Chapter 3

R&D Expenditures and Human Resources

Part B

Human resources in scientific and technological activities in São Paulo State

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The Detailed Tables for this chapter are available on the internet at: <http://www.fapesp.br/enindicadores2010>.

1. Introduction

There are two main approaches to the measuring of human resources for S&T indicators:[1] one seeks to count the number of people devoted to R&D; the other counts the number of people with high levels of skill as a proportion of the workforce or economically active population.

These two criteria evidently overlap to some extent, as most if not all of the people engaged in R&D activities are presumably highly qualified. Nevertheless, the two approaches are distinct in that they focus on specific aspects of human resources in science and technology (HRST).

The first relates to the dimension of R&D proper, typically performed by higher education institutions (HEIs) and research institutions, public or private, including the intramural R&D activities of business enterprises. In this case the number of people devoted to such activities ultimately reflects the capacity of such institutions – and by extension of the country or region concerned – to create and apply new knowledge.

The second focuses on the number of highly qualified people based on the view that the greater the size of this contingent, the greater the potential for creating, introducing and diffusing technological innovations and for appropriation of their benefits by society.

Thus while the first approach deals with the production and application of new knowledge as a set of activities with their own specific dynamics, which depend basically on the resources allocated to them, the second sees the innovation process as a function of the environment in which it takes place. In this case, while the amount of financial and human resources invested in R&D may vary, its outcomes will also depend on the extent to which the general environment is favorable to the creation, introduction and diffusion of technological innovations.

The existence of these two approaches is a good example of a question that is not always visible in the production, and above all the analyzis, of all kinds of indicators, including S&T indicators, which is that any indicator implies a specific analytical focus reflecting a particular view of whatever is to be measured. In other words, the choice of any approach to measure a phenomenon entails illuminating some of its facets and obscuring others. It does not necessarily flow from this implicit bias that measurements (or statistics) serve to sustain whatever arguments may interest their formulators. However, recognizing it means acknowledging that they should be used with appropriate care and with full awareness of their limitations and analytical possibilities.

For present purposes, the option is to present the results of both the above approaches, since both cast light on relevant phenomena for public policy evaluation and formulation, especially those relating to the education and training of highly qualified personnel. As a means of increasing both the capacity to produce new knowledge, synthesized. in the number of people engaged in R&D activities, and the diffusion of new techniques and the appropriation of their benefits, represented by the number of highly qualified workers, the training and employment of qualified personnel are key elements of any scientific and technological development policy.

2. Personnel devoted to R&D activities

The construction of S&T indicators began with the measurement of financial and human resources invested in R&D, which remains predominant today.[2] The main methodological reference is the *Frascati Manual* (OECD, 2002), whose first version was published in 1963.[3] The key concept on which its recommendations are based is research and experimental development (R&D) defined as "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 2002, p. 30). The indicators concerned therefore measure both the personnel devoted to R&D and R&D expenditure.

1. S&T indicators are conventionally considered a large family of indicators designed to measure inputs, outputs and related and contextual aspects of scientific and activities in a country or region. Given the very large number and diversity of S&T activities, they can be hard to itemise but it is generally accepted that research and experimental development (R&D) constitute the lion's share of S&T. Because R&D can be delimited with relative precision, some of the most widely used indicators in the S&T family, such as indicators of financial and human inputs, are confined to measuring R&D proper.

2. An interesting historical and conceptual account of ST&I indicators can be found in Viotti (2003).

3. Six editions of the *Frascati Manual* have been published all told, from the first in 1963 to the last in 2002. For an analyzis of the Manual's origin and evolution, see Godin (2008). The last edition differed from the previous one mainly in its more detailed recommendations on the measurement of R&D in the service sector and the collection of data on personnel allocated to R&D, as well as changes to the classification system.

The *Frascati Manual* recommends a sectoral approach to facilitate the collection and interpretation of data (OECD, 2002, p. 53 ff.), using the classification adopted in economic studies, especially the System of National Accounts (SNA), wherever possible. In institutional terms, the classification proposed by the *Frascati Manual* comprises five sectors: the private sector, government, private nonprofit institutions, higher education, and abroad. It is worth noting the recommendation to measure R&D in higher education separately because of its importance in the performance of R&D activities, although it is not classified as a specific sector in the SNA.

All these sectors are covered by the analyzis in this chapter, except what the *Frascati Manual* terms "abroad", which it defines as "institutions and individuals located outside the political borders of a country" and "international organizations (except business enterprises) ... within the country's borders" (OECD, 2002, p. 72), which is excluded both because it is apparently of little significance to the Brazilian case and because there are no data with which to measure it.

In the case of business, it is worth recalling that new theoretical perspectives on the innovation process and the role of firms therein, proposed in the 1980s, led to the development of what became known as "innovation research", beginning in 1993 in the European Union, and later to the publication of the *Oslo Manual* by the OECD (1997). This manual systematized a set of methodological guidelines for such research and became the principal international reference in the field. In Brazil, the first nationwide innovation research project based on its recommendations was IBGE's Survey of Technological Innovation (PINTEC), published in 2001 with data for base year 2000.[4] Since then the Science & Technology Ministry (MCT) has used PINTEC as one of its data sources for its indicators of financial and human resources invested in R&D in Brazil.

The concept of R&D personnel therefore encompasses not just academic researchers and the staff of research institutions but also R&D professionals employed by business enterprises. The indicators presented below are not based on exactly this methodological approach, but also use the findings of a primary survey conducted directly by FAPESP in addition to administrative records and PINTEC data.

The chapter partially adopts the classification of R&D personnel recommended by the *Frascati Manual* into three categories: (a) researchers – "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned" (OECD, 2002, p. 93); (b) technicians and equivalent staff – "persons whose main tasks require technical knowledge and experience in one or more fields of engineering {or science] ... normally under the supervision of researchers" (idem, p. 94); and (c) other supporting staff – "skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects" (idem, p. 94).

Postgraduate students and teachers also deserve a brief mention. In principle, these individuals can also be considered researchers, but in this case it is difficult to distinguish teaching and learning from research activities. As noted by the *Frascati Manual*, postgraduate programs are predominantly educational, involving teaching or learning in compulsory courses, knowledge of the literature on the subject being studied, teaching and learning research methods etc. (OECD, 2002, p. 36). However, in order to obtain a final qualification postgraduate students must also undertake independent research, albeit under the supervision of a teacher, and this usually contains the elements of novelty required by the definition of R&D. Thus there is no clear dividing line between educational and research activities, especially in HEIs.

In this analyzis, headcount takes into consideration doctoral and postdoctoral students who receive grants from FAPESP, CAPES and CNPq, as well as teachers with PhDs employed full-time by federal, state, municipal and private HEIs. Given the difficulty of counting R&D support personnel, it was decided to exclude this occupational category from the headcount. Thus the tables below display only two occupational categories, researchers and technical staff.

4. Before PINTEC, Fundação Seade had conducted a Survey of Economic Activity in São Paulo State (Pesquisa da Atividade Econômica Paulista, PAEP) in 1997-98, with data for base year 1996. This included a module on innovation, which followed the recommendations of the *Oslo Manual*.

Despite the importance attributed to this indicator, it is not easy to calculate, especially owing to the difficulty of accurately demarcating R&D activities. This is evidenced by the structure of the *Frascati Manual*[5] and its frequent revisions. In the Brazilian case this difficulty is greater still owing to the lack of systematic primary surveys on the subject (except the respective data collected by PINTEC). This would not be a problem if there were adequate administrative records, but while the records that do exist are plentiful and of good quality the possibility of their use in the construction of R&D indicators was not considered when they were designed. Thus strong hypotheses are required when setting out to construct R&D indicators, as discussed below, so that the findings are always open to question and unlikely to coincide with those obtained by other scholars or researchers in the same field.

2.1 General methodological procedures

Table 3.1B summarizes the results obtained with regard to the number of people devoted to R&D activities in São Paulo State. It is constructed so as to distinguish between researchers (or equivalent categories in business enterprises) and the technicians who support R&D.[6] However, it should be noted that none of the available data sources classifies professionals in this manner, so that besides several sources it was necessary to use several hypotheses and methods of estimating these contingents. The following sections discuss these issues in more detail.

The first point to stress is that two of the main sources of information on R&D – CNPq's Research Group Census and IBGE's PINTEC – do not have data for the same years. The RGD offers totals for even years, while PINTEC's reference periods are odd years from 2003 on.[7] Another point worth mentioning is the short length of the time series that can be produced with the information available. Various methods were used to estimate the missing information in the context of these limitations, as described below, and FAPESP also conducted its own primary survey.

These methods necessarily have arbitrary components and are not immune to criticism. However, the differences in quality of the available databases (Chart 3.1B) and the hypotheses adopted in calculating the indicators entail problems that may be more relevant than those associated with the methods used to estimate the missing data.

Chart 3.1B lists the data sources used to produce the indicators of researchers. Their heterogeneity is evident. PINTEC and the Census of Higher Education (INEP) were planned and designed to produce statistics, whereas the other data sources all have different specific objectives and characteristics. Although they may not follow international recommendations or best statistical practice in the concepts and data collection and treatment methods used, they are sufficiently comprehensive and rigorous to enable studies and indicators such as those presented here to be based on them, provided one or two additional hypotheses are adopted (as explained below). This does not mean the information required to produce the best indicators of HRST is completely available. On the contrary, it is important that time and skill be invested in improving the existing data sources, and even conducting new research to complement the information available, so that indicators of better quality and fully compatible with those of other countries can be produced.

5. The *Frascati Manual* contains many more pages on what R&D is not than on what it is. Thus it can be said that the operational concept of R&D is practically constructed by negation.

6. Technician headcount is based on the information available from CNPq's Research Group Census for 2002, 2004 and 2006. For intermediate years, the simple arithmetic mean for the first and last years was used; for years prior to 2002, the contingent of technical personnel was estimated assuming the same proportion relative to researchers as was verified for 2002, and for years subsequent to 2006 the proportion found for that year was used. It is important to note that this category is hard to demarcate since there are several institutions and foundations inside HEIs and separate records for these are not always kept, besides the apparent ambiguity of their institutional nature.

7. Strictly speaking, PINTEC is based on two reference periods: the year prior to execution of the survey for quantitative variables, and the three previous years for qualitative variables. Thus for the variable "number of people in intramural R&D" used here, the reference period is the year before the survey was carried out. The first three rounds of PINTEC took place in 2001, 2004 and 2006, so that the data then collected refer to 2000, 2003 and 2005 respectively. PINTEC was not carried out in 2008, although a field survey had been scheduled for that year, and no information was produced for 2007. Another round was executed in 2009. Thus the time lag between PINTEC and the RGD will be resolved, albeit by chance.

Table 3.1B

R&D personnel by function and type of institution – São Paulo State – 1995-2008

Function & type of institution	R&D personnel headcount													
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total R&D personnel	**53,710**	**52,739**	**56,780**	**56,348**	**55,163**	**56,791**	**61,611**	**63,230**	**63,135**	**67,612**	**72,631**	**77,508**	**85,277**	**90,450**
Research institutions	5,278	5,027	4,834	4,717	4,717	4,620	4,618	4,706	4,754	4,900	4,898	4,874	4,866	4,847
Higher education institutions	21,312	21,055	22,772	23,545	25,174	26,253	27,305	28,076	28,799	29,566	30,407	30,768	32,346	32,903
Business enterprises	27,119	26,657	29,174	28,085	25,272	25,918	29,688	30,448	29,582	33,146	37,326	41,866	48,065	52,700
Researchers	**37,894**	**37,225**	**39,861**	**39,642**	**39,300**	**40,492**	**43,723**	**44,877**	**44,488**	**47,011**	**50,865**	**54,269**	**59,526**	**62,897**
Research institutions	3,058	2,911	2,798	2,730	2,730	2,673	2,672	2,708	2,725	2,841	2,963	3,063	3,058	3,036
Higher education institutions	17,703	17,473	18,632	19,169	20,604	21,445	22,295	22,933	23,074	23,260	24,155	24,571	25,889	26,333
Business enterprises	17,133	16,841	18,431	17,743	15,966	16,374	18,756	19,236	18,689	20,910	23,747	26,635	30,579	33,528
Technicians	**15,816**	**15,514**	**16,919**	**16,706**	**15,863**	**16,299**	**17,888**	**18,353**	**18,647**	**20,601**	**21,766**	**23,239**	**25,751**	**27,553**
Research institutions	2,220	2,116	2,036	1,987	1,987	1,947	1,946	1,998	2,029	2,059	1,935	1,811	1,808	1,811
Higher education institutions	3,609	3,582	4,140	4,376	4,570	4,808	5,010	5,143	5,725	6,306	6,252	6,197	6,457	6,570
Business enterprises	9,986	9,816	10,743	10,342	9,306	9,544	10,932	11,212	10,893	12,236	13,579	15,231	17,486	19,172

Note: See Chart 3.1B.

Chart 3.1B
Data sources for personnel headcount by sector – São Paulo State – 1995-2008

Sector	Data source	Headcount	Formula for calculating full-time equivalent (FTE)
Higher Education Institutions (HEIs)			
State & federal HEIs	INEP Census of Higher Education	All academics	82.7% of full-time academics with PhDs plus 50% of academics with master's degrees (2) (3)
Municipal & private HEIs	INEP Census of Higher Education	Full-time academics with PhDs	82.7% of full-time academics with PhDs (2)
Postdoctoral grantees (1)	CNPq, FAPESP, CAPES (Geocapes)	CNPq, FAPESP, CAPES grantees	CNPq, FAPESP, CAPES grantees
Doctoral grantees	CNPq, FAPESP, CAPES (Geocapes)	CNPq, FAPESP, CAPES grantees	50% of CNPq, FAPESP, CAPES grantees (3)
Research Institutions (RIs)			
State RIs	Data furnished by management of each RI, supplemented by data from FAPESP where necessary (2005)	Career researchers for São Paulo State	Career researchers for São Paulo State
Federal RIs	Data furnished by management of each RI, supplemented by data from FAPESP where necessary (2005)	Researchers	Researchers
Private nonprofit RIs	CNPq Research Group Directory	Researchers (estimates for years before 2002 and after 2007)	Researchers (estimates for years before 2002 and after 2007)
Business			
Business enterprises	PINTEC and regression based on gross fixed capital formation (see Part A of this chapter	Employees with university degrees	Employees with university degrees devoted to intramural R&D, reduced by factor estimated on basis of PINTEC data

(1) Most postdoctoral grantees are in HEIs (in the case of FAPESP, which has data on its own grantees disaggregated by institution, the proportion was 87% in 2009), although a small proportion are in RIs and even business enterprises. Given the difficulty of disaggregating data by sector, all postdoc grantees are attributed to HEIs.

(2) The *Frascati Manual* recommends that the core element of the definition of R&D activities should be "an appreciable element of novelty or a resolution of scientific/technological uncertainty." Hence the option for counting only full-time academics with PhDs in the case of higher education. It also recommends adjusting this headcount for non-R&D activities (teaching, administration, representation etc.) using a discount factor to estimate the proportion of their time academics devote to R&D proper. The factor used In this chapter corresponds to the difference between the salaries paid to part-time and full-time academics by state universities in São Paulo. This has remained constant at 82.7% for the past several years. See Part A, item 3.2.1, for details.

(3) The *Frascati Manual* recommends adjusting the doctoral student grantee headcount for non-R&D activities using a discount factor to estimate the proportion of their time grantees devote to R&D proper. This chapter uses a 50% discount factor, in accordance with common practice in Brazil and other countries.

2.2 Estimating the number of researchers per sector

2.2.1 Research institutions

Given the lack of systematized information on the R&D activities performed by government research institutions in all three tiers and by private RIs, a method had to be developed for the purposes of this analyzis. One possible option would have been to use data from CNPq's Research Group Census to select the RIs to be included in the survey, based on the criterion that at least one professional affiliated with them is registered with the RGD.

The number of public RIs engaged in R&D in São Paulo State would be 26 on this criterion (Detailed Chart 3.1B). R&D is the core activity for some of these (such as Instituto Agronômico de Campinas or Centro de Tecnologia da Informação Renato Archer), while others have different core purposes but also perform research (such as the Department of Health's Disease Control Center or Instituto de Pesquisas Tecnológicas).

In the former case, the entire workforce should be counted as R&D personnel, while in the latter only personnel effectively performing R&D should be counted. Given the extreme difficulty of obtaining all the data required for this purpose, a more conservative procedure for both would be to count only researchers, students and technical support staff. However, in light of the RGD's limitations as a primary data source for demarcating these contingents,[8] the management of São Paulo's public RIs was asked to report the numbers of career scientific researchers who work there. This too is a conservative approach, since there may be non-career researchers doing R&D at such institutions.

In the case of state RIs, the data are organized in accordance with the state government's administrative structure, with the exception of Instituto de Pesquisas Tecnológicas (IPT). Thus RIs attached to the Department of Agriculture are classified under APTA (Agência Paulista de Tecnologia dos Agronegócios), the agency responsible for coordinating and managing agricultural research in the state. The other institutions and aggregations are self-explanatory.

Another restrictive hypothesis entailed not counting students in public RIs in order to avoid probable double counting, since they would certainly be counted as students at HEIs, as explained in the next item.

In the case of private nonprofit HEIs, the main data source was the Research Group Census (Detailed Chart 3.2B). Moreover, the number of researchers at these institutions was assumed to be the same before 2000 as in that year; an analogous assumption was made for the post-2007 period.

2.2.2 Higher education institutions

Counting researchers at HEIs is particularly complex, despite the fact that universities have historically been the main venue for scientific research in Brazil. While there is a great deal of information and an abundance of administrative records relating to higher education, the data do not clearly distinguish between researchers and other personnel or quantify the time devoted to research by the academic community. In any event, given that practically all staff at state and federal universities in São Paulo are employed under a work regime known as RDIDP (the acronym for full-time dedication to teaching and research in Portuguese) ultimately in order to ensure that these academics perform research, it was decided to count all of them as researchers.[9] In the case of private and public municipal HEIs the criteria were more rigorous, in that only full-time academics with PhDs were counted. All this information is available from the Higher Education Censuses performed by Instituto Nacional de Estudos e Pesquisas Educacionais (INEP), an agency of the Education Ministry.

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8. The main limitations of CNPq's Research Group Census are the imprecise concept of a "research group." whose members may not necessarily perform R&D; the virtual impossibility of avoiding double counting, given that many individuals are registered as belonging to more than one research group because of the method used to collect and display the data; the short time span covered by the RGD, which is a fairly recent creation; and the fact that it is only updated every two years.

9. This decision was taken after the limitations of the information in the Research Group Census were evaluated. As noted earlier, these limitations are especially problematical in the case of HEIs. Counting academics employed under the RDIDP work regime is considered appropriate because the rules governing their employment require them to perform research. University of São Paulo Resolution 3533, Chapter II, article 2, considered a paradigm for the work regime adopted by state HEIs in São Paulo, states that "staff employed under the RDIDP regime are obliged to devote themselves fully and exclusively to the work entailed by their position or function, especially as regards scientific research, and are prohibited from performing any other public or private activities except those allowed by law." For more details, see Part A, 3.3.2.1 and 3.3.2.2.

Doctoral and postdoctoral students with grants from FAPESP, CAPES and CNPq were also counted as researchers at HEIs. Because research constitutes a significant proportion of their activities, and given that this research contains the elements of relevance and novelty required to define R&D personnel as recommended by the *Frascati Manual*, these students must needs be counted as researchers, although they are classified separately in Table 3.2B. Technicians were counted by the same procedures as those already described for research institutions.

2.2.3 Business

The data source for business R&D was the Survey of Technological Innovation (PINTEC), conducted by IBGE. Regionalized tables furnished by IBGE were used, with the data for each local unit (LU) allocated to the state in which the respective head office is located.

This approach may overestimate the numbers of researchers in states with many corporate headquarters, given the procedure of allocating R&D activities performed at LUs located elsewhere to the state in which the head office is located. Nevertheless, it appears preferable to the alternative of distributing them proportionally to LUs since the latter may be empirically observable but in practice R&D activities are most often centralized at or near corporate HQ.[10]

Table 3.1B presents the numbers of researchers working in the intramural R&D units of business enterprises, identified as such by the fact that they have university degrees and postgraduate qualifications. Regionalized data from PINTEC 2005 included key segments of the service sector. For prior and subsequent years, the researcher headcount for this sector was estimated considering (1) the validity of the regression analyzis for business expenditure on R&D (BERD) based on gross fixed capital formation (GFCF);[11] (2) the hypothesis that BERD per researcher remained constant over time; and (3) the hypothesis that the ratio of BERD in industry to BERD in services was that observed in 2005 São Paulo State.

With these criteria and sources, it was possible to obtain the absolute number of researchers, regardless of the time devoted to R&D. To estimate their effective dedication to R&D, an additional procedure was used. This consisted of calculating the number of full-time equivalent (FTE) researchers. Here too a number of ad hoc hypotheses had to be introduced, since with the sole exception of PINTEC there are no data sources that detail the proportion of the work week devoted to R&D by these researchers. This is particularly relevant to HEIs, as professionals at research institutions can reasonably be assumed to devote all their time to R&D.

Chart 3.1B explains the criteria used for this estimate. Academics at state and federal public universities are counted differently depending on whether they hold PhDs or master's degrees: R&D is assumed to account for 82.7% of the work week for the former and 50% for the latter. In the case of academics at municipal HEIs, whether private or public, the 82.7% factor was applied to full-time academics with PhDs.

The criteria for students were as follows: all postdoctoral students receiving grants from CNPq, CAPES and FAPESP; and 50% of PhDs with grants from all three agencies, as recommended by the *Frascati Manual*. The findings, broken down by institutional sector and components, are presented in Table 3.2B (headcount) and Table 3.3B (FTE).

The same methodology was used to count the number of researchers in Brazil, albeit with two modifications:

a) for researchers at RIs, the numbers are those published by MCT, which has records only for the period 2000-08;

b) for full-time equivalent (FTE) doctoral students, calculated using the number of grantees, the data are from the two federal agencies (CAPES and CNPq) and FAPESP. To approximate the number of grants extended by other research funding agencies (FAPs), the total for FAPESP was increased by 40%.

The resulting series are presented in Table 3.4B (headcount) and Table 3.5B (FTE).

10. The close correlation between corporations' strategies for locating their HQs and R&D units is a key element in the debate about globalisation and regional development, as stressed by Strandell (2008) and Đadil et al. (2007). Although little research has been done on this subject in Brazil, Fundação Seade's 2001 survey (PAEP, see note 4 above) showed that 92.5% of firms with R&D units located them near their HQs, corroborating the procedure adopted by IBGE.

11. See item 3.3.4 in Part A of this chapter.

Table 3.2B
Number of researchers (headcount) by sector and administrative jurisdiction – São Paulo State – 1995-2008

Sector & administrative jurisdiction	No. of researchers (headcount)													
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	**37,894**	**37,225**	**39,861**	**39,642**	**39,300**	**40,492**	**43,723**	**44,877**	**44,488**	**47,011**	**50,865**	**54,269**	**59,526**	**62,897**
Higher Education Institutions (HEIs)	**17,703**	**17,473**	**18,632**	**19,169**	**20,604**	**21,445**	**22,295**	**22,933**	**23,074**	**23,260**	**24,155**	**24,571**	**25,889**	**26,333**
State HEIs	10,870	10,614	10,422	10,245	10,137	10,050	10,030	10,265	10,228	10,479	10,915	10,785	11,189	10,740
Federal HEIs	1,280	1,261	1,224	1,229	1,193	1,301	1,268	1,249	1,246	1,283	1,323	1,462	1,668	1,872
Private & municipal HEIs	466	466	466	505	679	988	1,143	1,282	1,200	1,428	1,741	1,974	2,123	2,123
Postdoctoral grantees	443	488	653	743	773	889	1,035	1,232	1,418	1,539	1,704	1,960	2,012	2,386
Doctoral grantees	4,644	4,644	5,867	6,447	7,822	8,217	8,819	8,905	8,982	8,531	8,472	8,390	8,897	9,212
Research Institutions (RIs)	**3,058**	**2,911**	**2,798**	**2,730**	**2,730**	**2,673**	**2,672**	**2,708**	**2,725**	**2,841**	**2,963**	**3,063**	**3,058**	**3,036**
State RIs	**2,122**	**1,984**	**1,891**	**1,833**	**1,824**	**1,771**	**1,750**	**1,752**	**1,698**	**1,792**	**1,781**	**1,758**	**1,737**	**1,710**
IPT	589	451	449	414	409	386	380	388	380	407	364	335	300	278
APTA	791	791	706	697	682	675	651	639	592	591	590	589	587	586
Dept. of Health	540	540	540	540	540	540	549	559	568	577	587	596	605	615
Dept. of Environment	202	202	196	182	193	170	170	166	158	217	241	238	244	231
Instituto Florestal	88	88	84	79	74	73	73	72	72	84	104	101	107	99
Instituto de Botânica	72	72	72	65	63	62	61	61	56	91	91	88	90	87
Instituto Geológico	42	42	40	38	56	35	36	33	30	42	46	49	47	45
Federal RIs	**786**	**777**	**757**	**747**	**756**	**752**	**772**	**806**	**842**	**829**	**857**	**878**	**893**	**898**
IPEN	278	282	266	285	280	293	302	314	323	335	340	339	337	334
INPE	212	200	205	194	190	187	185	195	190	195	195	193	192	190
LNLS	0	0	0	0	11	13	18	23	30	31	31	30	28	32
CTA	119	118	118	107	117	98	95	94	117	120	123	123	125	125
CTI	14	14	12	13	13	16	17	20	24	24	29	31	30	30
Embrapa SP	163	163	156	148	145	145	155	160	158	124	139	162	181	187
Private nonprofit RIs	150	150	150	150	150	150	150	150	185	220	324	428	428	428
Business	**17,133**	**16,841**	**18,431**	**17,743**	**15,966**	**16,374**	**18,756**	**19,236**	**18,689**	**20,910**	**23,747**	**26,635**	**30,579**	**33,528**

Note: See Chart 3.1B.

Table 3.3B
Number of researchers (full-time equivalent) by sector and administrative jurisdiction – São Paulo State – 1995-2008

Sector & administrative jurisdiction	No. of researchers (FTE)													
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	**24,875**	**24,584**	**26,865**	**27,698**	**27,236**	**27,808**	**31,346**	**32,955**	**33,423**	**35,654**	**39,080**	**42,307**	**46,788**	**50,544**
Higher Education Institutions (HEIs)	**8,580**	**8,662**	**9,828**	**11,260**	**12,171**	**12,485**	**13,512**	**14,007**	**14,251**	**14,275**	**14,909**	**15,458**	**16,421**	**17,565**
State HEIs	4,633	4,657	5,032	5,980	6,011	5,809	6,236	6,306	6,424	6,359	6,500	6,716	6,948	7,117
Federal HEIs	725	707	823	896	914	861	885	957	925	930	1,029	955	1,256	1,442
Private & municipal HEIs	457	488	386	417	562	817	946	1,060	993	1,181	1,440	1,632	1,756	2,014
Postdoctoral grantees	443	488	653	743	773	889	1,035	1,232	1,418	1,539	1,704	1,960	2,012	2,386
Doctoral grantees	2,322	2,322	2,934	3,224	3,911	4,109	4,410	4,452	4,491	4,266	4,236	4,195	4,449	4,606
Research Institutions (RIs)	**3,058**	**2,911**	**2,798**	**2,730**	**2,730**	**2,673**	**2,672**	**2,708**	**2,725**	**2,841**	**2,963**	**3,063**	**3,058**	**3,036**
State RIs	**2,122**	**1,984**	**1,891**	**1,833**	**1,824**	**1,771**	**1,750**	**1,752**	**1,698**	**1,792**	**1,781**	**1,758**	**1,737**	**1,710**
IPT	589	451	449	414	409	386	380	388	380	407	364	335	300	278
APTA	791	791	706	697	682	675	651	639	592	591	590	589	587	586
Dept. of Health	540	540	540	540	540	540	549	559	568	577	587	596	605	615
Dept. of Environment	202	202	196	182	193	170	170	166	158	217	241	238	244	231
Instituto Florestal	88	88	84	79	74	73	73	72	72	84	104	101	107	99
Instituto de Botânica	72	72	72	65	63	62	61	61	56	91	91	88	90	87
Instituto Geológico	42	42	40	38	56	35	36	33	30	42	46	49	47	45
Federal RIs	**786**	**777**	**757**	**747**	**756**	**752**	**772**	**806**	**842**	**829**	**857**	**878**	**893**	**898**
IPEN	278	282	266	285	280	293	302	314	323	335	340	339	337	334
INPE	212	200	205	194	190	187	185	195	190	195	195	193	192	190
LNLS	0	0	0	0	11	13	18	23	30	31	31	30	28	32
CTA	119	118	118	107	117	98	95	94	117	120	123	123	125	125
CTI	14	14	12	13	13	16	17	20	24	24	29	31	30	30
Embrapa SP	163	163	156	148	145	145	155	160	158	124	139	162	181	187
Private nonprofit RIs	**150**	**150**	**150**	**150**	**150**	**150**	**150**	**150**	**185**	**220**	**324**	**428**	**428**	**428**
Business	**13,237**	**13,011**	**14,239**	**13,708**	**12,335**	**12,650**	**15,162**	**16,240**	**16,447**	**18,538**	**21,208**	**23,786**	**27,309**	**29,943**

Note: See Chart 3.1B and Table 3.2B.

Table 3.4B
Number of researchers (headcount) by sector and administrative jurisdiction – Brazil – 1995-2008

Sector & administrative jurisdiction	No. of researchers (headcount)													
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	**124,751**	**123,920**	**133,558**	**137,316**	**135,872**	**148,661**	**155,742**	**158,348**	**163,743**	**174,874**	**183,512**	**194,851**	**211,921**	**229,121**
Higher Education Institutions (HEIs)	**86,932**	**85,604**	**92,311**	**96,193**	**97,732**	**108,839**	**113,380**	**115,349**	**118,980**	**123,949**	**128,511**	**134,899**	**144,202**	**152,519**
State HEIs	25,932	26,064	28,164	30,621	29,141	33,730	34,618	35,354	36,098	38,182	39,780	41,007	44,346	44,870
Federal HEIs	44,486	42,110	45,059	45,611	46,687	50,165	51,765	51,020	52,106	54,439	56,565	58,078	63,302	66,122
Private & municipal HEIs	1,383	1,476	1,168	1,116	1,445	2,051	2,586	2,859	2,925	3,245	3,882	4,161	4,752	5,287
Postdoctoral grantees	2,992	3,037	3,182	3,063	2,737	3,112	3,597	4,078	4,739	5,073	5,652	6,774	6,345	6,704
Doctoral grantees	12,139	12,917	14,738	15,782	17,722	19,781	20,814	22,038	23,112	23,010	22,632	24,879	25,457	29,536
Research Institutions (RIs)	**4,740**	**4,740**	**4,740**	**4,740**	**4,740**	**4,740**	**4,652**	**4,562**	**5,095**	**5,625**	**5,769**	**5,910**	**6,384**	**6,855**
Business	**33,079**	**33,576**	**36,507**	**36,383**	**33,400**	**35,082**	**37,710**	**38,437**	**39,668**	**45,300**	**49,232**	**54,042**	**61,335**	**69,747**

Source: MCT; CNPq; FAPESP; Viotti & Macedo (2003) (data adjusted by methods detailed in this chapter).

Note: See Chart 3.1B.

Table 3.5B
Number of researchers (full-time equivalent) by sector and administrative jurisdiction – Brazil – 1995-2008

Sector & administrative jurisdiction	No. of researchers (FTE)													
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	**65,160**	**65,264**	**70,110**	**70,277**	**69,347**	**75,902**	**81,081**	**84,909**	**89,158**	**96,370**	**102,895**	**112,390**	**123,157**	**136,510**
Higher Education Institutions (HEIs)	**32,351**	**32,033**	**34,391**	**34,664**	**36,265**	**41,393**	**44,430**	**47,731**	**50,402**	**52,306**	**55,350**	**60,622**	**64,727**	**70,471**
State HEIs	6,067	6,097	6,589	7,799	7,817	8,852	9,658	10,891	11,470	12,083	12,553	13,556	14,387	15,244
Federal HEIs	16,078	15,219	16,285	14,988	15,655	17,843	18,629	19,378	20,218	20,962	22,618	24,412	27,337	29,383
Private & municipal HEIs	1,144	1,221	,966	,923	1,195	1,696	2,139	2,365	2,419	2,683	3,211	3,441	3,930	4,372
Postdoctoral grantees	2,992	3,037	3,182	3,063	2,737	3,112	3,597	4,078	4,739	5,073	5,652	6,774	6,345	6,704
Doctoral grantees	6,070	6,459	7,369	7,891	8,861	9,890	10,407	11,019	11,556	11,505	11,316	12,439	12,728	14,768
Research Institutions (RIs)	**4,740**	**4,740**	**4,740**	**4,740**	**4,740**	**4,740**	**4,652**	**4,562**	**5,095**	**5,625**	**5,769**	**5,910**	**6,384**	**6,855**
Business	**28,069**	**28,491**	**30,979**	**30,873**	**28,342**	**29,769**	**31,999**	**32,616**	**33,661**	**38,439**	**41,776**	**45,858**	**52,046**	**59,184**

Source: MCT; CNPq; FAPESP; Viotti & Macedo (2003) (data adjusted by methods detailed in this chapter).

Note: See Chart 3.1B and Table 3.4B.

2.3 Evolution of number of researchers in São Paulo

According to the methodology used in this chapter, São Paulo State had almost 63,000 researchers in 2008, for an increase of 66% compared with the estimated number in 1995. Although most were in HEIs (42%), the number of researchers in business enterprises grew fastest in the period (96%), taking their share of the total from 45% in 1995 to 53% to 2008. At the same time, the number of researchers working in public research institutions located in São Paulo State stagnated, remaining in the range of 3,000 throughout the period, so that their share of the total fell from 8% in 1995 to less than 5% in 2008. Table 3.2B shows that this decrease was concentrated in IPT and in the RIs subordinated to APTA. Further study of this phenomenon would be useful to understand its significance.

Even with this dubious aspect, there can be no denying that São Paulo State has advanced in this field, thanks above all to growth in the number of researchers in business enterprises. It is a commonplace to point out that Brazil has not been able to appropriate, in the form of technological innovations, most of the undeniable scientific advances produced by its researchers, and various legal and institutional measures have been implemented with the aim of building closer ties between academia and business research institutions. Thus the finding that firms are increasing their contingents of researchers is itself an indication that an important change is taking place in business, which appears to be starting to see technological innovation as a key driver of competitiveness and growth.

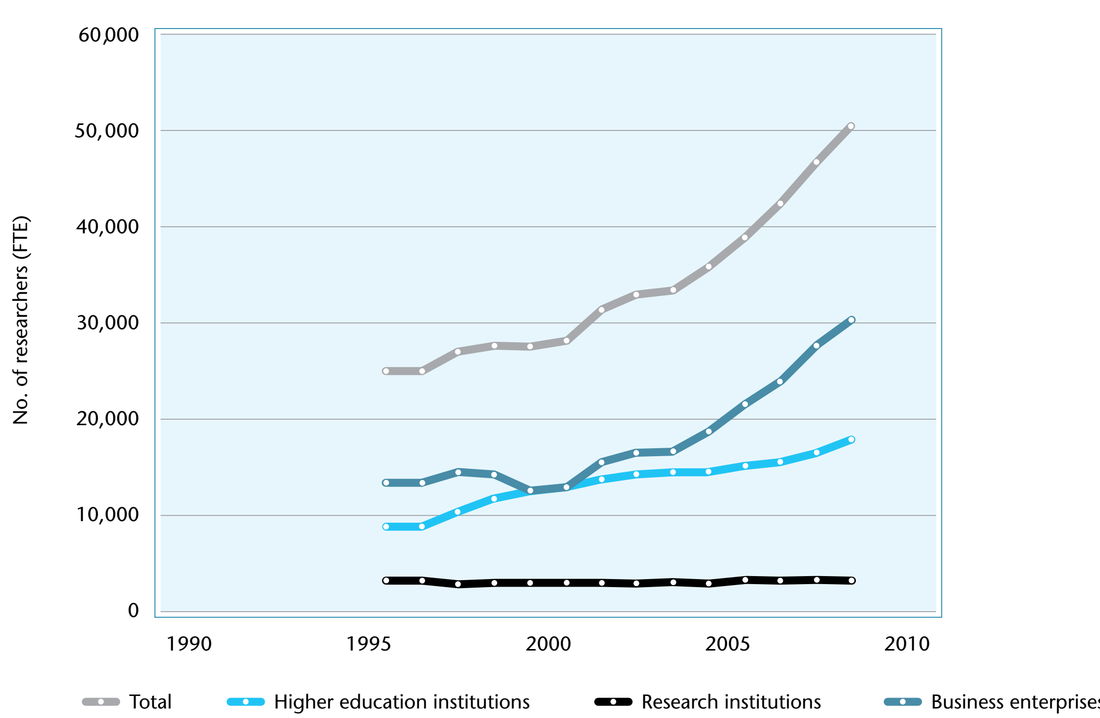
A brief point about the number of technical personnel in this field is also worth making. Firms were the main locus for research technicians at the start of the period and remained so with growing intensity, followed by HEIs. RIs have been losing share in this area, just as they have in the case of researchers.

2.4 Comparative analyzis

This section discusses the full-time equivalent (FTE) indicators calculated in order to avoid possible distortions deriving from the different work regimes in place in different geographical areas. The changes in the FTE numbers for São Paulo State in each of the three sectors analyzed are shown in Figure 3.1B.

In 2008 there were just over 50,000 active FTE researchers in São Paulo State: 17,565 were in HEIs, 3,036 in public and private RIs, and 29,943 in business enterprises.

Figure 3.1B
Number of researchers (full-time equivalent) by sector – São Paulo State – 1995-2008



Note: See Table 3.3B.

Between 1995 and 2002 this indicator rose mainly in HEIs, but after that the strongest growth was among researchers in firms. This pattern results from the model used here, which calculates the number of researchers in proportion to business expenditure in R&D (BERD). As shown in Part A of this chapter, BERD increased from 2002 on.

As a share of the Brazilian total, FTE researchers in São Paulo remained practically unchanged between the first and last years of the period analyzed, ranging from 38% in 1995 to 37% in 2008. However, given the more intense growth in FTE researchers working for firms in São Paulo (126%) than in Brazil (111%) during the period, it is estimated that almost 51% of the total were in São Paulo in 2008 (up from 47% in 1995).

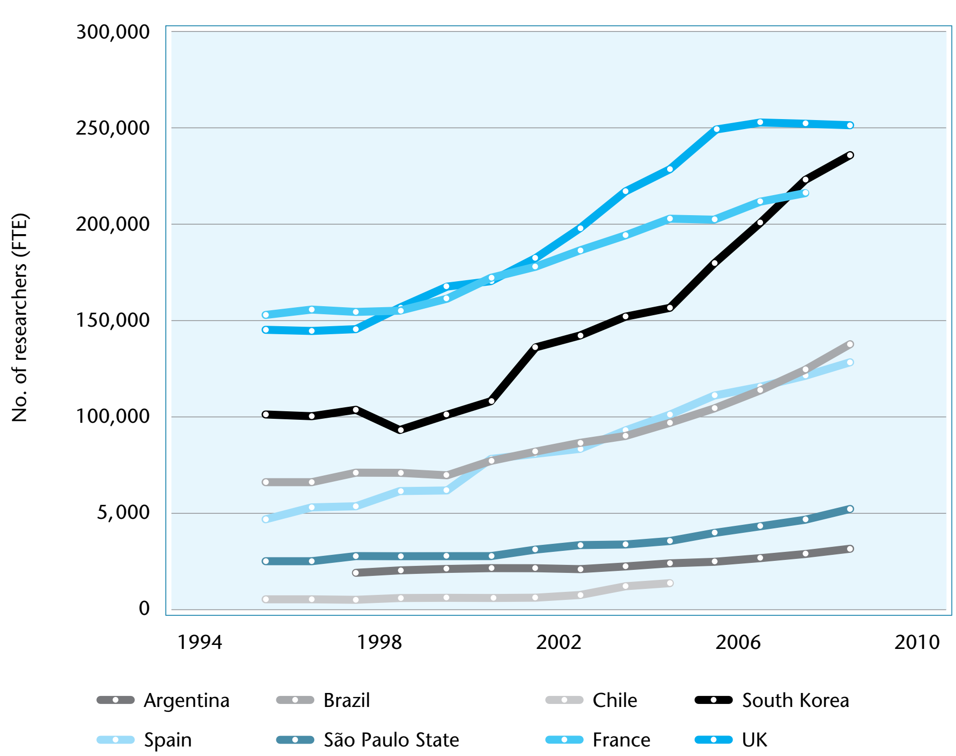
FTE researchers in firms accounted for 59% of the total in São Paulo in 2008, close to the proportions for South Korea (75%), the United States (80%), China (66%) and Germany (62%), and higher than those for Spain (34%), France (54%) and Canada (44%). In absolute terms, however, both Brazil and São Paulo lag far behind (Figure 3.2B).

In 2007 the number of FTE researchers was 21% of the number in South Korea and 38% of the number in Spain, to take as examples two countries with similar populations to São Paulo State's. A more complete comparison taking the population of each country into account can be seen in Figure 3.3B.

In this respect São Paulo is slightly ahead of China, Argentina, Chile, Mexico and Brazil overall but behind countries with which it competes in international markets. In these cases its research contingent is smaller by a factor of at least 2.3, indicating the fundamental importance of a strategy to increase the number of researchers in São Paulo in the years ahead. Given that the proportion between FTE researchers in firms and in HEIs is similar to that seen in the countries that perform best on this criterion in comparative terms, the research contingent must evidently grow in both academia and business. Moreover, it will be necessary to implement a strategy for research institutions, especially state RIs, as the indicators for this sector give cause for concern.

In the case of Brazil the challenge is greater still, since the number of researchers per 1 million inhabitants in Portugal and South Korea is respectively 4.1 times and 7.1 times higher than in Brazil (649), to take only two examples.

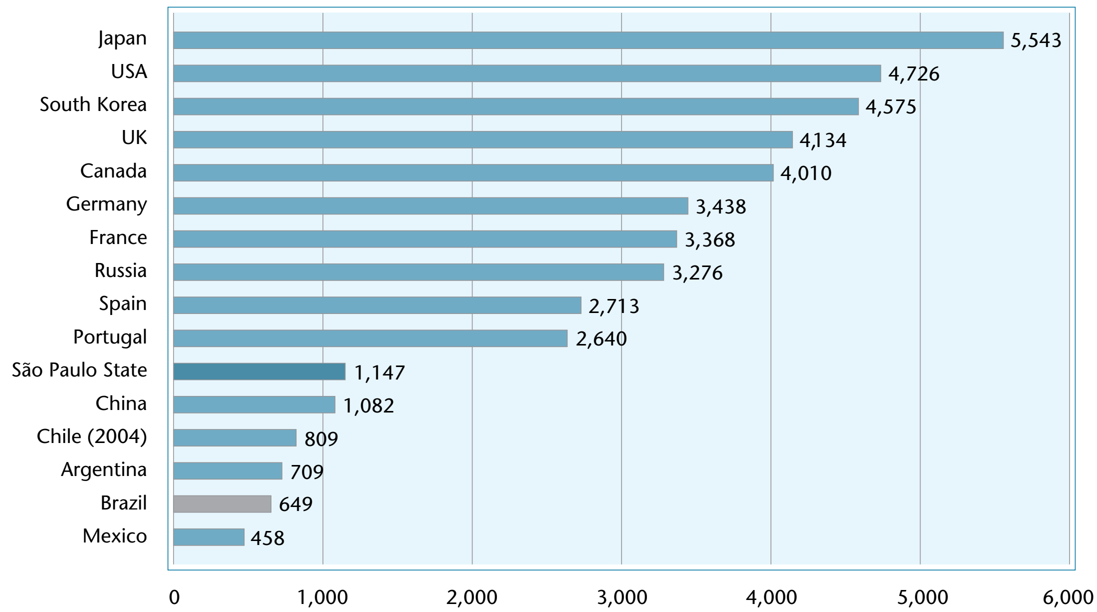
Figure 3.2B
Number of researchers (full-time equivalent) – Brazil, São Paulo State & selected countries – 1995-2008



Source: This chapter (São Paulo State & Brazil); RICyT, Tabla personal de ciencia y tecnología (Argentina & Chile); OECD, 2009 (other countries).

Note: See Detailed Table 3.1B.

Figure 3.3B
Researchers (full-time equivalent) per million inhabitants – Selected countries – 2007



Source: This chapter (São Paulo State & Brazil); RICyT, Tabla personal de ciencia y tecnología (Argentina & Chile); OECD, 2009 (other countries).

Note: See Detailed Table 3.2B.

2.5 Closing remarks

It is important to note the difficulty of constructing indicators of R&D personnel in Brazil and São Paulo State. The time required to evaluate, choose, collect and organize the data is far greater than the time required to analyze the results obtained. Moreover, the various hypotheses adopted and the heterogeneity of the sources used make a consensus regarding the meaning of the findings practically impossible. For this reason an effort has been made to ensure that the hypotheses adopted in this chapter and the limitations of the data sources are as transparent as possible, so that other researchers can interpret the indicators presented objectively. On this point, it would be advisable to begin an endeavour to enhance S&T statistics for Brazil and São Paulo State via an institutional initiative designed to standardize either the administrative records of the institutions that perform research in the two regions or primary collection of the information required to produce such statistics.

It should also be stressed that the findings show São Paulo's leadership of Brazil in terms of R&D personnel in all institutional affiliations analyzed and above all in absolute numbers of researchers. They also show that this contingent is steadily growing at a rapid pace, although the performance of the government research institutions located in the state is cause for concern in this regard. Lastly, they show that despite this strong overall growth the number of researchers in São Paulo and Brazil will have to grow much more if it is to reach a level compatible with the importance of both regions in the international arena.

As noted at the start of this chapter, human resources in R&D comprise the personnel directly engaged in the creation and application of new knowledge. The absolute number of people with this occupational profile undoubtedly says much about the capacity to perform R&D. From this perspective, São Paulo State, with R&D personnel amounting to over 90,000, 70% of whom are researchers, is strongly positioned both within Brazil and internationally, however small this contingent may seem in proportion to the population and workforce.

The growing proportion of researchers in the business sector, especially in São Paulo State, suggests that corporate strategists are becoming more sensitive to the need to enhance competitiveness via technological innovation.

In any event, effective diffusion of knowledge and innovations throughout the production chain and their ability to generate benefits that can be appropriated by most of the population depend on other elements, such as the supply of skilled workers. This is the focus for the second approach mentioned above, which measures highly qualified human resources and is analyzed in the next section.

3. Human resources in science and technology (HRST)

The second approach adopted here focuses on measuring the stock of highly qualified workers and does so as far as possible in accordance with the recommendations of the *Canberra Manual* (OECD, 1995). Skill is key in this context, both in the shape of formal qualifications obtained by education and training, and skills acquired on the job. Given this premise, the analyzis begins with a division into two groups: university-level personnel with qualifications acquired via formal education (HRSTe); and personnel not thus formally qualified but employed in occupations requiring high levels of skill (HRSTo). These two groups together comprise total HRST and the overlap between them can be termed core HRST (HRSTc).

In mathematical notation, the relations between HRST and the indicators derived from it can be represented as follows:

$$HRST = HRSTe \cup HRSTo$$

$$HRSTc = HRSTe \cap HRSTo$$

Thus HRST refers to total highly qualified human resources in S&T occupations, while HRSTc refers to those who have a university degree or the equivalent and are employed in S&T occupations requiring high levels of skill. It can be assumed that the larger the number of HRSTc, the better the educational system is supplying people with the skills required by the occupational structure in the country or region concerned.

This set of indicators links two kinds of phenomena, relating to the educational system and the occupational structure. While the former tends to be more sensitive to educational policy measures, the latter is less so because it is necessarily mediated by business enterprises and the labor market.

On the other hand, certain specific aspects of the methods used to measure these segments must also be noted. Whereas the level of educational attainment can be considered a personal attribute – i.e. something that becomes permanently part of the individual's personality once acquired – the practice of occupations that require high skill levels tends to be far less permanent and subject to the unpredictable fluctuations of the labor market. Moreover, while the former covers the entire population, the latter may be confined to the active workforce at the time of measurement: the educational attainment of the unemployed, retirees etc. may be recorded but these individuals may not be associated with highly skilled occupations simply because at the time they are not working in any occupation.

3.1 Methodological procedures

Estimates of human resources in science and technology (HRST), as defined by the *Canberra Manual*, cover four major groups of people: those with a high level of educational attainment (HRSTe), those working in occupations that require high levels of skill (HRSTo); the overlap between these two groups (HRSTc), i.e. individuals with a high level of educational attainment working in highly skilled occupations; and the two groups combined, i.e. the total contingent of individuals with high levels of education or skill (HRST).

In the case of education, the *Canberra Manual* recommends the International Standard Classification of Education (ISCED-76) as the best source for selecting individuals with (a) "education at the third level, first stage, of the type that leads to an award not equivalent to a first university degree"; (b) "education at the third level, first stage, of the type that leads to a first university degree or equivalent"; (c) "education at the third level, second stage, of the type that leads to a postgraduate university degree or equivalent."

To measure HRSTo, the equivalent of ISCED is the International Standard Classification of Occupations (ISCO-88). The following occupational groups and subgroups are applicable:

- 21 – Physical, mathematical and engineering science professionals
- 22 – Life science and health professionals
- 23 – Teaching professionals
- 24 – Other professionals
- 31 – Physical and engineering science technicians
- 32 – Life science and health technicians
- 33 – Teaching technicians
- 34 – Other technicians
- 122 – Production and operations department managers
- 123 – Other department managers
- 131 – General managers

However, the production of these indicators using data from IBGE's National Household Sample Survey (PNAD) requires adaptations, since the classifications of occupations and educational attainment used by IBGE are not consistent with those recommended internationally. This topic is discussed in the corresponding chapter ("Human resources available in science and technology") of the previous edition of this publication (FAPESP, 2005), but a number of additional comments must be made here.

The first problem with PNAD in this context concerns its failure to count the number of people who have successfully completed tertiary-level courses that do not award university degrees, corresponding to so-called technological education in Brazil. Thus the criteria used here to estimate HRST are less comprehensive than those recommended by the *Canberra Manual*. This problem is unimportant when the number of people with a technological education (third level, first stage, leading to an award not equivalent to a first university degree) is relatively small. However, the number of such people is rising in Brazil and especially in São Paulo State, where an intense government effort is under way to increase the supply of these courses.[12] Thus it would be desirable for IBGE to revise the educational classification it uses in PNAD so that the number of people with this qualification can be identified unambiguously.

With regard to the Brazilian Classification of Occupations (Classificação Brasileira de Ocupações, CBO), a methodological change has been made that hinders comparison with the findings in the previous edition (FAPESP, 2005), which used data from PNAD 2001. Until that year the classification used by PNAD was not entirely compatible with CBO and hence with ISCO-88. Since then, however, IBGE has introduced a conversion table to facilitate comparison of the three classifications concerned, and this assists identification of the PNAD groups corresponding to ISCO 122, 123 and 131, as well as major groups 2 and 3.[13]

In 2002 IBGE changed its occupation codes owing to adoption of a new occupational classification (CBO Domiciliar) used for the first time in the 2000 Population Census and in the household surveys conducted from 2002 on.[14] This change required a new table for conversion between ISCO and CBO Domiciliar. MCT produced the conversion table and supplied it to FAPESP to assist in the analyzis presented in this chapter (Detailed Table 3.3).

3.2 Results and analyzis

Based on PNAD and using the procedures summarized above, the stock of HRST in Brazil in 2006 is estimated at 21.4 million, of whom 6 million or 28% resided in São Paulo State (Table 3.6B). This is a large contingent, as can be seen from the international comparisons presented below, but it is relatively small in proportion to the active workforce: 20% for Brazil and

Table 3.6B
Human resources in science and technology (HRST) by component group – Brazil & São Paulo State – 2002-2006

Year	Total HRST (HRSTo U HRSTe)		In S&T occupations (HRSTo)		In S&T occupations w/ university degree (HRSTc)		University degree (HRSTe)	
	Brazil	São Paulo State	Brazil	São Paulo State	Brazil	São Paulo State	Brazil	São Paulo State
2002	17,300,615	5,044,026	14,709,591	4,129,508	4,346,963	1,549,694	6,937,987	2,464,212
2003	17,904,308	5,225,468	15,023,096	4,197,442	4,586,103	1,601,283	7,467,315	2,629,309
2004	18,759,649	5,174,713	15,618,700	4,069,382	4,908,906	1,590,792	8,049,855	2,696,123
2005	19,978,596	5,702,373	16,680,692	4,596,534	5,264,636	1,782,632	8,562,540	2,888,471
2006	21,350,776	5,974,878	17,732,974	4,760,898	5,846,504	1,943,676	9,464,306	3,157,656

Source: IBGE, PNAD (2002, 2006).

Note: Total HRST = In S&T occupations (HRSTo) + university degree (HRSTe) - In S&T occupations with university degree (HRSTc).

12. Chapter 2 of this publication contains a detailed analyzis of this topic.

13. See Notas Gerais: indicadores gerais de estoque de recursos humanos em ciência e tecnologia (RHCT), at <http://mct.gov.br/index.php/content/view/4080/Brasil_Estimativa_do_potencial_de_recursos_humanos_disponivel_para_a_ciencia_e_tecnologia_C_T_por_categoria.html>.

14. For more information, see <http://www.ibge.gov.br/concla/cl_corresp.php?sl=3>. Last visited June 4, 2009.

25% for São Paulo. Nevertheless, São Paulo is ahead of the national average by a small margin, reflecting the higher level of skill in its workforce compared with Brazil overall.

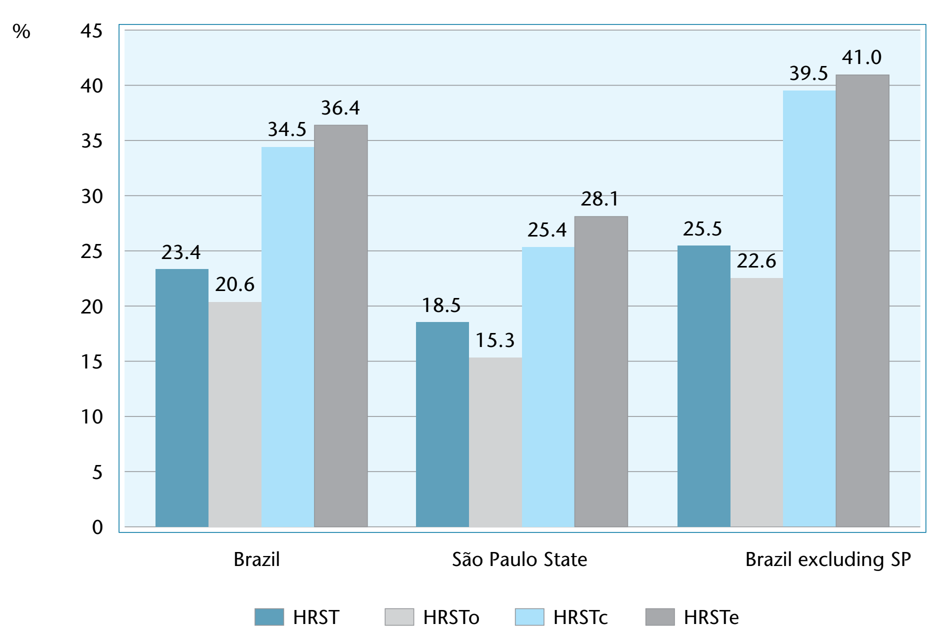
On the other hand, in 2006 Brazil had 17.7 million people in highly skilled occupations, or about 20% of the workforce, which totalled almost 90 million. In São Paulo, the number was 4.8 million, or about a quarter of the workforce (20 million). Thus the occupational structure in São Paulo was more complex than the national average in terms of the stock of HRSTo in proportion to the total workforce. This can also be seen from another angle: in that year São Paulo had 22% of the nation's workforce and 27% of its workers in highly skilled occupations. The stock of HRSTe amounted in São Paulo to 3.2 million, or about a third of the nationwide total (9.5 million). In other words, São Paulo is ahead of the national average in terms of both occupational structure and educational attainment.

The fact that the number of people in highly skilled occupations was much larger than the number with a university degree, both in São Paulo and in Brazil, suggests a degree of educational deficit in the workforce overall and in this occupational group. One way of measuring the discrepancy is to focus on HRSTc, the core group with a university education and employed in highly skilled occupations. This contingent numbered 5.8 million in Brazil, corresponding to 33% of HRSTo, and 1.9 million in São Paulo, or 41% of HRSTo. Thus even in São Paulo 60% of those working in highly skilled occupations did not have a university degree.

Only 62% of HRSTe in both Brazil and São Paulo were employed in highly skilled occupations. Thus despite the apparent educational deficit just noted, in 2006 a significant proportion of the contingent with university degrees worked in occupations theoretically requiring a lower skill level than they had acquired in their formal education. If this phenomenon derives from the fact that the university courses taken by the people concerned do not impart the knowledge required by the labor market, it could eventually lead to a paradoxical situation in which the number of holders of university degrees increases and there is a shortage of qualified professionals at the same time.

The evolution of these contingents in the period 2002-06 is displayed in Figure 3.4B. It is important to recall that whereas the stock of HRSTe rises in step with the number of university graduates, growth in

Figure 3.4B
Growth of human resources in science and technology (HRST) by component group – Brazil, São Paulo State & Brazil excluding São Paulo State – 2006/2002



Brazil : IBGE, PNAD (2002, 2006).

Notes: 1. HRSTc = people in S&T occupations with university degrees.
2. See Table 3.6B

HRSTo depends on the pace of job creation in highly skilled occupations, i.e. on economic growth and the growing complexity of the occupational structure.

This correlation is confirmed by the finding that HRSTe rose considerably more than HRSTo both in Brazil and in São Paulo between 2002 and 2006. First, HRSTe rose 36% and 28% respectively, reflecting the progress achieved in recent decades in improving access to primary and secondary education, as well as student retention for these levels, and in increasing the number of places in higher education. The faster pace of growth in HRSTe in Brazil than in São Paulo can be explained by growth in both the number of places at HEIs and demand for this level of education, again as a reflection of virtually universal access to basic education, involving far more expansion of higher education in the country as a whole than specifically in São Paulo, which was already at a more advanced stage in the initial year of the series. Nevertheless, a more conclusive diagnosis of this phenomenon depends on more detailed evaluation of São Paulo's performance.

Second, HRSTo rose 21% and 15% in Brazil and São Paulo, respectively, in the same period. Again, São Paulo was already well ahead of the rest of the country to start with, yet it may also be the case that faster growth of HRSTo in Brazil reflected stronger economic growth in other states than in São Paulo. In the period 2002-04, São Paulo's GDP grew less than Brazil's, leading to a fall in the state's share of the total (from 34.6% to 33.1%). In 2005 the trend reversed and São Paulo's share in Brazil's GDP rose again (to 33.9%, where it remained in subsequent years). Not by chance, HRSTo in São Paulo rose about 13% in 2005, compared with 7% in Brazil overall.

Despite these transient fluctuations, HRSTe grew more than HRSTo in both São Paulo and Brazil in the period 2022-06 as a whole. HRSTo rose 15.3% in São Paulo, practically in step with growth in the total workforce (15%). In Brazil, however, HRSTo rose 20%, far outpacing growth in the workforce (14%). This suggests that the occupational structure in Brazil excluding São Paulo became more complex in the period, with highly skilled occupations increasing their share of the total so that the gap between the occupational structure in São Paulo and elsewhere narrowed in terms of skill requirements. Nevertheless, the key driver of growth in HRSTc appears to have been growth in HRSTe, reducing the educational deficit among HRST noted earlier.

In sum, the growth in highly skilled human resources was due predominantly to growth in the number of university graduates. Low economic dynamism with low creation of jobs in highly skilled occupations, especially in São Paulo, is a cause for concern and calls for more detailed research.

International comparisons

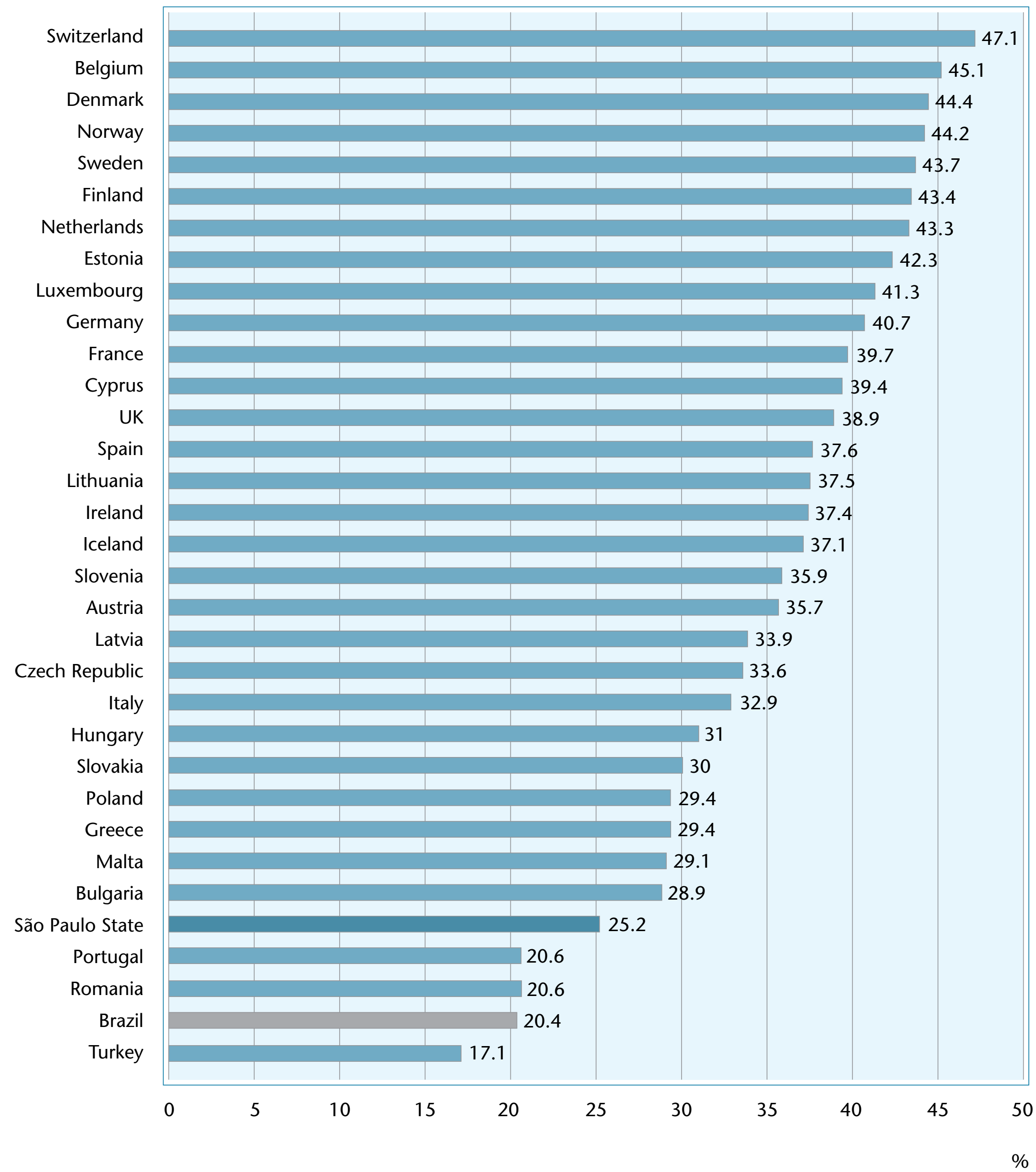
This section does not set out to propose any hypotheses to explain variations in these indicators for selected countries, but simply to compare the results for Brazil and São Paulo State with those of other countries, pointing up the similarities as well as the differences.

In absolute terms the stock of HRST in Brazil (21.4 million) exceeds those of several European countries, such as Germany (19.4 million), France (12.9 million), the UK (12.6 million), Spain (9.5 million) and Italy (9.1 million). If São Paulo, with almost 6 million, were a country it would rank sixth on this criterion, ahead of Poland (5.7 million), Turkey (5.0 million), the Netherlands (4.2 million), Sweden (2.4 million) and Greece (1.7 million), for example.

However, a comparison based on HRST in proportion to the workforce is highly unfavorable to Brazil and São Paulo State. HRST account for 20.4% and 25.2% respectively in Brazil and São Paulo, placing both near the bottom of the rank order of the European countries for which this quotient is available (Figure 3.5B). Indeed, Brazil outperforms only Turkey on this criterion and more or less ties with Portugal and Romania. São Paulo is ahead of the latter two countries, but lags behind Bulgaria, for example.

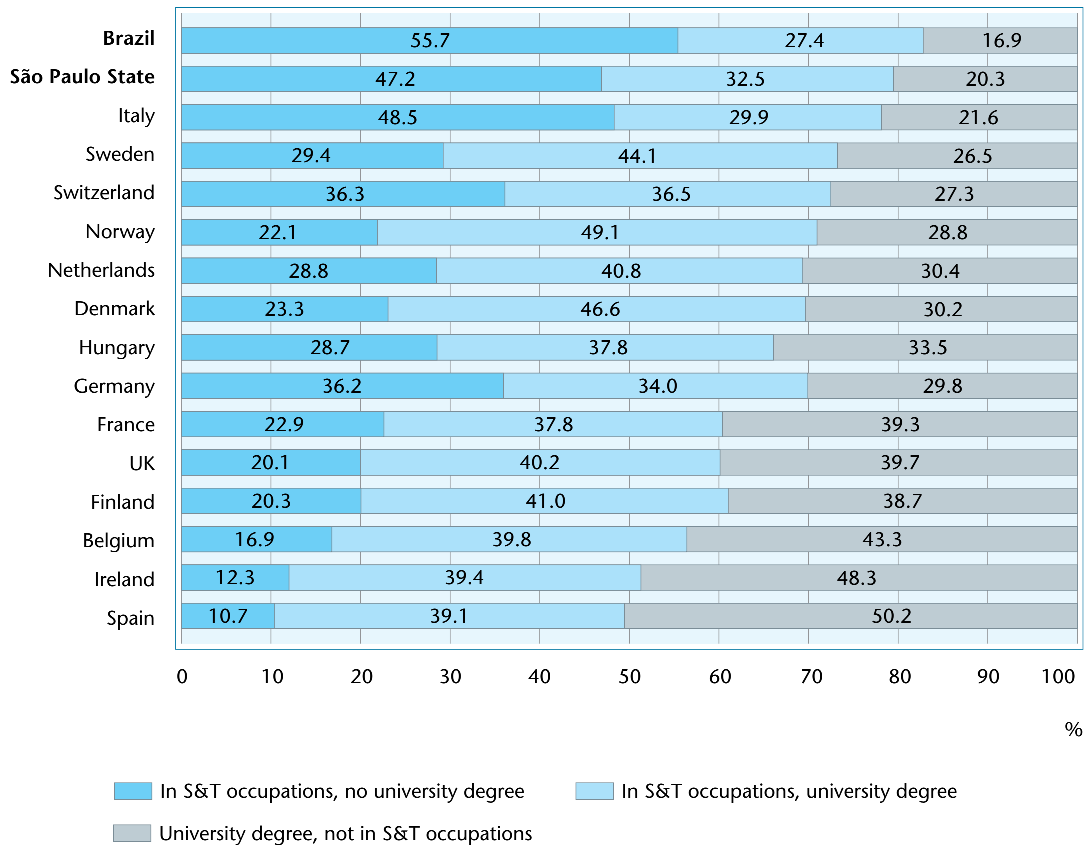
Certain aspects of the composition of HRST in Brazil and São Paulo are also worth noting. Although stronger growth in HRSTe than HRSTo led to a change in the composition of total HRST, its profile remained different from those of the most developed countries (Figure 3.6B). HRSTe accounts for a distinctly larger proportion of total HRST in both Brazil and São Paulo. The only European country with a similar composition is Italy. This is due partly to access to higher education, which is still relatively restricted, while the occupational structure is growing steadily more complex and diversified. The mismatch is set to decrease as the number of university graduates rises, but there is still a long way to go until a balance is achieved.

Figure 3.5B
HRST in proportion to workforce (economically active population aged 15-75) – Brazil, São Paulo State & selected European countries – 2006



Source: IBGE, PNAD (2002, 2006); Eurostat.

Figure 3.6B
Human resources in science and technology (HRST) by *Canberra Manual* category – Brazil, São Paulo State & selected European countries, 2006

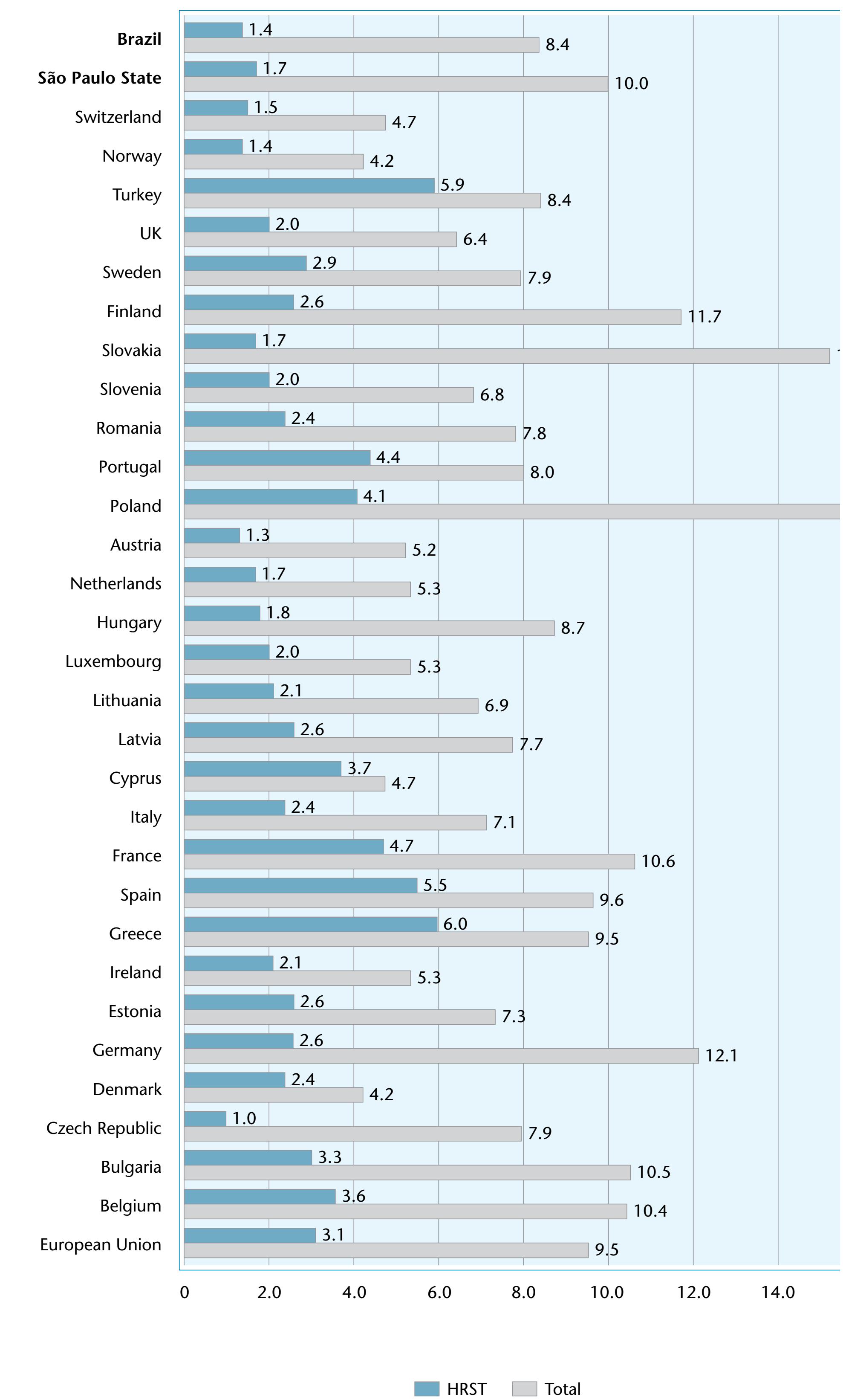


Source: IBGE, PNAD (2002, 2006); Eurostat.

Figure 3.7B shows another peculiarity of the situation in Brazil: the importance of higher education as an employment credential. The unemployment rate among university graduates was 1.7% in São Paulo in 2006, only slightly higher than the unemployment rate for university graduates throughout Brazil (1.4%) at a time when the overall unemployment rate was 10%. In no other countries with comparable unemployment rates, and in very few with low unemployment, are university graduates in such a favorable situation. This also reflects the shortage of university-level professionals in Brazil and São Paulo, so that graduates can find a job far more easily than the average citizen. Even so, judging from the large proportion of HRST who have not successfully completed tertiary education, there is a clear need to investigate the extent to which the profile of the courses offered by HEIs and of graduates meet the nation's real needs.

HRST indicators can also be used to analyze the demographics of these contingents. The breakdown by gender shows a similar situation in Brazil and São Paulo to the international pattern: women account for about half the stock of HRST in Brazil. It is also worth stressing that an even larger proportion of HRSTe consists of women, who accounted for 58% of this contingent nationwide in 2006 (Table 3.7B).

Figure 3.7B
Total unemployment rate and unemployment rate among HRST – Brazil, São Paulo State & European countries – 2006



Source: IBGE, PNAD (2002, 2006); Eurostat.

Table 3.7B
Breakdown of human resources in science and technology (HRST) by *Canberra Manual* category and gender – Brazil & São Paulo State – 2002-2006

Canberra Manual category	% HRST by gender					
	Brazil			São Paulo State		
	Total	Men	Women	Total	Men	Women
2006						
Total HRST	100.0	48.9	51.1	100.0	49.3	50.7
In S&T occupations (HRSTo)	100.0	50.7	49.3	100.0	51.0	49.0
In S&T occupations, university degree (HRSTo U HRSTe)	100.0	43.7	56.3	100.0	47.1	52.9
University degree (HRSTe)	100.0	42.4	57.6	100.0	45.4	54.6
2002						
Total HRST	100.0	50.1	49.9	100.0	49.2	50.8
In S&T occupations (HRSTo)	100.0	51.5	48.5	100.0	51.5	48.5
In S&T occupations, university degree (HRSTo U HRSTe)	100.0	45.8	54.2	100.0	47.4	52.6
University degree (HRSTe)	100.0	44.4	55.6	100.0	44.3	55.7

Source: INEP, Census of Higher Education (microdata).

Note: Table based on Durham & Schwartzman (1992).

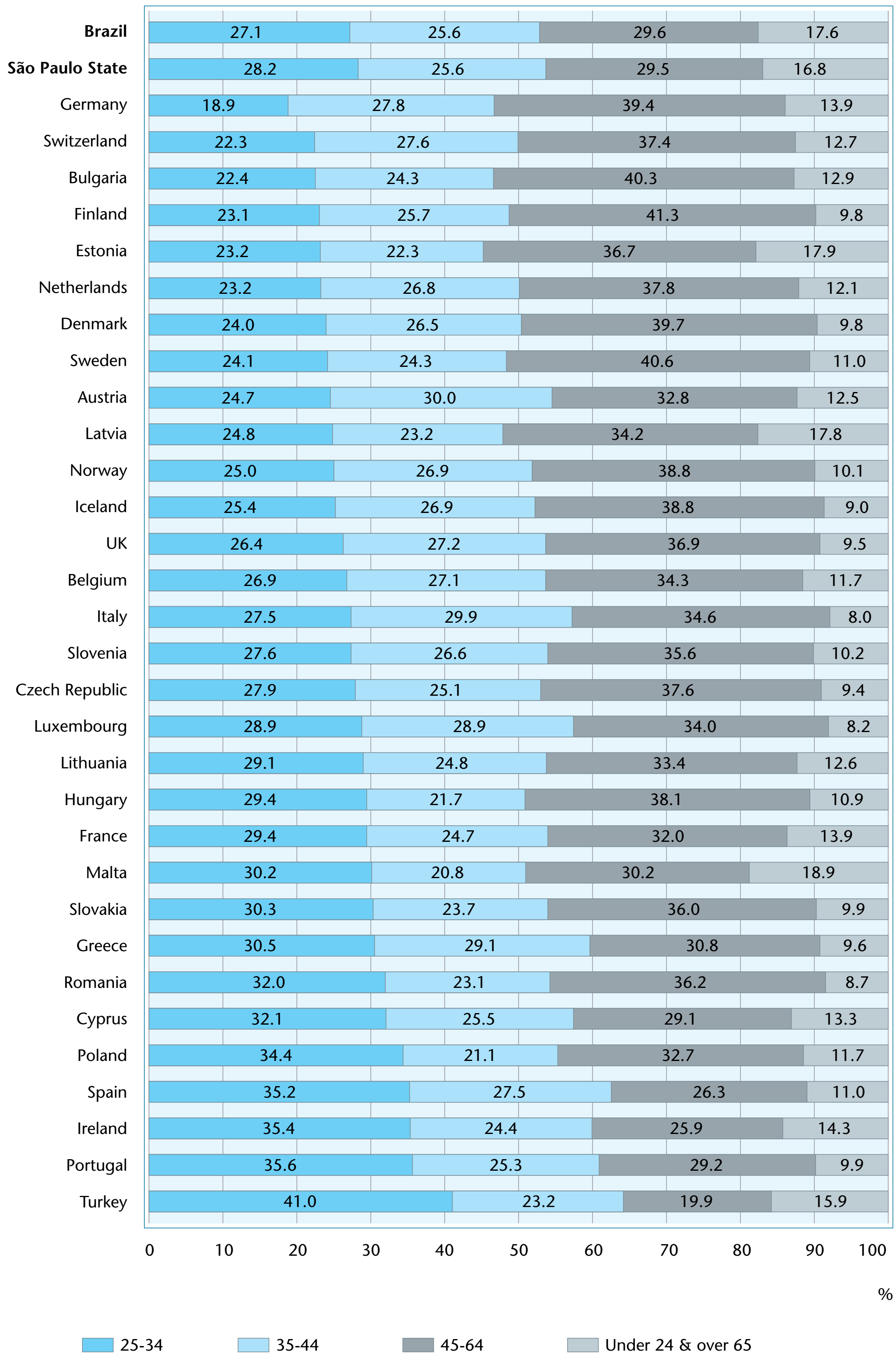
The age breakdown (Figure 3.8B) varies widely among countries. Brazil and São Paulo are in an intermediate position. Thus there are countries whose HRST are older, such as Germany,[15] and others with a large proportion of younger people, such as Spain, Portugal and Turkey. The age structure of HRST in Brazil and São Paulo is more balanced, although in São Paulo it is older than in Brazil overall.

How these structures evolve will depend on the pace at which new, presumably younger individuals join this contingent and the pace at which the population that is already part of HRST ages. In several countries the latter is occurring much faster than the former, and this has led to discussions about migration policies to help reduce the gap.

Selected countries where "ageing" outpaced "rejuvenation" between 2002 and 2006 are featured in Figure 3.9B. It can be seen that even in Spain and Portugal, where a relatively large proportion of HRST are in the 25-44 age group, the older segment has grown fastest. The gravity of the German case is even more conspicuous: the younger segment in Germany is not only much smaller but grew only 2.7% in the period. This contrasts with France, which succeeded in maintaining higher growth rates and a relative balance in age terms during the period. Brazil and São Paulo are noteworthy for the fact that although growth in the stock of HRST has been driven by expansion in the numbers of university-level personnel, presumably younger, the older segment has grown even faster. In other words, however vigorously the number of graduates has grown, this growth has not been sufficient to "rejuvenate" HRST in Brazil and São Paulo to a significant extent. This can be considered one more reason for arguing that its dynamism leaves much to be desired.

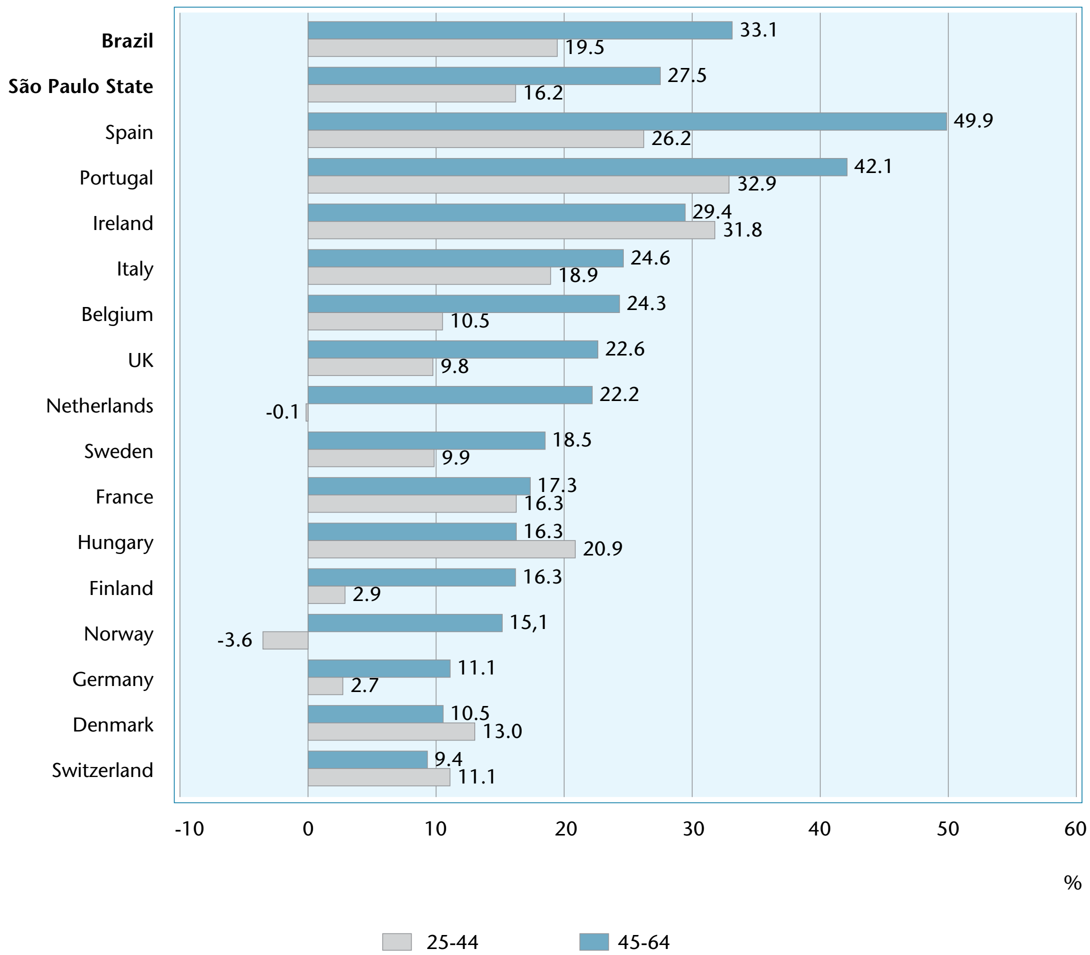
15. The situation is Germany is one of the most unfavorable, as described in detail by Wilén (2006).

Figure 3.8B
Breakdown of human resources in science and technology (HRST) by age group – Brazil, São Paulo State & selected European countries – 2006



Source: IBGE, PNAD (2002, 2006); Eurostat.

Figure 3.9B
Growth of human resources in science and technology (HRST) by age group – Brazil, São Paulo State & selected European countries – 2006/2002



Source: IBGE, PNAD (2002, 2006); Eurostat.

3.3 Closing remarks

IBGE's National Household Sample Survey (PNAD) is an excellent source of information on HRST, but it presents problems nonetheless. The main problem is the method used to collect data on educational attainment, which tends to underestimate the number of graduates from post-secondary non-tertiary education (ISCED 4) and short-cycle tertiary education (ISCED 5), known in Brazil as technical and technological education.[16] Although the number of these graduates is relatively small, it is highly likely to rise in response to the efforts to increase the supply of these types of education and the problem of underestimation will therefore tend to worsen.

The findings of this study show that while the stock of HRST in São Paulo is large in absolute terms, it is not large in relative terms (as a percentage of the workforce) when compared with other countries, even though it exceeds the national average for Brazil, which is 20%.

The study also shows that HRST in both Brazil and São Paulo significantly outnumber the contingent of university graduates, suggesting an educational deficit in the highly skilled workforce. At the same time, a large proportion of university graduates are employed in occupations that apparently require a lower skill level than that imparted by their formal education. This entails an apparent paradox: there is a shortage of qualified professionals, but simultaneously the number of university graduates is rising.

From a dynamic perspective it is clear that the growth of HRST is due more to growth in the number of university graduates than in the number of people in highly skilled occupations. Low economic dynamism with low creation of jobs in highly skilled occupations, especially in São Paulo, is a cause for concern and calls for more detailed research. Similarly, the profile of university graduates requires more thorough assessment than merely estimating numbers, as noted earlier.

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16. The International Standard Classification of Education (ISCED) is established by UNESCO and part of the methodology for measuring HRST recommended by the *Canberra Manual*.