Chapter 8

The regional dimension of ST&I 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

The regional dimension of science, technology and innovation (ST&I) is extremely important because the knowledge flows that feed business innovation are mediated to a significant extent by the proximity of firms, universities, other educational establishments, research institutions and service providers. This spatial proximity acts as a strong stimulus to the creation and diffusion of new knowledge and capacity building among economic agents.

The importance of the regional dimension is justified by the existence of a number of positive externalities or local benefits and scope advantages for the maintenance of interactions between economic agents located in regions where firms and ST&I institutions are geographically concentrated. Regionalized ST&I indicators therefore need to be produced and analyzed as part of an effort to understand in greater depth and quantify the relations between geography and innovation.

The main hypothesis to explain these relations is that important knowledge flows are mediated by the geographical space in which the agents in question operate. These knowledge flows may foster innovation processes in firms by supplying innovation inputs such as academic research, education, skilled labor, research centers, and laboratories that provide technical and technological services, all of which factor into the firms' own efforts to develop technology in house.

The debate about the influence of location on innovation in manufacturing began with the groundbreaking work of Marshall (1984), who showed the importance of positive externalities for English firms located in what he called "industrial districts" in the late 19th century. In the 1980s the concept of local product systems or clusters gained exposure and visibility because of some successful experiences such as the industrial districts in Italy and Silicon Valley in the United States, where clustering provided significant benefits to producers and their innovation efforts. In the case of Silicon Valley, development of the firms located there was boosted by a vast ST&I infrastructure, which was appropriated by producers and their routines with positive effects for local firms.[1] A basic assumption in this literature is that clustering facilitates access by producers to a number of benefits that enhance their competitiveness in the marketplace, including key innovation inputs such as skilled labor, the presence of specialized suppliers, and local knowledge spillovers due to geographical concentration of key economic agents, especially service providers, research institutions and universities.

Several studies have empirically proved the existence of a positive correlation between local knowledge flows and innovation processes in firms. Examples include Feldman (1999) and Audretsch & Feldman (2003), who used various databases (such as scientific publications, patents and citations) to measure the links between innovation inputs and innovation outcomes grounded in the concept of the knowledge production function. Others, including Dahl & Pedersen (2004), have set out to measure local knowledge spillovers through informal contact among workers. In the case of Brazil, chapter 9 of the 2004 edition of *Science, Technology & Innovation Indicators for São Paulo State* (FAPESP, 2005), which like the present chapter deals with the regional dimension of ST&I activities in the state, also identified a convergence between the regional production structure and the presence of ST&I institutions.

This has important implications for local policy in support of producers. Public policy, as well as local policy bodies, can enhance the capacity for interactive learning of a local nature among agents. This effect can be obtained by means of local policy measures designed to stimulate the accumulation of technical, technological, financial and market competencies, especially by intensifying interaction among local agents.

Within this context, the purpose of the present chapter is to analyze the regional dimension of ST&I indicators in São Paulo State and, as was done for the previous edition (FAPESP, 2005, chapter 9), establish the links between innovation inputs (skilled labor, the ST&I system, the education system and institutions that provide services to firms), innovation activities in firms and innovation outputs.

The methodological approach used to define the regional dimension consists of using the concept of geographical microregion wherever possible, as defined by the Brazilian Institute of Geography & Statistics (IBGE). In some cases where a breakdown to the microregion level is impossible, other levels of aggregation such as mesoregion are used instead.

A number of methodological difficulties must be mentioned before beginning the analysis proper. First, it is hard to aggregate some data at the microregional level, such as the number of indexed scientific articles

1. As a result of these important empirical experiences, several authors including Saxenian (1994), Schmitz (1997), Scott (1998, 2004), Belussi & Gotardi (2000) and Lombardi (2003), among others, began to focus more intensely on the study of local production systems and the benefits offered to producers by geographical clustering. In Brazil, local production systems are typically referred to as arranjos produtivos locais (APLs). See Cassiolato & Lastres (2001) and Suzigan *et al*. (2004).

and the supply of places in post-graduate courses. The difficulty with scientific articles is attributing them to a municipality or city, since the addresses recorded by publications are those of the author's domicile. For articles by more than one author, each of the cities involved is counted and hence the greater the disaggregation the greater the possibility of double counting and error. For post-graduate courses, although the databases specify the city, this is typically the location of educational institution's headquarters, so that places in post-graduate courses cannot always be accurately apportioned to microregions or even specific cities.

Another difficulty in connection with data relates to periodicity: it has not been possible to obtain all data from all databases for the same period. Most of the data refers to the period 2004-06, but data for the year 2008 is used when it has not been possible to obtain series covering previous years. Finally, comparisons are difficult owing to the absence of similar studies for other states or regions. Where they are possible (and relevant to the analysis), as in the case of manpower in ST&I activities, the option is to construct national indicators and compare these with São Paulo State's performance.

The results of the analysis of regionalized quantitative and qualitative ST&I indicators for São Paulo State show significant links between geography and innovation, given the strong geographical concentration of innovation inputs and outputs. These indicators are presented and discussed in the following sections. Section 2 addressed the quantitative indicators, while qualitative indicators are the focus for Section 3, followed by a cross-section of selected regions with outstanding indicators.

2. Regionalized quantitative indicators of ST&I activities

The discussion of regionalized ST&I indicators presented in this section highlights information on some of the elements that contribute to a characterization of the regions of São Paulo State from the standpoint of ST&I efforts and activities. A set of indicators has been produced on the basis of this information, including: (i) the profile and geographical distribution of skilled labor; (ii) innovative firms; (iii) patenting; (iv) scientific publications; and (v) indicators of university-business interaction. The first four sets of indicators (skilled labor, innovative firms, patenting and publications) largely follows the approach adopted in chapter 9 of the previous edition (FAPESP, 2005). University-business action is analyzed in a groundbreaking manner in this edition. It is worth noting that an attempt was made to analyze another important ST&I indicator, which is the funding of innovation activities by firms, but satisfactory regionalization of the data obtained proved impossible.

2.1 Profile and geographical distribution of skilled labor

Skilled labor is a key input for the business innovation process, since tacit knowledge is embodied in workers and their production routines. As a basis for understanding the distribution of skilled labor, the same methodology was used as in the previous edition (FAPESP, 2005, chapter 9).

The primary source of labor data for that edition was the Annual Employee Register (RAIS) produced by the Ministry of Labor & Employment (MTE). RAIS data was used to identify ST&I-related occupations based on the 1994 Brazilian Classification of Occupations (CBO 1994), divided into 353 base groups or occupational families, 62 of which were selected, and 2,353 occupations.

However, the CBO was revised in 2002 and a new version was published comprising 596 base groups or occupational families and 2,422 occupations (MTE, 2002; Detailed Tables 8.1 and 8.2). The new classification is linearly incompatible with the previous version, since CBO 2002 is not a mere expansion in the number of families and occupations but reflects structural and methodological changes leading to: greater specificity in the identification of the different categories; the disappearance of some occupations and families; elimination of the residual code (code 90), used to designate amorphous occupations not clearly delimited in the previous classification; the introduction of new occupational categories; and a new distribution of occupations into occupational families.[2] An analysis of the changes made to the classification of occupations shows a large number of occupations that were grouped together in the 1994 version, either with a distinct classification (e.g. architects and engineers) or allocated to code 90 ("workers not elsewhere classified"), and now specifically classified and defined in the current version. This is the main reason for the increase in the number of occupations selected for this edition.

Furthermore, given the need to include more information relating to education and training at the

2. Detailed Chart 8.3 shows the correspondences between CBO 1994 and CBO 2002.

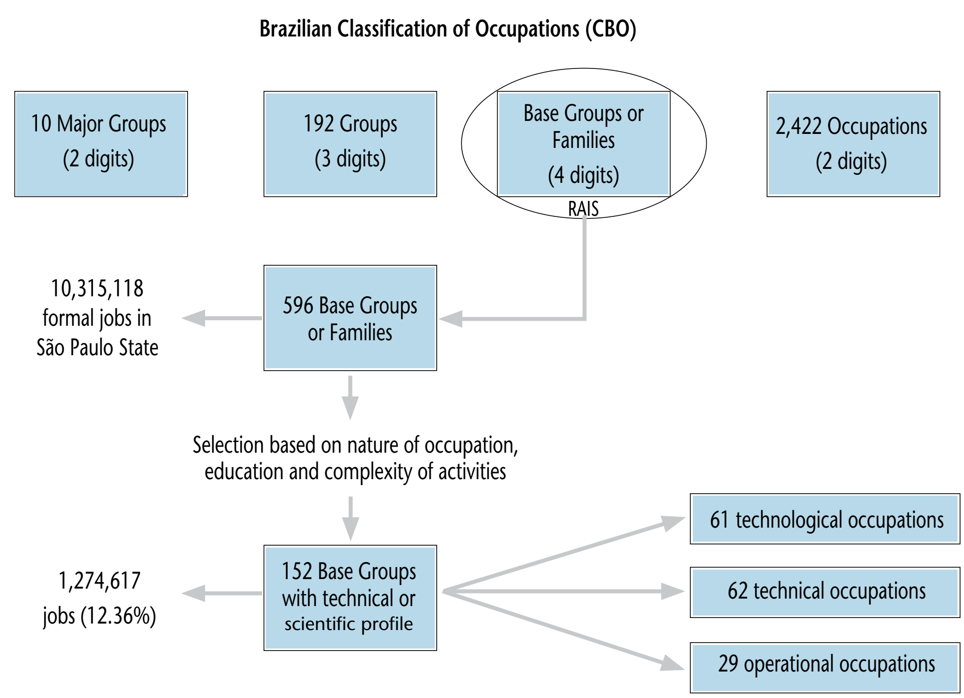
post-graduate level, since 2006 the RAIS has specified the number of employees with master's degrees and PhDs, and this information has been incorporated into the ST&I indicators discussed here.[3] Given the significant changes made to the CBO and RAIS, there is a clear discontinuity between the indicators for qualified human resources in innovation activities discussed in the 2004 edition (FAPESP, 2005, chapter 9) and in the present chapter, somewhat jeopardizing the comparability of the series but affording valuable analytical gains.

For the analysis presented below, 152 occupational families were selected from a total of 596 in CBO 2002 (Detailed Table 8.1) for having a technical or scientific profile and including workers involved in ST&I-related activities. These occupations are performed by workers whose specific tacit knowledge is relevant to the innovation process. As in the methodology used for the previous edition (FAPESP, 2005, chapter 9), the 152 selected occupations were regrouped into three categories according to the degree of complexity of the activities performed and the level of educational attainment ("competency level" in CBO 2002), resulting in:

- 61 "technological occupations" relating to highly complex research and management tasks and predominantly involving workers with a complete or incomplete tertiary education;
- 62 "technical occupations" relating to tasks of medium complexity and predominantly involving workers with a complete or incomplete secondary education; and
- 29 "operational occupations" relating to tasks of low complexity but requiring a high level of skill in operating and assembling machines and predominantly involving workers with a complete or incomplete primary education.

Chart 8.1 shows the sequence of steps in the process of selecting the occupations covered by the indica-

Chart 8.1
Steps in the process of selecting occupations in ST&I – São Paulo State



Source: Ministério do Trabalho e Emprego. RAIS 2006.

3. It is worth recalling that the lack of information on employees with post-graduate qualifications was noted as a gap in the 2004 edition (FAPESP, 2005). The revised CBO has filled the gap.

tors for human resources employed in ST&I activities in São Paulo State.

In 2006 the total number of formal employees in all economic activities in the state was 10,315,118. The number of employees working in ST&I activities was 1,274,617, or 12.4% of the total. Of these, 440,523 (34.6%) were employed in technological occupations, 491,215 (38.5%) in technical occupations, and 342,879 (26.9%) in operational occupations (Figure 8.1).

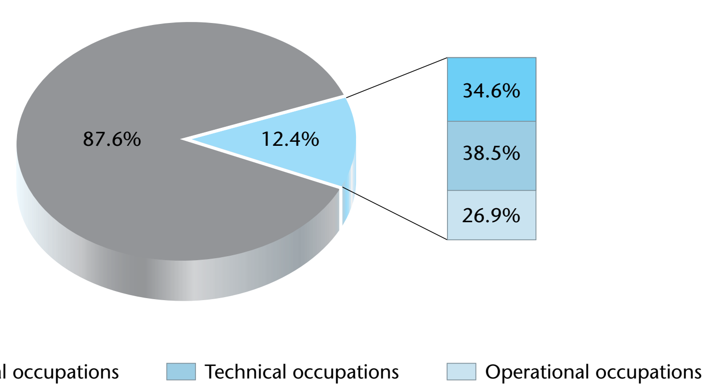
With regard to educational attainment (Figure 8.2), 91.2% of the workers employed in technological occupations had reached the tertiary level of the education system (holding a university degree, having taken but failed to complete an undergraduate degree course or holding a post-graduate qualification) and 78.5% of those employed in technical occupations had a secondary education (52.8%) or a tertiary education (25.9%). The workers employed in operational occupations displayed a higher-than-expected average level of educational attainment: only 37.9% had a primary education, which means that almost two-thirds had a higher level of schooling than required for the performance of routine tasks. This information suggests the existence of a recent phenomenon with regard to the employment of skilled labor in São Paulo State, inasmuch as the level of qualification required for these operational jobs has evidently risen. On the other hand, this may also be an indication that the workers in these jobs are overqualified owing to the conditions of supply and demand in the labor market, so that workers with tertiary-level qualifications assume technical and operational functions in firms.[4]

In the national context, the formally employed workforce in São Paulo State accounted in 2006 for 30.3% of the total workforce reported by the RAIS and for 30.6% of ST&I jobs nationwide. As can be seen from Figure 8.3, average educational attainment both for the workforce as a whole and for employees in ST&I activities in São Paulo State was also slightly higher than the national average.

A breakdown of employment by economic activity (Figure 8.4 and Detailed Chart 8.6) shows the largest proportions of technological jobs in São Paulo State in the following segments: corporate services, with 202,841 jobs (16%); commerce, vehicle repair, personal & domestic articles, lodging & catering, with 137,234 jobs (10.8%); social, collective, personal & domestic services, with 106,717 jobs (8.4%); chemicals & petrochemicals, with 90,925 jobs (7.2%); healthcare & veterinary services, with 90,840 jobs (7.2%); and communications, with 81,294 jobs (6.4%). The importance of corporate services derives largely from the outsourcing of several activities by industry as part of a restructuring of production that began in the mid-1990s in Brazil.

The regional dimension of human resources in ST&I was assessed on the basis of the spatial distribu-

Figure 8.1
Employment in ST&I occupations by occupational category – São Paulo State, 2006

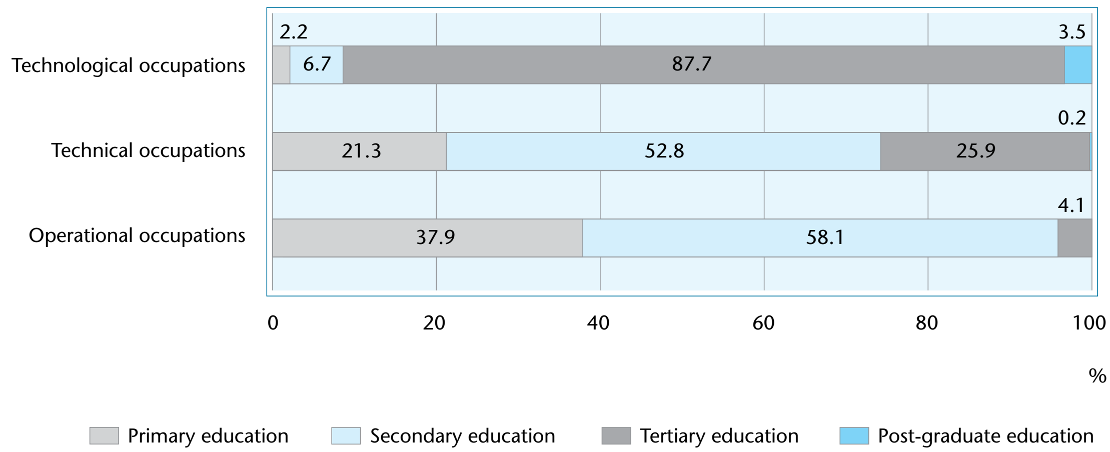


Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

Note: See Detailed Table 8.1.

4. Moreover, as discussed in chapter 2 of this publication, during their training many of these workers (even those with a tertiary education) have not acquired basic skills required in these jobs. Thus there are workers with a tertiary education but skills and functions compatible with those required for technical occupations.

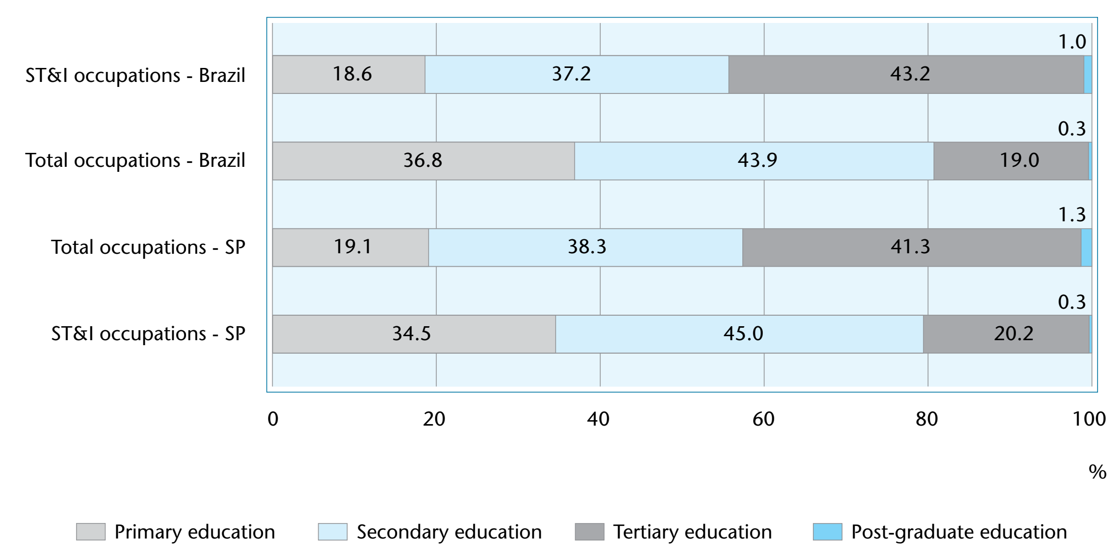
Figure 8.2
Employment in ST&I occupations by occupational category and educational attainment – São Paulo State, 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

Note: See Detailed Table 8.1.

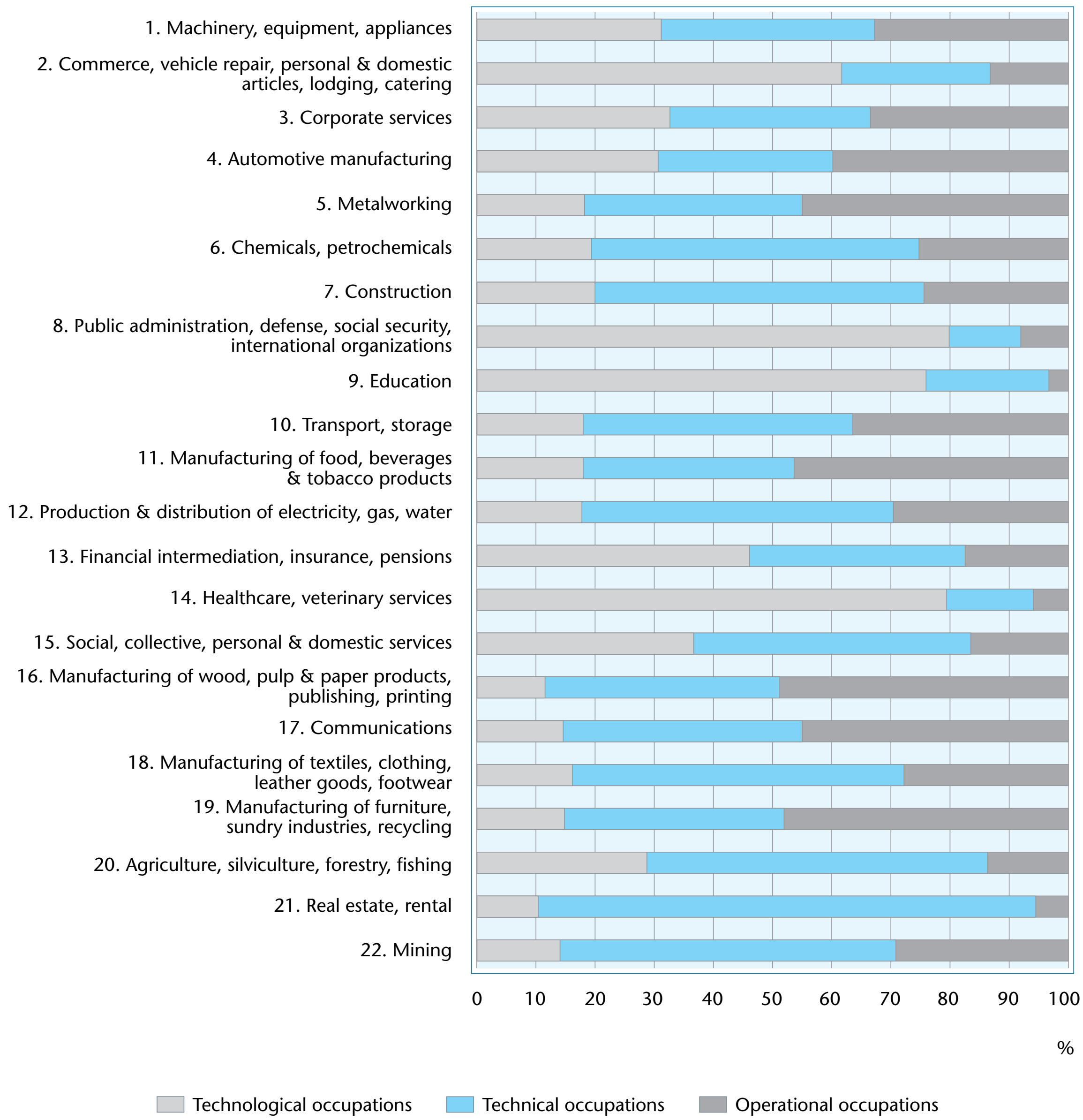
Figure 8.3
Employment by type of occupation and educational attainment – Brazil & São Paulo State, Paulo – 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

Note: See Detailed Table 8.2.

Figure 8.4
Employment in ST&I occupations by economic activity and occupational category – São Paulo State, 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

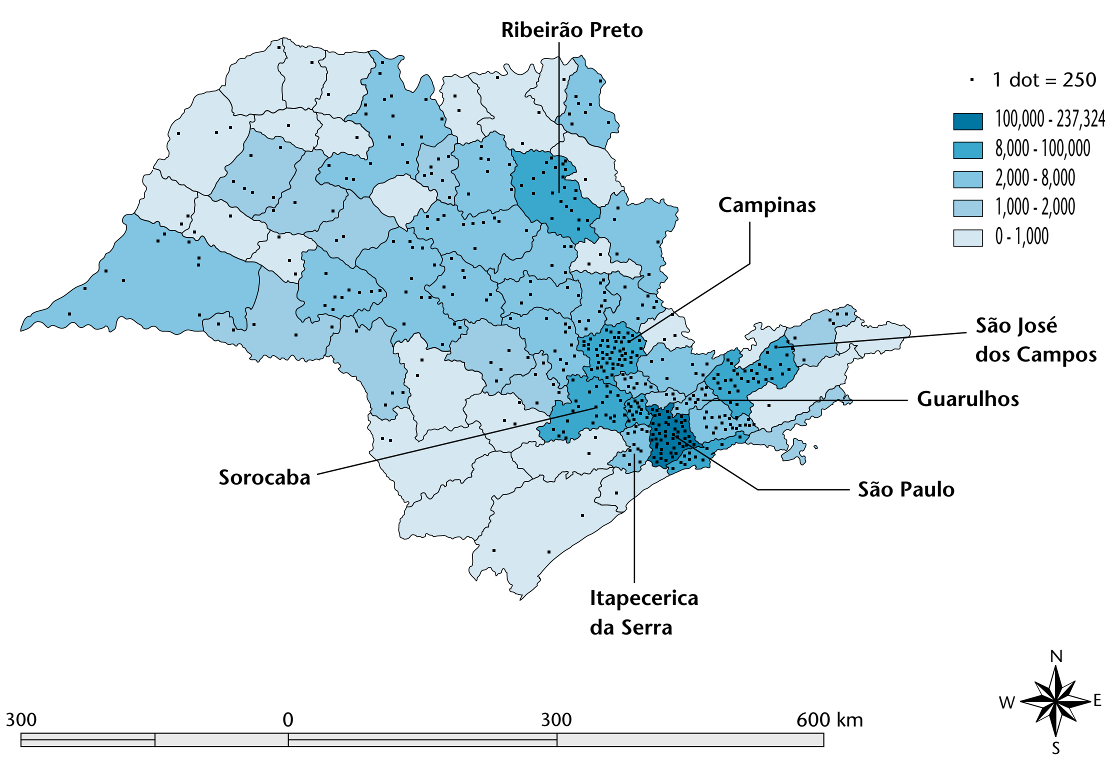
Note: See Detailed Table 8.3.

tion of workers in the 63 microregions of São Paulo State. The first point to be stressed in this analysis is the high level of regional concentration of employment in general, and of employment in ST&I activities in particular. Ten microregions (São Paulo, Campinas, Osasco, São José dos Campos, Sorocaba, Guarulhos, Santos, Ribeirão Preto, Mogi das Cruzes and Itapecerica da Serra) account for 72.2% of all jobs in the state, 80.7% of jobs in technological occupations, 74.8% in technical occupations and 73.7% in operational occupations (Detailed Table 8.2).

The São Paulo microregion alone has 44.1% of all jobs in the state and 44.7% of ST&I jobs, of which 38.8% in operational occupations, 40.7% in technical occupations and 53.9% in technological occupations. This results in greater density for this occupational category (52.2 out of every 1,000 jobs are in technological occupations in the São Paulo microregion) and determines the predominance of technological occupations (which account for 41.6% of all ST&I jobs in the microregion). As will be seen below in items 3.1 and 3.2, the predominance of technological occupations reflects the intense concentration of places in higher education and other institutions that support innovation activities.

The relatively large share of technological occupations in the São Paulo microregion as well as the metropolitan area (Map 8.1), as opposed to the relatively small share of operational occupations, reflects regional deconcentration by business organizations that have transferred production units away from São Paulo to other parts of the state or elsewhere, while research laboratories and general management structures remain concentrated in metropolitan São Paulo, typically in the city of São Paulo itself.[5]

Map 8.1
Density of employment in technological occupations by microregion – São Paulo State, 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

Notes: 1. Density corresponds to the number of jobs per occupation for every 1,000 jobs in all categories in a given microregion of the state.

2. The intervals refer to minimum and maximum values for each magnitude of employment density considered.

3. See Detailed Table 8.2

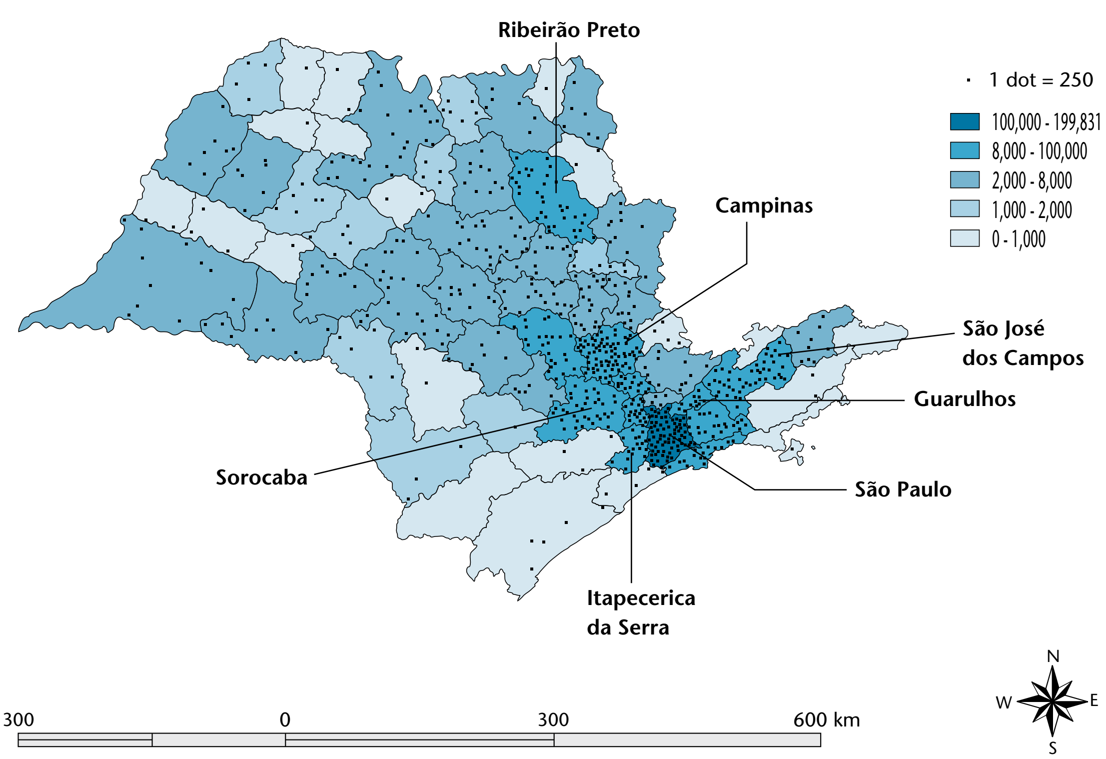
5. This argument converges with the approach taken by Diniz (1993), who argues that reversal of the concentration of economic and industrial activity in metropolitan São Paulo occurred via expansion of these activities in adjacent regions, forming what has been called the "polygon", which comprises much of Brazil's South and Southeast regions and includes the interior of São Paulo State.

Another important piece of evidence brought to light by the data is that metropolitan São Paulo, and more specifically the city of São Paulo, is home to a very large number of firms that provide high value added services, such as firms of consultants, auditors and IT services, among others. These firms employ a significant number of skilled workers, and their location is associated with the existence of a comparatively large and diversified infrastructure for ST&I, high-level training, and especially proximity to their customers, all of which reinforces the high density of technological occupations. As noted in Diniz & Diniz (2004), the restructuring of production led metropolitan São Paulo to assume new functions, such as acting as Brazil's main financial services and banking center, the command center for the national and much of the Latin American economy, and the hub for networking with the international community. Owing to these characteristics, metropolitan São Paulo became highly attractive for activities such as financial services and banking, and for sectors intensive in scientific and technological knowledge, such as IT, communications and microelectronics.

Other important microregions from the standpoint of employment density in technological occupations are São José dos Campos, with 51.3, Osasco, with 50.3, Campinas, with 43.6, and Marília, with 42.9 (Detailed Table 8.2). Like metropolitan São Paulo, albeit less intensely, these microregions display a coincidence between the large number of jobs in technological occupations and the presence of a large infrastructure for ST&I and training of highly qualified human resources.

Turning to technical occupations (Map 8.2), the statistics show a significant change in the profile of the main microregions. São José dos Campos is well in the lead in terms of technical employment, with a density of 73.9 jobs in technical occupations for every 1,000 jobs. Campinas and Sorocaba rank second, with 61.5, followed by Andradina, with 61, and Rio Claro, with 60.4. The São Paulo microregion ranks 26th, with a density of

Map 8.2
Density of employment in technical occupations by microregion – São Paulo State, 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

Notes: 1. Density corresponds to the number of jobs per occupation for every 1,000 jobs in all categories in a given microregion of the state.

2. The intervals refer to minimum and maximum values for each magnitude of employment density considered.

3. See Detailed Table 8.2.

43.9 (Detailed Table 8.2). As will be seen below in item 3.2, São José dos Campos's high density in technical employment is accompanied by a large supply of places in technical courses in the region. In addition, this indicator is convergent with the characteristics of the region's productive structure: many manufacturing firms are headquartered or have factories there, and thus use large numbers of technically qualified workers. The sectors represented in the microregion range from aircraft, automotive and auto parts manufacturing to chemicals, pharmaceuticals and personal hygiene products.

Moreover, the high density of technical employment in these regions is strongly convergent with the perception that manufacturing activities, which are the largest employers of technical labor, have continuously moved into the interior of São Paulo State.

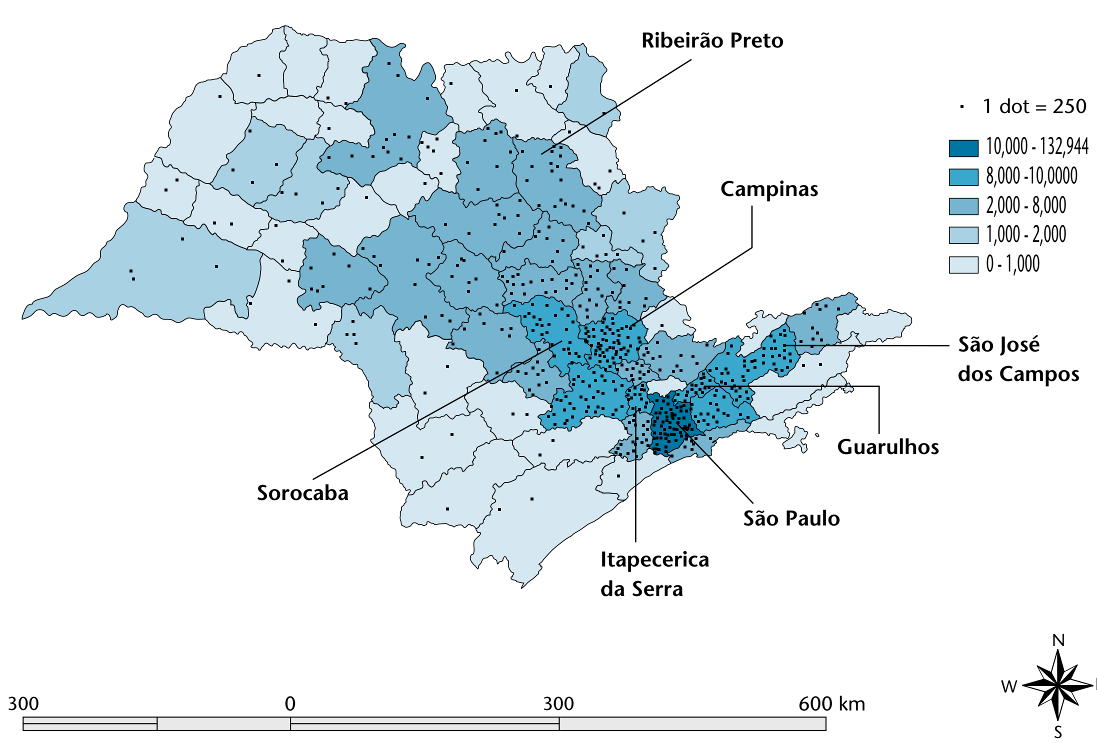
With regard to operational occupations (Map 8.3), regions in the interior of the state are even more important. In this case the leading microregions are Rio Claro (65.5), São José dos Campos (64.1), Guarulhos (59.8), Piracicaba (59.1) and Sorocaba (58.0). Again, São Paulo ranks 26th, with a density of 29.2 (Detailed Table 8.2).

Observed from the standpoint of economic activities, the spatial distribution of these jobs evidences the most relevant activities for the creation of jobs in general (Detailed Table 8.4) and in ST&I activities (Detailed Table 8.3) in each microregion, highlighting differences and similarities and enabling productive specializations to be identified.

The largest source of job creation in the state is "commerce, vehicle repair, personal & domestic articles, lodging & catering," accounting on average for 22.2% of the total number of jobs created in each microregion.

From the standpoint of technological employment, however, the sector "commerce, vehicle repair, personal & domestic articles, lodging & catering" is less significant, as expected, and the largest employer of this category in the state is "corporate services," which accounts on average for 13.4% of all jobs statewide (De-

Map 8.3
Density of employment in operational occupations by microregion – São Paulo State, 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

Notes: 1. Density corresponds to the number of jobs per occupation for every 1,000 jobs in all categories in a given microregion of the state.

2. The intervals refer to minimum and maximum values for each magnitude of employment density considered.

3. See Detailed Table 8.2.

tailed Table 8.4), 15.5% in the top ten microregions for ST&I jobs and 15.9% of ST&I jobs statewide (Detailed Table 8.3). In the São Paulo microregion, the sector accounts for 19.3% of technological jobs, which matches the perception that these activities are more intensive in technological competencies and more strongly concentrated in metropolitan São Paulo, or more specifically in the city of São Paulo.

In "machinery, equipment & appliances," the leading microregions are Rio Claro and São Carlos, where the sector accounts for 16.1% and 13% of total employment respectively (Detailed Table 8.4) and for 33.4% and 12.1% of technological jobs (Detailed Table 8.3). "Chemicals & petrochemicals" is the main source of technological jobs in these microregions: Pirassununga (25.8%), Santos (18.1%) and Guarulhos (16.4%).

2.2 Innovative firms

Qualified labor is a strategic input for firms in their innovation efforts and practices. The results of innovation efforts can be measured in terms of the innovation rate, calculated as the ratio of innovative firms to total firms in a given geographical space. This chapter uses data from PINTEC, IBGE's Survey of Technological Innovation in Industry, enabling regionalized innovation rates to be computed using special tabulations. The mesoregion was the parameter used in this case, since the PINTEC statistics do not permit very high levels of disaggregation.[6]

This indicator represents an innovation outcome variable, since it evidences the number of firms that introduced product and/or process innovations during the 2005 survey period. The innovation rate therefore differs from the labor qualification indicator, which measures an innovation input.[7]

An analysis of the regionalized PINTEC data for São Paulo State shows that the innovation rate for the state is 33.6%, slightly higher than the rate for Brazil, which is 33.4% (Detailed Table 8.5). The mesoregions with the highest innovation rates are Marília, with 62.5%, well above the average, Araraquara, with 39.3%, Campinas, with 39.1%, and Ribeirão Preto, with 34.7%.[8]

The São Paulo mesoregion, which approximates well to the metropolitan area, accounts for more than 50% of the innovative firms in São Paulo State and almost 20% of all such firms in Brazil, with an innovation rate of 33.1% (Figure 8.5).

A breakdown of product and process innovation rates shows the latter surpassing the former generally speaking in almost all regions of the state. Once again the leader is Marília, which has the highest product and process rates.

On the other hand, innovation rates are significantly higher in terms of products and processes new to the firm than new to the market (Detailed Table 8.5), reflecting the strongly imitative nature of firms' innovation strategies, which break relatively little new ground. Nevertheless, the incremental innovations concerned are important as an indication of competitiveness via absorption of new technical and technological developments into the products, and above all the processes, of these firms. Such innovation strategies may not enable firms to achieve significantly enhanced in-house capabilities, but at least they reflect the capacity to respond quickly to technical and technological advances occurring outside.

The same tendencies can be seen from an analysis by microregion, which also shows a significant difference between new-to-the-firm and new-to-the-market innovation rates (Detailed Table 8.5).

As for the origin of innovation efforts, the acquisition of machinery and equipment and training are the main sources of technological development both in São Paulo State and in Brazil overall (Detailed Table 8.6).

This same pattern in innovation efforts can be seen in terms of mesoregions: acquisition of machinery and equipment was the main innovation-related activity in all mesoregions except Assis and Presidente Prudente in the period 2003-05, followed by training (Detailed Table 8.6). This type of technological effort is passive and of limited extent. If the main innovation activities undertaken by firms are the acquisition of machinery and equipment and training, it is hardly surprising that their product innovation rates are low, since such efforts tend to lead to process improvements rather than the creation of new products or improvements to existing products.

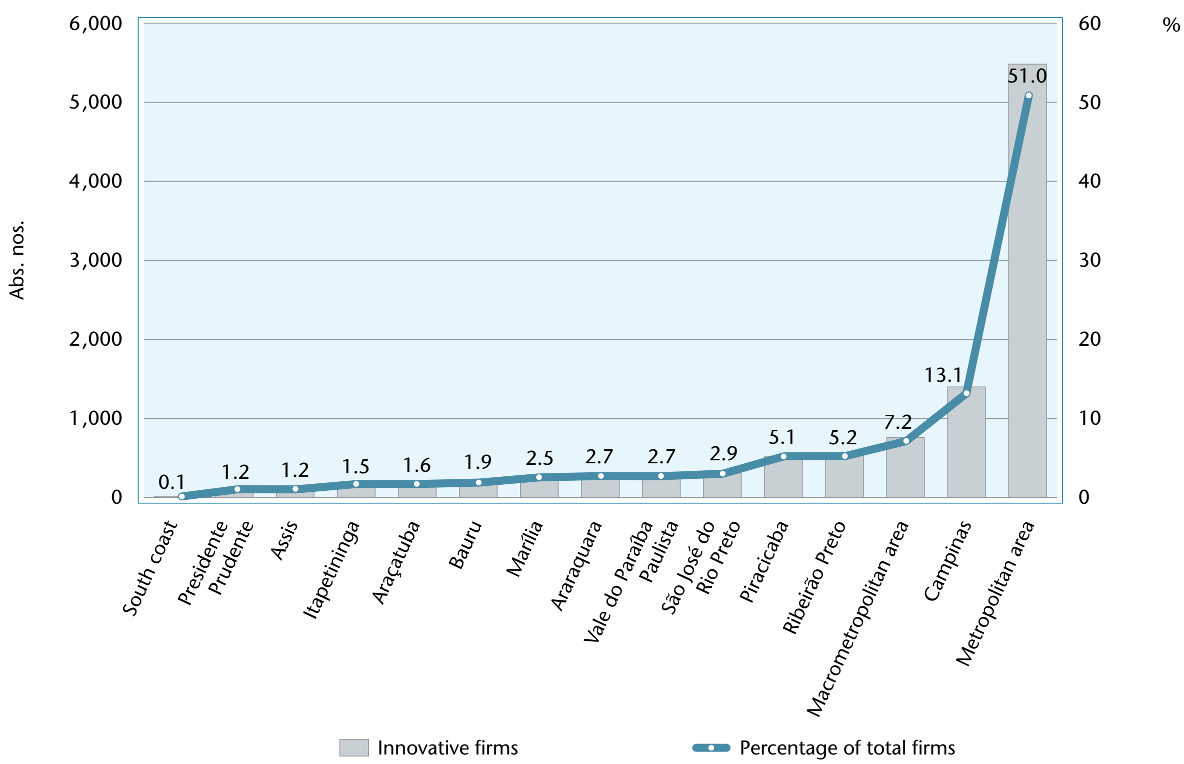
Intramural R&D is important for 23.5% of firms in São Paulo State and 16.6% of firms in Brazil. Several mesoregions of the state stand out for the importance attributed to intramural R&D, including Marília, with 43%, Presidente Prudente, with 39.5%, metropolitan São Pau-

6. Special tabulations calculated by IBGE's technical staff gave the authors access to some PINTEC data at the microregional level (Detailed Table 8.7).

7. In this sense it is possible to establish relations between innovation inputs and outcomes to compute the knowledge production function, as found in authors such as Audretsch & Feldman (2003).

8. The Marília mesoregion stands out not only for its high innovation rate, but also for the large number of patent applications filed, as discussed in the next section.

Figure 8.5
Firms introducing innovations by mesoregion of São Paulo State – 2003-2005



Source: IBGE, PINTEC 2005.

Note: See Detailed Table 8.5.

lo, with 27%, and Campinas, with 26.2% (Detailed Table 8.6). Besides Marília and Presidente Prudente, it is worth highlighting the importance of intramural R&D in the Campinas mesoregion, which is home to a large number of firms that invest significantly in R&D and benefit from the presence of leading education and research institutions, and in metropolitan São Paulo, justifying the assumption that this mesoregion, which comprises the city of São Paulo and the Greater ABC region, is home to the R&D units of many leading firms.

These findings corroborate Diniz & Diniz (2004), which notes that firms have kept important R&D activities in metropolitan São Paulo despite deconcentration of industrial employment in the region since the 1990s. Moreover, the same authors also note that the firms in question benefit from a swathe of modern services including business and IT consultants and other providers of corporate services.

Finally, a breakdown by microregion produces a similar picture. First, the acquisition of machinery and equipment is important to most firms (with only a few exceptions), followed by training. Second, intramural R&D is also important in some microregions, especially Marília, with 49.9%, Ribeirão Preto, with 45.8%, and microregions in the Campinas region and metropolitan São Paulo (Detailed Table 8.7).

2.3 Patenting

A patent application by an individual inventor or corporate assignee is designed to guarantee the benefits of intellectual property rights to an innovation via commercialization, either directly or embodied in a product or production process.

Patenting indicators are therefore a measure of firms' innovation outputs, although patents can also be awarded to individuals and institutions such as universities.[9] Patenting has some limitations as an indicator, and the analysis should take these into account. The main limitation derives from the fact that in several industries the appropriation of innovation outputs is often associated with other instruments, such as trade secrets and the ownership of commercial assets. Despite its limitations, however, patenting data can be useful to an analysis of technology production in São Paulo State.[10]

The analysis presented here is based on data from the National Industrial Property Institute (INPI), Brazil's patent office.[11] The INPI database contains information on applications for patents and utility models filed by individuals and legal entities domiciled in São Paulo State in the period 2002-05. Using the same analytical approach as the previous edition of this series (FAPESP, 2005, chapter 9), three sets of indicators were produced: (1) technological density in terms of the number of patents per 100,000 inhabitants; (2) regional technological specialization in terms of revealed technology advantage (RTA); and (3) patenting in technologies considered strategic.

Before presenting the analysis of these regionalized indicators, it should be borne in mind that in the case of multinationals or business groups the address registered in the INPI database for any given patent filing may not be the address of the unit that actually developed the innovation, but may be that of the head office, for example. In other words, a patent filing may be associated with a certain location whereas the innovation efforts concerned were performed in a different region, and this may have led to distortions in the indicators.[12]

The INPI statistics are very useful despite these possible distortions. They show that there was an overall increase in patenting activity in São Paulo State in the period. The number of filings totalled 12,663 in 2002-05, up from 10,069 in 1998-2001 (Detailed Table 8.8). The regions with the largest numbers of filings in 2002-05 were the city of São Paulo, with 5,280 patent applications, and Campinas, with 1,054, followed by three regions that are part of metropolitan São Paulo: ABCD Paulista (with 828 patent filings), Osasco (with 481) and Guarulhos (with 282).[13] These numbers show that technological production was concentrated along the São Paulo-Campinas axis, which can be explained by the density of firms and their technology development units in that region (Suzigan, Cerron & Diegues, 2005).

For a more precise understanding of regional differences in patenting, it is necessary to take into account the size of each microregion. An indicator of patenting density was therefore calculated to reflect the geographical distribution of patent filings per 100,000 inhabitants. According to this indicator, the city of São Paulo had the largest number of filings per 100,000 inhabitants, with 48, followed by the Campinas microregion and ABCD Paulista, both with 42 (Detailed Table 8.9). The Campinas microregion displayed significant growth between the two periods: patenting density rose from 32.2 in 1998-2001 to 42.5 in 2002-05. This largely reflected patenting activity by universities (Box 1). In the case of Campinas, the indicator was strongly influenced by the State University of Campinas (Unicamp), which accounted for over 20% of the patent applications filed for the microregion in 2002-05.

It is necessary to mention at least two other microregions that are not among the top ten in the state in terms of patenting but nevertheless display densities of more than 40 filings per 100,000 inhabitants. One is Marília, with a total of 189 filings in the period 2002-05 and a density of 56.6. In this microregion, the technological activities of Jacto S.A., an important manufacturer of farm machinery and implements, with 45 patent filings in the period, influenced the regional indicator to a significant extent.[14] The other is São Carlos, with 156 filings in the same period and a density of 51.7. This intense patent-

9. Several academic studies have used patenting as an innovation output indicator. One of the most important is by Jaffe (1989), who developed the knowledge production function based on the classical production function proposed by Griliches (1979). This method enabled Jaffe (1989) to correlate innovation inputs such as public and private spending on R&D with innovation results such as patents for different geographical units of the U.S. For a more detailed discussion of this point, see Araújo (2007).

10. It is important to stress that patenting is only one way to guarantee appropriation of the benefits of innovation, since innovation often derives from efforts to create new products as well as new manufacturing and marketing processes.

11. The data analyzed in this section constitutes a special regionalized extraction from the database used in chapter 5 of this publication.

12. The same goes for international patenting statistics. Innovation efforts are increasingly performed by decentralized R&D units of large corporations, which typically file for patents deriving from such efforts under the address of the parent company's headquarters.

13. The database contained 12,663 patent filings, of which 747 (5.9%) did not identify the applicant's city of origin.

14. As noted in the previous edition (FAPESP, 2005, chapter 9), it must be stressed that because relatively small numbers of patent filings are covered by this sample, especially at the level of microregions, the patenting activities of certain firms have a significant effect on the regionalized indicators. This is the case, for example, for the Marília microregion, where the state's fifth-largest patentee, Máquinas Agrícolas Jacto S.A., is located.

Box 1 – Patenting by universities

Patenting by Brazilian universities has increased in recent years, in line with a tendency also observed in other countries. In the United States, for example, the *Bay-Dohle Act* was passed in 1980 to foster patenting by universities, small business enterprises and nonprofits, and to encourage the transfer of technology from universities to firms.

The Bay-Dohle Act has aroused considerable controversy in the U.S. On one hand, authors such as Etzkowitz & Leydesdorff (1997) argue that this instrument for transferring technology from universities to firms fosters patenting and acts as a stimulus to the diffusion of knowledge from academic researchers to business, as well as representing an additional source of revenue for universities via the licensing of the technologies they create. On the other hand, authors such as Nelson (2006) and David (2004) argue that this instrument has directed university research towards the search for solutions to corporate problems, weakening its disruptive nature and undermining the open science principle that traditionally governs academic activity.

Taking the U.S. regulatory framework as a model, several Brazilian universities have begun patenting or encouraging their researchers to patent their inventions, often using their own technology transfer offices (TTOs) for this purpose. Some have even established patenting targets. As a result, patenting by some Brazilian universities has increased significantly. The leader in this respect is Unicamp, which has become the largest single patentee in Brazil. Unicamp's patent filings with INPI rose from 103 in the period 1998-2001 to 217 in 2002-05, making it the largest Brazilian patentee in the period, with significant repercussions for the regionalized patenting indicator for the Campinas region.

Two reservations are pertinent here. First, the basic motivation for patenting is different for universities and firms. Firms use patenting to protect and commercialize profitable innovations, whereas the goals of patenting for universities are much more flexible. Second, a substantial proportion of university patenting does not relate to commercial applications. Hence the need to track the numbers of these patents that are licensed and the rationale for defining licensing as a more accurate indicator of the success of this policy orientation.

ing activity is associated with the vast ST&I infrastructure in the region, which has two universities of national importance as well as research institutions and firms with intense technological activities or operations in sectors highly intensive in scientific and technological knowledge, such as optics, photonics and new materials.[15]

Next come São Paulo and Campinas, with patenting densities of 48 and 42.5 respectively. Two other microregions that stand out are Limeira, with 37.7, and Jundiaí, with 36.2.

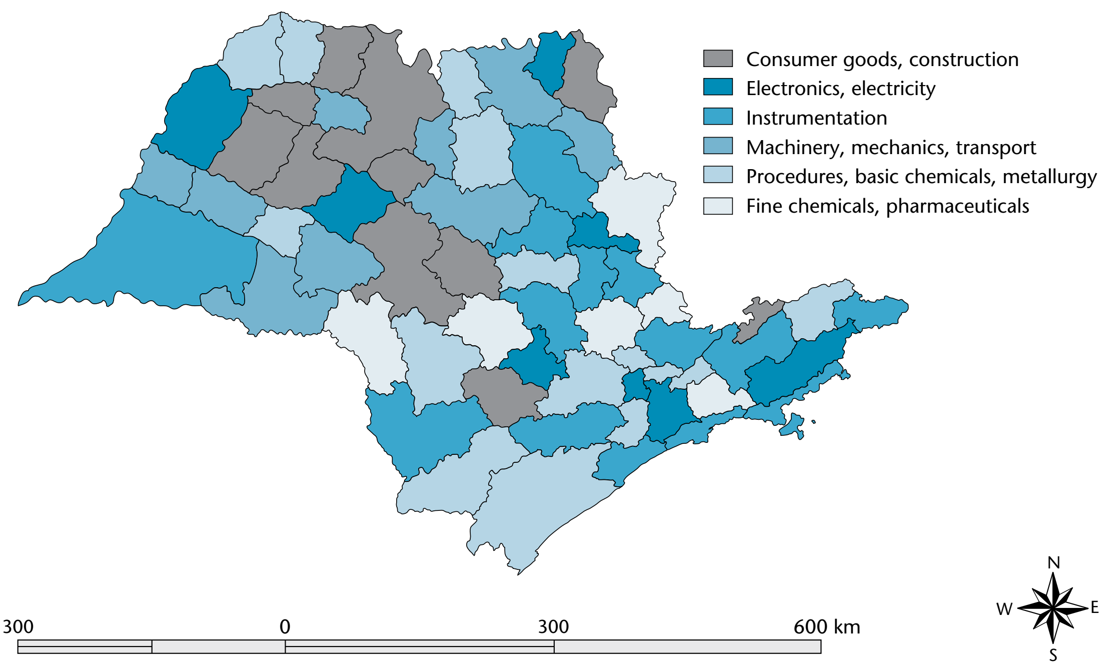
The information furnished by patenting density indicators is complemented in what follows by an analysis of technological specialization, identifying the technological domains in which patenting activity is most intense.[16] The technological specialization index is calculated as the ratio of two percentages: the first is the number of patent filings in a given microregion for a technological domain divided by the total for the domain in question; the second is the number of patent filings for the microregion divided by total patent filings. A specialization index greater than 1 indicates above-average technological activity in the domain in question.

The technological specialization profile of São Paulo State resulting from the calculation of these indices for each of its microregions is presented in Map 8.4 and Table 8.1. Table 8.2 presents specialization indices for the 14 leading microregions by number of patent filings.

15. The characteristics of the local ST&I system in selected regions and their linkages with the production structure are discussed below in Section 4.

16. The International Patent Classification (IPC) system, administered by the World Intellectual Property Organization (WIPO), is divided into eight sections relating to general technological areas, subdivided into hundreds of classes and subclasses. Patents are given one or more IPC codes to classify and index their content by area of technology. The specialization indices discussed here were constructed using only the first or "original" classification to allocate each patent to a key technological domain. Technological domains are groupings of the hundreds of patent subclasses in accordance with the methodology elaborated by Observatoire des Sciences et des Techniques (OST, 1996).

Map 8.4
Microregional technological specialization indices (1) by technological domain – São Paulo State, 2002-2005



Source: INPI (special extraction 2008).

Notes: 1. The International Patent Classification (IPC) system, administered by the World Intellectual Property Organization (WIPO), is divided into eight sections relating to general technological areas, subdivided into hundreds of classes and subclasses. Patents are given one or more IPC codes to classify and index their content by area of technology. The specialization indices discussed here were constructed using only the first or “original” classification to allocate each patent to a key technological domain. Technological domains are groupings of the hundreds of patent subclasses in accordance with the methodology elaborated by Observatoire des Sciences et des Techniques (OST, 1996). See Detailed Chart 8.5.

2. Because relatively small numbers of patent filings are covered by this sample, especially at the level of microregions, the patenting activities of certain firms have a significant effect on the regionalized indicators.

3. See Detailed Table 8.10.

(1) The technological specialization index is calculated as the ratio of two percentages: the first is the number of patent filings in a given microregion for a technological domain divided by the total for the domain in question; the second is the number of patent filings for the microregion divided by total patent filings. A specialization index greater than one (1.000) indicates above-average technological activity in the domain in question.

Table 8.1
Patent filings for selected microregions by technological domain – São Paulo State, 2002-2005

Microregion	Patent filings by technological domain							
	Total	Consumer goods, construction	Electronics, electricity	Instrumentation	Machinery, mechanics, transport	Procedures, basic chemicals, metallurgy	Fine chemicals, pharmaceuticals	Not classified
Total (A+B+C)	**12,663**	**3,661**	**1,142**	**1,481**	**3,056**	**2,859**	**413**	**51**
São Paulo (1)	5,280	1,637	591	658	1,067	1,140	172	15
Campinas	1,054	199	92	170	224	312	50	7
Região ABCD de São Paulo (1)	828	217	56	60	266	202	21	6
Osasco	481	154	49	56	91	116	14	1
Guarulhos	282	87	14	21	69	80	9	2
Sorocaba	254	74	21	29	63	59	8	
São José dos Campos	252	67	29	41	67	37	8	3
Itapecerica da Serra	245	75	25	20	51	65	8	1
Ribeirão Preto	226	39	12	42	78	45	7	3
Jundiaí	213	58	12	22	50	65	5	1
Limeira	213	35	5	20	96	49	8	
São José do Rio Preto	194	72	13	23	48	31	7	0
Marília	189	46	10	10	68	52	2	1
Santos	160	55	8	21	46	24	6	0
São Carlos	156	20	8	33	46	42	6	1
Subtotal (A)	10,027	2,835	945	1,226	2,330	2,319	331	41
Other (B)	1,889	579	139	162	552	395	55	7
City not identified (C)	747	247	58	93	174	145	27	3

Source: INPI (special extraction 2008).

Notes: 1. The International Patent Classification (IPC) system, administered by the World Intellectual Property Organization (WIPO), is divided into eight sections relating to general technological areas, subdivided into hundreds of classes and subclasses. Patents are given one or more IPC codes to classify and index their content by area of technology. The specialization indices discussed here were constructed using only the first or "original" classification to allocate each patent to a key technological domain. Technological domains are groupings of the hundreds of patent subclasses in accordance with the methodology elaborated by Observatoire des Sciences et des Techniques (OST, 1996). See Detailed Chart 8.5.

2. The 14 microregions in the table accounted for 10,027 out of 12,663 patent filings (79.2%) for São Paulo State in the period 2002-05.

3. See Detailed Table 8.10.

(1) São Paulo microregion = São Paulo City, ABCD Paulista (Santo André, São Bernardo do Campo, São Caetano do Sul, Diadema), Mauá, Ribeirão Pires, Rio Grande da Serra.

Table 8.2
Technological specialization indices (1) for selected microregions by technological domain – São Paulo State, 2002-2005

Microregion	Technological specialization index (1) by technological domain - SP					
	Consumer goods, construction	Electronics, electricity	Instrumentation	Machinery, mechanics, transport	Procedures, basic chemicals, metallurgy	Fine chemicals, pharmaceuticals
São Paulo (2)	1.072	1.241	1.066	0.837	0.956	0.999
Campinas	0.653	0.968	1.379	0.881	1.311	1.455
Região ABCD de São Paulo (2)	0.906	0.750	0.620	1.331	1.081	0.778
Osasco	1.107	1.130	0.995	0.784	1.068	0.892
Guarulhos	1.067	0.550	0.637	1.014	1.257	0.979
Sorocaba	1.008	0.917	0.976	1.028	1.029	0.966
São José dos Campos	0.920	1.276	1.391	1.102	0.650	0.973
Itapecerica da Serra	1.059	1.131	0.698	0.863	1.175	1.001
Ribeirão Preto	0.597	0.589	1.589	1.430	0.882	0.950
Jundiaí	0.942	0.625	0.883	0.973	1.352	0.720
Limeira	0.568	0.260	0.803	1.868	1.019	1.152
São José do Rio Preto	1.284	0.743	1.014	1.025	0.708	1.106
Marília	0.842	0.587	0.452	1.491	1.219	0.324
Santos	1.189	0.554	1.122	1.191	0.664	1.150
São Carlos	0.443	0.569	1.809	1.222	1.192	1.179

Source: INPI (special extraction 2008).

Notes: 1. The International Patent Classification (IPC) system, administered by the World Intellectual Property Organization (WIPO), is divided into eight sections relating to general technological areas, subdivided into hundreds of classes and subclasses. Patents are given one or more IPC codes to classify and index their content by area of technology. The specialization indices discussed here were constructed using only the first or "original" classification to allocate each patent to a key technological domain. Technological domains are groupings of the hundreds of patent subclasses in accordance with the methodology elaborated by Observatoire des Sciences et des Techniques (OST, 1996). See Detailed Chart 8.5

2. The 14 microregions in the table accounted for 10,027 out of 12,663 patent filings (79.2%) for São Paulo State in the period 2002-05.

3. Because relatively small numbers of patent filings are covered by this sample, especially at the level of microregions, the patenting activities of certain firms have a significant effect on the regionalized indicators.

4. See Detailed Table 8.10.

(1) The technological specialization index is calculated as the ratio of two percentages: the first is the number of patent filings in a given microregion for a technological domain divided by the total for the domain in question; the second is the number of patent filings for the microregion divided by total patent filings. A specialization index greater than one (1.000) indicates above-average technological activity in the domain in question.

(2) São Paulo microregion = São Paulo City, ABCD Paulista (Santo André, São Bernardo do Campo, São Caetano do Sul, Diadema), Mauá, Ribeirão Pires, Rio Grande da Serra.

In the city of São Paulo, the domain with the largest number of patent filings is consumer goods and construction, with 1,637, followed by procedures, basic chemicals and metallurgy, with 1,140, and machinery, mechanics and transport, with 1,067. In Campinas, procedures, basic chemicals and metallurgy account for about a third (312).

An analysis of the technological specialization indices, however, shows that some technological domains stand out. In the city of São Paulo, the indices are about 1 in all technological domains because of the relatively large number of patent filings and diversity of local technological activities, but even so it is possible to identify some areas of specialization. The technological domain with the highest specialization index in the city is electronics and electricity, with 1.241, followed by consumer goods and construction, with 1.072, and instrumentation, with 1.066 (Detailed Table 8.10). In Campinas, the technological domains with the highest specialization indices are fine chemicals and pharmaceuticals, with 1.455, instrumentation, with 1.379, and procedures, basic chemicals and metallurgy, with 1.311, all of which have close links to the technological activities conducted by both local firms and universities.

Some technological domains also stand out in other microregions. In ABCD Paulista, the highest specialization index is in machinery, mechanics and transport (1.331), closely associated with local activities in metalworking and automotive manufacturing. In São José dos Campos, specialization indices are high in instrumentation (1.391) and in electronics and electricity (1.276). In Ribeirão Preto and São Carlos, instrumentation also stands out (with 1.589 and 1.809 respectively). In Limeira and Marília, the leader is machinery, mechanics and transport (1.868 and 1.491).[17]

It is relevant to analyze patenting activities in selected technological areas because of their role in creating and especially diffusing new knowledge to the production system in general, as for example in IT, pharmaceuticals, cosmetics and machine-tools.[18] Moreover, patenting in these areas is an important form of protection for innovation outcomes, as evidenced by the relatively high numbers of patent filings. Maps 8.5, 8.6 and 8.7 show the microregions of São Paulo State with specialization indices of more than 1 for the selected technological subdomains and the numbers of patent filings in these subdomains per microregion.

Four microregions lead in the IT subdomain: São Paulo, Campinas, Osasco and Sorocaba account in aggregate for over 77% of total patent filings in this subdomain, with 125 out of 162 filings (Map 8.5). The city of São Paulo stands out both for the absolute number of patent filings and the specialization index, accounting for almost 50% of filings in this subdomain, with 78 out of 162 between 2002 and 2005, and a specialization index of more than 1. Similar results were found for patenting in the IT subdomain in the previous edition, with Sorocaba, Campinas and Osasco leading among the most specialized microregions in terms of patent filings. The São Paulo microregion, however, had a specialization index of less than 1. Maintenance of this level of technological specialization, albeit influenced in some regions by fairly low absolute numbers, was expected because structural changes in the production system and the local ST&I system do not occur in such short intervals of time.

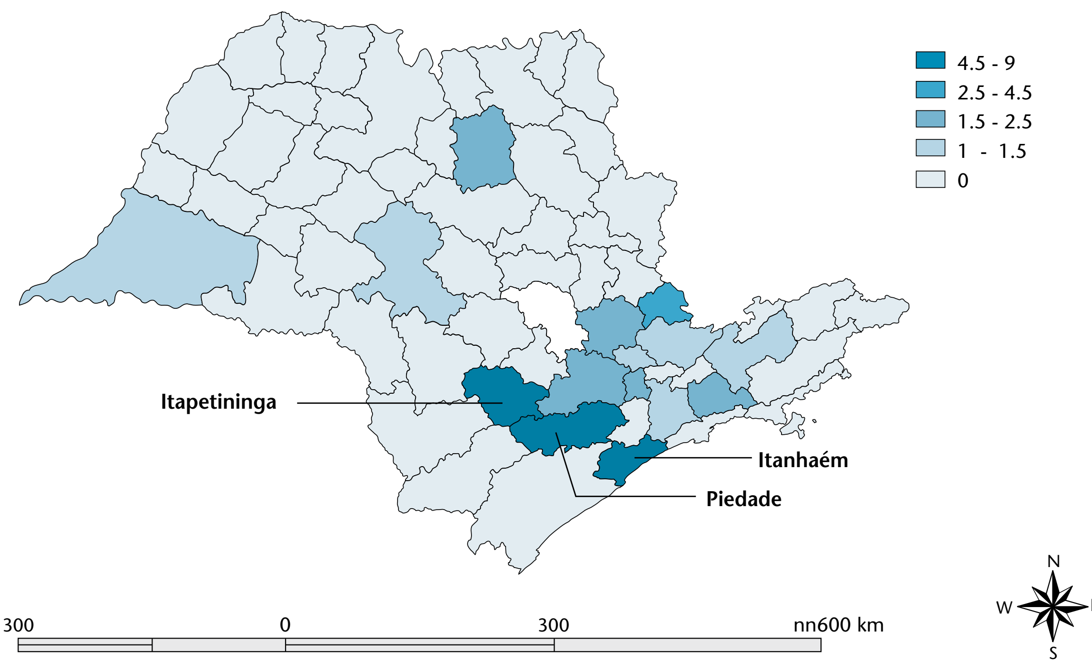
In patenting of pharmaceuticals and cosmetics, the leading microregions are Campinas, Itapecerica da Serra, Ribeirão Preto and Mogi Mirim. The São Paulo microregion also displays a high level of patenting activity in this technological subdomain, with the largest number of filings (145 out of 341, or more than 42%), but the specialization index (0.87) is below the average for the state because of the diversity of patenting in the metropolitan area (Map 8.6). In the city of São Paulo alone, 134 patent applications were filed, or almost 40% of the total for the state in this subdomain, corresponding to a specialization index of slightly less than 1. In contrast with the result found for the previous edition (FAPESP, 2005, chapter 9), Osasco and Presidente Prudente did not display an above-average specialization index in the period 2002-05 (0.77 and 0.52 respectively) owing to the small number of patent filings in this subdomain for these microregions.

In the machine-tools subdomain, as in the case of pharmaceuticals and cosmetics, patenting activity is most intense in the São Paulo microregion, with 96 filings out of a total of 240, or 40% (Map 8.7). The number of filings for the city of São Paulo alone is 72, or 30% of

17. Because the number of patent filings in any microregion is relatively small, more intense technological activities by certain firms have a significant effect on the regionalized indicators.

18. These areas were also selected in accordance with the methodology used in the 2004 edition's chapter on "The regional dimension of ST&I efforts" (FAPESP, 2005, chapter 9). Technological subdomains were selected in this analysis instead of technological domains (higher aggregation level). Thie preference for subdomains in this part of the chapter was associated with the intention of producing a more specific analysis for a given technology. The list of technological domains and their respective subdomains is presented in Detailed Chart 8.5.

Map 8.5
Microregional technological specialization indices (1) in the IT subdomain – São Paulo State, 2002-2005



Source: INPI (special extraction 2008).

Notes: 1. The International Patent Classification (IPC) system, administered by the World Intellectual Property Organization (WIPO), is divided into eight sections relating to general technological areas, subdivided into hundreds of classes and subclasses. Patents are given one or more IPC codes to classify and index their content by area of technology. The specialization indices discussed here were constructed using only the first or "original" classification to allocate each patent to a key technological domain. Technological domains are groupings of the hundreds of patent subclasses in accordance with the methodology elaborated by Observatoire des Sciences et des Techniques (OST, 1996). See Detailed Chart 8.5.

2. Because relatively small numbers of patent filings are covered by this sample, especially at the level of microregions, the patenting activities of certain firms have a significant effect on the regionalized indicators.

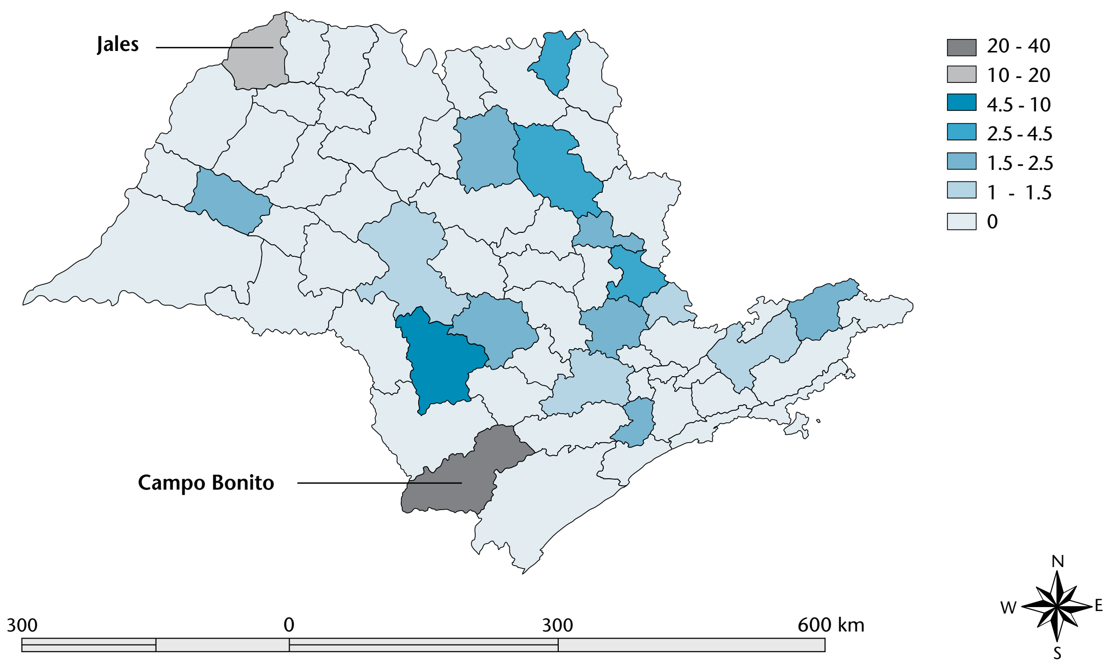
3. See Detailed Table 8.11.

(1) The technological specialization index is calculated as the ratio of two percentages: the first is the number of patent filings in a given microregion for a technological domain divided by the total for the domain in question; the second is the number of patent filings for the microregion divided by total patent filings. A specialization index greater than one (1.000) indicates above-average technological activity in the domain in question.

the total, for a specialization index of 0.72. Other leading microregions include Campinas, Osasco, Limeira and Guarulhos, which in aggregate account for 22.5% of total patent filings in this subdomain (54 out of 240). The machine industry corresponds to a significant share of the industrial structure in these microregions.

An analysis of all three selected subdomains (IT, pharmaceuticals and cosmetics, and machine-tools) points to a number of important trends. The first is the importance of patenting activity in the city of São Paulo, the leader in numbers of patent filings and percentage share of the total, even though its specialization indices are not outstanding. Second, Campinas has a major share of these technological subdomains as well as high specialization indices, permitting the inference that local patenting activity is closely associated with the selected technological subdomains. Third, patenting in the region around the city of São Paulo, especially the microregions that are part of the metropolitan area, appears to be associated with the occurrence of local knowledge spillovers created by the city's role as a dynamic hub. Fourth and last, patenting activity is significant in some microregions that are home to important university campuses, such as Ribeirão Preto and Campinas, suggesting a link between scientific and patenting activities.

Map 8.6
Microregional technological specialization indices (1) in the pharmaceuticals-cosmetics subdomain – São Paulo State, 2002-2005



Source: INPI (special extraction 2008).

Notes: 1. The International Patent Classification (IPC) system, administered by the World Intellectual Property Organization (WIPO), is divided into eight sections relating to general technological areas, subdivided into hundreds of classes and subclasses. Patents are given one or more IPC codes to classify and index their content by area of technology. The specialisation indices discussed here were constructed using only the first or "original" classification to allocate each patent to a key technological domain. Technological domains are groupings of the hundreds of patent subclasses in accordance with the methodology elaborated by Observatoire des Sciences et des Techniques (OST, 1996). See Detailed Chart 8.5.

2. Because relatively small numbers of patent filings are covered by this sample, especially at the level of microregions, the patenting activities of certain firms have a significant effect on the regionalised indicators.

3. See Detailed Table 8.12.

(1) The technological specialization index is calculated as the ratio of two percentages: the first is the number of patent filings in a given microregion for a technological domain divided by the total for the domain in question; the second is the number of patent filings for the microregion divided by total patent filings. A specialization index greater than one (1.000) indicates above-average technological activity in the domain in question.

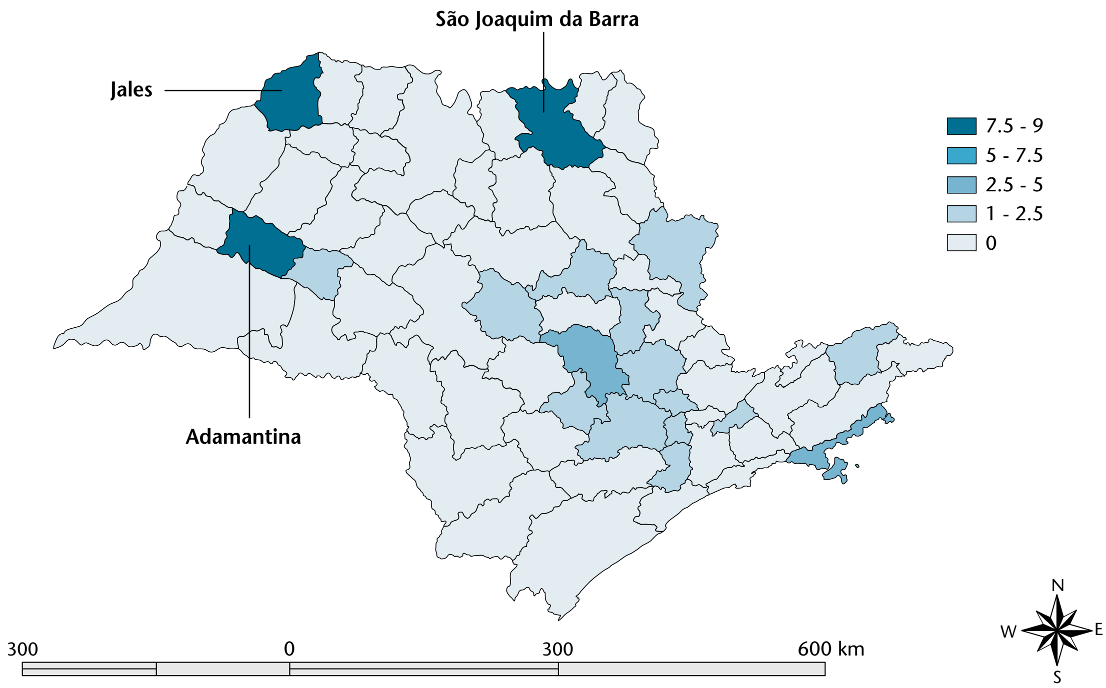
2.4 Scientific articles

Scientific articles are the main form of dissemination of new scientific knowledge, in the Brazilian case produced above all in universities. They are a source of new knowledge that business organizations can use to develop their innovation activities.[19] This section discusses data for scientific articles published in journals indexed by internationally recognized bibliographical databases. The findings are grouped by microregion of São Paulo State to provide an overview of the regional distribution of scientific production in the state.

The scientific production indicators presented in this chapter are the numbers of articles indexed by the *Science Citation Index Expanded* (SCIE) and *Social Sciences Citation Index* (SSCI) databases, collected via *Web of Sci-*

19. Several authors, such as Audretsch & Feldman (2003), use scientific publications and citations of scientific articles in patents, for example, to measure the effects of knowledge spillovers from universities to firms.

Map 8.7
Microregional technological specialization indices (1) in the machine-tools subdomain – São Paulo State, 2002-2005



Source: INPI (special extraction 2008).

Notes: 1.The International Patent Classification (IPC) system, administered by the World Intellectual Property Organization (WIPO), is divided into eight sections relating to general technological areas, subdivided into hundreds of classes and subclasses. Patents are given one or more IPC codes to classify and index their content by area of technology. The specialisation indices discussed here were constructed using only the first or "original" classification to allocate each patent to a key technological domain. Technological domains are groupings of the hundreds of patent subclasses in accordance with the methodology elaborated by Observatoire des Sciences et des Techniques (OST, 1996). See Detailed Chart 8.5.

2. Because relatively small numbers of patent filings are covered by this sample, especially at the level of microregions, the patenting activities of certain firms have a significant effect on the regionalised indicators.

3. See Detailed Table 8.13.

(1) The technological specialisation index is calculated as the ratio of two percentages: the first is the number of patent filings in a given microregion for a technological domain divided by the total for the domain in question; the second is the number of patent filings for the microregion divided by total patent filings. A specialisation index greater than one (1.000) indicates above-average technological activity in the domain in question.

ence, and published between 2003 and 2006 by authors affiliated with institutions in São Paulo State.[20] The scientific articles in question totalled 33,819, or 51% of Brazilian production in the period. No information regarding the scientific field or location of the first author for 663 of these articles.

An analysis of the regional distribution of these scientific articles shows that the front-ranking microregions were those containing cities with the most intense academic activity, led by São Paulo (17,672), Campinas (6,614), São Carlos (3,732), Ribeirão Preto (2,546), Piracicaba (1,494) and São José dos Campos (1,390) (Detailed Table 8.14). These six microregions in aggregate accounted for 99% of scientific production in the state between 2003 and 2006, measured in terms of the number of scientific articles. This finding confirms those of the previous edition (FAPESP, 2005, chapter 9), which indicated strong regional concentration of scientific production in São Paulo State, with the same six microregions accounting for 97% of the indexed articles published between 1998 and 2002. To a large extent, the regional concentration of scientific

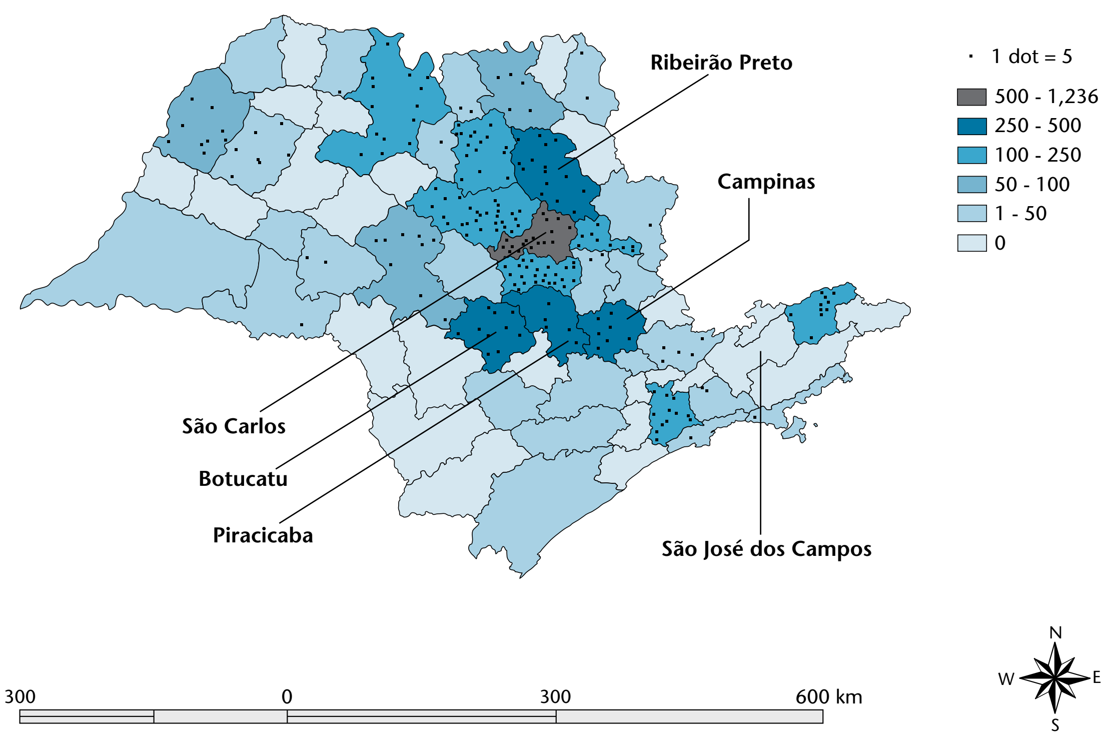
20. The data presented in this chapter represent a special extraction from the larger database used in Chapter 4 of this publication. Thus the methodological commentary presented in Chapter 4 also applies to the analysis of regional dimension discussed here.

publications matches the geographical distribution of the leading universities in São Paulo State, which are the main sources of local and national scientific production in terms of indexed articles.[21]

Weighting the number of publications by the population of each microregion produces an indicator that shows the other side of regional concentration in the state's scientific production. In the period 1998-2006, the density of scientific production (measured by the number of scientific articles per 100,000 inhabitants) was highest in the smaller microregions, especially São Carlos (1236.4) and, to a lesser extent, Botucatu (477.7) and Piracicaba (274.8). These can be described as regions, or even urban concentrations, in which scientific activity is predominant, creating a favorable environment for research and technological development. In medium to large microregions, on the other hand, where economic activities are more diversified, the density of scientific production tends to be lower, although it would be wrong to overlook the importance of clusters of scientific activities and their links and complementarities with a more diversified productive structure. A case in point is metropolitan São Paulo (131.2 publications per 100,000 inhabitants). The borderline cases include Campinas and Ribeirão Preto, both medium-size microregions, and both with 267 publications per 100,000 inhabitants (Map 8.8).

Scientific specialization of São Paulo State's microregions was also analyzed. Scientific specialization is an indicator of a knowledge area's contribution to scientific production in a given microregion compared with the same knowledge area's contribution to scientific production in the state as a whole. The scientific specializations of all microregions in São Paulo State are presented in Map 8.9.

Map 8.8
Density of scientific production by microregion – São Paulo State, 1998-2006

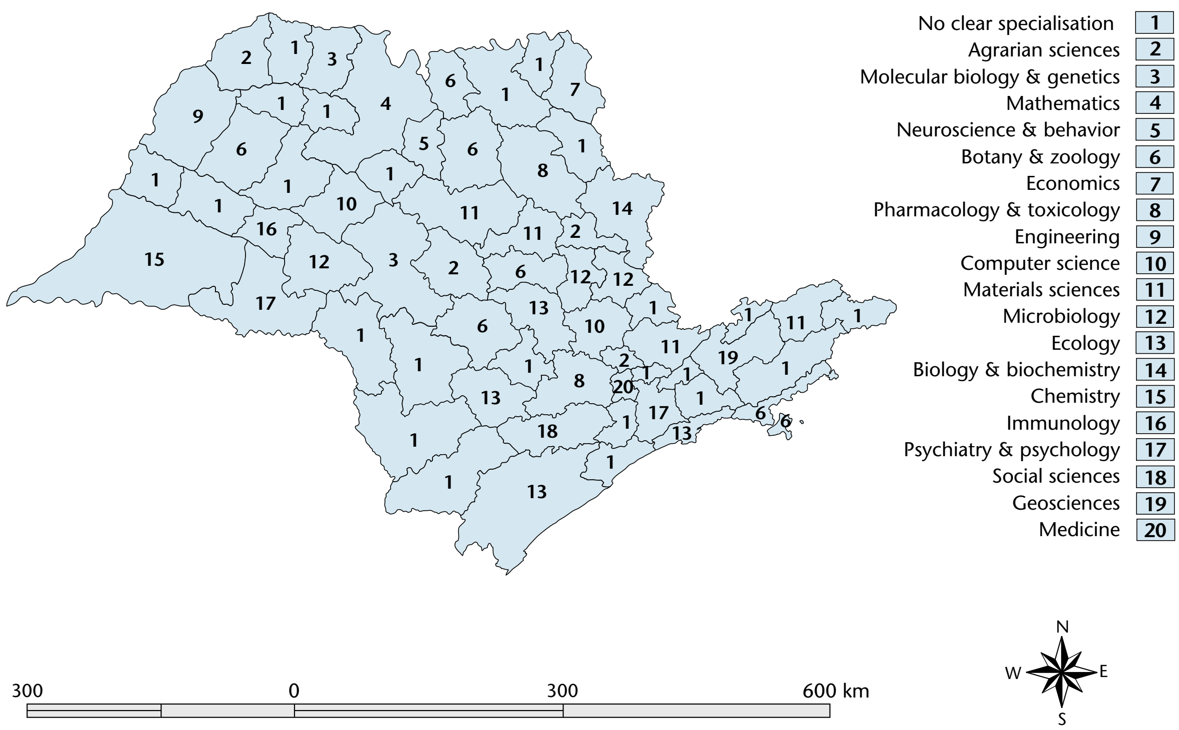


Source: ISI via *Web of Science*, SCIE & SSCI (extraction 2008).

Note: See Detailed Table 8.14.

21. As noted in the previous section, patenting activity has also been increasingly influenced by technological production in universities. The international literature includes studies such as those cited by Audretsch & Feldman (2003) which detect spatial correlations between scientific production measured in terms of published articles and technological production measured in terms of patenting.

Map 8.9
Scientific specialization (1) by microregion – São Paulo State, 2002-2005



Source: ISI via *Web of Science,* SCIE & SSCI (extraction 2008).

Note: See Detailed Table 8.15.

(1) Scientific specialization is calculated as a knowledge area's contribution to scientific production in a given microregion divided by its contribution to scientific production in São Paulo State as a whole.

An examination of the microregions with the largest numbers of scientific publications shows that São Paulo, which has a great diversity of scientific activities with substantial dispersion of knowledge areas, displays low specialization as a result. In fact, São Paulo's specialization indices are all less than 2. Indexed scientific articles from the region were found in 22 knowledge areas, led by psychiatry, with the highest specialization index (1.65), immunology (1.5) and economics (1.49).

Campinas, which ranked second in terms of the number of scientific articles published, was found to specialize in three important areas: computer science (2.01), agrarian sciences (1.73) and chemistry (1.63). São Carlos was also found to have 22 knowledge areas with indexed articles, especially in materials sciences (2.80), chemistry (2.56) and engineering (1.69). The areas with the highest specialization indices in Ribeirão Preto were pharmacology and toxicology (3,34), neuroscience and behavior (2.50), and immunology (1.81).

2.5 University-business interaction

Innovation is an evolutionary and cumulative process, in which several actors take part. Interaction between universities and business contributes significantly to the process, as universities and research institutions are an important source of knowledge for technological learning by firms. The role of universities in supporting innovation activities by firms goes beyond the knowledge spillovers that occur through the publication of new scientific knowledge developed in universities, as discussed in the previous section. University-business interaction can stimulate technological learning processes in firms and provide inputs for solutions to problems arising in the business sector's productive and innovation activities.

This section analyzes university-business interaction and its effects on the regional dimension of innovation activities in the business sector, based on data from CNPq's Research Group Directory. The basic assumption, mentioned in the introduction to this chap-

Box 2 – The role of technology transfer offices

In Brazil, as in other countries, several universities have established technology transfer offices (TTOs) to facilitate the transfer of new knowledge from the university to business. In doing so Brazilian universities were strongly inspired by the U.S. experience. Following the passage of the Bay-Dohle Act in 1980, U.S. universities began using TTOs more intensely to obtain revenue from the licensing of technology to firms.

TTOs can be a useful instrument for local knowledge transfer, acting as a link between academic research and local small business enterprises that perform activities with high technology content.

The leading Brazilian universities all have TTOs, mainly to pursue the overall objectives mentioned above, although there is an intense debate about the real role of these institutions in the process of transferring new knowledge and scientific discoveries to society. For the U.S. case, the numbers suggest that most TTOs do not generate sufficient revenue even to cover their costs. This is because three universities (the University of California, Stanford University and Columbia University) account alone for a third of university patent royalties, while 45% of TTOs earn no revenue at all (Colyvas *et al.*, 2002; David, 2006).

In any event, for certain scientific and technological discoveries TTOs can undeniably play a key role in fostering university-business interaction. However, sectoral and institutional specificities must be taken into consideration in the process of transferring technology from universities to firms, and TTOs in isolation cannot be expected to produce an increase in the number of discoveries or inventions by universities that become available for commercialization.

ter, is that geographical proximity can be conducive to the establishment and maintenance of university-business interaction.[22]

An institutional structure often used to manage this interaction is the technology transfer office (see Box 2). The role of a TTO is to license the knowledge created in the university to business enterprises on a formal basis.

The database for the 2006 CNPq Research Directory Group Census (see Methodological Annexes) was used to produce indicators that reveal some characteristics of university-business interaction. The Directory has compiled information on research groups active throughout Brazil since 1992. The census is held every two years, producing an overview of the research groups based on a consolidation of the information registered with the Directory. Since 2002 it has included information on the relationships with business in the form of a declaration by the research group leader (responsible for supplying all the information) on the existence and types of relationship with firms and other non-academic institutions, such as hospitals, service providers, non-governmental organizations and other non-profit or for-profit entities. The incorporation of this new dataset has contributed, albeit to a limited extent, to progress in the study of university-business interaction in Brazil.[23]

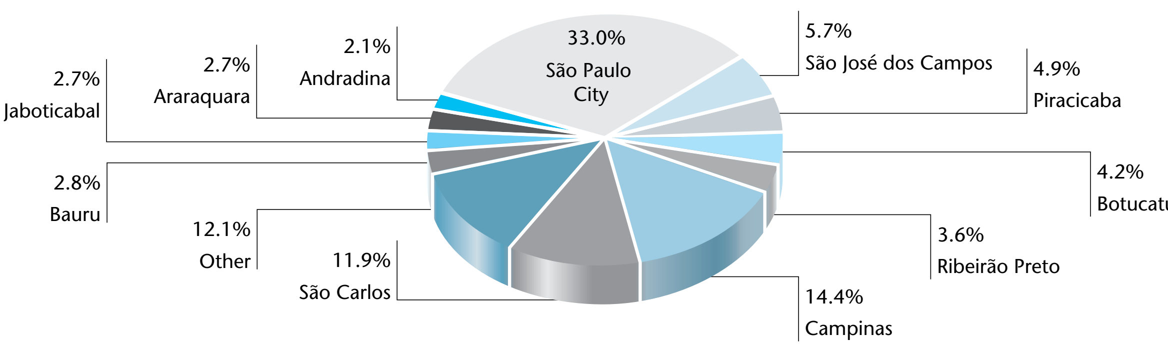
The 2006 Census registered 528 research groups in São Paulo State, affiliated with 59 institutions and reporting 1,970 relationships with business organizations. Figure 8.6 presents a percentage breakdown of these interactive research groups by microregion of São Paulo State. It shows that the city of São Paulo and the Campinas and São Carlos microregions have the largest numbers of interactive research groups, accounting in aggregate for 60%. This large proportion derives from the presence of major universities in these three microregions. A third of all interactive research groups are based in the city of São Paulo, several in units of USP, the largest Brazilian university. Campinas is home to Unicamp, another leading university, and São Carlos to UFSCar and a decentralized unit of USP, both of which specialize strongly in engineering, where interaction with business tends to be significant.

The firms interacting with research groups in São Paulo State and the number of relationships declared by microregion are presented in Figures 8.7 and 8.8, respec-

22. The production and insertion into this chapter of indicators of university-business interaction represent an attempt to establish new indicators of the regional dimension of ST&I activities and to advance further in this discussion compared with the previous edition (FAPESP, 2005, chapter 9).

23. University-business interaction was first analyzed using the CNPq Research Group Directory (Lattes) database by Rapini & Righi (2006). The methodology proposed by these authors is used here. However, it is necessary to note a significant limitation of this database, which is that information is collected via self-declaration by the research group leader and its accuracy is not verified. This has two implications for the analysis. First, respondents may interpret differently any questions on the type of relationship they have with firms, for example. Second and more important, there is clear evidence that university-business interaction is underestimated by this census since completion of the questionnaire is far from being mandatory and is neglected by the leaders of several groups.

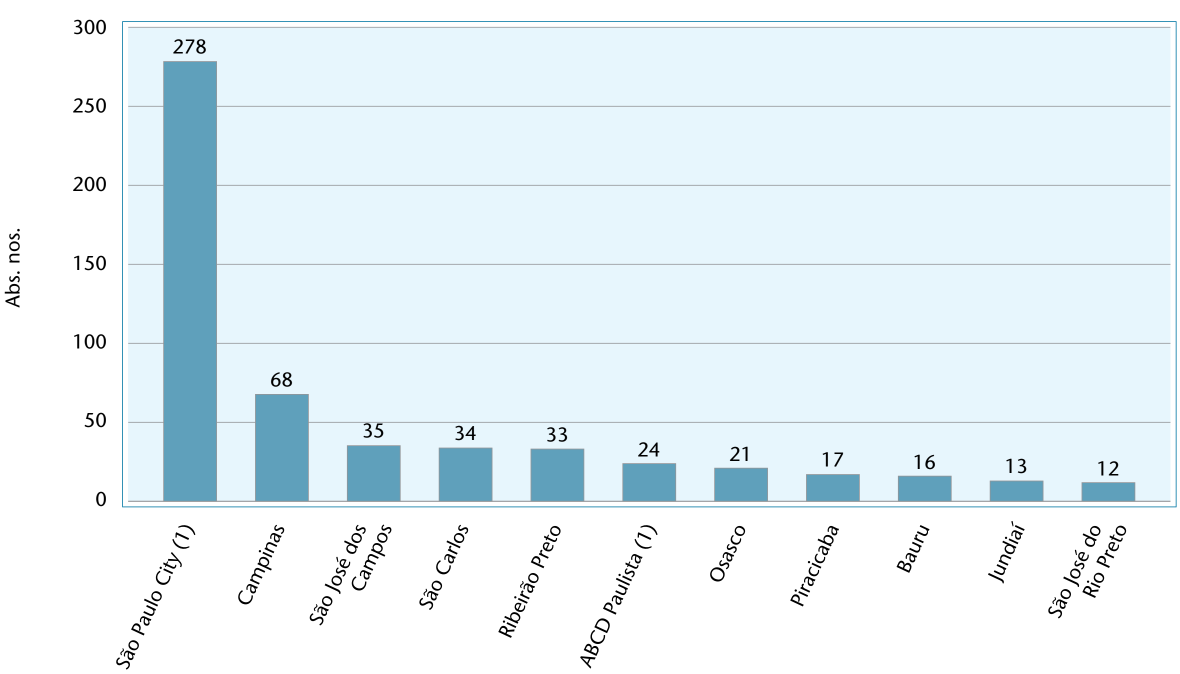
Figure 8.6
Research groups declaring interaction with firms and other non-academic institutions by microregion – São Paulo State, 2006



Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

Note: See Detailed Table 8.16.

Figure 8.7
Firms interacting with research groups by microregion – São Paulo State, 2006

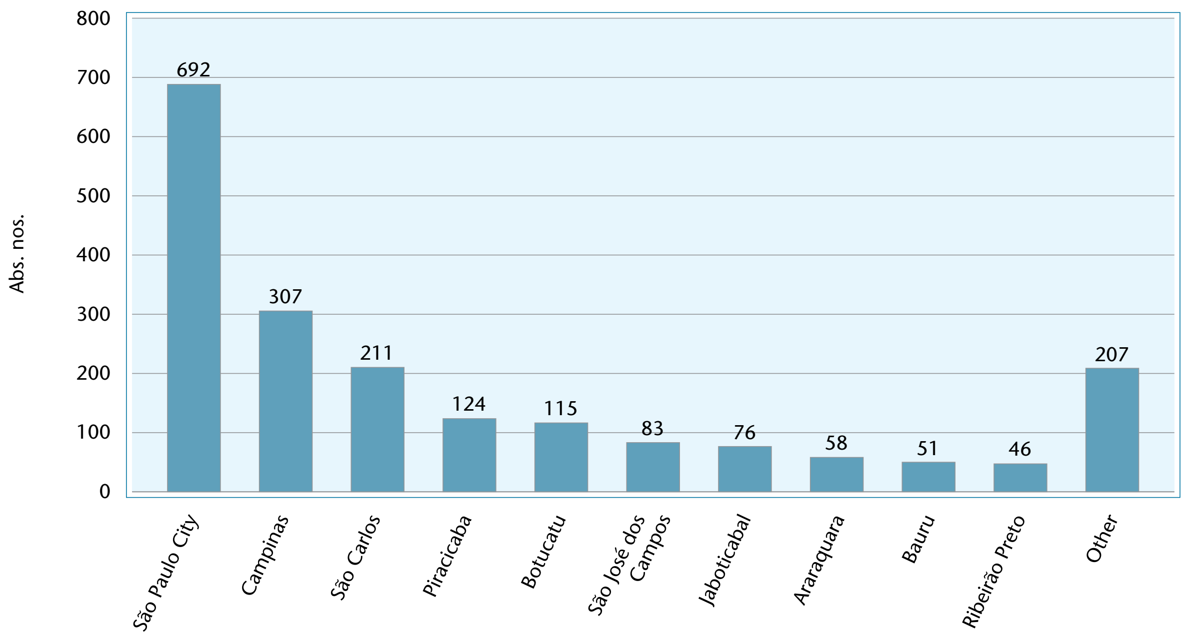


Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

Note: Some firms are counted more than once as they interact with research groups located in different microregions, so that the total number of firms is not found simply by adding the numbers in each microregion.

(1) São Paulo microregion = São Paulo City, ABCD Paulista (Santo André, São Bernardo do Campo, São Caetano do Sul, Diadema), Mauá, Ribeirão Pires, Rio Grande da Serra.

Figure 8.8
Number of relationships between research groups and firms by microregion – São Paulo State, 2006



Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

Note: Some firms are counted more than once as they interact with research groups located in different microregions, so that the total number of firms is not found simply by adding the numbers in each microregion.

tively. The analysis identified 852 firms that declared interaction with research groups in São Paulo State; 701 of these firms are also located in the state. Figure 8.7 presents a breakdown of these firms by microregion. As in the case of research groups, São Paulo is also the leader here, with 278 interactive firms, or about 40% of the total. Next come three microregions with much smaller numbers of interactive firms: Campinas (68), São José dos Campos (35) and São Carlos (34). These findings show a significant match between the geographical locations of the research groups concerned and the location of the firms with which they interact in São Paulo State, indicating that geographical proximity may play a relevant role in bringing about such interaction.

The same pattern of regional distribution can be seen in the relationships between universities and firms. The microregion with the most relationships is the city of São Paulo (692), followed by Campinas (307) and São Carlos (211) (Figure 8.8).

Table 8.3 presents the regional distribution of the most important interactive research groups and the types of relationships they have with firms, based on the microregions with the largest numbers of relationships.[24] The predominant type of relationship is scientific research with immediate application of results, typically established by a contract with a research group to develop a solution for a problem faced by the firm in collaboration with intramural researchers or for joint development of a specific product.

The second most frequent type of relationship is scientific research without immediate application of results, which is more interactive and often leads to the development of new lines of collaborative research between universities and firms. This type of univer-

24. The Research Group Directory allows respondents to select three principal types of relationship from a list of 14 but does not allow relationships to be ranked by importance.

Table 8.3
Relationships between research groups and firms by selected microregion and type of relationship – São Paulo State, 2006

Type of relationship	No. of relationships by selected microregion						
	Total	São Paulo City	Campinas	São Carlos	Piracicaba	Botucatu	Other
Grand total	**1,970**	**692**	**307**	**211**	**124**	**115**	**521**
Group -> Firm	**1,658**	**587**	**268**	**178**	**110**	**91**	**424**
Scientific research with immediate use of results	552	187	81	65	43	28	148
Scientific research without immediate use of results	272	101	47	27	15	12	70
Technology transfer	259	64	41	31	22	26	75
Technical consulting	160	81	26	20	0	5	28
Training (1)	138	34	23	12	16	8	45
Other	126	61	24	12	4	3	22
Non-routine engineering (2)	86	39	18	4	1	4	20
Software development	56	16	7	5	9	4	15
Supplying material inputs (3)	9	4	1	2	0	1	1
Firm -> Group	**274**	**90**	**35**	**30**	**14**	**19**	**86**
Non-routine engineering (4)	27	11	2	0	1	1	12
Software development	24	8	5	5	1	0	5
Supplying material inputs (3)	120	37	14	15	3	11	40
Technology transfer	43	9	7	5	3	6	13
Training (1)	60	25	7	5	6	1	16
City not identified	**38**	**15**	**4**	**3**	**0**	**5**	**11**

Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

(1) Includes on-the-job training and courses.
(2) Includes development prototypes, first-run prototypes and pilot plants for partner firms.
(3) Without a link to a specific project of mutual interest.
(4) Includes development and/or manufacturing of equipment for the group.

sity-business interaction tends to be richer in terms of creating two-way knowledge flows, since both the university and the firm can benefit from a more intense exchange of information and knowledge. The third most frequent type of relationship is technology transfer, which may consist of the purchase of a technology package developed by a university (often via patent licensing) or the simple purchase of products developed by the research group.

An analysis of the distribution of relationship types by microregion shows close resemblances, with the order of importance of relationships varying little. However, a few minor differences among microregions can be detected. In the city of São Paulo, for example, consulting activities rank third instead of technology transfer. In Campinas, the pattern of distribution is very similar to that found for São Paulo State as a whole, except that training ranks fifth and other types of relationship rank sixth in the state, while in Campinas these positions in the rank order are switched. In São Carlos, technology transfer ranks second and scientific research without immediate application ranks third.

Table 8.4 presents the relationships between research groups and firms by major knowledge area in selected microregions. The leading knowledge area in São Paulo State in terms of interactivity is engineering, with 39.5% of all these relationships, followed by agrarian sciences (21.3%), health sciences (12.3%) and exact and earth sciences (10.8%).

Table 8.4
Relationships between research groups and firms by selected microregion and knowledge area – São Paulo State, 2006

Microregion	Relationships between research groups and firms by knowledge area									
	Total	Agrarian sciences	Biological sciences	Health sciences	Exact & earth sciences	Human sciences	Applied social sciences	Engineering	Linguistics	Area not identified
Total	**1,970**	**419**	**130**	**242**	**213**	**46**	**133**	**778**	**2**	**7**
São Paulo City	692	23	31	137	45	10	82	359	2	3
Campinas	307	98	32	17	34	11	11	103	0	1
São Carlos	211	0	13	13	34	11	8	131	0	1
Piracicaba	124	88	10	13	4	0	4	5	0	0
Botucatu	115	86	7	7	6	0	0	8	0	1
São José dos Campos	83	2	0	2	26	0	1	52	0	0
Jaboticabal	76	74	2	0	0	0	0	0	0	0
Araraquara	58	6	0	19	25	0	8	0	0	0
Bauru	51	7	1	7	3	2	1	30	0	0
Ribeirão Preto	46	12	11	14	1	1	7	0	0	0
Other	207	23	26	13	35	15	11	88	0	1

Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

For engineering, the leading microregions in numbers of relationships are São Paulo (46.1%), São Carlos (16.8%) and Campinas (13.2%), all of which have nationally important engineering research centers. For agrarian sciences, the leaders are Campinas (23.4%), Piracicaba (21.0%), Botucatu (20.5%) and Jaboticabal (17.7%), all of which have important research centers with constant relationships with firms in this area. In health sciences, São Paulo is by far the leader in interactivity (56.6%).

Tables 8.5, 8.6 and 8.7 present the numbers of relationships between research groups and firms by knowledge area and sector of activity in the three main microregions of São Paulo State (São Paulo, Campinas and São Carlos). In other words, they show the main interaction points.[25] An analysis of the ranked pairs in each cell (groups/firms) highlights three key elements: (1) the disciplines in which the most interactive research groups are found; (2) the economic sectors that most intensely interact with academic institutions; and (3) the location of the main interaction points (pairs with the largest numbers of group-firm interaction).

The leading discipline by group-firm interaction in the São Paulo microregion is medicine, with 25 research groups interacting with 19 firms. Next come mechanical engineering, with 12 groups and 30 firms; collective health, with 12 groups and 17 firms; electrical engineering, with 11 groups and 31 firms; administration, with 10 groups and 44 firms; and civil engineering, with 9 groups and 48 firms (Table 8.5).

In the Campinas microregion, the most interactive areas are agronomy, in which 10 research groups interact with 16 firms; agricultural engineering, with 8 groups and 17 firms; food science and technology, with 7 groups and 26 firms; and chemistry, with 7 groups and 9 firms (Table 8.6). In São Carlos, the most interactive areas are materials and metallurgical engineering, with 9 groups and 32 firms; civil engineering, with 7 groups and 12 firms; production engineering, with 4 groups and 14 firms; and physics, with 4 groups and 10 firms (Table 8.7).

As for the most interactive sectors of economic activity, in the São Paulo microregion they are human

25. Interaction points are defined as the locations at which interactions between agents are most numerous in any given economic sector and knowledge area.

Table 8.5
Relationships between research groups and firms by economic activity and knowledge area – São Paulo microregion, 2006

Economic activity (CNAE division)		Relationships between research groups and firms by knowledge area														
		Total	Administration	Communications	Civil engineering	Materials & metallurgical engineering	Mining engineering	Transport engineering	Electrical engineering	Mechanical engineering	Nuclear engineering	Chemical engineering	Physics	Medicine	Collective health	Other
Total		**177/308**	**10/44**	**4/10**	**9/48**	**9/23**	**2/13**	**2/16**	**11/31**	**12/30**	**6/6**	**3/10**	**5/10**	**25/19**	**12/17**	**67/78**
20	Chemicals	10/17	1/1	*	*	3/4	2/6	*	*	1/1	*	2/4	*	1/1	*	*
21	Pharmaceuticals, medicinal chemicals	15/18	2/2	*	*	*	*	*	*	1/1	*	1/1	*	2/4	*	9/10
23	Non-metallic minerals	6/11	1/1	*	3/4	1/5	*	*	1/1	*	*	*	*	*	*	*
26	IT equipment, electronics, optics	8/11	*	*	*	*	*	*	4/6	2/2	*	*	*	*	*	1/3
27	Machinery, appliances, electrical material	5/7	*	*	1/3	1/1	*	*	1/1	1/1	*	*	*	1/1	*	*
28	Plant, equipment	7/7	*	*	1/1	*	*	*	1/1	3/3	*	1/1	1/1	*	*	*
32	Sundry products	9/9	1/1	*	*	*	*	*	*	*	1/1	*	1/1	1/1	*	5/5
35	Electricity, gas, other	10/17	1/1	*	*	*	*	*	2/8	3/4	2/1	*	*	*	1/2	1/1
41	Construction of buildings	5/10	2/3	*	3/7	*	*	*	*	*	*	*	*	*	*	*
46+47	Commerce	20/20	2/2	1/1	1/1	2/2	*	1/1	2/2	2/2	*	*	1/1	*	*	8/8
52	Storage, ancillary transport	4/7	*	*	/	*	1/1	1/4	1/1	*	*	*	*	*	*	1/1
64	Financial services	6/10	1/1	*	3/5	*	*	1/2	1/2	*	*	*	*	*	*	*
72	Scientific R&D	23/20	3/3	*	1/1	*	*	*	*	6/4	*	1/2	*	2/2	*	10/8
82	Office services, corporate services	7/7	1/1	1/1	*	*	*	1/1	*	*	1/1	1/1	*	1/1	*	1/1
84	Public administration, defense, social security	18/18	2/2	*	4/3	*	*	1/1	2/2	1/1	*	*	*	*	2/2	6/7
85	Education	21/23	2/2	1/4	*	2/2	*	1/1	*	2/2	*	*	*	3/2	3/3	7/7
86	Human health activities	27/20	*	*	*	*	*	*	*	2/2	2/2	*	1/4	17/6	2/3	3/3
94	Membership organizations	16/26	2/10	*	2/4	*	*	1/1	2/2	*	*	*	1/1	1/1	4/4	3/3
Other		90/97	9/14	4/4	14/19	9/9	3/6	5/5	6/5	8/7	1/1	1/1	2/2	*	3/3	25/21

Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

Notes: 1. Notation: no. of interactive research groups in knowledge area concerned / no. of interactive research groups in industrial sector concerned.

2. Shaded pairs represent interaction points, defined as the locations at which interactions between agents are most numerous in any given economic sector and knowledge area.

Table 8.6
Relationships between research groups and firms by economic activity and knowledge area – Campinas microregion, 2006

Economic activity (CNAE division)		Relationships between research groups and firms by knowledge area											
		Total	Administration	Agronomy	Food S&T	Agricultural engineering	Production engineering	Electrical engineering	Mechanical engineering	Genetic	Geosciences	Chemistry	Other
Total		**76/162**	**1/7**	**10/16**	**7/26**	**8/17**	**3/8**	**5/25**	**4/11**	**3/15**	**3/6**	**7/9**	**25/34**
10	Food	2/5	1/2	*	1/3	*	*	*	*	*	*	*	*
17	Pulp, paper	4/7	*	*	2/2	*	*	*	*	2/5	*	*	*
20	Chemicals	7/7	*	1/1	2/2	*	*	*	*	*	*	3/3	1/1
21	Pharmaceuticals, medicinal chemicals	5/6	*	*	*	*	*	*	*	*	*	1/1	4/5
23	Non-metallic minerals	2/6	*	*	1/5	*	*	*	*	*	*	*	1/1
24	Metallurgy	4/5	*	*	*	1/1	*	*	*	*	*	*	3/4
25	Metal products except plant & equipment	2/5	*	*	1/4	*	*	*	*	*	*	*	1/1
26	IT equipment, electronics, optics	4/11	*	*	*	1/1	*	2/9	*	*	*	1/1	*
28	Plant, equipment	9/10	*	1/1	1/1	3/4	*	*	1/1	*	*	1/1	2/2
35	Electricity, gas, other	4/8	1/2	*	*	*	*	1/4	1/1	*	*	*	1/1
46	Commerce	8/8	*	1/1	1/1	*	*	*	1/2	2/1	*	1/1	2/2
72	Scientific R&D	5/5	*	3/3	*	*	*	*	*	*	1/1	1/1	*
82	Office services, corporate services	5/5	*	1/1	*	*	*	1/1	*	*	1/1	*	2/2
84	Public administration, defense, social security	4/5	*	2/3	*	*	*	*	*	*	2/2	*	*
85	Education	3/6	*	*	*	*	1/4	1/1	*	*	*	*	1/1
94	Membership organizations	11/14	*	3/4	2/2	2/3	1/2	*	1/1	*	*	*	2/2
Other		49/61	3/3	2/2	4/6	7/8	2/2	7/10	5/6	4/9	2/2	1/1	12/12

Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

Notas: 1. Notation: no. of interactive research groups in knowledge area concerned / no. of interactive research groups in industrial sector concerned.
2. Shaded pairs represent interaction points, defined as the locations at which interactions between agents are most numerous in any given economic sector and knowledge area.

Table 8.7
Relationships between research groups and firms by economic activity and knowledge area – São Carlos microregion, 2006

	Economic activity (CNAE division)	Relationships between research groups and firms by knowledge area														
		Total	Architecture & urbanism	Computer sciences	Education	Civil engineering	Materials & metallurgical engineering	Production engineering	Electrical engineering	Mechanical engineering	Chemical engineering	Physics	Geosciences	Chemistry	Collective health	Other
Total		**63/116**	**3/4**	**4/5**	**3/8**	**7/12**	**9/32**	**4/14**	**2/4**	**2/9**	**4/4**	**4/10**	**2/4**	**4/4**	**2/4**	**13/13**
20	Chemicals	9/10	*	*	*	*	4/5	1/1	*	1/1	2/2	1/1	*	*	*	*
22	Rubber, plastic	4/4	*	*	*	2/2	2/2	*	*	*	*	*	*	*	*	*
23	Non-metallic minerals	4/5	*	*	*	*	4/5	*	*	*	*	*	*	*	*	*
24	Metallurgy	6/7	*	*	*	1/1	3/4	1/1	*	1/1	*	*	*	*	*	*
25	Metal products except plant & equipment	4/4	*	*	*	1/1	*	1/1	*	1/1	*	*	*	1/1	*	*
26	IT equipment, electronics, optics	5/8	*	1/1	1/1	*	*	*	*	*	*	2/5	*	*	*	1/1
28	Plant, equipment	4/8	*	*	*	1/1	*	2/4	*	1/3	*	*	*	*	*	*
29	Automotive vehicles	4/3	*	*	*	*	1/1	2/1	*	1/1	*	*	*	*	*	*
46	Commerce	3/4	*	*	*	*	*	*	1/2	1/1	*	1/1	*	*	*	*
72	Scientific R&D	9/8	*	2/2	*	1/1	*	*	*	*	1/1	1/1	1/1	*	*	3/2
84	Public administration, defense, social security	6/6	*	*	*	1/1	1/1	*	*	*	*	*	*	*	1/1	3/3
85	Education	3/4	*	*	1/2	*	*	*	*	*	*	*	1/1	*	1/1	*
94	Membership organizations	6/12	*	1/1	1/2	2/2	1/6	1/1	*	*	*	*	*	*	*	*
Other		43/44	3/4	1/1	3/3	3/3	8/8	5/5	2/2	1/1	2/1	2/2	2/2	3/3	2/2	6/7

Source: CNPq, 2006 Census, Research Group Directory (Diretório dos Grupos de Pesquisa).

Notas: 1. Notation: no. of interactive research groups in knowledge area concerned / no. of interactive research groups in industrial sector concerned.
2. Shaded pairs represent interaction points, defined as the locations at which interactions between agents are most numerous in any given economic sector and knowledge area.

health activities (27/20), scientific R&D (23/20), education (21/23), commerce (20/20), and public administration, defense and compulsory social security (18/18) (Table 8.5). In the Campinas microregion, they are membership organizations (11/14), manufacturing of plant and equipment (9/10), electricity, gas and other (4/8), and chemicals (7/7) (Table 8.6). In São Carlos, they are chemicals (9/10), scientific R&D (9/8), and membership organizations (6/12) (Table 8.7). The industrial sector accounts for a larger share of the Campinas microregion, while non-industrial activities such as membership organizations, commerce, and public administration, defense and compulsory social security stand out in São Paulo and São Carlos. These findings appear to indicate that universities and research institutions in the Campinas microregion focus more on fulfilling the private sector's needs than in other microregions where research activities are more diversified.

Third, crossing industrial sectors and scientific disciplines in which large numbers of research groups and firms interact indicates the interaction points in each region, i.e. the sectors and knowledge areas in which university-business interaction is significant. São Paulo has seven interaction points: three civil engineering research groups with seven building construction firms (3/7) and five financial services firms (3/5); electrical engineering with IT equipment, electronics and optics (4/6) and electricity, gas and other (2/8); mining engineering with chemicals (2/6); mechanical engineering with scientific R&D (6/4); and medicine with human healthcare (17/6) (Table 8.5).

The Campinas microregion has three interaction points: electrical engineering with IT equipment, electronics and optics (2/9); genetics with pulp and paper (2/5); and food science and technology with non-metallic minerals (1/5) (Table 8.6). São Carlos has four interaction points, three involving materials and metallurgical engineering research groups that interact with firms in chemicals (4/5), non-metallic minerals (4/5) and membership organizations (1/6); and a fourth involving physics research groups interacting with IT, electronics and optics manufacturers (2/5) (Table 8.7).

3. Institutional structure supporting technological and innovation activities in firms

Another aspect of regionalized ST& indicators that needs to be analyzed is institutional support for business innovation. Such institutions can play an important role in the process of creating and disseminating innovations by providing services that dynamise local production structures and creating knowledge flows, especially of tacit and specific knowledge, that foster innovation by firms. Among the most relevant organizations that support innovation activities in local firms are educational institutions, to qualify manpower at the tertiary, technological and technical levels; institutions that provide technical and technological services, such as laboratory tests; and ST&I research and technology centers.[26]

This section presents an overview of the structure of institutional support for the technical, technological and innovation activities of firms in São Paulo State, highlighting its regional distribution. The analysis covers information collected on the supply of education, technical and technological services, research services, training of human resources at the undergraduate and post-graduate levels in selected areas, technical and technological undergraduate courses, research centers and R&D laboratories.

3.1 Business support institutions (education and research)

The Ministry of Labor's Annual Employment Register (RAIS) shows that in 2006 there were 127 R&D institutions in physical and natural sciences (CNAE 2.0, Group 72.1), distributed in 25 microregions, with 4,791 employees (Table 8.8). A comparison with similar data for 2002, presented in the previous edition of this publication (FAPESP, 2005, chapter 9), shows significant growth (89.5%) in the number of these institutions and a rise of 11.8% in the number of employees.[27]

26. The previous edition of this series (FAPESP, 2005, chapter 9) included an analysis of the regional distribution of other business support entities, such as trade associations and semi-public bodies such as Sebrae, which supports small business. A survey of such entities was performed for this edition, but the analysis of the data collected showed that these institutions play a limited role in supporting innovation and it was therefore decided not to present and discuss this information.

27. While the RAIS database shows very significant growth in the number of R&D institutions in São Paulo State, such expansion in a short period is simply not credible. The explanation appears to lie in the methodology used to collect data for the RAIS, in particular completion of the form. The same reservation applies to the other RAIS data presented in this section.

Despite reservations about the reliability of these numbers, they are consistent with others presented in this chapter as far as regional distribution is concerned, displaying significant concentration in the microregions seen to be leaders in other indicators. Three microregions (São Paulo, Campinas and São Carlos) account for 57.5% of the R&D institutions in physical and natural sciences and for 90.3% of the employees. Five microregions (Piracicaba, Sorocaba, São José dos Campos, Ribeirão Preto and Jaboticabal), also seen to be leaders in other indicators, account for 19.7% of the institutions and 7.4% of the jobs (Table 8.8).

Besides R&D institutions in physical and natural sciences, São Paulo State has R&D institutions in social and human sciences (CNAE 2.0, Group 72.2), which employ 692 people and are located in 17 microregions (Table 8.8). Once again the São Paulo and Campinas microregions stand out, accounting for roughly three-quarters of the total number of these institutions and for 95.4% of their workforce.

The number of higher education institutions offering undergraduate, post-graduate and extension courses (CNAE 2.0, Group 85.3), again according to the RAIS for 2006, was 784; they were located in 58 microregions

Table 8.8
R&D institutions, employees and average size of establishments in physical and natural sciences (CNAE Group 72.1) and in social and human sciences (CNAE Group 72,2) by microregion – São Paulo State, 2006

Microregion	R&D institutions		
	No. of establishments	No. of employees	Average establishment size (no. of employees)
Physical & natural sciences (CNAE Group 72,1)			
Total	**127**	**4 791**	**38**
São Paulo	34	1 473	43
Campinas	27	2 616	97
São Carlos	12	236	20
Piracicaba	7	129	18
Sorocaba	7	90	13
São José dos Campos	4	43	11
Ribeirão Preto	4	11	3
Jaboticabal	3	80	27
Catanduva	3	3	1
Presidente Prudente	3	2	1
Osasco	3	1	0
Araraquara	2	34	17
Jaú	2	14	7
Rio Claro	2	14	7
Mogi das Cruzes	2	10	5
Guarulhos	2	2	1
Botucatu	2	1	1
Franca	1	9	9
Lins	1	6	6
Itapecerica da Serra	1	6	6
Andradina	1	4	4
Jundiaí	1	4	4
Votuporanga	1	1	1
Bragança Paulista	1	1	1
Santos	1	1	1

(CONTINUES ON NEXT PAGE)

Table 8.8 (continued)
R&D institutions, employees and average size of establishments in physical and natural sciences (CNAE Group 72.1) and in social and human sciences (CNAE Group 72,2) by microregion – São Paulo State, 2006

Microregion	R&D institutions		
	No. of establishments	No. of employees	Average establishment size (no. of employees)
	Physical & natural sciences (CNAE Group 72,1)		
Total	**62**	**692**	**11**
São Paulo	38	557	15
Campinas	7	103	15
Ribeirão Preto	2	2	1
Bragança Paulista	2	2	1
São José do Rio Preto	1	6	6
Sorocaba	1	6	6
Osasco	1	5	5
Bauru	1	3	3
Marília	1	3	3
Presidente Prudente	1	2	2
Botucatu	1	1	1
Tatuí	1	1	1
Itapecerica da Serra	1	1	1
Franca	1	0	0
Avaré	1	0	0
São João da Boa Vista	1	0	0
Santos	1	0	0

Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

and employed 151,430 people (Detailed Table 8.17). Their regional distribution was less concentrated than that of R&D institutions, as is natural in the case of HEIs, which cater for the general population. However, the demand to higher education is evidently associated with economic, social and research activities, which tend to be regionally concentrated. This is reflected by the data presented in Detailed Table 8.17. Four regional "axes" comprising 17 microregions of São Paulo State account for 77.4% of the state's HEIs and 85% of their employees. The first and most important "axis" comprises the São Paulo and Campinas microregions, which together account for 48.5% of the institutions and 57.4% of their employees. The other three "axes," which account in aggregate for 29% of the institutions and 27.7% of their employees, are: (1) the microregions surrounding metropolitan São Paulo, i.e. Jundiaí, São José dos Campos, Osasco, Mogi das Cruzes, Guarulhos, Sorocaba and Santos; (2) the mid-north of the state, especially the Ribeirão Preto, São José do Rio Preto, São Carlos and Araraquara microregions; and (3) the Piracicaba, Jaboticabal, Botucatu and Bauru microregions in the mid-west.

The number of HEIs throughout the state in 2006 was roughly a third higher than in 2002, the base year for the data published in the previous edition (FAPESP, 2005, chapter 9, Detailed Table 9.13). In regional terms, the number of HEIs (and hence the supply of undergraduate, post-graduate and extension courses) varies considerably from one microregion to another. Returning to the four regional "axes," in the first (São Paulo and Campinas) the number of institutions rose more sharply in Campinas; in the second (microregions adjacent to metropolitan São Paulo) it rose most in Sorocaba, São José dos Campos, Osasco and Jundiaí; in the third it rose most in Araraquara; and in the fourth it rose most in Botucatu, Jaboticabal and Bauru (Detailed Table 8.17; FAPESP, 2005, chapter 9, Detailed Table 9.13).

The number of vocational education institutions at the technical and technological levels (CNAE Group

85.4) totalled 450 in 2006, according to the RAIS database. They were located in 53 microregions and employed 7,062 people (Detailed Table 8.18). The São Paulo microregion contained 33.6% of the state's VEIs and 44.1% of the total workforce they employed. A comparison with the data collected for the previous edition (FAPESP, 2005, chapter 9) shows growth of 35.1% in the number of VEIs and 50.3% in the workforce.

As for regional distribution, VEIs are heavily concentrated in the most industrialized regions, such as São Paulo, Osasco (clearly a spillover from São Paulo), Campinas and São José dos Campos. It is interesting to note that some less outstanding microregions in terms of ST&I indicators, such as Bauru and Santos, have large numbers of VEIs and large VEI workforces. Local demand for qualified labor determines the large relative weight of these microregions in the state (Detailed Table 8.18).

Despite the concentration of technical and technological schools in some microregions, their regional distribution is less concentrated than that of other ST&I indicators, such as HEIs, as noted above. The main reason is that VEIs are located in areas where there is demand for skilled labor, giving rise to the establishment of such schools in regions with less significant overall ST&I indicators.

3.2 Vocational and technical-scientific education institutions

The aim of identifying the technical-scientific education infrastructure is to measure the availability of human resources trained for innovation activities in São Paulo State. The working assumption is that technological qualifications are imparted by the different levels of the education system and that training for innovation activities is stronger in some areas. Information was therefore collected on industrial apprenticeship, technical, technological and tertiary courses from the following institutions' databases: Anísio Teixeira National Institute for Educational Studies and Research (INEP), Coordination Office for the Improvement of Higher Education Personnel (CAPES), and National Industrial Apprenticeship Service (SENAI). The main variables used in the analysis were the number of education institutions and their geographical distribution; and the number of students enrollled or the number of places offered by these institutions, depending on the type of information available.

The courses selected to analyze tertiary-level institutions (undergraduate and post-graduate courses) were in engineering (all disciplines and specialties), pharmacy and biochemistry, chemistry, biology, and agronomy, since professionals in these areas perform relatively more important functions in the innovation activities of firms and thus play a key role in creating and diffusing new knowledge in the business sector.[28]

As noted earlier in connection with other ST&I indicators, a salient feature of the supply of higher education in careers with a technological profile is concentration in the São Paulo-Campinas axis, which accounts for 33.1% of the courses and 47.7% of enrolllment. As for other educational levels, the São Paulo and Campinas microregions account in aggregate for 66.4% of enrolllment in technological courses and 40% of enrolllment in technical courses (Detailed Tables 8.19 and 8.20).

However, the supply of education at these levels in the São Paulo and Campinas microregions is less concentrated when relativized by the spatial distribution of the population. An analysis of enrolllment density, calculated as the number of students enrolllled per 100,000 inhabitants, shows the Rio Claro, São Carlos, Barretos, São José dos Campos, Guaratinguetá, Adamantina and Andradina microregions in the lead, with more than 1,690 students enrolllled per 100,000 inhabitants, well above the statewide average of 982.1. In the case of the Rio Claro, São Carlos, São José dos Campos and Guaratinguetá microregions, the large number of students enrolllled is associated with the presence of major university campuses. In other microregions, high enrollment levels are probably due to the ability of institutions in these regions to attract many students from adjacent regions.

In tertiary-level enrollment the leading microregions are São Carlos (1967.32 students enrollled per 100,000 inhabitants), Andradina, Barretos, Fernandópolis, Guaratinguetá, São José dos Campos and Araraquara, all with enrollment densities of more than 623, well above the statewide average of 325.54. In technological courses, the leading microregions are Limeira (138.25), Jaboticabal, Sorocaba, Guaratinguetá, Mogi das Cruzes and São Paulo.

Technical-level courses are offered in 62 of the state's 63 microregions. The leaders are Rio Claro (1836.05), Adamantina, São José dos Campos, Catanduva, Barretos, Dracena, Lins and Guaratinguetá, all with densities of more than 1,030, well above the statewide average of 605.55.

Industrial apprenticeship courses, offered mainly by SENAI, are present in 29 microregions with a total of 21,226 students enrollled and an average density of 51.70. The leading microregions are Rio Claro (439.26), Jundiaí, Sorocaba, São José dos Campos and Limeira, all

28. It should be stressed that these areas were selected in accordance with the methodology used for the previous edition of this publication (FAPESP, 2005, chapter 9).

with densities of more than double the average for the state. An analysis of the data also shows the comprehensive coverage of these courses throughout the state, mostly in response to local demand for skilled labor, justifying the extensive coverage.

A comparison with the data collected for the previous edition (FAPESP, 2005, chapter 9) highlights strong growth in enrollment in the period 2002-06 and more extensive geographical coverage of courses at the tertiary, technological and technical levels. The number of new students enrollled in 2006 alone was 285,000. The number of technological courses rose 132% (from 46 in 2002 to 107 in 2006), while the number of students enrollled rose 495% (from 2,670 in 2002 to 15,880 in 2006). The number of industrial apprenticeship courses rose 36% (from 194 in 2002 to 263 in 2006) (Detailed Table 8.19). All microregions of the state saw significant growth in the supply of technological courses at every level, although growth was stronger in microregions with lower indicators, especially in the interior of the state.

The spatial distribution of vocational courses in the state is presented in Table 8.9, which shows that their

Table 8.9
Technical, technological and industrial apprenticeship courses, enrollment and graduates by microregion – São Paulo State, 2006

Microregion	Technological courses			Technical courses			Industrial apprenticeship courses		
	No. of courses	Enrollment	Graduates	No. of courses	Enrollment	Graduates	No. of courses	Enrollment	Graduates
Total	**107**	**15,880**	**2,592**	**4,408**	**248,612**	**641,47**	**263**	**21,226**	**8,879**
São Paulo	54	10,085	1,795	995	78,693	29,319	60	6,870	2,670
Campinas	6	452	124	358	20,754	6,648	17	1,734	718
São José dos Campos	2	77	0	284	16,729	2,438	16	1,557	694
Santos	6	368	22	184	11,349	3,310	11	648	246
Sorocaba	5	1,504	272	177	9,901	2,295	19	1,521	684
Mogi das Cruzes	7	1,017	107	144	7,433	1,451	7	784	308
Ribeirão Preto	1	55	12	139	6,850	2,022	17	698	451
Limeira	5	794	110	100	5,515	604	7	634	327
Guarulhos	1	22	0	89	5,453	548	3	643	249
Osasco	1	23	0	86	5,259	1,773	7	723	267
São José do Rio Preto	2	27	0	89	4,376	934	5	253	60
Guaratinguetá	1	340	43	83	4,160	179	2	97	90
Piracicaba	0	0	0	75	4,085	981	10	703	273
Jundiaí	4	189	0	69	4,041	1,333	9	840	274
São João da Boa Vista	0	0	0	84	3,501	531	0	0	0
Presidente Prudente	1	81	19	89	2,725	608	5	241	104
Araraquara	0	0	0	57	2,644	325	6	427	208
Catanduva	0	0	0	55	2,636	450	0	0	0
Bauru	0	0	0	51	2,462	145	8	549	163
Mogi Mirim	0	0	0	56	2,454	640	4	99	82
Ourinhos	0	0	0	46	2,351	488	3	88	67
Assis	0	0	0	63	2,312	336	0	0	0
Marília	3	90	0	54	2,177	386	6	316	59
Adamantina	0	0	0	46	2,083	593	0	0	0
Jaú	0	0	0	46	1,998	532	4	78	72
Other	8	756	88	889	36,671	5,278	37	1,723	813

Sources: MEC, INEP; SENAI.

Nota: See Detailed Table 8.19.

regional concentration in the São Paulo and Campinas microregions is not completely matched by enrollment density. For example, enrollment density in higher education in the São Carlos microregion (1967.32 per 100,000 inhabitants) is five times higher than in the São Paulo microregion (367.47) and double that of the Andradina microregion, which ranks second with 904.83. The Rio Claro microregion has the highest aggregate enrollment density in technical, technological and industrial apprenticeship courses (2275.31).

The São José dos Campos microregion also stands out in vocational education, with 6.2% of the education institutions concerned (Detailed Table 8.18) and more than 18,000 students enrollled (Detailed Table 8.19). A comparison with the occupational indicators presented above (in item 2.1 of this chapter) shows the sectors that require qualified workers (corporate services, automotive manufacturing, metalworking, chemicals and petrochemicals) with a significant share of employment in the microregion: together these sectors account for roughly 33% of total employment (Detailed Table 8.3). From this it can be inferred that the supply of places in the educational system correlates closely with the dynamics of the labor market in this microregion.

Table 8.10 and Map 8.10 summarise the data collected on tertiary-level technological education. A

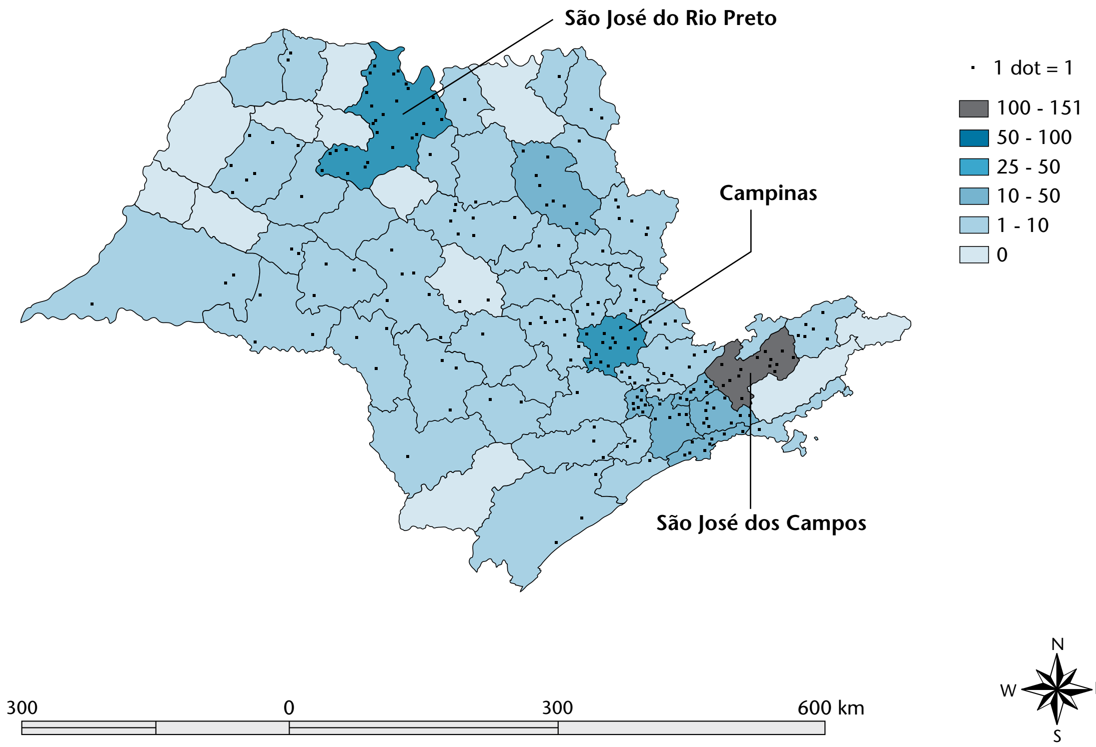
Table 8.10
Tertiary-level technological courses, enrollment and graduates by microregion – São Paulo State, 2006

Microregion	Tertiary-level technological courses		
	No. of courses	Enrollment	Graduates
Total	**477**	**133,653**	**17,999**
São Paulo	106	49,967	6,629
Campinas	52	13,810	1,702
São José dos Campos	41	8,673	1,043
São Carlos	29	5,903	694
Osasco	12	4,186	391
Sorocaba	17	4,113	487
Santos	14	3,805	566
Guarulhos	7	3,464	1,095
Mogi das Cruzes	10	3,074	488
Araraquara	16	2,895	325
Ribeirão Preto	17	2,838	368
Piracicaba	7	2,768	376
Guaratinguetá	9	2,694	293
Bauru	15	2,419	233
São José do Rio Preto	15	2,231	388
Jundiaí	7	2,049	334
Andradina	4	1,625	250
Limeira	9	1,525	179
Marília	8	1,192	138
São João da Boa Vista	9	1,175	141
Franca	3	1,167	231
Botucatu	3	1,133	245
Barretos	9	1,111	178
Americana	6	1,014	86
Other	52	8,822	1139

Source: MEC, INEP; SENAI.

Nota: See Detailed Table 8.20.

Map 8.10
Technical- and technological-level vocational education institutions by microregion – São Paulo State, 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

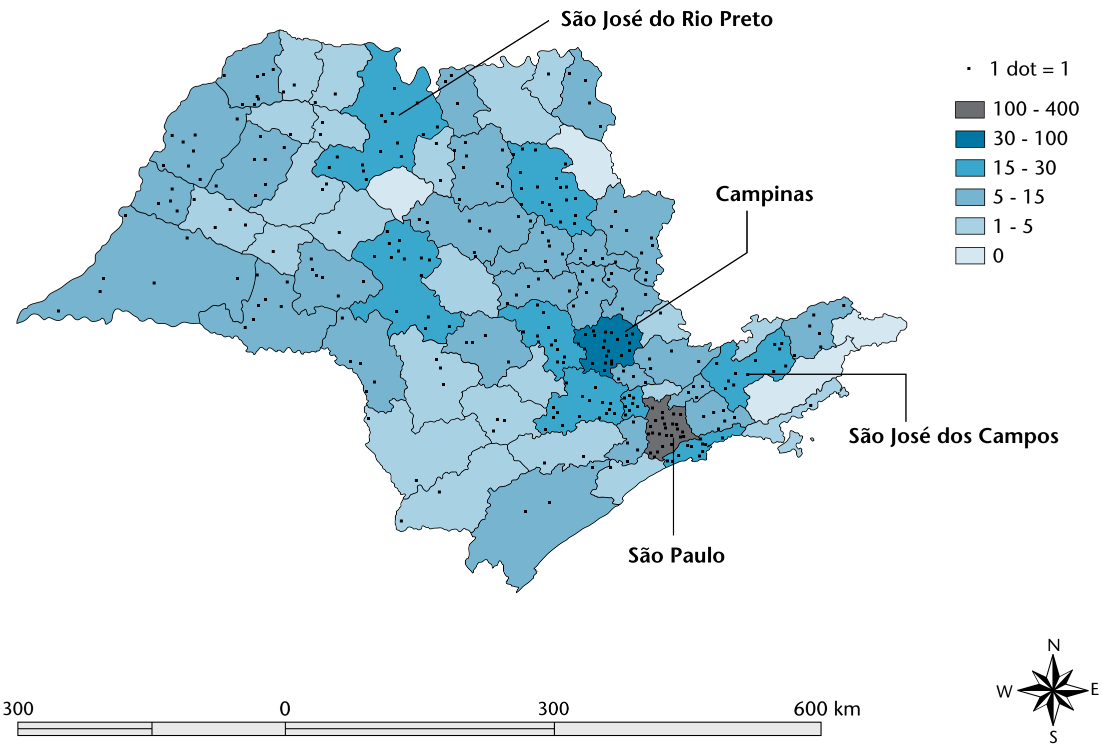
Note: See Detailed Table 8.18.

comparison with the findings presented in the previous edition of this publication (FAPESP, 2005, chapter 9) for this level of education shows growth of 39% in the number of graduates (from 12,881 in 2002 to 17,899 in 2006) and 91.6% in the number of courses in the selected areas (from 249 to 477). In the São Paulo microregion, the number of graduates rose 36.3% and the number of courses 41.3%, while in the other microregions in aggregate the number of graduates rose 42.8% and the number of courses 113.3%. The leading microregions in terms of growth in the number of courses were again São José dos Campos (272.7%) and São Carlos (262.5%).

Higher education in São Paulo State has expanded in recent years, and particularly so in microregions in the interior (Map 8.11), where growth rates have surpassed the average for the state. The supply of qualified labor is therefore set to expand in these microregions in the coming years, probably with significant effects on the competitiveness of firms.[29]

29. It has not been possible to include quality indicators for these courses, even at the tertiary level. The previous edition (FAPESP, 2005, chapter 9) used data from the National Examination of Courses (popularly known as "Provão"), which has since been replaced by the National Student Performance Assessment Examination (Enade). No data for Enade was available at the level of disaggregation required for a regional analysis.

Map 8.11
Higher education institutions offering undergraduate, post-graduate and extension courses by microregion – São Paulo State, 2006



Source: Ministério do Trabalho e Emprego (MTE), RAIS 2006.

Note: See Detailed Table 8.17.

3.3 Technology centers, test laboratories and R&D institutions

Test laboratories and technology and R&D centers are also part of the infrastructure that supports firms' innovation activities, providing technological and other services. The importance of the role played by these institutions has been reinforced in the recent past by the need for firms to sharpen the focus of their innovation activities and to engage increasingly in partnerships to develop joint R&D projects.

Labs and technology centers in São Paulo State were identified institutionally and geographically for the purposes of this analysis. The main institutions identified were calibration and testing labs accredited by the National of Metrology, Standardization & Industrial Quality (Inmetro) and public and private R&D labs accredited by the Ministry of Science & Technology, Inmetro and participants in the Embrapa system.

Calibration and testing labs provide firms with essential services for some products and processes. Such calibration and testing services are indispensable for certain markets, especially in the case of exports. Data collected in 2008 shows that 57% of the 409 Inmetro-certified calibration and testing labs in São Paulo State were in the São Paulo microregion (Table 8.11). This concentration in metropolitan São Paulo clearly reflects the presence of a large number of high value added service providers. The relocation of industry has brought these labs geographically closer to firms' R&D units. Nevertheless, despite the significant proportion in the capital, a great many of these labs are located in other microregions of the state, frequently linked to producers' local specializations and catering for specific needs of these firms in laboratory testing. An example is the metrology lab at the IPT unit in Franca, dedicated almost exclusively to the provision of services to local footwear producers. Detailed Chart 8.6 contains information on the location of these labs and their areas of influence.

Test labs and R&D labs support firms' intramural R&D activities, offering benefits from synergies and

Table 8.11
Inmetro-certified calibration and testing labs by microregion - São Paulo State, 2008

Microregion	Inmetro-certified calibration and testing labs
Total	409
São Paulo	233
Campinas	34
São José dos Campos	29
São Carlos	27
Piracicaba	15
Santos	6
Sorocaba	9
Osasco	8
Guarulhos	5
Mogi das Cruzes	5
Jundiaí	4
Limeira	4
Franca	3
Lins	3
Bauru	2
Franco da Rocha	2
Guaratinguetá	2
Itapecerica da Serra	2
Mogi Mirim	2
Piedade	2
Tatuí	2
Araçatuba	1
Botucatu	1
Caraguatatuba	1
Fernandópolis	1
Itapetininga	1
Marília	1
Presidente Prudente	1
Registro	1
Ribeirão Preto	1
Rio Claro	1

Source: Inmetro.

Note: See Detailed Table 8.6.

complementarities. The perception of these benefits may have stimulated the recent creation of private research institutions, such as Instituto Eldorado, located in the city of Campinas.

Table 8.12 summarizes the spatial distribution of test and R&D labs. The São Paulo microregion also accounts for a large share of this category (55.6%). In contrast with other components of the support infrastructure, however, these institutions are found in few microregions. R&D structures, unlike test labs, do not need to be geographically close to users. The list of test and R&D labs can be consulted in Detailed Chart 8.7.[30]

It is worth noting that the number of both testing and calibration labs and R&D labs increased significantly in all microregions. The number of such labs identified was 151 in 2004 (FAPESP, 2005, chapter 9) and 302 in 2008.

4. The configuration of local innovation systems in São Paulo State

A comprehensive overview of ST&I efforts and activities in São Paulo State can be constructed on the basis of regionalized indicators of these activities. By analyzing a cross-section of these activities in selected regions, it is possible to capture differentiating characteristics of local ST&I systems. This approach represents an application at the local level of the concept of innovation systems proposed by Freeman (1995) and Nelson (1993). Local innovation systems comprise a cluster of geographically concentrated pro-

Table 8.12
Test labs and R&D labs by microregion – São Paulo State, 2008

Microregion	Test labs & R&D labs
Total	**302**
São Paulo	168
Campinas	65
São Carlos	24
São José dos Campos	9
Ribeirão Preto	8
Piracicaba	5
Guarulhos	4
Osasco	4
Santos	4
Jundiaí	3
Mogi das Cruzes	3
Limeira	2
Franca	1
Lins	1
Sorocaba	1

Source: Inmetro; Embrapa; SENAI.

Note: See Detailed Chart 8.6.

30. The list of R&D labs discussed here is certainly incomplete, as there are existing research institutions that were not located by the survey performed, which selected test labs accredited by Inmetro (excluding calibration labs) and the Ministry of Science & Technology (MCT), in this case to be eligible for benefits pursuant to the Informatics Law, as well as labs belonging to the Embrapa system. In light of this insufficiency, it was decided to present the list of all the institutions identified (Detailed Chart 8.7).

ducers and institutions linked to the ST&I system and whose interactions create local flows of information and knowledge, contributing to the development of innovative processes by firms. Thus geographical proximity among the agents, firms and institutions that make up the local innovation system strengthens local processes of knowledge transmission, especially tacit and specific knowledge, with positive effects for the competitiveness of local firms.

Empirical evidence shows that local systems can specialize in a given productive activity or can be characterized by a high level of local diversification. In both cases it is possible to identify elements that contribute to an improvement in the economic and innovation performance of firms.[31]

São Paulo State has pioneered the creation of dynamic knowledge centers in Brazil, with conspicuous effects arising from geographical proximity. Five regions stand out, as evidenced by the ST&I indicators in Detailed Table 8.21. These regions are analyzed in the following subsections.

4.1 Metropolitan São Paulo

Metropolitan São Paulo accounts for approximately 42% of the state's GDP and almost 20% of Brazil's GDP. Its S&T activities are also much more intense than those of other parts of the state, favoring innovation efforts by local firms.

Box 3 – Interpretations of industrial deconcentration in metropolitan São Paulo

There is considerable disagreement regarding the interpretation of São Paulo State's loss of share in Brazilian industry (Cunha, 2008). Diniz (1993) argues that the decline in the state's participation, and more specifically that of the São Paulo metropolitan area, relates to the expansion of some adjacent regions whose industrial agglomerations in the Central South of Brazil form a polygon delimited by the cities of Belo Horizonte, Uberlândia, Maringá, Porto Alegre, Florianópolis and São José dos Campos. Expansion of industry in these regions reflects the existence of a strong and extensive urban network equipped with basic services and ST&I infrastructure, including education and research institutions and providers of corporate services.

Another study (Diniz & Diniz, 2004) propounds the thesis that metropolitan São Paulo has seen a process of deindustrialization similar to those of London, New York, Paris and Tokyo, albeit less intense. In the view of these authors, however, São Paulo does not display all the characteristics of the typical "global city". The city proper has not undergone such significant deindustrialization as have global cities, but the metropolitan area has increasingly assumed new functions typical of global cities, acting as the nation's (and South America's) main financial and banking center, as the command center for the Brazilian economy, and as the hub for Brazil's relations with the international community. This position has been guaranteed by its capacity to attract knowledge-intensive businesses such as IT and microelectronics. At the same time, and converging with the approach adopted in this chapter, education institutions, research centers and service providers play a key role in the region's economy.

Pacheco (1998) attributes São Paulo State's loss of share to what he calls "fragmentation of the nation," in which the integration of the Brazilian economy into new international circuits since the 1990s has intensified regional disparities. Thus Pacheco points to a process of "deconcentration/reconcentration" in the Central South of Brazil, with relatively low-tech industries clustering in the regions adjacent to the city of São Paulo, including the Campinas and São José dos Campos regions, along with services less intensive in knowledge, especially in the metropolitan area.

In line with this interpretation, Matteo (2007) argues that the restructuring of industry in metropolitan São Paulo took place in the context of intensifying integration with adjacent regions in the interior of the state, such as Campinas, Jundiaí, Piracicaba, São José dos Campos and Sorocaba, while stressing that the metropolitan area still has a significant share of some industries, such as apparel, cosmetics, pharmaceuticals, software, precision mechanics and electronic automation.

31. A recapitulation of this debate can be found in Beaudry & Schiffauerova (2009), who reviewed the empirical research into the benefits of clustering and verified the benefits of specialization and diversification of local production systems on the economic and innovation performance of local firms.

However, a process of industrial deconcentration has recently occurred in Brazil and São Paulo State, with many firms choosing to transfer activities, especially in manufacturing, from the city of São Paulo and the metropolitan area to other regions (Box 3). This has led to a fall in the region's share of the manufacturing industry, and especially of industrial employment.

The intensity of ST&I efforts in the São Paulo metropolitan area is evidenced by its indicators.

The first of these is the density of employment in technological occupations, particularly in the São Paulo microregion, where technological jobs account for 52.17 out of every 1,000 jobs (Detailed Table 8.21). This is the highest density for any microregion in the state.

Note should be taken of a difficulty with delimiting the São Paulo region that was experienced throughout the production of the analysis presented in this chapter. According to IBGE's delineation of Brazil's geographical regions, the São Paulo microregion comprises the city of São Paulo, the cities of the ABCD region (Santo André, São Bernardo do Campo, São Caetano do Sul and Diadema), and the cities of Mauá, Ribeirão Pires and Rio Grande da Serra. The São Paulo metropolitan area is very large and includes several microregions.[32] The high indicators for microregions adjacent to São Paulo and belonging to the metropolitan area may therefore represent spillovers from the local dynamic center, in this case the city of São Paulo.[33] For this reason, it was decided to separate some indicators for the city of São Paulo and other cities in the same microregion.

The number of innovative local firms was again largest in São Paulo, which is home to more than 5,470 such firms identified by PINTEC 2005, and more than 50% of the total number of innovative firms in São Paulo State[34] (Detailed Table 8.5).

The São Paulo microregion also performs outstandingly in terms of results, with 6,108 patent filings in the period 2002-05, or 48.8% of the total for the state (Detailed Table 8.8). The city of São Paulo accounted for 5,280 of these (48 patents per 100,000 inhabitants) and the Greater ABCD region for 828 (42 patents). These are the regions with the greatest technological density in the state.[35]

In scientific publications, authors from the São Paulo region are also more productive, publishing 17,672 articles or 45.4% of the total for the state (Detailed Table 8.14). The knowledge areas with the highest specialization indices are psychiatry and psychology, immunology, and economics, but the numbers of articles are also high in some technological areas, such as medicine, physics, chemistry, and biology and biochemistry.[36]

Besides significant scientific production, the region houses the largest Brazilian university (USP) as well as other local universities that interact closely with firms, judging from the many research groups that declare relationships with firms both in the region and elsewhere.

Supporting institutions are also relatively concentrated in the São Paulo region, which has 106 tertiary-level courses in technological areas (22.2% of the total for the state) and 37.4% of the enrollled students (Detailed Table 8.20). In addition, a large number of research institutions and corporate service providers are headquartered in the region.

4.2 Campinas region

The Campinas region accounts for approximately 7.5% of São Paulo State's GDP. It stands out not only for its importance to the structure of industrial and other production in the state, but also for its role in the creation of new scientific and technological knowledge, thanks especially to the number of S&T institutions located there, led by Unicamp and several S&T research institutions.

The Campinas region has displayed strong dynamism in recent decades and has been chosen as a destination for new investments, partly in association with the process of industrial deconcentration in metropolitan São Paulo (Matteo, 2007). The region has also received new investment from multinational firms, especially in scientific and technological knowledge-intensive sectors such as telecommunications and IT equipment. This investment growth has been driven by several factors, including the region's proximity to the main markets for consumers of these products in Brazil, its logistical facilities, its S&T infrastructure, highly qualified workforce, many research groups at local universities, and service centers for collaboration. This interaction is particularly important for small and medium firms, since large firms have their own intramural

32. According to IBGE, metropolitan São Paulo comprises the following microregions: Osasco, Franco da Rocha, Guarulhos, Itapecerica da Serra, São Paulo and Mogi das Cruzes.

33. For an in-depth discussion of this point, see Matteo (2007) and Freire (2006).

34. In this case the number of innovative firms corresponds to the entire metropolitan area because of the possible aggregation of data in IBGE's PINTEC survey.

35. Alongside Campinas and behind less populous regions such as São Carlos and Marília, where small numbers of patent filings produce high densities.

36. A methodological reservation regarding this information is required. Specialization indices do not take absolute numbers into account, since they are ratios calculated as a region's share of scientific production in the state. Some knowledge areas with few publications may therefore display high specialization indices. This is the case for economics (68 indexed articles in the period 2002-06) and psychiatry and psychology (277).

structures to support innovation efforts and typically build such activities into their routines.[37]

The region has 43.6 workers in technological occupations per 1,000 employees and 61.5 in technical occupations (Detailed Table 8.2). In the period 2003-05 it was home to 1,411 that introduced innovations, or 13.1% of the state's total[38] (Detailed Table 8.5).

The Campinas region also performs strongly in patenting, with 1,054 filings in the 2002-05 (42.5 per 100,000 inhabitants), or 8.3% of the total for São Paulo State (Detailed Table 8.8). The leading technological domains were fine chemicals and pharmaceuticals, instrumentation, and procedures, basic chemicals and metallurgy.[39] Unicamp's scientific activity contributed significantly to the 6,614 scientific articles attributed to the Campinas region in the period 2003-06, equivalent to 266.6 per 100,000 inhabitants (Detailed Table 8.14). The main knowledge areas were computer sciences, agrarian sciences, chemistry and mathematics (Detailed Table 8.15).

Lastly, the importance of the Campinas region's institutional ST&I infrastructure should be stressed, in terms of education institutions and qualified labor as well as research institutions and services. The number of tertiary-level courses in technological areas totalled 52, or 10.9% of the total for São Paulo State (Detailed Table 8.20). The region also has 34 product certification laboratories, or 8.3% of the total (Table 8.11) and 65 test labs, or 21.5% of the total (Table 8.12). In R&D, the region has several public and private research labs, especially in information and communications technology (ICT). The leading public research labs include the Renato Archer Center for Information Technology (CTI) and the National Synchrotron Light Laboratory (LNLS), both subordinated to the Ministry of Science & Technology. The leading private research institutions include CPqD (formerly the Telebrás Research Center) and Instituto Eldorado (Detailed Chart 8.7). The strong performance of the local ST&I system in this area can be illustrated by the experience of Padtec (Box 4).

4.3 São José dos Campos region

ST&I activities in the São José dos Campos region relate largely to the aircraft industry and Embraer. However, the local ST&I infrastructure, which predates Embraer, has always played a key role in supporting the aircraft manufacturer's innovation activities. This is particularly true of the two leading education and research institutions, the Aeronautics Technology Institute (Instituto Tecnológico de Aeronáutica, ITA) and the Department of Aerospace Science & Technology (Departamento de Ciência e Tecnologia Aeroespacial,

Box 4 – The Padtec experience

Padtec is the result of interaction among institutions in the Campinas region's ST&I system. Headquartered in the city of Campinas, it was founded in 2001 as a spinoff[40] from CPqD, which holds an equity interest in the company. Its incorporation was financed by Banco Pactual's internet equity fund. Padtec specializes in the development and manufacturing of optical communications systems, including solutions for long-distance, metropolitan and access networks. In collaboration with CPqD and with a significant contribution from researchers at Unicamp, the company developed optical communications systems and equipment that use WDM (wavelength division multiplexing), a new transmission technology that multiplies the transmission capacity of fiber optic systems. It is Latin America's first manufacturer of DWDM (dense wavelength division multiplexing) systems. It has expanded twelvefold since 2004 and reported sales of R$ 80 million in 2008.

Padtec has representative offices in Argentina, Colombia, Peru and Mexico. In February 2008, it acquired 100% of Civcom, an Israeli manufacturer of optical systems. This acquisition and its offices in Latin America are part of the company's export strategy.

Source: corporate information; Inovação Unicamp.

37. Studies by several authors, including Souza & Garcia (1999) and Diegues & Roselino (2006), show that activities developed by multinational firms located in the Campinas region consist essentially of equipment assembly and that R&D activities performed by firms are not significantly intensive in new knowledge. This point is confirmed by Araújo (2007), who notes that the importance of informal contacts to foster local learning processes is far greater for small locally owned firms than for foreign firms.

38. These numbers actually refer to the Campinas mesoregion.

39. As noted earlier, the largest single patentee in Brazil in the period analyzed was Unicamp, which has its headquarters in the city of Campinas.

40. Spinoffs and startups in this context are firms set up by universities, research institutions or other public- or private-sector organizations to commercialize new high-tech products and services developed by researchers.

DCTA). The creation of this local innovation system specific to the aerospace industry is a Brazilian example of a specialized local system (Box 5).

An analysis of the ST&I indicators for the São José dos Campos region shows that they reach outstanding levels for the state. To begin with labor qualification indicators, the density of employment in technological occupations in the São José dos Campos microregion is 51.3 per 100,000 inhabitants, placing it second only to the São Paulo microregion (Detailed Table 8.2). The density of employment in technical and operational occupations is higher still, in fact the highest in the state at 73.9 and 64.1 respectively.

Other local indicators do not reach such significant levels. The innovation rate for firms in the Paraíba Valley is slightly above 30%, less than the average for the state (33%). The number of patent applications filed in the period 2002-05 totalled 252, or 18.5 per 100,000 inhabitants (Detailed Table 8.9). The main technological domains (i.e. with the highest specialization indices) were instrumentation, and electronics and electricity (Detailed Table 8.10). In scientific production, local authors published 1,390 scientific articles, or 102 per 100,000 inhabitants, in the period 2003-06. The knowledge areas with the highest specialization indices were geosciences, space sciences, engineering, and materials sciences (Detailed Tables 8.14 and 8.15).

The qualitative indicators for supporting institutions show the existence of 41 tertiary-level courses in various technological areas, two technology degree courses and 284 secondary-level technical courses (Detailed Tables 8.19 and 8.20). The region has 29 product certification laboratories and nine product testing labs (Tables 8.11 and 8.12).

It is clear that local ST&I activities match local production activities very closely, evidencing the importance of linkages among the different agents in the ST&I system.

4.4 São Carlos region

The São Carlos region is home to a unit of USP and to UFSCar, both of which conduct significant S&T activi-

Box 5 – Formation of the aerospace industry local innovation system

The leading position enjoyed today by Embraer (Empresa Brasileira de Aeronáutica) as one of the world's foremost aircraft manufacturers results from a long history of efforts involving government, the company, and education and research institutions. Embraer was founded in 1969, but since the 1930s the armed services and civilian experts alike had tried to persuade the government that Brazil needed an aeronautical industry as part of the industrialization process and national defense strategy (Forjaz, 2005).

The first step, taken in the 1940s in the context of World War II, was the creation of the Air Force Ministry to merge military aviation subordinated to the army and naval aviation into a single force. The project was designed from the start to assure mastery of aeronautical technology. As a result, well before aircraft production began an aeronautical engineering course was created at ITA and CTA (later DCTA) was set up as a research center. Both were planned in late 1945. ITA began operating in 1948 on the premises of the Institute of Military Engineering in Rio de Janeiro, and was formally created in early 1950, when it was installed at São José dos Campos. CTA was set up shortly afterwards, with ITA formally subordinated to it.

Thus the training of aeronautical engineers and mastery of aeronautical technology preceded creation of the industry. To assure a standard of excellence in these activities, agreements were signed with foreign institutions that sent scientists, researchers and professors to Brazil while accepting Brazilian graduate students to study abroad. In 1961, ITA began its own graduate course, and a prototype of the Bandeirante aircraft designed and built at CTA flew in 1968. Embraer was founded in 1969.

This was a pioneering experience in linkages between education, research and industry, with flows of people between Brazil and abroad contributing decisively to the industry's successful implementation. Analyzing this case, Forjaz (2005, p. 292) stresses that "native S&T development requires a relatively long maturation period and thus requires persistence and confidence in the future. However, it enables a domestic industry to offer the products that markets want and that are capable of surviving in a fiercely competitive international environment."

Extracted from Suzigan & Albuquerque (2008).

ties, especially in engineering. The local ST&I system has a long track record in university-business interaction and knowledge transfer via continuing virtuous processes.

The regionalized indicators that stand out are for patenting, indexed scientific articles and university-business interaction. The number of patent applications filed in the period 2002-05 with the first-named inventor residing in São Carlos totalled 156, or 51.7 per 100,000 inhabitants (Detailed Table 8.9). The technological domains with high specialization indices included instrumentation, and machinery, mechanics and transport (Detailed Table 8.10).

In scientific production, authors affiliated with institutions in the region published 3,732 scientific articles (1236.4 per 100,000 inhabitants) in the period 2003-06, mainly in materials sciences, chemistry, engineering, mathematics and physics (Detailed Tables 8.14 and 8.15).

The region accounts for 11.9% of research groups that interact with firms in São Paulo State and 10.7% of the relationships with firms declared in the CNPq Research Group Directory Census (Detailed Table 8.16). More than 50% of these relationships are in engineering (Table 8.4). Another point worth noting is the large number of tertiary-level courses in various technological areas, totalling 29 (Detailed Table 8.20).

4.5 Ribeirão Preto region

Like São Carlos, Ribeirão Preto is home to a decentralized unit of USP, whose presence has highly positive effects on the development of local S&T capabilities.

It is no accident that the region excels in scientific production. The number of indexed scientific articles by authors affiliated to institutions in the region totalled 2,546 in the period 2003-06, (267.4 per 100,000 inhabitants), mainly in pharmacology and toxicology, neuroscience and behavior, immunology, molecular biology and genetics, and biology and biochemistry, all of which displayed high specialization indices in the period (Detailed Tables 8.14 and 8.15).

The region has a relatively high proportion of innovative firms. The innovation rate for the period 2003-05 was 34.7%, slightly higher than the average for the state, which was 33% (Detailed Table 8.5).

In patenting, the number of applications filed in the period 200-05 totalled 226 (23.7 per 100,000 inhabitants), mainly in instrumentation, and in machinery, mechanics and transport (Detailed Tables 8.8 and 8.9).

Local production systems are often targeted by industrial and ST&I policy measures, which typically aim to boost the positive effects of geographical proximity between innovative firms and other agents of the local ST&I system, especially university-business interaction.

The above analysis of these five regions shows that São Paulo State has pioneered the constitution of dynamic knowledge and production centers in Brazil. With world-class universities such as USP, a Unicamp and Unesp, as well as a diversified cluster of research institutions and ST&I supporting organizations, the state has a significant infrastructure for technical and technological capacity building. In addition, it has a robust and diversified production structure that serves as a potential user of these capabilities. The São Paulo State Department of Development recently launched an initiative to stimulate interaction between the ST&I system and industry, known as the São Paulo State Technology Park System (Box 6).

Box 6 – São Paulo State Technology Park System (SPTec)

International experience suggests that technology parks are suitable venues for transforming knowledge into wealth by building linkages between centers of knowledge creation and production.

The São Paulo State Technology Park System (SPTec), administered by the Department of Development, promotes cooperation among technology parks accredited by the state government and among the firms and institutions installed there. It also seeks to facilitate integration between technology parks and public-sector entities, international organizations, research institutions, and development, investment and funding agencies.

State Decree 53826 (Pró-Parques), published on December 16, 2008, provides incentives for the establishment of technology-based firms in these parks, mainly via the use of cumulative ICMS state sales tax credits.

The Department of Development has implemented 16 initiatives to implement technology parks in 13 municipalities. Six have been provisionally accredited, in Campinas, Piracicaba, Sorocaba, São José dos Campos, São José do Rio Preto and São Carlos (ParqTec). The state government intends to implement at least ten technology parks in São Paulo State.

With the collaboration of Vahan Agopian.

5. Conclusions

This chapter presents an analysis and mapping of the geographical distribution of ST&I activities in São Paulo State based on a set of regionalized indicators for innovation inputs, such as skilled labor, scientific publications and university-business interaction, as well as proxies for innovation outputs such as patenting and innovative firms. It analyzes selected regions with outstanding ST&I indicators capable of configuring local innovation systems.

ST&I activities cannot always be measured by means of indicators, because a substantial proportion of firms' innovation capabilities consists of tacit and specific competencies that are embodied in their workers and in their operating routines. However, these capabilities can be captured to some extent by indicators relating to skilled labor, the characteristics of innovative firms, patenting, scientific publications, and institutions that support and provide services for ST&I activities.

Generally speaking, this mapping of the regional distribution of ST&I inputs and outputs in São Paulo State highlights three important phenomena.

The first is the importance of the city of São Paulo and the São Paulo metropolitan area, shown to be the largest center of scientific and technological development in the state (and indeed in Brazil). São Paulo's ST&I indicators are substantially higher than those of any other region of the state, especially in absolute terms. This vast ST&I structure entails the presence of large number of agents who comprise the local innovation system, including firms engaged in significant innovation efforts and their R&D units; large universities, which contribute in a fundamental manner to the education and training of a skilled workforce and, in the specific case of USP, to S&T research as well; and institutions that support firms' innovation activities. This cluster of ST&I agents and activities is capable of generating a series of benefits associated with the bringing together of firms and supporting institutions, especially relating to the ample diversity of the local production structure and the institutional ST&I apparatus.

The second phenomenon is the importance of the regions located in the interior of São Paulo State, adjacent to the São Paulo metropolitan area and also outstanding in terms of ST&I activities, such as Campinas and São José dos Campos. While their indicators are less significant than those of the São Paulo metropolitan area, especially in absolute terms, they reveal the force of the local ST&I system, including innovative local firms and good universities. In the case of Campinas, the highlight is Unicamp, which displays high indicators for patenting, scientific publications and interaction with business, all of which certainly favour local knowledge spillovers. São José dos Campos has an ample and diversified local production structure, and above all a successful aircraft industry thanks to the presence of Embraer and a group of institutions associated with the sector.

The third phenomenon relates to the regions in the interior of São Paulo State with less outstanding ST&I indicators. A comparison with the information presented in the previous edition (FAPESP, 2005, chapter 9) shows substantial growth in the supply of skilled labor, in the number of institutions that support firms' innovation activities, and above all in the number of education institutions that offer technical, technological and industrial apprenticeship courses. This evolution in regions that have not traditionally acted as important local innovation systems may offer opportunities for the creation and diffusion of new knowledge to support firms' innovation processes.

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