Chapter 11

ST&I Indicators in Health in São Paulo State

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1. Introduction*

The purpose of this chapter is to discuss the progress achieved in science, technology and innovation (ST&I) in the health sector in Brazil, with special emphasis on São Paulo State. This discussion is particularly important for at least two reasons: first because it involves a sector that exists to meet human needs and is therefore highly relevant from the social standpoint and for public policy; second because the importance of the health sector to ST&I activities and job creation means that it has a significant impact on economic development (Gadelha, 2006). The health sector is one of the leaders in innovation, alongside the military industrial complex. According to information from the Ministry of Health (Brazil, 2008a), the health sector accounts for 7%-8% of GDP in Brazil, mobilizing some R$ 160 billion and employing 9 million people directly or indirectly. Moreover, public investment in research and development (R&D) in the health sector exceeds that in any other sector of the Brazilian economy.

It is important to stress that the analysis presented in this chapter refers to what is increasingly called the health industrial complex in its entirety, and not just to the industry that produces pharmaceuticals and medicines. Health and healthcare cannot be treated merely as a single sector that combats diseases. Its concern is the general conditions for life, and all the sectors concerned must therefore be treated in an integrated manner (Gadelha, 2006). Thus the health industrial complex encompasses an array of productive activities related intersectorally through the purchase and sale of goods and services and/or knowledge and technologies (Gadelha, 2003). It includes the industries that produce chemicals, biotechnology, machinery, electronics and materials, as well as key segments of the service sector, such as hospitals, outpatient clinics, and diagnosis and treatment units.

According to information extracted from PINTEC, IBGE’s Survey of Technological Innovation in Industry (IBGE, 2005), the Brazilian health industrial complex displays low innovation intensity. An assessment of the firms that produce pharmaceuticals and medical and hospital instruments shows that 52.4% of pharmaceutical firms (326 out of a total of 622 firms) and 68.1% of instrument manufacturers (627 out of 921) introduced product or process innovations between 2003 and 2005, outperforming the industry average, which was 33.4% in the same period. A more detailed analysis, however, shows that innovative activities by these firms mostly involved the acquisition of equipment to improve processes and produce new products and processes for the firms in question but not for the market. Moreover, according to a study by the Ministry of Health (Brazil, 2008a), the health industrial complex is strongly dependent on imports of knowledge-intensive and technology-intensive products, generating a trade deficit of some R$ 5.5 billion in 2007.

Despite the adverse diagnosis in terms of the production and generation of innovations, government efforts have been made to boost the dynamism of the Brazilian health industrial complex in the sphere of production as well as science and technology (S&T). These include the Productive Development Policy (PDP) launched in 2008 by the Ministry of Development, Industry & Trade (MDIC), and the ST&I Action Plan (Pacti) launched in late 2007 by the Ministry of Science & Technology (MCT), in both of which the health industrial complex is a priority. Initiatives undertaken by the Ministry of Health through the More Health Program are designed, among other things, to make progress toward the consolidation of a universal, equitable and integral health system, thus enhancing the quality of life for all Brazilians.

Since 2004 Proframa, the Pharmaceutical Supply Chain Support Program run by BNDES, the national development bank, has financed investment by firms in the health industrial complex with headquarters in Brazil. These long-term lines of credit are used to build, expand and modernize production facilities, tailor products to the requirements of the Brazilian regulator (Anvisa) and international regulatory agencies such as the U.S. Food & Drug Administration (FDA) and the European Medicines Agency (EMEA), promote exports, implement radical or incremental innovation projects (in-house or in cooperation with S&T institutions), and acquire or merge with firms to establish larger and/or more vertically integrated domestic firms, among other benefits. Another important BNDES program is Finame Modenaq, the National Industry & Health Services Modernization Program, which finances the acquisition of new plant and equipment made in Brazil for the modernization of various sectors including healthcare.

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* FAPESP wishes to thank Professor Dr. Júlio Cesar Rodrigues Pereira and his staff (Dr. Paula Schiavom Duarte, Bruna Bronhara and Daniel Garkauskas Ramos) for helping to draft the initial version of this chapter. Parts of that version were retained in the final text, which has been reformulated by the executive coordinator with the assistance of researchers Eduardo Muniz Pereira Urías and Thays Murakami.

1. The Health Ministry defines the “health sector” so as to include industrial activities as well as services, despite the significant differences between the nature of the respective activities. See Brazil, 2008a, 2008b.

2. This category includes not just manufacturers of medical and hospital instrumentation and equipment, but also producers of precision and optical instruments, industrial automation equipment, clocks, watches and chronometers.
One of the key features of the health industrial complex is its significant science base, by virtue of which it can be classed as a knowledge-intensive sector. This means that the technological frontier in healthcare is continually shifted by advancement of the scientific frontier, developed predominantly at universities and public and private research institutions. Because science and technology interrelate with and depend on each other more and more intensely, interaction among actors in these two fields is steadily increasing, especially in the developed countries, such as the United States.

In the case of the Brazilian health complex, networks of collaboration between public and private agents are still incipient when compared with the advanced countries. Data from PINTEC 2005 show that 57.4% of pharmaceutical firms (187 out of 326) and 73.7% of medical and hospital instrument firms (462 out of 627) that reported innovations between 2003 and 2005 rated universities and research centers low in importance as a source of information for innovation purposes. However, this does not mean Brazilian scientific production in health is weak. On the contrary, Brazil’s main weakness in health is in the business sphere, where production is decoupled from the national science base. To a large extent this situation derives from firms’ low capacity to perform R&D activities.

Given this characterization of the health industrial complex and its relations with science, the chapter discusses scientific and technological production and the development of human resources in the health sector in Brazil, situating São Paulo State within the national context. Indicators for inputs, outputs and outcomes were used for assessment purposes (as detailed in Section 2).

A systematic approach to the health industrial complex permits a better interpretation of the indicators for inputs, outputs and outcomes, as defined in Adam Jaffe’s seminal paper *Measuring Knowledge in the Health Sector* (Jaffe, 1999). According to this author, at a very general level identifying inputs, outputs and outcomes is useful for any effort designed to develop indicators of the performance of the knowledge economy (see Box 1). While the concept of inputs is self-evident, the distinction between outputs and outcomes is sometimes blurry. The conceptual dividing line is that outputs are produced by the research process itself (inputs), while outcomes only materialize after the outputs of the research process interact with the economic and social system.

The indicators presented here were constructed using information of various kinds, such as public and private spending on R&D and innovation, grants awarded by the National Council for Scientific & Technological Development (CNPq), articles published, and patent applications, among others. It is important to note the limitations of using patent applications as an indicator of the outputs of technological efforts, given that not all the technology developed is patented. In the case of the health industrial complex, however, this is a relevant methodological procedure insofar as patents play a key role as a mechanism of knowledge appropriation by firms, especially producers of medications.

The chapter is divided into five sections including this introduction. Section 2 presents an overview of scientific and technological production in the Brazilian health sector, emphasizing São Paulo State. These indicators were constructed using data from the Institute for Scientific Information (ISI), the CNPq Census, PINTEC, the National Industrial Property Institute (INPI) and the Unified Health System Database (DataSUS). Section 3 discusses human resources in health S&T in Brazil, using data from MCT, ISI, PINTEC, the Coordination Office for the Improvement of Higher Education Personnel (CAPES), and the Ministry of Labor & Employment’s Annual Employee Register (RAIS/MTE). Section 4 sets out the conclusions and Section 5 contains the bibliographical references.
Chapter 11 – ST&I Indicators in Health in São Paulo State

2. Indicators of ST&I inputs, outputs and outcomes in health in São Paulo State

The development and use of ST&I indicators for health activities has received growing attention from governments and national and international agencies. The main justification for this effort is the recognized impact of progress in S&T on health systems, not just in terms of cost savings but also by extending possibilities for curing and treating various diseases.

The health sector is highly complex and heterogeneous, including public biomedical research institutions, universities that conduct research in health and life sciences, pharmaceutical companies, manufacturers of medical and hospital equipment, university and private laboratories that perform clinical studies, and a wide array of healthcare providers.

All this variety has favored the use of a systemic approach to the development and classification of indicators as a way of capturing the dynamics of the process of technological change. The starting-point for the approach commonly adopted is the economic agent, such as a firm, public institution or individual. These agents participate in ST&I activities through R&D, in-

Box 1 – Limitations of ST&I indicators in health

The development of indicators for science, technology and innovation (ST&I) in health is a complex task. This complexity increases where indicators of outcomes are concerned. Buss (2000) stresses that many components of social life which contribute to the quality of life are also fundamental to the wellness of individuals and populations. Thus it is argued that more than assuring access to high-quality medical and healthcare services, it is necessary to address the full range of determinants of wellness, including infant mortality, life expectancy, potable water and basic sanitation, healthcare spending, total fertility, and adult literacy.

Particularly in countries such as Brazil and others in Latin America, highly unequal distribution of income, illiteracy and low levels of educational attainment, as well as rudimentary housing and poor environmental conditions, all play a very important role in determining the quality of life and health. With regard to sanitation, Heller (1998) highlights the importance of action to improve the following:

- water supply, defined as the universal supply of potable water in sufficient quantity;
- sewerage, comprising the connection of the entire population to an efficient sewage system and the disposal of sewage in an environmentally sustainable manner;
- public cleaning, including all stages of environmentally sustainable solid waste disposal and management;
- stormwater drainage to collect and dispose of urban runoff in such a way as to minimize the damage from seasonal heavy rainfall to people and property;
- control of transmissible disease vectors, especially arthropods and rodents.

Heller & Nascimento (2005) argue that action to universalize basic sanitation services must be complemented by R&D activities. This proposition is based on the finding that sanitation research in Brazil is grounded in a range of initiatives and programs which cannot be considered a research policy for the sector. Such a policy is essential, given the significance of the sector and the recognized need for scientific and technological research to help overcome its perverse deficiencies as quickly as possible. In light of this, the authors propose the organization of an array of efforts by the various segments involved with sanitation research – development agencies, federal agencies that coordinate the sector, service providers, and technical and professional organizations – to develop an overarching research plan.

Thus the indicators presented in this chapter by no means exhaust the topic. On the contrary, by acknowledging the insufficiency of our analysis we mean to cast light on the different explanatory variables relating to the problem expounded here and contribute to the development of future initiatives that address the problem by integrating quantitative and qualitative contributions from other knowledge areas.
vention, innovation, diffusion of practices and technologies, or development of human resources for all these activities, for example. In addition, efficient interaction among these agents – a precondition for the constitution of a system – takes place in the form of contracts and agreements for cooperation, co-authorship, commercialization of intellectual property, and flows of knowledge and competencies promoted by informal arrangements (events, conferences etc.) or the circulation of people (OECD, 2009).

Understanding the system requires more than a set of statistics produced at regular intervals of time. The microdata relating to agents must be available for analysis, which will be better if different datasets can be related to provide more information. Thus it will be possible to track the behavior of statistics over time and make inferences regarding causality relationships. However, impact assessments require a variety of techniques including case studies, since the paths of technological change and its impact on economic and social organization are rarely clear (OECD, 2009). Chart 11.1 specifies the indicators presented in this chapter for each of the three levels.

A good indicator should not be too difficult to obtain and should be reproducible or verifiable by independent observers. However, most of the problems that arise when an indicator is evaluated have to do with the relationship between the indicator and the underlying concept concerned. Thus the relations among inputs, outputs and outcomes must be carefully assessed, given that an indicator is by definition an imprecise measure of the underlying concept (Jaffe, 1999; OECD, 2005).

According to the Ministry of Health (Brazil, 2008b), it is not easy to quantify ST&I efforts in health (ST&I/H) in Brazil. For business R&D, the available data are not of high quality, and there is little information on the sector. In addition, there is no continuous, reliable and accessible set of data on R&D expenditure in health (R&D/H), so that as a result there are no accurate estimates of the resources allocated to research on the main diseases and risk factors. Nor is there information on the health outcomes, outputs and impacts of this investment (Brazil, 2008a, 2008b).

R&D/H expenditure in Brazil is estimated to have totaled some R$ 994 million in 2007. Ministry of Health data show that the public sector (federal government, states and municipalities) invested R$ 700 million, of which R$ 147.2 million came out of the ministry’s budget. Universities and research institutions are the main users of public funds for R&D/H in Brazil, receiving 55.5% of total expenditure. However, these numbers should be seen with reservations, given the low quality of the data concerned (Brazil, 2008a, 2008b).

For São Paulo State, it has been possible to extract information on funds allocated to ST&I/H in the health budget and on expenditure from the relevant report issued by the São Paulo State Department of Finance (São Paulo, 2008). This information has been disaggregated to three levels: subfunction, program and activity.

From Figure 11.1, which shows the amount spent on health by the São Paulo State Government for the

![Chart 11.1](chart.png)

**Chart 11.1**
Indicators of inputs, outputs and outcomes in health

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public expenditure on ST&amp;I-related activities</td>
<td>Articles published</td>
<td>Citations</td>
</tr>
<tr>
<td>CNPq grants outstanding</td>
<td>Patents</td>
<td>Reductions in cost of healthcare</td>
</tr>
<tr>
<td>Private expenditure on innovation activities</td>
<td>Technological products</td>
<td></td>
</tr>
<tr>
<td>Private expenditure on R&amp;D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Jaffe (1999).
subfunction “scientific development”, it can be seen that expenditure on this item in 2008 was 7.5 times greater than in 2000. The amounts spent in 2002 and 2003 were relatively small, but expenditure on this item rose sharply from 2004 on.

From Figure 11.2 it can be seen that the state government invested R$ 7.8 million per year on average between 2004 and 2007 in its program for technological innovation and scientific development in health.

Figure 11.3 illustrates expenditure by the state government on three ST&I/H activities. For technological innovation in methods and processes, data are available only for 2008, when expenditure was R$ 56,600. Expenditure on both scientific and technological research in general and on S&T research relating to endemic diseases rose sharply in 2008 compared with the previous year: the former rose 231.6%, while the latter rose 96.7%, albeit on a much smaller base than the former.

Another indicator of public efforts in health is the number of grants awarded by CNPq. Figures 11.4 and 11.5 present this information for two knowledge areas: biological sciences and health sciences. In biological sciences (Figure 11.4), São Paulo State accounted on average for 32% of the outstanding grants in the selected types, led by Retention of Doctors, in which 52% of grants were awarded to researchers in São Paulo State. In health sciences (Figure 11.5), 44% of the outstanding grants in the selected types were awarded to researchers in the state, which accounted for at least 50% of four out of the six main types of grant.

3. For a definition of the fields in each knowledge area, see the Methodological Annex.
Figure 11.2

![Chart showing budget execution from 2004 to 2007.]

Source: SIAFEM, Relatório da Execução Orçamentária (Funcional e Programática) do Governo do Estado de São Paulo.

Note: See Detailed Table 11.2.

Figure 11.3
São Paulo State budget execution: Health function; ST&I-related activities – São Paulo State, 2004-2008

![Chart showing budget execution from 2004 to 2008.]

Source: SIAFEM, Relatório da Execução Orçamentária (Funcional e Programática) do Governo do Estado de São Paulo.

Note: See Detailed Table 11.3.
Figure 11.4
CNPq grants for biological sciences outstanding in 2008 (selected types) & São Paulo State’s share in Brazil total – São Paulo State, 2008

Source: CNPq.
Note: See Detailed Table 11.4.

Figure 11.5
CNPq grants for health sciences outstanding in 2008 (selected types) & São Paulo State’s share in Brazil total – São Paulo State, 2008

Source: CNPq.
Note: See Detailed Table 11.5.
With regard to private ST&I efforts, the analysis refers to expenditure on innovation activities by firms in two segments of the health industrial complex using data from PINTEC: manufacturing of pharmaceutical products, and manufacturing of medical and hospital equipment. The most widely used indicator is R&D expenditure (OECD, 2009), but PINTEC aggregates other items of expenditure on innovation with intramural R&D. Thus both items were considered to be input indicators, and indicators of R&D intensity and other types of spending on innovation were calculated as a percentage of net sales for each segment.

Manufacturers of pharmaceuticals located in São Paulo State invested 4.7 times more in innovation in 2005 than their peers in the rest of Brazil (Figures 11.6 and 11.7). When R&D expenditure alone is analyzed, the ratio falls to 1.6 for the same year (Figures 11.8 and 11.9). However, a comparison of Figures 11.8 and 11.9 shows that firms outside São Paulo State are more R&D intensive since they invest a larger proportion of net sales in R&D, although firms in São Paulo invest proportionally more in innovation activities. In 2005, for example, R&D accounted for only 13% of expenditure on innovation activities by firms in São Paulo, compared with 38% for the rest of Brazil.

**Figure 11.6**
Expenditure on innovation by manufacturers of pharmaceutical products: monetary value & proportion of net sales – São Paulo State, 2003 & 2005

![Expenditure on innovation by manufacturers of pharmaceutical products](image)


Note: See Detailed Table 11.6.
Figure 11.7
Expenditure on innovation by manufacturers of pharmaceutical products: monetary value & proportion of net sales – Brazil (except São Paulo), 2003 & 2005


Note: See Detailed Table 11.7.

Figure 11.8


Note: See Detailed Table 11.8.
São Paulo State also accounted for a significant proportion of innovation expenditure by manufacturers of medical and hospital equipment, albeit to a lesser extent than in the case of the pharmaceutical industry. In 2005, manufacturers of medical and hospital equipment located in the state invested 1.4 times more in innovation than the industry in the rest of Brazil (Figures 11.10 and 11.11). As for intramural R&D, firms in São Paulo invested 1.5 times more (Figures 11.12 and 11.13). Moreover, R&D corresponded to a larger proportion of innovation expenditure in this industry than in the pharmaceutical industry. In 2005 the proportion was 45% in São Paulo State and almost 40% in the rest of Brazil.

It is important to note that all the indicators based on data extracted from PINTEC rose in the period 2003-05, which despite the short length of the period may be a sign that S&T activities received more attention from firms as an instrument for improving their competitiveness. However, the levels observed here were considerably lower than the international average. According to the National Science Foundation, the U.S. pharmaceutical and medical and hospital equipment industries spend the equivalent of 11.8% of net sales on R&D. This is the largest proportion for any U.S. industry. In Brazil and São Paulo State the level of expenditure is much lower, even considering all innovation activities and not just R&D. In 2005 the pharmaceutical industry invested 4.3% of net sales in innovation in São Paulo State and 3.6% in the rest of Brazil; the proportions for the medical and hospital equipment industry were 4.9% and 5.9% respectively. On the other hand, according to data from PINTEC 2005 these numbers exceeded the average for manufacturing as a whole, which was 3.5% in São Paulo State and 2.8% in the rest of Brazil.
Figure 11.10


Note: See Detailed Table 11.10.

Figure 11.11
Expenditure on innovation by manufacturers of medical & hospital equipment: monetary value & proportion of net sales – Brazil (except São Paulo), 2003 & 2005


Note: See Detailed Table 11.11.
Figure 11.12

Note: See Detailed Table 11.12.

Figure 11.13
Expenditure on R&D by manufacturers of medical & hospital equipment: monetary value & proportion of net sales – Brazil (except São Paulo), 2003 & 2005

Note: See Detailed Table 11.13.
2.1.1 FAPESP’s role in promoting ST&I in health in São Paulo State

Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), the São Paulo State Research Development Agency, invests a substantial amount every year in health research, in the form of scholarships, standard grants and regular programs. As shown in Figure 11.14, the knowledge area corresponding to Health received more than R$ 160 million of this investment in 2008, or 25% of the total resources allocated by FAPESP to scholarships and research grants. Health was the area that received most funding from FAPESP in the period 2004-08. The amount invested in health almost doubled in the period.

In addition to its regular programs, FAPESP has a set of special programs whose main objectives are to develop human resources for research, provide support for academic research in priority areas and modernize the infrastructure of São Paulo State’s S&T system. In 2008 FAPESP disbursed some R$ 91.1 million for special programs. It appears that 20% of this total went to the health area.4 Figure 11.15 shows the amounts disbursed by FAPESP for special programs in 2008 and the share of the health area in each one. The standout is Inter-Institutional Cooperation to Support Brain Research (CInAPCe), a program that invested R$ 6.9 million in health in 2008, or 7.5% of the amount allocated by FAPESP to all of its special programs. The CInAPCe program was established in 2004 to promote the development of research in neuroscience. It operates as a network of research groups in São Paulo State linked together to form a virtual institute dedicated to studying the nervous system. The first stage of the program, which began effectively in 2007, focuses on the study of epilepsy. Investment in this program has reached R$ 14.4 million to date.

Figure 11.14
FAPESP’s research grants and scholarships: total disbursed and disbursements for health sciences – São Paulo State, 2004-2008


Note: See Detailed Table 11.14.4.

4. This may be an underestimate. FAPESP’s 2008 annual report (FAPESP, 2008) does not specify the knowledge areas relating to investment of more than R$ 30 million in these programs, some of which may have been subareas of the health sciences.
Another important program is CEPID (an acronym for Centers of Research, Innovation & Dissemination), which was launched in 1999 and in 2000 approved ten out of 227 proposals, later extended to eleven, for support to centers of excellence in various knowledge areas for a period of up to 11 years. Each of the centers is running a multidisciplinary program at the frontier of knowledge. Besides their innovative thrust, they seek to develop mechanisms for transferring research results to different levels of government as public policy inputs, or to the private sector via technology creation. FAPESP invested a total of R$ 25.6 million in all 11 centers in 2008. This was 32.4% more than in 2007 and corresponded to 34.3% of the same agency’s investment in its Technological Innovation Research Programs during the same year. Figure 11.16 shows the growth in disbursements for CEPID since 2004.

Although FAPESP’s annual reports (Relatórios de Atividades) do not provide information on CEPID broken down by knowledge area, not least because of the program’s multidisciplinary nature, it is important to note that six of the 11 centers focus on health-related issues:

- Center for Applied Toxinology, linked to Instituto Butantan, conducts research on animal and microbial toxins and their use in drug development.
- Center for Structural Molecular Biotechnology, based at the São Carlos campus of the University of São Paulo (USP), conducts research in protein engineering for drug development.
- Human Genome Research Center, based at USP’s Institute of Biosciences, conducts research on genetic disorders and treatment options.
- Antonio Prudente Center for Cancer Research & Treatment, with researchers at Hospital do Câncer A.C. Camargo, Brazil’s foremost cancer hospital.
- Center for Cell-Based Therapy, based at USP’s Ribeirão Preto School of Medicine, with researchers from the Blood Center, University Hospital Bone Marrow Transplant Unit and Protein Chemistry Laboratory.
- Center for Sleep Research, based at the Federal University of São Paulo (Unifesp), conducts research on sleep-related disorders.

5. For a complete list of these centers, see the Methodological Annex.
FAPESP’s Research Innovation Programs support research projects with the potential to develop new technology for application by business and projects that contribute to public policy formulation. They include Partnership for Technological Innovation (PITE), Technological Innovation in Small Business (PIPE) and Public Policy Research for the Unified Health System (PP-SUS).

PITE funds research projects by S&T institutions such as universities and research centers. These projects must be developed in cooperation with researchers at centers located in Brazil or abroad, with matching funding from the centers concerned. Thus PITE aims to intensify relationships among universities, research institutions and business organizations via cooperative co-funded research projects. Partner firms must provide matching funds either of their own or via third parties. As shown in Figure 11.17, FAPESP invested only a small proportion of PITE funding in health during the period 2004-08 except for 2007, when health exceeded 25% of the total. In 2008, it invested some R$ 260,000 in health via PITE.

Since 2006, however, FAPESP has allocated funds to PITE-SUS, a subprogram established specifically to create innovative products and processes that meet the needs of the Unified Health System (SUS). Figure 11.18 shows the amounts invested in PITE-SUS between 2006 and 2008, which totaled some R$ 2 million, with 2008 alone accounting for 44.4%.

PIPE was established in 1997 to promote small business ST&I research in São Paulo State. To qualify for PIPE funding, a small firm must have research projects developed by researchers who are employees or associated with it for research purposes. As shown in Figure 11.19, the health area received more than R$ 7.7 million from PIPE, or roughly 8% of the total disbursed by PIPE in the period 2004-08.

PP-SUS was launched in late 2005 in partnership with the São Paulo State Department of Health. This joint initiative of the Ministry of Health, CNPq and the São Paulo State Government supports R&D and innovation projects designed to help SUS take preventive action. Funding has risen substantially since the program’s inception in 2006, from some R$ 593,000 to about R$ 1.6 million in 2008 (Figure 11.20), for growth of 165%.
Figure 11.17
FAPESP’s PITE (Partnership for Technological Innovation Program): total disbursed and disbursements for grants in health sciences – São Paulo State, 2004-2008


Note: See Detailed Table 11.17.

Figure 11.18


Note: See Detailed Table 11.16.
Figure 11.19


Note: See Detailed Table 11.18.

Figure 11.20


Note: See Detailed Table 11.16
2.2 Output indicators

The output indicators discussed in this subsection relate to scientific production in health by researchers in São Paulo State, compared with their peers in other parts of Brazil, and to patenting by agents of the health sector based in São Paulo State and other parts of Brazil.

2.2.1 Overview of scientific production in health in Brazil and São Paulo State

The data source for this analysis of Brazilian scientific production is ISI Web of Science, in which 124 Brazilian journals were indexed in October 2009. Although this is a relatively small number, the journals in question cover a major proportion of Brazilian scientific production and ISI's databases represent the best source of information for Brazilian scientists. In a study of the citation patterns for 43 Brazilian journals, Cunha-Melo, Santos & Andrade (2006) found that 86% of citations in these journals referred to foreign journals and 95% of the foreign journals cited were indexed by ISI.

This analysis covers data on Brazilian scientific production in the period 1995-2006 relating to the absolute and proportional share of health sciences in each region. Articles with co-authors in different regions are indexed for each author and region, so that the total for Brazil is less than the sum of all the scientific articles attributed to the various regions. São Paulo State is shown separately from the other states of the Southeast Region, which for the purposes of this analysis comprises only Minas Gerais State, Rio de Janeiro State and Espírito Santo State. São Paulo State’s scientific production in the period exceeded that of other states by between 1.5 and 28 times in all knowledge areas (Table 11.1). It also displayed the highest ratio of health sciences to other disciplines (and to the total), with 77:100, followed closely by the South, with 64:100.

In order to construct indicators of scientific production in the area of human health that are reliable and adequately reflect Brazilian conditions, we have incorporated datasets from CNPq’s Census Tabular Plan for the years 2000, 2002, 2004, 2006 and 2008.

<table>
<thead>
<tr>
<th>Region</th>
<th>ISI-indexed scientific articles</th>
<th></th>
<th></th>
<th></th>
<th>Ratio of health to other areas (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Health sciences</td>
<td>Other areas</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abs. nos</td>
<td>%</td>
<td>Abs. nos</td>
<td>%</td>
<td>Abs. nos</td>
</tr>
<tr>
<td>São Paulo State</td>
<td>33,420</td>
<td>43.4</td>
<td>43,576</td>
<td>56.6</td>
<td>76,996</td>
</tr>
<tr>
<td>Southeast (except SP)</td>
<td>16,571</td>
<td>36.1</td>
<td>9,364</td>
<td>63.9</td>
<td>45,935</td>
</tr>
<tr>
<td>Central West</td>
<td>2,530</td>
<td>33.5</td>
<td>5,015</td>
<td>66.5</td>
<td>7,545</td>
</tr>
<tr>
<td>North</td>
<td>1,212</td>
<td>32.2</td>
<td>2,556</td>
<td>67.8</td>
<td>3,768</td>
</tr>
<tr>
<td>Northeast</td>
<td>4,930</td>
<td>31.1</td>
<td>10,912</td>
<td>68.9</td>
<td>15,842</td>
</tr>
<tr>
<td>South</td>
<td>10,077</td>
<td>39.1</td>
<td>15,706</td>
<td>60.9</td>
<td>25,783</td>
</tr>
</tbody>
</table>

Source: ISI. Web of Science.

(1) Ratio of articles in health science to articles in other knowledge areas. For example, 3:4 means that for every three articles in health sciences there were four articles in other knowledge areas.

6. The number of ISI-indexed Brazilian journals has risen significantly in recent years. For a more detailed discussion of this phenomenon, see Chapter 4 of this publication.

7. Research Group Directory Tabular Plan from the Lattes CV database, available at: http://dgp.cnpg.br/planotabular, last visited in Dec. 2009. Although the data are presented as a time series, census years overlap. In addition, the growth discussed here may be overestimated because more recent censuses probably cover a larger proportion of total Brazilian production: coverage has expanded so substantially that the number of institutions surveyed by the census rose 89% between 2000 and 2008, while the number of doctors in the database rose 175%. This compares with 115% growth in the number of PhDs awarded annually.
Census information comes from the CNPq Research Group Directory registration database, the Lattes CV database and the CAPES Data Collection System. The information analyzed here was supplied voluntarily by the individuals concerned. Nevertheless, the universe encompassed by the census has expanded over time and can be considered satisfactorily representative of the Brazilian scientific community and of national S&T output.

The Tabular Plan is segmented into seven units of analysis, comprising information on research groups, researchers, students, technical staff, research lines, interaction with business, and scientific, technological and artistic production. The analysis in this chapter is concerned only with the latter, given that scientific production is an acceptable indicator of S&T outputs. Furthermore, the analysis focuses on researchers who have PhDs, as doctors are the most significant portion of the scientific production universe.

Although the indicators presented here are not directly comparable to those available from ISI Web of Science, they display at least two advantages: they cover a wider range of publications not indexed by ISI, especially Brazilian journals; and they can be disaggregated by health-related subareas to verify whether the patterns vary significantly within this knowledge area. The tabulations have therefore been confined to two major areas: biological sciences and health sciences. In addition, four subareas within biological sciences have been excluded, namely biophysics, general biology, botany and zoology, because scientific production in these subareas does not as significantly influence human health as the rest. Nevertheless, it must be acknowledged that the advancement of knowledge in these disciplines may lead to important outcomes and opportunities for human health, albeit with a considerable time lag.

São Paulo State’s share of the scientific articles published in Brazilian journals in the selected subareas of health sciences was substantial in the period 2000-08 (Figure 11.21). Although institutions in São Paulo State accounted for the smallest proportion of scientific production in the subareas pharmacy and collective health according to the 2008 census, even so their shares were almost a quarter and 30% of Brazilian production respectively. In the other seven areas São Paulo State accounted for over a third of all scientific articles by Brazilians published in domestic journals, and for over 50% in three areas (physiotherapy and occupational therapy, speech-language therapy, and medicine).

In the selected subareas of biological sciences (Figure 11.22), São Paulo State’s share was smaller but still accounted for a significant proportion of the total. With the sole exception of parasitology, institutions in São Paulo State accounted for at last 22% of Brazilian scientific production in 2008.

São Paulo State’s share of articles in health sciences and selected areas of biological sciences published by international journals is shown in Figures 11.23 and 11.24 respectively. The state accounted for a significant proportion of production in all subareas of health sciences (Figure 11.23). Indeed, its share of articles published internationally was larger than its share of articles published in domestic journals on health sciences overall. Once again, pharmacy and collective health underperformed the average for the state, which was 37% in the case of articles published by international journals. However, in five of the seven remaining subareas (physiotherapy and occupational therapy, nursing, speech-language therapy, dentistry and medicine) São Paulo State’s share of the total published in Brazil exceeded 50%, with speech-language therapy accounting for over 80%.

Figure 11.24 shows that in the case of biological sciences São Paulo State’s share of international publications was also larger than its share of Brazilian publications. With the exception of parasitology, institutions in the state accounted for more than a third of Brazilian articles published by international journals in all subareas.

8. The CAPES Data Collection Application is a computerized information system designed to collect information on master’s and PhD courses accredited by the National System of Post-Graduate Studies: Sistema Nacional de Pós-Graduação, available at: http://www.CAPES.gov.br/avaliacao/coleta-de-dados, last visited in Dec. 2009.
Figure 11.21
Scientific articles on health sciences published in Brazilian journals by knowledge subarea – São Paulo State, 2000-2008

**Physical education**

**Nursing**

**Pharmacy**

**Physiotherapy & occupational therapy**

**Speech-language therapy**

(Continued)
Figure 11.21
Scientific articles on health sciences published in Brazilian journals by knowledge subarea – São Paulo State, 2000-2008


Note: See Detailed Table 11.19.
Figure 11.22
Scientific articles on biological sciences published in Brazilian journals by knowledge subarea – São Paulo State, 2000-2008

Biochemistry

Pharmacology

Physiology

Genetics

São Paulo State (abs. nos.)

São Paulo State/Brazil (%)
Figure 11.22
Scientific articles on biological sciences published in Brazilian journals by knowledge subarea – São Paulo State, 2000-2008


Note: See Detailed Table 11.20.
Figure 11.23
Scientific articles on health sciences published in international journals by knowledge subarea – São Paulo State, 2000-2008

(CONTINUED)
**Figure 11.23**
Scientific articles on health sciences published in international journals by knowledge subarea – São Paulo State, 2000-2008


**Note:** See Detailed Table 11.21.
Figure 11.24
Scientific articles on biological sciences published in international journals by knowledge subarea – São Paulo State, 2000-2008

Biochemistry

Pharmacology

Physiology

Genetics
Figure 11.24
Scientific articles on biological sciences published in international journals by knowledge subarea – São Paulo State, 2000-2008


Note: See Detailed Table 11.22.
2.2.2 Brazilian scientific production on selected diseases and the share of institutions in São Paulo State

The indicators discussed in this subsection were obtained from ISI Web of Science. The methodology used to search the database for scientific articles focused on the diseases most intensively researched in the United States in terms of the volume of funds invested. Information was collected for this purpose from the National Institutes of Health (NIH) website, which publishes the amounts invested in such research by knowledge area and disease. The ten diseases most

Box 2 – Neglected diseases due to 10/90 gap

In 1990 the Global Forum for Health Research coined the term “10/90 gap” to refer to its finding that only 10% of worldwide expenditure on health research and development is devoted to diseases that primarily afflict the poorest 90% of the world’s population, or conversely that 90% of the world’s scientific research resources is devoted to improving the health of 10%. The result is a list of “neglected diseases”, which are particularly important in poor countries, and even in developing countries such as Brazil. These are mostly endemic tropical diseases prevalent in Africa, Asia and Latin America, such as malaria, ascariasis, schistosomiasis, leishmaniasis, hanseniasis, sleeping sickness and Chagas disease, among others.

More than 8 million people are estimated to have Chagas disease in the 21 countries of Latin America, where it is endemic and the most lethal parasitic disease. Two million are in the chronic stage, which is often fatal. Only 0.5% of these people are estimated to be receiving treatment. The largest number of cases is in Brazil, with 23% of the Latin American total, according to the World Health Organization.

Some 12 million people are infected with leishmaniasis in 88 countries, especially Bangladesh, Brazil, Ethiopia, India, Kenya and Sudan. Brazil accounts for 90% of new cases occurring in Latin America. Tuberculosis, also considered a neglected disease, is thought to affect roughly 2 billion people, a third of the world population, and kills as many as 2 million every year. It is concentrated in 22 countries (80% of cases) including Brazil.

The high incidence of these diseases in poor and developing countries is associated not only with poverty, inadequate housing and lack of sanitation, but also with lack of access to healthcare and medical facilities for diagnosis and treatment. Ignorance is also a factor, since many people in these situations are not aware of the importance of good environmental management. Worldwide deaths from neglected diseases amount to over 1 million per year, or about 3,000 per day.

The lack of adequate facilities for diagnosis and treatment reflects the fact that these diseases afflict the poor and therefore do not provide a profitable market for suppliers of medical drugs, most of which are multinational pharmaceutical firms based in the developed countries. Diseases such as leishmaniasis, dengue fever, tuberculosis and hanseniasis no longer represent a public health hazard in the developed countries, which do not invest in their treatment. Only 1.3% of the new drugs brought to market between 1975 and 2004 (21 out of 1,556) were designed to treat neglected diseases even though the latter account for 12% of the global disease burden. As a result, it is up to the public sector to fund and perform research in this field. Only 5% of global investment in R&D in
researched in the U.S. are as follows, in descending order: cancer, AIDS, cardiovascular disorders, diabetes, atherosclerosis, Alzheimer’s, pneumonia/influenza, hypertension, schizophrenia and asthma.

It is important to stress that funding for research on specific diseases in the U.S. is based on mortality rates. Thus diseases with the highest death rates receive the most investment. In the Brazilian case, the diseases that kill most are basically the same as in the U.S. (see Box 2), with minor differences in the rank order. Thus the top ten diseases are also important for Brazil and were used as keywords in the search for scientific articles.9

In the field of neglected diseases comes from private-sector firms, with the rest coming from philanthropic institutions (54%) and the public sector (41%).

In the Brazilian case, government incentives for R&D in neglected diseases are rising and have reached some R$ 75 million per year. In 2008, about 30% (R$ 25 million) came from the Ministry of Science & Technology via its main development agencies, CNPq and FINEP (FINEP, 2009). FINEP, for example, provided R$ 2.2 million for a visceral leishmaniasis project, in the largest amount of public-sector funding to combat any single disease in Brazil. In terms of public investment in the fight against neglected diseases, Brazil ranks sixth among all countries (behind the U.S., the E.U., the U.K., the Netherlands and Ireland) and first among developing countries.

In São Paulo State, it is worth highlighting the initiatives undertaken by FAPESP, which in 2000 set up the CEPID Program. CEPID stands for Centers of Research, Innovation & Dissemination. One of these was the Center for Structural Molecular Biotechnology (CBME), which gave rise to INBEQMeDI, the National Institute of Structural Biotechnology & Medicinal Chemistry in Infectious Diseases (FAPESP, 2010). INBEQMeDI carries out structural and biological studies on specific molecular targets of microorganisms associated with infectious diseases, particularly neglected tropical diseases. In addition to conducting basic research, it develops new drugs to treat endemic diseases, especially leishmaniasis, schistosomiasis, Chagas disease, malaria and leptospirosis. In 2009 approval was announced for investment of R$ 4.8 million in INBEQMeDI as part of a R$ 553 million funding package, the largest ever for research networks in Brazil, to be invested in 101 national S&T institutions in the next three to five years. The World Health Organization’s Special Program for Research and Training in Tropical Diseases (TDR) recently selected INBEQMeDI as a world reference center in medicinal chemistry for Chagas disease.

Other institutions in São Paulo State have contributed to progress in the diagnosis and treatment of neglected diseases, including Instituto Butantan and Instituto Adolfo Lutz. The results of a joint research project by these two institutions, announced in 2008, showed that two active steroids derived from cane toad venom can destroy the leishmania parasite without damaging mammalian cells. One of the molecules is also lethal to Trypanosoma cruzi, which causes Chagas disease. The research was supported by FAPESP under its standard research grant program (FAPESP, 2008b). Institutions in other states that are also reference centers for research on neglected diseases include Fiocruz (Rio de Janeiro) and Instituto Evandro Chagas (Pará).

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9. The importance of these diseases to Brazil can be seen from the Ministry of Health’s website (Brazil, 2008a, 2008b). Available at: <http://portal.saude.gov.br/portal/arquivos/pdf/coletiva_saude_061008.pdf>.
As can be seen from Table 11.2, the number of ISI-indexed scientific articles on the selected diseases (only scientific articles and for all years covered by the database, from 1900 to 2009) exceeded 591,000, of which 38% (224,638) had at least one U.S. author and 1.6% (9,219) had at least one Brazilian author. It should be noted that there may have been some double counting, since some articles by researchers at Brazilian institutions were co-authored by researchers at U.S. institutions and vice-versa, and these will have been counted in both the “U.S.” column and the “Brazil” column. Duplication does not impair the analysis, however. As expected, researchers at U.S. institutions contributed significantly to the relevant articles in ISI-indexed journals.10

Scientific publications on the diseases concerned by U.S. and Brazilian researchers displayed several relevant differences. U.S. researchers published more on diseases such as AIDS (51.1% of all ISI-indexed articles on AIDS involved at least one U.S. institution), Alzheimer’s (46.6%) and schizophrenia (39.7%), while Brazilian researchers focused more on diseases such as hypertension (2.5%), cardiovascular disorders (2.2%) and diabetes (2.1%).

Table 11.2
Scientific articles on the top ten diseases by U.S. funding and their share of total ISI-indexed articles – United States & Brazil, 1900-2009

<table>
<thead>
<tr>
<th>Disease</th>
<th>Total</th>
<th>USA</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>591,035</td>
<td>224,638</td>
<td>9,219</td>
</tr>
<tr>
<td>Aids</td>
<td>67,429</td>
<td>34,461</td>
<td>1,236</td>
</tr>
<tr>
<td>Pneumonia, influenza</td>
<td>67,760</td>
<td>25,842</td>
<td>664</td>
</tr>
<tr>
<td>Cancer</td>
<td>65,645</td>
<td>23,821</td>
<td>1,433</td>
</tr>
<tr>
<td>Cardiovascular disorder</td>
<td>65,528</td>
<td>23,588</td>
<td>1,433</td>
</tr>
<tr>
<td>Hypertension</td>
<td>64,285</td>
<td>20,970</td>
<td>1,609</td>
</tr>
<tr>
<td>Diabetes</td>
<td>60,929</td>
<td>22,135</td>
<td>1,279</td>
</tr>
<tr>
<td>Asthma</td>
<td>57,210</td>
<td>17,707</td>
<td>597</td>
</tr>
<tr>
<td>Atherosclerosis</td>
<td>54,788</td>
<td>18,648</td>
<td>583</td>
</tr>
<tr>
<td>Schizophrenia</td>
<td>48,033</td>
<td>19,089</td>
<td>393</td>
</tr>
<tr>
<td>Alzheimer’s</td>
<td>39,428</td>
<td>18,377</td>
<td>333</td>
</tr>
</tbody>
</table>

Source: ISI. Web of Science.

10. For a detailed methodological discussion of how ISI Web of Science was used for this publication, see Chapter 4.
11. Data from ISI Web of Science: http://www.isiknowledge.com (subscribers only).
2.2.3 Overview of technological production in health in Brazil and São Paulo State

Patenting is the most important means of appropriating the results of innovation efforts in the health sector. Product and process innovations in health correlate closely with scientific progress. INPI, Brazil’s patent office, granted 4,846 patents in the health area to Brazilian residents in the period 1980-2005. Of these, 2,493 contained information in the patentee’s state of residence. Figure 11.26 and Map 11.1 compare the patents awarded to residents of São Paulo State and other states of Brazil. São Paulo State had the largest share of patents awarded in all the periods analyzed. It should be noted that the group Other States contained no patents for residents of Roraima, Rondônia, Acre, Sergipe, Alagoas or Tocantins (there are no records for patent filings by residents of these states in the periods analyzed). The large number of patents awarded in the period 1995-99 was largely due to the fact that Brazil began granting patents to pharmaceutical products and processes only in 1997. As a result, a large number of patents were already in force in other countries before they were recognized by INPI for Brazil.

Source: ISI, Web of Science.

Note: See Detailed Table 11.23.
Figure 11.26
Number of patents in Class A61, Medical or Veterinary Science: Hygiene, granted to residents by INPI – São Paulo State & other states, 1980-2005

Source: INPI.

Notes: 1. The following subclasses of Class A61 were excluded: A61D (veterinary instruments, implements, tools or methods); A61Q (specific use of cosmetics or similar toilet preparations for personal hygiene).
2. See Detailed Table 11.24.

Map 11.1
Number of INPI patents in Class A61, Medical or Veterinary Science: Hygiene, granted to residents by state – Brazil, 1980-2005


Notes: 1. The following subclasses of Class A61 were excluded: A61D (veterinary instruments, implements, tools or methods); A61Q (specific use of cosmetics or similar toilet preparations for personal hygiene).
2. See Detailed Table 11.25.
Map 11.1
Number of INPI patents in Class A61, Medical or Veterinary Science: Hygiene, granted to residents by state – Brazil, 1980-2005

Source: INPI; IBGE Malha Municipal 2007.
Notes: 1. The following subclasses of Class A61 were excluded: A61D (veterinary instruments, implements, tools or methods); A61Q (specific use of cosmetics or similar toilet preparations for personal hygiene).
2. See Detailed Table 11.25.
Map 11.1
Number of INPI patents in Class A61, Medical or Veterinary Science: Hygiene, granted to residents by state – Brazil, 1980-2005

1995-1999

Source: INPI; IBGE Malha Municipal 2007.
Notes: 1. The following subclasses of Class A61 were excluded: A61D (veterinary instruments, implements, tools or methods); A61Q (specific use of cosmetics or similar toilet preparations for personal hygiene).
2. See Detailed Table 11.25.

2000-2005

Source: INPI; IBGE Malha Municipal 2007.
Notes: 1. The following subclasses of Class A61 were excluded: A61D (veterinary instruments, implements, tools or methods); A61Q (specific use of cosmetics or similar toilet preparations for personal hygiene).
2. See Detailed Table 11.25.
Map 11.2 presents a more detailed picture of health-related patenting in São Paulo State, displaying the number of patents for each of the state’s 15 Administrative Areas (RA) in the period 1980-2005. In all five subperiods the leader was the São Paulo Administrative Area, which includes the city of São Paulo. This RA accounted for 908 (65%) out of 1,396 patents granted to residents of São Paulo State, 728 of them located in the state capital. Next was the Campinas RA with 227 patents (16.3%), 134 of them granted to patentees in the city of Campinas. The Ribeirão Preto RA ranked third with 62 patents (4.4%), 53 granted to patentees in the city of Ribeirão Preto.

To complement the patent data, the CNPq Research Group Directory Census Tabular Plan was used to produce indicators of technological outputs in São Paulo State. The following were selected for this analysis:

- **Technological products** (pilot projects, designs, prototypes) *with or without patents*: apparatus, instruments, equipment, drugs etc;
- **Processes and techniques** *with or without registration or patents*: analytical, instrumental, pedagogical, therapeutic etc.

Although it is difficult to relate the indicators for products and processes, with or without registration or patents, to the patenting indicators based on data from INPI, the method enabled elements appropriate to Brazilian conditions to be assembled, since as already noted the CNPq database contains a great deal of information on research efforts in Brazil. As in several branches of Brazilian industry, S&T efforts in health take place above all in universities, making the CNPq database particularly effective at capturing such efforts. Moreover, as in the case of scientific production, the data extracted from the Tabular Plan can be broken down by knowledge subarea and used to find those with the best performance in São Paulo State.

The next sequence of figures present the share of São Paulo State’s institutions in health science and biological science technological outputs. A common feature of “technological products”, “technological processes” and “software” as units of analysis is the erratic pattern of both absolute and relative numbers. Whereas the bibliometric indicators display certain regularities in terms of growth, stability or decline, the distribution in this case is more irregular, owing mainly to the smaller volume of production by these research groups as far as technological outputs are concerned. A second point in common, which helps explain the first, is that the absolute numbers are significantly lower than in the case of bibliographic production.

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14. It is important to note that information is inserted by self-declaration into the CNPq Research Group Directory and Lattes database, without verification by CNPq. Moreover, inclusion in the Directory is voluntary, albeit growing. See: <http://dgp.cnpq.br/>. 
Map 11.2
Number of INPI patents in Class A61, Medical or Veterinary Science: Hygiene, granted to residents by administrative area – São Paulo State

Notes: 1. The following subclasses of Class A61 were excluded: A61D (veterinary instruments, implements, tools or methods); A61Q (specific use of cosmetics or similar toilet preparations for personal hygiene).
2. See Detailed Table 11.26.
Figure 11.27 presents the volumes of technological products in health sciences in São Paulo State. The top subareas, with the largest volume of product outputs in each CNPq census analyzed, were medicine, pharmacy, dentistry and collective health. São Paulo State’s share of registered and patented technological products in the first three of these subareas was larger than its share of unregistered and unpatented products. In the case of collective health, the number of registered and patented products was significantly smaller than the number of unregistered and unpatented products.
Figure 11.27
Total technological products in health sciences and São Paulo State’s share by knowledge subarea – São Paulo State, 2000-2008
Figure 11.27
Total technological products in health sciences and São Paulo State’s share by knowledge subarea – São Paulo State, 2000-2008

Figure 11.28 presents the same type of information for biological sciences. Only two subareas, biochemistry and microbiology, produced more than 30 registered or patented technological product output units in at least one of the censuses analyzed. In both subareas, São Paulo State’s share was high in the 2008 census: 41.7% for the former and 41.3% for the latter. It was highest in genetics, reaching 34.1% of all unregistered and unpatented products. The fact that Brazil’s IP legislation (Law 9279/1996) does not allow the patenting of natural living organisms or biological materials found in nature helps explain low patenting in this subarea.

São Paulo State also performed well in health science technology process outputs, plotted by Figure 11.29. In the 2008 census, institutions in the state ranked highly in registered and patented technological processes in the following subareas: medicine (31), dentistry (21) and pharmacy (29), accounting respectively for 39%, 29% and 24% of all such processes created in Brazil. In other subareas, although the absolute numbers were low, São Paulo State’s share was significant, especially in registered and patented technological processes. Collective health was again the exception, with 47 unregistered or unpatented processes in 2008, representing 35% of the Brazilian total. Only five registered or patented processes were produced in the period, accounting for 14% of the total.
Figure 11.28
Total technological products in biological sciences and São Paulo State’s share by knowledge subarea – São Paulo State, 2000-2008

Biochemistry

Pharmacology

Physiology

Genetics

Total SP, registered & patented (abs. nos.)
Total SP, unregistered & unpatented (abs. nos.)
SP/Brazil registered & patented (%)
SP/Brazil unregistered & unpatented (%)

(CONTINUED)
Figure 11.28
Total technological products in biological sciences and São Paulo State’s share by knowledge subarea – São Paulo State, 2000-2008


Note: See Detailed Table 11.28.
Figure 11.29
Total technological processes produced in health sciences and São Paulo State’s share by knowledge subarea – São Paulo State, 2000-2008

Physical education

Nursing

Pharmacy

Physiotherapy & occupational therapy

Speech-language therapy


Note: See Detailed Table 11.29.
The subareas of biological sciences in which São Paulo State performed best (Figure 11.30) were biochemistry, microbiology, pharmacology, immunology and genetics, although production in the latter fell significantly between 2006 and 2008. In biochemistry, São Paulo State accounted for at least 35 registered or patented technological processes per subperiod according to the 2004, 2006 and 2008 censuses, with shares ranging between 32% (2008) and 37% (2004). In microbiology, 38 unregistered or unpatented technological processes were developed by researchers at institutions in São Paulo State, accounting for 59% of the Brazilian total according to the 2008 census. The number of registered or patented processes developed in microbiology was 25, or 21% of the national total. In immunology, São Paulo State performed best in 2004, developing 32 technological processes, 13 of them registered or patented. In 2008, 17 processes were developed in the state, 11 of them patented, accounting for 25% of all Brazilian registered and patented processes in the period.
Figure 11.30
Total technological processes produced in biological sciences and São Paulo State's share by knowledge subarea – São Paulo State, 2000-2008

(CONTINUED)
Figure 11.30
Total technological processes produced in biological sciences and São Paulo State’s share by knowledge subarea – São Paulo State, 2000-2008


Note: See Detailed Table 11.30.
2.3 Outcome indicators

The production of outcome (or impact) indicators is a major challenge. In many cases it is extremely difficult to prove the existence of a direct or indirect cause-and-effect relationship between phenomena that underlie indicators of inputs, outputs and outcomes. This does not diminish the importance of such indicators, which by definition do not represent “the truth” about the status of science and technology but are incomplete expressions of or approximations to it. The impact of inputs is indirect and difficult to quantify (Trzesniak, 1998).

In this study the first step was to produce indicators of the outcomes of scientific activity, measured by the number of citations and the ratio of these to the total number of articles published. The study of citations is one way to demonstrate the connections among scientific researchers and their possible influences on each other. Citing previous research is considered important, above all because it confers credibility on the article or paper in question. Citation indicators can therefore be understood as indicators of the quality and pervasiveness of the ideas and discoveries contained in a scientific article.

Health sciences outperformed other areas in terms of citations received in São Paulo State, as shown by Table 11.3. In addition to its leading position in health-related scientific production, these citation indicators suggest that the state is also more widely recognized by the research community.

Table 11.4 presents citations per article for health sciences and other knowledge areas within regions, as well as shares of the total for each region (with the overall share for all knowledge areas corresponding to 1). São Paulo State had the largest number of citations per article in the health area (8.1), followed closely by the South (7.9). However, the impact of health within each of the other regions was more significant. The exception was the North, where the impact of other knowledge areas was greater.

<table>
<thead>
<tr>
<th>Region</th>
<th>Abs. nos.</th>
<th>%</th>
<th>Abs. nos.</th>
<th>%</th>
<th>Abs. nos.</th>
<th>%</th>
<th>Ratio of health to other areas (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo State</td>
<td>270,053</td>
<td>53.0</td>
<td>239,857</td>
<td>47.0</td>
<td>509,910</td>
<td>100.0</td>
<td>9.8</td>
</tr>
<tr>
<td>Southeast (except SP)</td>
<td>127,952</td>
<td>47.1</td>
<td>143,578</td>
<td>52.9</td>
<td>271,530</td>
<td>100.0</td>
<td>7.8</td>
</tr>
<tr>
<td>Central West</td>
<td>15,960</td>
<td>43.7</td>
<td>20,586</td>
<td>56.3</td>
<td>36,546</td>
<td>100.0</td>
<td>6.8</td>
</tr>
<tr>
<td>North</td>
<td>8,054</td>
<td>29.2</td>
<td>19,495</td>
<td>70.8</td>
<td>27,549</td>
<td>100.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Northeast</td>
<td>30,551</td>
<td>39.7</td>
<td>46,439</td>
<td>60.3</td>
<td>76,990</td>
<td>100.0</td>
<td>5.8</td>
</tr>
<tr>
<td>South</td>
<td>79,101</td>
<td>51.9</td>
<td>73,380</td>
<td>48.1</td>
<td>152,481</td>
<td>100.0</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Source: ISI, Web of Science.

(1) Ratio of article citations in health science to citations in other knowledge areas. For example, 9:8 means that for every nine citations of articles in health sciences there were four citations of articles in other knowledge areas.
One of the ST&I/H outcomes most pursued by public policy makers is a reduction in public spending (OECD, 2005). This is analyzed here in terms of the average cost of hospitalization for the Unified Health System (SUS) by medical specialty in São Paulo State in the period 2000-07, as a proxy for successful incorporation of S&T outputs in activities relating to health sciences. The average cost of hospital care is measured here using SUS’s hospital admission authorization (AIH) records. While acknowledging that the costs calculated by SUS are influenced by socioeconomic and epidemiological factors, as well as public policy in healthcare, we believe aggregate-level analysis is adequate for testing the hypothesis of ST&I/H diffusion impact.

As shown by Table 11.5, the cost of 25% or more of the procedures covered by SUS fell in 22 of the 37 selected medical specialties. In addition, the average cost saving for procedures covered by SUS was 16%, and savings exceeded 20% in 12 specialties.15

---

15. Respiratory medicine, endocrine & metabolic diseases, neurology, active search for organ donors, trauma, thoracic surgery, infectious diseases, congenital anomalies, allergy & immunology, cardiovascular pathology, pediatric nephrology, and obstetric surgery.
### Table 11.5
Medical specialties displaying a reduction in the average cost of hospitalization – São Paulo State, 2000-2007 (cumulative)

<table>
<thead>
<tr>
<th>Medical specialty</th>
<th>No. of procedures analyzed</th>
<th>No. of procedures displaying reduction in average cost</th>
<th>Procedures displaying reduction in average cost (%)</th>
<th>Average reduction in cost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Respiratory medicine</td>
<td>34</td>
<td>3</td>
<td>8.8</td>
<td>39.2</td>
</tr>
<tr>
<td>2 Endocrine &amp; metabolic diseases</td>
<td>26</td>
<td>6</td>
<td>23.1</td>
<td>27.1</td>
</tr>
<tr>
<td>3 Neurology</td>
<td>35</td>
<td>8</td>
<td>22.9</td>
<td>26.9</td>
</tr>
<tr>
<td>4 Active search for organ donors</td>
<td>3</td>
<td>1</td>
<td>33.3</td>
<td>25.9</td>
</tr>
<tr>
<td>5 Trauma</td>
<td>23</td>
<td>6</td>
<td>26.1</td>
<td>25.2</td>
</tr>
<tr>
<td>6 Thoracic surgery</td>
<td>80</td>
<td>20</td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td>7 Infectious diseases</td>
<td>103</td>
<td>32</td>
<td>31.1</td>
<td>22.1</td>
</tr>
<tr>
<td>8 Congenital anomalies</td>
<td>21</td>
<td>5</td>
<td>23.8</td>
<td>21.5</td>
</tr>
<tr>
<td>9 Allergy &amp; immunology</td>
<td>5</td>
<td>1</td>
<td>20.0</td>
<td>20.9</td>
</tr>
<tr>
<td>10 Cardiovasculopathy</td>
<td>39</td>
<td>8</td>
<td>20.5</td>
<td>20.8</td>
</tr>
<tr>
<td>11 Pediatric nephrology</td>
<td>35</td>
<td>7</td>
<td>20.0</td>
<td>20.6</td>
</tr>
<tr>
<td>12 Obstetric surgery</td>
<td>27</td>
<td>3</td>
<td>11.1</td>
<td>20.4</td>
</tr>
<tr>
<td>13 Collagenosis</td>
<td>12</td>
<td>2</td>
<td>16.7</td>
<td>19.7</td>
</tr>
<tr>
<td>14 Accident</td>
<td>15</td>
<td>5</td>
<td>33.3</td>
<td>19.3</td>
</tr>
<tr>
<td>15 Otolaryngological (ENT) surgery</td>
<td>71</td>
<td>24</td>
<td>33.8</td>
<td>19.0</td>
</tr>
<tr>
<td>16 Cardiovascular surgery</td>
<td>213</td>
<td>63</td>
<td>29.6</td>
<td>17.6</td>
</tr>
<tr>
<td>17 Endocrine surgery</td>
<td>16</td>
<td>8</td>
<td>50.0</td>
<td>17.4</td>
</tr>
<tr>
<td>18 Clinical treatment of malign tumours/radiation therapy</td>
<td>31</td>
<td>10</td>
<td>32.3</td>
<td>17.0</td>
</tr>
<tr>
<td>19 Poisoning &amp; intoxiciation</td>
<td>20</td>
<td>8</td>
<td>40.0</td>
<td>16.2</td>
</tr>
<tr>
<td>20 Haemopathy &amp; clinical chemotherapy</td>
<td>23</td>
<td>5</td>
<td>21.7</td>
<td>13.8</td>
</tr>
<tr>
<td>21 Rehabilitation</td>
<td>2</td>
<td>1</td>
<td>50.0</td>
<td>15.6</td>
</tr>
<tr>
<td>22 Skin disease/cellular tissue &amp; lymphatic system</td>
<td>6</td>
<td>2</td>
<td>33.3</td>
<td>14.8</td>
</tr>
<tr>
<td>23 Neurosurgery</td>
<td>210</td>
<td>52</td>
<td>24.8</td>
<td>13.9</td>
</tr>
<tr>
<td>24 Clinical obstetrics</td>
<td>17</td>
<td>1</td>
<td>5.9</td>
<td>13.2</td>
</tr>
<tr>
<td>25 Oncology &amp; transplantation</td>
<td>24</td>
<td>6</td>
<td>25.0</td>
<td>12.1</td>
</tr>
<tr>
<td>26 Nutritional disorders</td>
<td>9</td>
<td>1</td>
<td>11.1</td>
<td>12.1</td>
</tr>
<tr>
<td>27 Muscular-osteoarticular disease</td>
<td>22</td>
<td>4</td>
<td>18.2</td>
<td>12.0</td>
</tr>
<tr>
<td>28 Orthopedic &amp; trauma surgery</td>
<td>554</td>
<td>208</td>
<td>37.6</td>
<td>11.9</td>
</tr>
<tr>
<td>29 Gastroenterological surgery</td>
<td>187</td>
<td>53</td>
<td>28.3</td>
<td>10.2</td>
</tr>
<tr>
<td>30 Ophthalmic surgery</td>
<td>90</td>
<td>45</td>
<td>50.0</td>
<td>6.7</td>
</tr>
<tr>
<td>31 Vascular surgery</td>
<td>34</td>
<td>13</td>
<td>38.2</td>
<td>6.7</td>
</tr>
<tr>
<td>32 Urological surgery</td>
<td>128</td>
<td>42</td>
<td>32.8</td>
<td>6.7</td>
</tr>
<tr>
<td>33 Oral maxillofacial surgery</td>
<td>17</td>
<td>8</td>
<td>47.1</td>
<td>5.9</td>
</tr>
<tr>
<td>34 Psychiatry</td>
<td>26</td>
<td>7</td>
<td>26.9</td>
<td>5.2</td>
</tr>
<tr>
<td>35 Plastic surgery</td>
<td>136</td>
<td>45</td>
<td>33.1</td>
<td>4.7</td>
</tr>
<tr>
<td>36 Gynaecological surgery</td>
<td>60</td>
<td>17</td>
<td>28.3</td>
<td>2.2</td>
</tr>
<tr>
<td>37 Diagnostics</td>
<td>5</td>
<td>1</td>
<td>20.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Source: DataSUS.
3. Indicators of ST&I/H human resources in São Paulo State

Human resources are discussed separately in this chapter because they can be considered both ST&I inputs and outputs. For human resources to develop to full potential in S&T, characterising them as inputs, significant prior investment is required, and from this standpoint human resources are outputs.

Section 3 focuses on ST&I/H human resources in Brazil and São Paulo State, in terms of post-graduate students and employees in two segments of the health industrial complex, namely manufacturing of pharmaceutical products, and manufacturing of medical and hospital equipment.

3.1 Human resources in post-graduate programs

MCT’s national S&T indicators for human resources measure schooling, post-graduate education, technical and scientific employment, researchers etc. To complement the indicators furnished by MCT, this section presents indicators of potential human resources for research in health sciences.

According to information published by MCT on degrees awarded by CAPES-recognized post-graduate programs, 14.4% of all master’s degrees and 18.5% of all doctoral degrees are awarded in health sciences. The number of PhDs awarded in health sciences rose at an exponential rate of 11.1% per year on average in the period 1987-2006 (Figure 11.31). Data were collected on 257 post-graduate programs in health sciences, or 20.6% of all post-graduate programs in Brazil. The number of post-graduate teachers in Brazil totaled 50,597 in 2007, 17.2% of them in health sciences.

To assess the quality of teaching and research activities in human health in São Paulo State, all Brazilian post-graduate programs in this knowledge area were analyzed. Information was taken from the CAPES website. CAPES evaluated 2,256 post-graduate programs in 45 major knowledge areas in 2007. Four of these knowledge areas related directly to human health, namely medicine I, medicine II, medicine III, and collective health.16

The total number of post-graduate programs in health sciences identified nationwide was 235: 70 in medicine I, 82 in medicine II, 49 in medicine III and 34 in collective health. An analysis of the location of these 235 post-graduate programs shows the Southeast region in the lead with 157 (66.8%), followed by the South and Northeast with 33 (14%) each, the Central West and North with nine (3.8%) and three (1.3%) respectively.

Figure 11.31
Doctoral degrees awarded in health sciences – Brazil, 1987-2006

Source: CAPES.

Note: 1. The dotted line plots a fitted exponential function (R² = 0.97), with a growth rate of λ = 0.111.
2. See Detailed Table 11.31.

16. These areas are defined in the Methodological Annex.
Of the 157 programs in the Southeast, 108 (68.8%) were in São Paulo State (followed by Rio de Janeiro State with 31 or 19.7%). These 108 programs broke down as follows into the major knowledge areas evaluated by CAPES (CAPES, 2009): 30 in medicine I, 34 in medicine II, 35 in medicine III and nine in collective health. Figure 11.32 shows the distribution of these programs by region and, in the case of the Southeast, by state.

São Paulo State’s leadership is not confined to the mere number of post-graduate programs in health sciences located there. These programs also scored highly compared with those located in other parts of Brazil in the 2007 CAPES assessment (covering the three-year period between 2004 and 2007), which rated the quality of teaching and research at the institutions concerned. Table 11.6 presents these scores.

The post-graduate programs in São Paulo State scored highest in the CAPES assessment. Out of 108 programs assessed, 59 (54.6%) scored between 5 and 7. Rio Grande do Sul ranked second with 20 programs, 12 of which scored between 5 and 7. Rio de Janeiro ranked third with 15 of its 31 programs scoring 5 or 6. No institution in this latter state was awarded the top score, and for this reason it ranked third overall even though it had more institutions that scored 5 or 6 than the second-ranking state.
Six of the seven top-scoring programs in Brazil (85.7%) were in São Paulo State; the other was in Rio Grande do Sul. Eleven of the 19 programs that scored 6 (57.9%) were in São Paulo. The others were in Rio Grande do Sul (1), Rio de Janeiro (3), Bahia (3) and Minas Gerais (1). Finally, 42 of the 76 programs scoring 5 (55.3%) were in São Paulo. Thus the institutions in São Paulo scoring 7, 6 or 5 accounted for 57.8% of all institutions with these scores in the same period. Table 11.7 sets out these numbers in full.

Given the recent introduction of the Hirsch index (h) as a bibliometric indicator (Hirsch, 2005), the analysis was extended to find h for the various health science categories or disciplines, as a basis for indicators of the quality of human resources in research. The h-index is used for evaluating and comparing the activity of individual scientists according to their scientific publications. h is defined as the number such that, for a general group of articles or papers, h articles received at least h citations while the other articles received no more than h citations. For example, an author of five articles with at least five citations is h = 5 regardless of the total number of articles written by that author.

Disciplines were classified into four major areas of health sciences, in accordance with the classification used by CAPES: collective health (Table 11.8), medicine I (Table 11.9), medicine II (Table 11.10) and medicine III (Table 11.11). A sample of licensed teachers was selected for each post-graduate program, although the human resources engaged in health-related research activities are not confined to teachers. Once potential authors of scientific articles had been identified in this manner, the “Citation Report” page of ISI Web of Science was used to find the h-index.17

### Table 11.7
CAPES scores for human science post-graduate programs & shares of São Paulo State institutions in total – São Paulo State, 2004-2006

<table>
<thead>
<tr>
<th>Score</th>
<th>Total (A)</th>
<th>São Paulo State (B)</th>
<th>B / A (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>235</td>
<td>108</td>
<td>46.0</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>6</td>
<td>85.7</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>11</td>
<td>57.9</td>
</tr>
<tr>
<td>5</td>
<td>76</td>
<td>42</td>
<td>55.3</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
<td>28</td>
<td>37.3</td>
</tr>
<tr>
<td>3</td>
<td>44</td>
<td>17</td>
<td>38.6</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>4</td>
<td>28.6</td>
</tr>
</tbody>
</table>

Source: CAPES Evaluation of Post-Graduate Programs, 2007

17. The Hirsch index calculated here refers to citations of ISI-indexed articles. See Methodological Annexes.
### Table 11.8
Citation indicators for scientific articles on collective health (1) by region – Brazil & São Paulo State, 1H2008

<table>
<thead>
<tr>
<th>Region</th>
<th>Authors sampled</th>
<th>Authors with one or more citations</th>
<th>Authors with ( h = 0 ) (%)</th>
<th>Decrease rate (%)</th>
<th>Mean ( h ) for authors with one or more citations</th>
<th>Required ( h ) for top-ranking author</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo State</td>
<td>141</td>
<td>100</td>
<td>29.0</td>
<td>39.8</td>
<td>2.5</td>
<td>11</td>
<td>0.92</td>
</tr>
<tr>
<td>Southeast (except SP)</td>
<td>194</td>
<td>100</td>
<td>48.5</td>
<td>56.4</td>
<td>1.8</td>
<td>8</td>
<td>0.92</td>
</tr>
<tr>
<td>South</td>
<td>88</td>
<td>57</td>
<td>35.0</td>
<td>32.3</td>
<td>3.1</td>
<td>14</td>
<td>0.84</td>
</tr>
<tr>
<td>Central West (2)</td>
<td>20</td>
<td>9</td>
<td>55.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Northeast</td>
<td>159</td>
<td>84</td>
<td>47.0</td>
<td>49.2</td>
<td>2.0</td>
<td>9</td>
<td>0.90</td>
</tr>
<tr>
<td>North (3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: ISI, Web of Science.

(1) Includes post-graduate programs in collective healthcare, health sciences, epidemiology, preventive medicine, collective health, community health, family health, women's and children's health, public health, and public health and environment.

(2) Distribution not suitable for goodness of fit test.

(3) No post-graduate programs in collective health.

### Table 11.9
Citation indicators for scientific articles on medicine I (1) by region – Brazil & São Paulo State, 1H2008

<table>
<thead>
<tr>
<th>Region</th>
<th>Authors sampled</th>
<th>Authors with one or more citations</th>
<th>Authors with ( h = 0 ) (%)</th>
<th>Decrease rate (%)</th>
<th>Mean ( h ) for authors with one or more citations</th>
<th>Required ( h ) for top-ranking author</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo State</td>
<td>468</td>
<td>466</td>
<td>5.0</td>
<td>11.8</td>
<td>8.5</td>
<td>36</td>
<td>0.8</td>
</tr>
<tr>
<td>Southeast (except SP)</td>
<td>260</td>
<td>222</td>
<td>15.0</td>
<td>16.3</td>
<td>6.1</td>
<td>26</td>
<td>0.8</td>
</tr>
<tr>
<td>South</td>
<td>230</td>
<td>215</td>
<td>7.0</td>
<td>16.7</td>
<td>6.0</td>
<td>26</td>
<td>0.8</td>
</tr>
<tr>
<td>Central West (2)</td>
<td>46</td>
<td>39</td>
<td>15.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Northeast</td>
<td>126</td>
<td>99</td>
<td>21.0</td>
<td>22.7</td>
<td>4.4</td>
<td>18</td>
<td>0.9</td>
</tr>
<tr>
<td>North (3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: ISI, Web of Science.

(1) Includes post-graduate programs in cancer care, cardiology, rehabilitation, health, gastroenterology, medical sciences, clinical medicine, dermatology, health economics, clinical emergencies, physiopathology, hepatology, health informatics, internal medicine and therapeutics, medicine, pulmonology, nephrology, oncology, clinical research on infectious diseases, and health and behavior.

(2) Distribution not suitable for goodness of fit test.

(3) No post-graduate programs in medicine I.
### Table 11.10
Citation indicators for scientific articles on medicine II (1) by region – Brazil & São Paulo State, 1H2008

<table>
<thead>
<tr>
<th>Region</th>
<th>Authors sampled</th>
<th>Authors with one or more citations</th>
<th>Authors with ( h = 0 ) (%)</th>
<th>Decrease rate (%)</th>
<th>Mean ( h ) for authors with one or more citations</th>
<th>Required ( h ) for top-ranking author</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo State</td>
<td>565</td>
<td>538</td>
<td>3.0</td>
<td>13.3</td>
<td>7.5</td>
<td>32</td>
<td>0.8</td>
</tr>
<tr>
<td>Southeast (except SP)</td>
<td>267</td>
<td>232</td>
<td>13.0</td>
<td>19.8</td>
<td>5.1</td>
<td>13</td>
<td>0.9</td>
</tr>
<tr>
<td>South</td>
<td>105</td>
<td>90</td>
<td>14.0</td>
<td>18.2</td>
<td>5.5</td>
<td>24</td>
<td>0.5</td>
</tr>
<tr>
<td>Central West</td>
<td>122</td>
<td>99</td>
<td>19.0</td>
<td>32.8</td>
<td>3.0</td>
<td>13</td>
<td>0.8</td>
</tr>
<tr>
<td>Northeast</td>
<td>223</td>
<td>167</td>
<td>25.0</td>
<td>40.4</td>
<td>2.5</td>
<td>11</td>
<td>1.0</td>
</tr>
<tr>
<td>North</td>
<td>59</td>
<td>45</td>
<td>24.0</td>
<td>35.3</td>
<td>2.8</td>
<td>12</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Source: ISI, Web of Science.

(1) Includes post-graduate programs in allergy, immunopathology, food, nutrition and health, clinical analysis, science, physiopathology, nutrition, human nutrition, applied human nutrition, health sciences, pediatrics, psychiatry, infectious and parasitic diseases, tropical diseases, physics applied to medicine and biology, infectology, neurology, anatomical pathology, haematology, neurology, radiology, mental health, pediatric medicine and child health, tropical medicine, neuropsychiatry and behavioral sciences, pathology, psychobiology, rheumatology, child and adolescent health, and mother and child health.

### Table 11.11
Citation indicators for scientific articles on medicine III (1) by region – Brazil & São Paulo State, 1H2008

<table>
<thead>
<tr>
<th>Region</th>
<th>Authors sampled</th>
<th>Authors with one or more citation</th>
<th>Authors with ( h = 0 ) (%)</th>
<th>Decrease rate (%)</th>
<th>Mean ( h ) for authors with one or more citations</th>
<th>Required ( h ) for top-ranking author</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo State</td>
<td>509</td>
<td>458</td>
<td>10.0</td>
<td>27.3</td>
<td>3.7</td>
<td>16</td>
<td>1.0</td>
</tr>
<tr>
<td>Southeast (except SP)</td>
<td>88</td>
<td>64</td>
<td>27.0</td>
<td>29.9</td>
<td>3.3</td>
<td>13</td>
<td>0.8</td>
</tr>
<tr>
<td>South</td>
<td>55</td>
<td>41</td>
<td>25.0</td>
<td>27.9</td>
<td>3.6</td>
<td>16</td>
<td>0.6</td>
</tr>
<tr>
<td>Central West (2)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Northeast</td>
<td>37</td>
<td>25</td>
<td>32.0</td>
<td>42.1</td>
<td>2.4</td>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>North (3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: ISI, Web of Science.

(1) Includes post-graduate programs in anaesthesiology, general surgery, health sciences, surgery, surgery and experimentation, plastic surgery, physiopathology and surgical sciences, gynaecology, obstetrics and mastology, otorhinolaryngology, obstetrics and gynaecology, urology, digestive surgery, cardiovascular surgery, general surgery, thoracic surgery, clinical surgery, surgical gastroenterology, neurosurgery, ophthalmology, orthopedics and trauma, head and neck surgery, principles of surgery.

(2) Distribution not suitable for goodness of fit test.

(3) No post-graduate programs in medicine III.
The number of authors ranked by $h$ displays a descending exponential distribution, in which a higher proportion of authors with lower values of $h$ decreases exponentially until it reaches a smaller proportion of authors with higher values of $h$. An exponential probability density function was calculated for each major CAPES area and each region, giving the following indicators:

- Proportion of uncited authors ($h = 0$)
- Rate of decrease from $h = 1$
- Mean $h$ for authors with one or more citations (exponential distribution mean = $1/\lambda$)
- Required $h$ in each region and major areas of health sciences for an author to rank first among top 100 (complement of distribution percentile).

### 3.2 Human resources in the health industrial complex

The data presented in this subsection were obtained from RAIS/MTE and PINTEC (IBGE, 2005). Since 2006 the former has detailed the numbers of masters and doctors employed in each branch of industry. Both the scientific literature (Cohen & Levinthal, 1990; Cohen, Nelson & Walsh, 2002) and international reports on S&T indicators (OECD, 2005; OECD, 2007; OECD, 2009) recognize that the numbers of qualified human resources and of masters and doctors employed in industrial activities correlate directly with the business sector’s capacity to use the existing knowledge base to produce goods and services, and to create new knowledge.

As illustrated by Figures 11.33, 11.34, 11.35 and 11.36, the numbers of masters and doctors employed by both manufacturers of pharmaceutical products and manufacturers of medical and hospital equipment have increased at a significant rate since 2006. Moreover, substantial numbers of these masters and doctors are employed in São Paulo State and are also increasing in proportion to the total employed in Brazil, with the exception of doctors employed in the pharmaceutical industry.

Human resources employed in R&D in the health industrial complex, another indicator widely used in international reports (OECD, 2009), were again concentrated in São Paulo State according to PINTEC (Figure 11.37). Firms in São Paulo State employed

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**Figure 11.33**

**Masters employed by manufacturers of pharmaceutical products – Brazil (except São Paulo) & São Paulo State, 2006-2008**

![Bar chart showing masters employed by manufacturers of pharmaceutical products](chart)

**Source:** MTE, RAIS.

**Note:** See Detailed Table 11.33.
Figure 11.34
Doctors employed by manufacturers of pharmaceutical products – Brazil (except São Paulo) & São Paulo State, 2006-2008

Source: MTE, RAIS.

Note: See Detailed Table 11.34.

Figure 11.35
Masters employed by manufacturers of medical and hospital equipment – Brazil (except São Paulo) & São Paulo State, 2006-2008

Source: MTE, RAIS.

Note: See Detailed Table 11.35.
Figure 11.36
Doctors employed by manufacturers of medical and hospital equipment – Brazil (except São Paulo) & São Paulo State, 2006-2008

Source: MTE, RAIS.

Note: See Detailed Table 11.36.

Figure 11.37
Personnel employed in R&D in the health industrial complex – Brazil (except São Paulo) & São Paulo State, 2003 & 2005


Note: See Detailed Table 11.37.
63% of these professionals in 63% and 61% in 2005. Professionals with post-graduate qualifications employed in R&D, again according to PINTEC (Figure 11.38), were also concentrated in São Paulo State but fell in absolute terms between PINTEC 2003 and PINTEC 2005, reducing the state’s share from 64% to 53%. A comparison with the RAIS/MTE data will be possible only when the results of the next PINTEC survey are published.

Although the data analyzed in this subsection show a rise in employment of both highly qualified personnel and dedicated intramural R&D personnel by industry, the differences with the health industrial complex in other countries are very significant. Pfizer, the world’s largest pharmaceutical firm, recognized for its S&T capacity, employs some 7,000 people in R&D. On the other hand, Ranbaxy, India’s leading pharmaceutical firm and which cannot yet be considered capable of creating more robust innovations although it has mastered the technological stages of pharmaceutical production, employs 1,200 people in its technical departments. This shows that Brazilian firms still have a long way to go in terms of developing world-class S&T capabilities.

Figure 11.38
Personnel with post-graduate qualifications employed in R&D in the health industrial complex – Brazil (except São Paulo) & São Paulo State, 2003 & 2005


Note: See Detailed Table 11.38.
4. Final considerations

The health industrial complex in Brazil, which encompasses the manufacturing of pharmaceuticals and medical and hospital equipment, displays low innovation intensity. The 2005 PINTEC survey (IBGE, 2005) showed that the main innovation activities of pharmaceutical firms and manufacturers of medical and hospital equipment were the acquisition of equipment for process improvement and the production of new products and processes for the firms themselves but not for the market.

Nevertheless, firms located in São Paulo State invested 4.7 times more in innovation activities in 2005 than the rest of the Brazilian pharmaceutical industry. In the medical and hospital equipment industry, São Paulo State also accounted for a significant proportion of expenditure on innovation activities: firms in the state invested 1.4 times more in these activities in 2005 than the rest of the Brazilian equipment industry. The large science base of firms in the health industrial complex is evidenced by their linkages with universities and research institutions. According to PINTEC 2005, universities and research institutions were considered an important source of information by 57.4% of the pharmaceutical firms (187 out of 326) and 73.7% of the medical and hospital equipment manufacturers (462 out of 627) that innovated in the period 2003-05.

Investment in R&D/H in Brazil in 2007 is estimated to have totaled some R$ 994 million. The public sector invested R$ 700 million, with the Ministry of Health contributing R$ 147.2 million. Universities and research institutions were the main users of public funding for R&D/H, receiving 55.5% of the national total.

With regard to the number of grants awarded by CNPq for research in biological sciences, São Paulo State accounted on average for 30%, with Retention of Doctors in the lead. In health sciences the proportion was 52%, with grants for Research Productivity in the lead (53%). As for scientific production measured by the number of ISI-indexed scientific articles in health sciences, São Paulo State outperformed all other regions of Brazil by between 2 and 28 times in the health area. The area of health sciences was also important for São Paulo State, with a specialization index that also exceeded those of other areas.

An analysis of the indicators for selected diseases evidences the importance of research institutions in São Paulo State. In the case of articles on cancer, for example, 313 out of 1,090 articles whose authors included Brazilians (28.7%) had at least one author affiliated with USP. Similar proportions were found for articles on cardiovascular disorders (36.2%), AIDS (26.9%) and atherosclerosis (42.5%). Another important institution is Unifesp, which ranked second in this analysis, accounting for significant proportions of articles on Alzheimer’s (16.1%) and asthma (15.6%). The third-ranking institution was Unicamp, with a strong performance in cancer research (9.5%). Unesp, Instituto Adolfo Lutz, Instituto de Infectologia Emilio Ribas, Hospital A.C. Camargo and Instituto Pasteur were also among the top performers.

São Paulo State also accounted for a significant proportion of health-related patent filings with INPI. Taking only the period 2000-05, residents of São Paulo State accounted for 55% of patent filings (among all those for which it was possible to locate information on the patentee’s state).

The analysis of S&T outcomes, measured by the ratio of citations to total articles published, highlights the significant impact of articles with at least one author from São Paulo State, which had the highest citation index of all Brazilian regions. As for the qualifications of researchers in health-related areas, 14.4% of master’s degrees and 18.5% of doctoral degrees awarded by post-graduate programs recognized by CAPES were in the health area. For the main post-graduate programs in Brazil in the health area (medicine I, medicine II, medicine III and collective health), six out of seven programs scoring 7 in the 2007 CAPES assessment and 11 out of 19 programs scoring 6 were located in São Paulo State.

According to data from RAIS/MTE, the number of masters and doctors employed in the health industrial complex (pharmaceutical firms and manufacturers of medical and hospital equipment) rose significantly in the period 2006-08, although Brazil continued to perform modestly in this field by international standards. This growth was mainly driven by São Paulo State, where most of the jobs in question were located. For example, 88% of the masters and 80% of the doctors employed by the pharmaceutical industry worked for firms located in the state in 2008. Finally, with regard to human resources, an analysis of employment in R&D in the health industrial complex also evidences significant concentration in São Paulo State, which accounted for 61% of all R&D jobs in 2005.
References


