addressing the question, frequently raised in many political circles in Brazil: "Why should the taxpayer money pay for R&D?" As a tentative answer, I would say that there are at least two equally relevant reasons for this.

One is that contributing to the universal pool of knowledge makes Brazilians more capable of leading and creating its own destiny. Like any human being, Brazilians are visited by the fundamental questions that we all ask ourselves: how did the universe begins, how does it work, why is that society behaves the way it does, what drives human beings towards good or evil, understanding the classics or studying literature. Studying these and countless other questions improves the human being and this alone would be reason enough to use taxpayer money to discover science-based answers, even partial ones, to the fundamental questions and to improve our knowledge of the universe and of mankind. Making Brazilians, and mankind, wiser through good and sound science is a beautiful and worthy endeavour, which certainly justifies public investment in science by itself. This is much more the job of Universities, the best ones, than the job of industry or the private sector.

The other reason, which seems to be far more popular nowadays, is that more knowledge, obtained according to the rules of the scientific method, makes society richer. This is a utilitarian view, and it has a strong appeal, especially since the Atomic Bomb, The Genome and the Internet. In this view, which I believe is complementary to the preceding one, but not (mostly) antagonistic to it, science is seen as a productive force, as it has been since the early steps of mankind. This line of reasoning depends strongly on industry and other enterprises, and, if successfully trailed, translates into making Brazilians richer.

The big challenge is to couple these two reasons, seeking to obtain the most and the best from the two worlds; to create the conditions in which Universities and the Private Sector might, through good and sound research as Francis Bacon once wrote, make the country a better place and a full member in the concert of Nations. I believe this can be done, but I also know that accomplishing it requires a lot of study, thinking and tolerance from all of the parties involved.

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