Innovation in Brazil

Advancing Development in the 21st Century

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5 Benchmarking university/industry research collaboration in Brazil

Carlos Henrique de Brito Cruz

> The errors which arise from the absence of facts are far more numerous and more durable than those which result from unsound reasoning respecting true data.
>
> – Babbage, 1832[1]

Introduction

University/industry research collaboration has been an important part of science, technology, and innovation policy in many regions. Such collaboration is widely viewed as an important driver of business-sector competitiveness and has been a subject of policy discussions for many years. In 1968 the Brazilian National Confederation of Industry (CNI) released a statement on university/industry interactions:[2]

> It is not a new fact that industry and university share a mutual dependency . . . It is well known that the process of production makes industry a servant of science, and of its practical applications. For this very reason, research represents one of the motivations for its intimate and permanent association with the university.

The topic of university/industry research collaboration has been studied by several authors. For developing countries that are seeking to "catch up" economically, Mazzoleni and Nelson argue that "universities and public research organizations are key institutions supporting this process of catching up." Agreeing on the relevance of university/business interactions is one matter – understanding how to make these interactions work in support of development, however, is another problem. According to Mazzoleni and Nelson:

> Successful public research programs of other countries can and should serve as broad guides for countries trying to establish their own programs, but as indicators of principles to follow, not as templates. There is first of all the problem that it is very difficult to identify just what features of another country's successful program were key to its success, and which ones were peripheral. Second, what works in one country setting is unlikely to work in the same way in another.[3]

As the quote suggests, few indicators have been developed for assessing the state of the relationship between universities and businesses. In most discussions in Brazil, policymakers and researchers start by stating that collaboration is "imminent" and conclude that more government money is necessary to foster it. Measures of success have rarely been established, beyond counting the value of funds spent to foster joint research.

This article proposes four indicators that might allow for a more effective tracking of policies in this area. The indicators are not new, but they have rarely been explored in Brazil: (a) business expenditures in support of university research, (b) quantity and intensity of university/business co-authorship in scientific articles, (c) number of patents filed and related indicators, and (d) number of business startups created by university students and faculty. These are reasonably simple indicators that can be identified and tracked by universities and government agencies to measure the success (or lack thereof) of innovation policies.

Modes of interaction between universities and businesses

The complexity of interactions between universities and businesses is well illustrated in Figure 5.1, which captures various modes of interaction, from the "flow of university graduates to industry" to "joint labs." The modes of interaction chosen, and their intensity, are affected by government policies such as intellectual property (IP) regulations and public procurement practices, as well as by broad characteristics of the larger economy, such as its openness (or lack of openness) to competition. The flow of graduates appears at the base of Figure 5.1, since training students for future employment is integral to the educational mission of the university and also because many of the opportunities that arise from other modes of interaction stem from relationships between university graduates and professional colleagues or former professors. Many of the benefits that come from these interactions are diffuse and uncodified – and thus difficult to measure. Other types of interaction – such as joint projects, funds related to these projects, IP licensing, joint labs, jointly authored scientific articles and reports, and joint patents – are more easily measured.

Despite the complexity of these interactions and the multiple factors that affect them, the relevance of university and business-sector interactions tends to be highly ranked in surveys of the business sector, as highlighted in a recent report for CNI that focuses on the case of Brazil.[4]

In his classic text *An Inquiry into the Nature and Causes of the Wealth of Nations*,[5] Adam Smith succinctly described the process by which "improvements in machinery" are achieved, stating roles for the users of machines, for the makers of machines (these two classes would be the business sector), and for the "philosophers or men of speculation" (these would be the present-day equivalent of university professors):

> All the improvements in machinery, however, have by no means been the inventions of those who had occasion to use the machines. Many

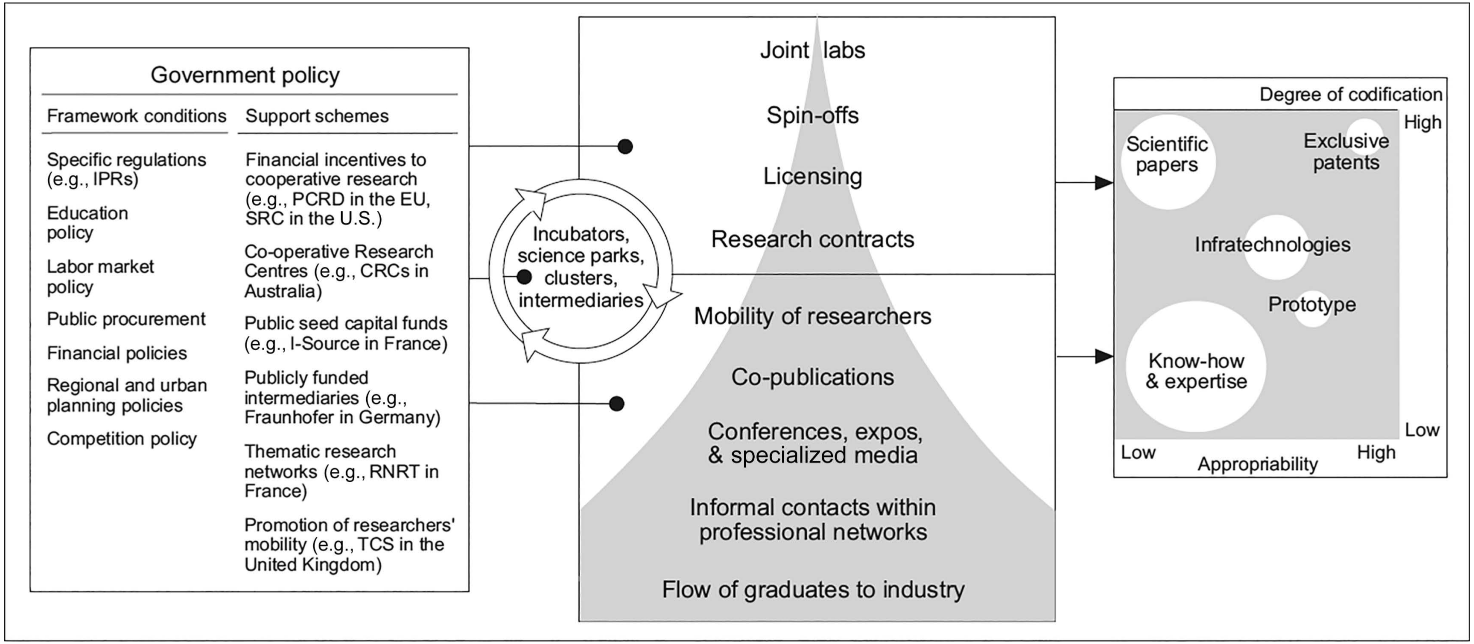

Figure 5.1 Formal mechanisms that might be involved in university/business interactions in research

Source: OECD (2002), Benchmarking Industry-Science Relationships, p. 23.

> improvements have been made by the ingenuity of the makers of the machines, when to make them became the business of a peculiar trade; and some by that of those who are called philosophers or men of speculation, whose trade it is not to do anything, but to observe everything; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects.

In modern times, several surveys confirm the relevance of university collaboration for business-sector innovation. In the PINTEC surveys of technological innovation conducted by the Brazilian Institute of Geography and Statistics (IBGE),[6] university interactions repeatedly rank among the five or ten most important sources of ideas for industry. A recent study by Pinho and Fernandes[7] on university/industry linkages (UILs) finds that, among the countries studied, firms in Brazil rank public research institutes and universities higher in terms of their importance as sources of innovation – fourth and third, respectively, compared to other sources – than do firms in other countries. By contrast, U.S. and Chinese firms ranked universities sixth and ninth, respectively, relative to other sources of innovation. According to the authors:

> These data call into question the common notion that in emerging countries UILs are missing or weak. There is no clear and sound evidence to support this conjecture. Nevertheless, data on the importance attributed by firms to universities as a source of information for innovation cannot be considered as evidence of stronger or more frequent relationships in developing countries. As a matter of fact, there are no data to support any of these positions.

More than two decades ago, Mansfield sounded a note of caution about university/industry research collaboration in the context of university/business interactions,[8] emphasizing that, if universities contribute to the innovation creation process, they cannot act alone: the role of the business sector is paramount. At the time, Mansfield found that academic research made an essential and immediate contribution to less than 10% of the new products or processes introduced by U.S. companies. This percentage might have increased in recent years[9] given the implementation of policies to promote university/industry collaboration by governments in the United States and elsewhere. As already noted, the survey results shown in Table 5.1 (which are from 2013) show that U.S. firms rank universities sixth in importance as sources of ideas for innovation. Results from a National Science Foundation (NSF) survey, "National Patterns of R&D Resources," indicate that industry expenditures to fund collaborative research and development (R&D) with U.S. universities from 1953–2016 have never been above 1.2% of total industry R&D expenditures.[10]

Recognizing the essential role of businesses in carrying out internal R&D is especially critical for developing countries, where both the business sector and the government often fall prey to the illusion (or, worse, *delusion*) that

Table 5.1 Sources of information used by firms for innovation; the column % shows the percentage of answers pointing to the factor on the respective line; the column R shows the ranking of the factor on the line

Sources	*India*		*China*		*Malaysia*		*Mexico*		*Brazil*		*S. Africa*		*U.S.*	
	%	*R*	*%*	*R*	*%*	*R*	*%*	*R*	*%*	*R*	*%*	*R*	*%*	*R*
Firms' own manufacturing process	81	1	76	3	87	1	49	4	75	1	49	1	78	2
Customers	72	2	89	1	71	3	64	1	68	2	35	2	90	1
Public research institutes	17	12	51	13	37	12	27	9	55	4	3	8	na	na
Independent suppliers	41	6	53	12	46	9	40	6	45	9	24	3	61	4
Technical publications and reports	51	4	56	9	62	5	44	5	50	7	4	7	na	na
Affiliated suppliers	38	7	63	7	80	2	25	11	50	6	na	na	na	na
Universities	**14**	**13**	**56**	**9**	**34**	**13**	**28**	**8**	**60**	**3**	**5**	**5**	**36**	**6**
Competitors	33	8	71	5	54	7	34	7	37	11	13	4	41	5
Internet	55	3	71	4	62	4	57	2	49	8	Na	na	na	na
Consulting or contract R&D firms	24	11	56	9	57	6	20	12	29	12	4	6	34	7
Fairs and expositions	29	10	59	8	42	10	53	3	53	5	na	na	na	na
Indigenous knowledge systems	51	4	82	2	41	11	na	na	42	10	na	na	na	na
Cooperative or joint venture with other firms	29	9	68	6	54	8	27	9	25	13	na	na	50	3

Source: Albuquerque et al., 5 Table 5.5, adapted by the author of this article.

university research will substitute for nonexistent business R&D through some magical process of "technology transfer" from scientists and engineers in universities to accountants and lawyers in industry. The CNI report mentioned previously is explicit on this point, emphasizing the importance of the business sector's "absorptive capacity." Without some knowledge of R&D and without teams dedicated to R&D, it is difficult for firms to benefit from university R&D[11] (Cohen & Levinthal, 1990). Interestingly, the same sentiment was voiced, 99 years before, by F. B. Jewett,[12] the first director of Bell Laboratories, in describing his views on the importance of absorptive capacity:

> to succeed in its proper field, industrial research must receive a continual stream of capable men and women thoroughly trained in methods of

scientific research, thoroughly grounded as to the geography of knowledge, and competent to appreciate any extensions in its boundaries and capable of immediately cultivating such extensions for the benefit of the particular industrial research organization with which they are connected.

Thus, it is not enough to increase technology transfer capacity from the university lab to industry – it is also necessary to build the capacity at the firm level to work as a willing and able partner with the university to make joint collaborations fruitful.

This chapter aims to show that it is possible to construct more meaningful indicators for understanding university/industry relationships. A better understanding of these processes in Brazil requires better measurement and evaluation using multiple indicators. For the present discussion, we analyze four indicators of university/industry research collaboration in Brazil:

1 Expenditures for industry-sponsored research at universities
2 Intensity of industry and university researcher co-authorship in scientific articles
3 Patent portfolio, intensity of industry and university co-titleship in patents, and licensing
4 Number of startups created by university students and faculty

We present examples to demonstrate the feasibility and potential usefulness of each of these indicators.

Business-sponsored research

One way to assess the intensity of university/industry research collaboration is to measure the volume of financial resources allocated by industry to universities yearly to support sponsored research activities. In most universities, contracts for sponsored research with industry are a coveted resource, not only to complement government funds but to support academic exploration in new and promising research areas. Collaborative research also plays an important role in training students and postdocs, especially in applied fields. In the United States and Europe, universities have "offices of sponsored research" that help identify and develop opportunities for joint research projects with industry. In Brazil most research-oriented universities have organized "innovation agencies" (or "innovative technology nuclei") to this end.

In Brazil, industry-sourced funds are especially interesting, and for this reason valued by the research community, as they can be used with much more flexibility than government funds and also because they can be used to pay additional salaries to university investigators on a contracted project. Government organizations, such as FINEP (Financiadora de Estudos e Projetos, or Financing Agency for Studies and Projects), FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo, or São Paulo Research Foundation), and EMBRAPII

(Empresa Brasileira de Pesquisa e Inovação Industrial, or the Brazilian Enterprise for Research and Industrial Innovation) have programs to foster university/industry research collaboration, offering funds to be matched by industry and by the universities that host the research activities.

Even though university/industry research collaboration has been fostered in Brazil, there are very few measurements of its intensity or impact. Research funding agencies tend to have data about yearly expenditures on collaborative projects, but few universities publish open data on the value of their research contracts with industry. In the state of São Paulo, only the State University of Campinas (Unicamp) publishes these data as a time series in its Statistical Yearbook.[13]

For this work we used the Unicamp data, which are publicly accessible and cover the period 1995–2017. We also obtained a specially built time series from the University of São Paulo (USP), covering the period 2006–15. In both cases, the data include only research contracts and not funds donated for other purposes. For U.S. universities, we used data published by the NSF's National Center for Science and Engineering Statistics (NCSES),[14] which provides information on doctorates, graduate students, funding, and expenditures for 2,014 universities and colleges from four surveys. We also referred to MIT's Report of the Treasurer for 2010 and 2015, which is available at http://web.mit.edu/annualreports/. To compare the data, we converted nominal values using the purchase power parity (PPP) exchange rate published by the World Bank.[15]

Before analyzing the data shown in Table 5.2, we must comment on a discrepancy that results from the way the data are calculated for the institutions considered. In the row labeled "Institutional funds," the values for Unicamp and USP are substantially larger than the values for MIT. For 2010, the figure for Unicamp is approximately five times higher than MIT's, while the figure for USP is 14 times higher. This disparity seems likely to be due to the use of different methodologies to estimate the value of institutional funds devoted to R&D.[16] For the Brazilian universities, the institutional funds dedicated to R&D are calculated considering full-time additional salary and its impacts on other costs to the institution. The costs of hospitals, museums, and retirement pay are subtracted from the total as these do not relate to R&D.[17] In the case of MIT, we were unable to obtain information about how institutional funds are specified.

Considering this discrepancy, we concluded it was more meaningful to use the ratio of expenditures covered by business contracts to expenditures covered by government contracts to compare the intensity of university/business research interactions (line "Business/gov. funding agencies %" of Table 5.2 displays this ratio for the years 2010 and 2016). The ratio is meaningful because most universities – whether public or private – rely on the private sector and government for research support, particularly government. Other sources may also be important to some universities, but typically they contribute a smaller share of research funds. At MIT, for example, approximately 30% of research

Table 5.2 Descriptive data for the years 2010 and 2016 for MIT, all U.S. universities included in the NCSES data, Unicamp, and USP

	MIT		*All U.S. univ. in NCSES*		*Unicamp*		*USP*	
In US $millions	*2010*	*2016*	*2010*	*2016*	*2010*	*2016*	*2010*	*2016*
Total revenues	2.663,1	3.426,8	–	–	1.295,1	952,9	2.507,4	2.175,1
Research expenditures	677,1	946,2	61.253,7	71.833,3	723,3	536,6	1.931,9	1.707,2
Governmental	458,0	504,4	41.327,7	41.902,2	178,1	144,1	532,1	410,4
Institutional funds	102,9	92,1	11.940,5	17.975,0	509,8	373,2	1.332,7	1.246,6
Business	68,9	159,5	3.197,6	4.210,6	35,4	19,3	67,1	50,1
Non-profit organizations	12,5	94,8	3.740,1	4.614,8				
All other sources	34,9	94,8	1.047,8	2.214,2				
HERD/total Revenues	25,4%	27,6%	–	–	55,9%	56,3%	77,0%	78,5%
Business/ gov. funding agencies %	15,0%	31,6%	7,7%	10%	19,9%	13,4%	12,6%	12,2%
Business/total revenues %	2,6%	4,7%	–	–	2,7%	2,0%	2,7%	2,3%
Faculty	1.025	1.04			1.75	1.91	5.865	5845
Undergraduate students	4.299	4.524			17.083	19.581	57.3	58.823
Graduate students	6.267	6.852			14.571	16.137	31.662	37.509
PhDs awarded	582	646			826	966	2.338	3.086

HERD: Higher education R&D expenditures
Data sources:
Financial: explained in the text
MIT students: http://web.mit.edu/registrar/stats/yrpts/index.html
MIT faculty: http://web.mit.edu/ir/pop/faculty_staff.html
USP, Unicamp: Statistical Yearbooks

expenditures come from other sources including nonprofits (foundations) as well as institutional investments and gifts.

Figure 5.2 shows the time series of the business-to-government (B/G) ratio for MIT, Unicamp, USP, and the set of U.S. universities in the NCSES database, according to the availability of the data. Several features are worth mentioning:

1 For both Unicamp and USP, the ratio of B/G expenditures is above the average for the set of U.S. entities covered in the NSF HERD survey.
2 Figure 5.3 compares the 25 universities in the United States with the highest R&D expenditures.

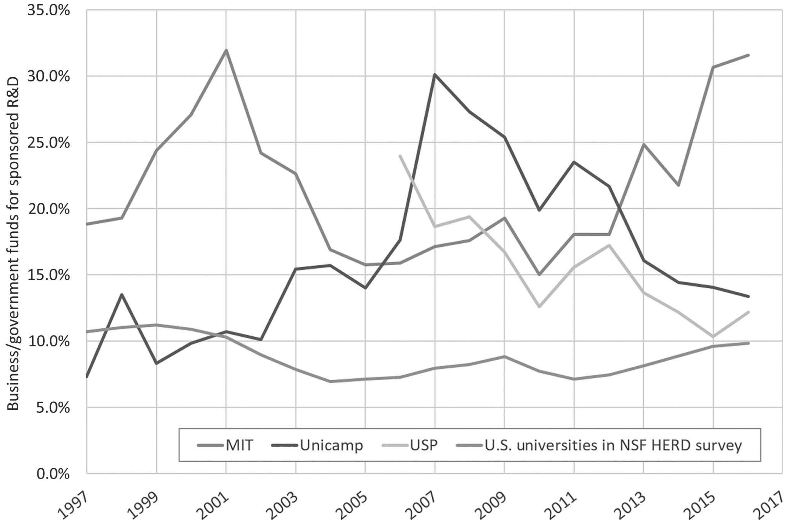

Figure 5.2 Ratio of business to government agency funds spent in research at MIT, Unicamp, USP, and the set of U.S. universities included in NSF's NCSES database (HERD = higher-education expenditures in R&D).

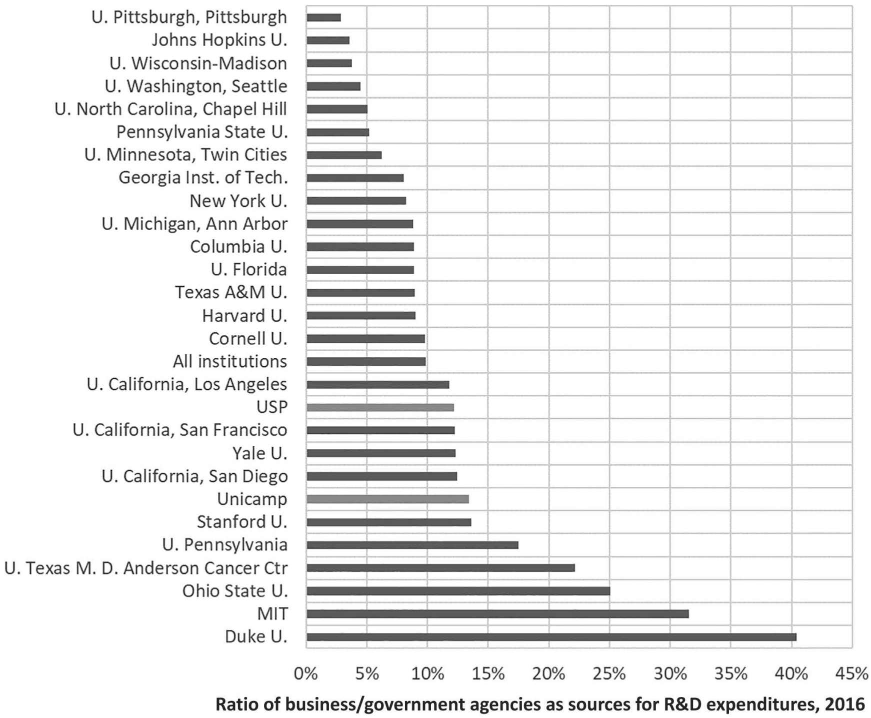

Figure 5.3 Ratio of business-to-government R&D expenditures at the 25 U.S. universities that have the highest R&D expenditures, and for USP and Unicamp

Source for U.S. universities: NSF HERD Survey, https://ncsesdata.nsf.gov/herd/2016/html/HERD2016_DST_21.html; for USP and Unicamp: this chapter.

3 For Unicamp, the B/G expenditure ratio ranges from 7% to 30% from 1997 to 2015, while for USP the range is from 25% to 10% from 2006 to 2015.
4 For the years between 2006 and 2012, the B/G ratio for Unicamp was higher than for MIT.
5 MIT saw a steep decline in its B/G ratio after 2001, which might be related to the economic troubles that started that year, compounded by the recession after 2008.
6 Starting in 2010, the B/G ratio for MIT rose steeply, reaching 32% in 2016. This change could be attributed in part to the U.S. economy recovering from the Great Recession.
7 For both USP and Unicamp, the B/G ratio has been falling since 2007, a decline that seems to have worsened after 2012, but that can be understood in light of the economic and political troubles that have afflicted Brazil since that year.[18]

Figure 5.3 shows that the ratio of business-to-government R&D expenditures at USP and Unicamp is not only higher than the average for the U.S. universities, as we have already noted, but also places USP and Unicamp in a good position relative to the 25 U.S. universities with the largest R&D expenditures. Only six U.S. universities have B/G ratios above Unicamp's ratio of 14% (i.e., Duke, MIT, Ohio State, University of Texas M.D. Anderson Cancer Center, University of Pennsylvania, and Stanford), while the other large U.S. research universities display percentages below 14%.

Before concluding this section, it is worth mentioning that USP and Unicamp are among the strongest research universities in Brazil. Thus, the finding that indicators for their level of collaboration with industry, such as the B/G ratio, are higher than the average for U.S. universities and in the same range as MIT should be generalized with care, or not at all. It is very likely that other research-oriented universities in Brazil display a similar level of university/industry interactions as USP and Unicamp, in Figure 5.2. ITA (Instituto Tecnológico de Aeronáutica), UFSCAR (Universidade Federal de São Carlos), UFRJ (Universidade Federal do Rio de Janeiro), UFSC (Universidade Federal de Santa Catarina), and UFMG (Universidade Federal de Minas Gerais) come to mind, but unfortunately no data are available at present.[19] The data that are available, however, clearly indicate that it is misleading to state, as many do, that there is little university/business collaboration in Brazil.

Co-authorship in scientific articles

Another indicator for university/industry research collaboration that is widely available for numerous institutions is the number and share of published articles co-authored by researchers from a university and the business sector. To explore this indicator, we used data from the Web of Science (WoS), obtained through searches performed at the normal WoS interface available to researchers.

While the InCites database has information on the percentage of articles with industry co-authorship, these data are incomplete as InCites is not yet able to correctly classify a large number of business organizations in Brazil (and elsewhere, for that matter). To obtain the data shown here, we devised a search routine that was specially built to unveil affiliations with Brazil's business sector. The procedure involved identifying all scientific documents in the database with at least one author in Brazil (> 300,000 records), checking the authors' organizational affiliation (> 22,000), and then checking for organizations that were in the business sector. In the end, we identified more than 4,000 organizations. At this point we ran a search for articles with authors who were affiliated with one of the 4,000+ business-sector organizations and any Brazilian university (obtained in a separate list).

The result is shown in Figure 5.4, which charts the number of articles with co-authors in the business sector and in universities over time. The lighter color bars indicate articles co-authored with researchers at Petrobras. While the growth seen in Figure 5.4 is interesting, it is also relevant that the volume of articles with business co-authors has been increasing as a percentage of the total scientific output of universities in Brazil and in São Paulo specifically (Figure 5.5).

Three distinct periods in the evolution of university/business co-authorships in Brazil can be discerned in Figure 5.5. In the first period, from 1972 to 1984, the share is somewhat stable, fluctuating around 0.5%. Between 1985 and 2004 there is a pronounced growth, albeit with large oscillations, with the percentage

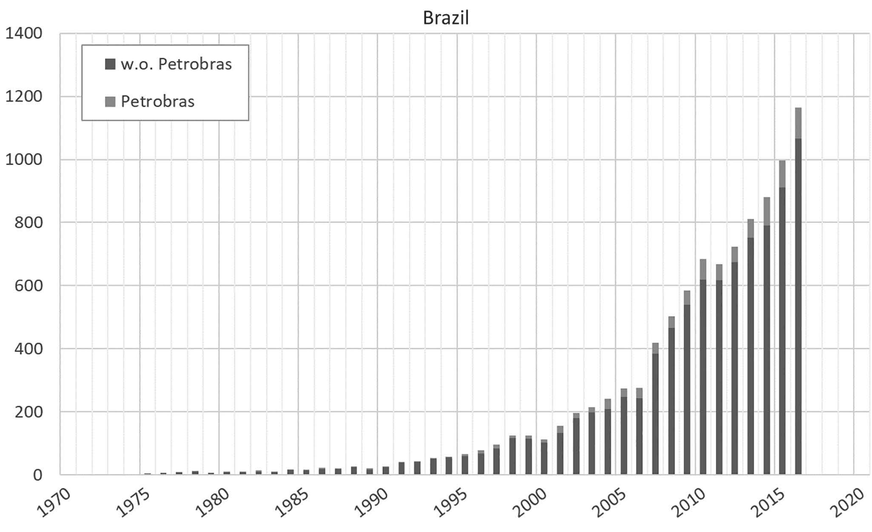

Figure 5.4 Quantity of articles, by year, with authors in universities in Brazil and co-authors in the business sector; we included a separate mark for the number in each year with co-authors from Petrobrás to make it clear that, although relevant, the set is not dominated by these

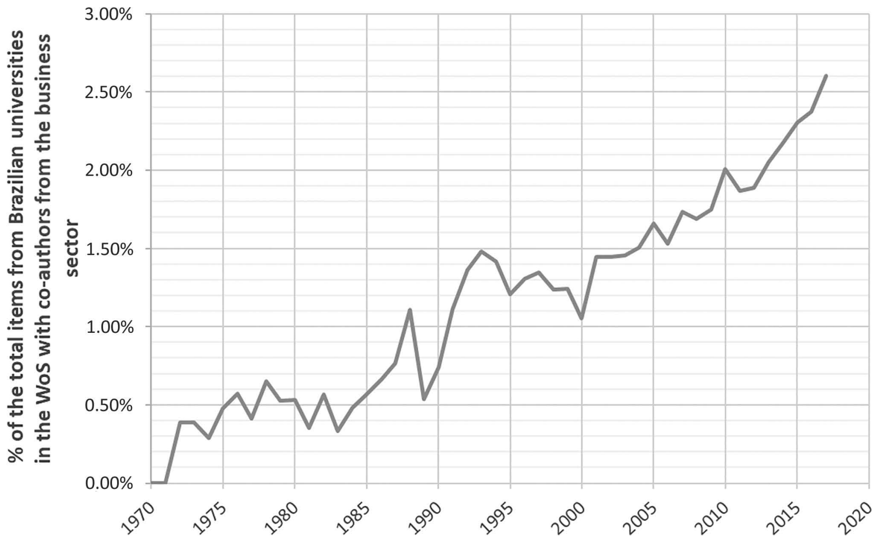

Figure 5.5 Fraction of the total scientific production in Brazil, São Paulo, and Brazil outside São Paulo that have co-authors from universities and business

of co-authored articles reaching 1.5% in 2004. Then, after 2006, the curve rises steeply, with growth accelerating in the years after 2012. Though this growth is encouraging, an international comparison (Figure 5.6) demonstrates that there is room for greater progress. In Brazil, the share of articles co-authored with business is at 2.4% (2.5% in the state of São Paulo); by contrast, the shares in South Korea, Germany, and France range from 3.8% to 4.4%.

At 2.5%, the percentage of articles co-authored with businesses for universities in the state of São Paulo, between 2015 and 2017, was similar to the share found in 28 European countries, 3% above the share for Spain, and 54% above the global baseline. On the other hand, the percentage for Brazil is 44% below that found in France and 42% below the share in Germany.

Comparing rates of business co-authorship at Brazilian universities

Figure 5.7 shows how the university/business co-authorship percentage has been evolving for some research-intensive universities in Brazil. ITA (the Aeronautics Institute of Technology) has the highest ratio (around 6%), with a steep increase after 2007, albeit over a small total number of publications (188 articles in 2016). UFRJ (Federal University of Rio de Janeiro) also displays strong growth in university/business co-authorship after 2013, almost doubling its percentage in only four years. Rates increased consistently at USP, Unicamp, and UFSC (Federal University of Santa Catarina) over the last several years, with more intense growth in the last two years (2015–17).

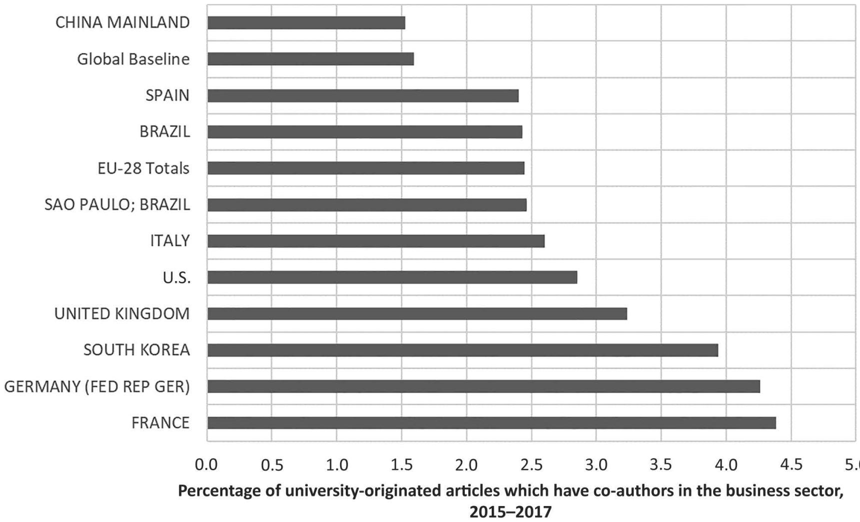

Figure 5.6 Fraction of articles with co-authors from universities and the business sector in a set of countries and regions

Source: For Brazil and São Paulo, author's measurements in the Web of Science database; for the other regions: Clarivate's Incites.

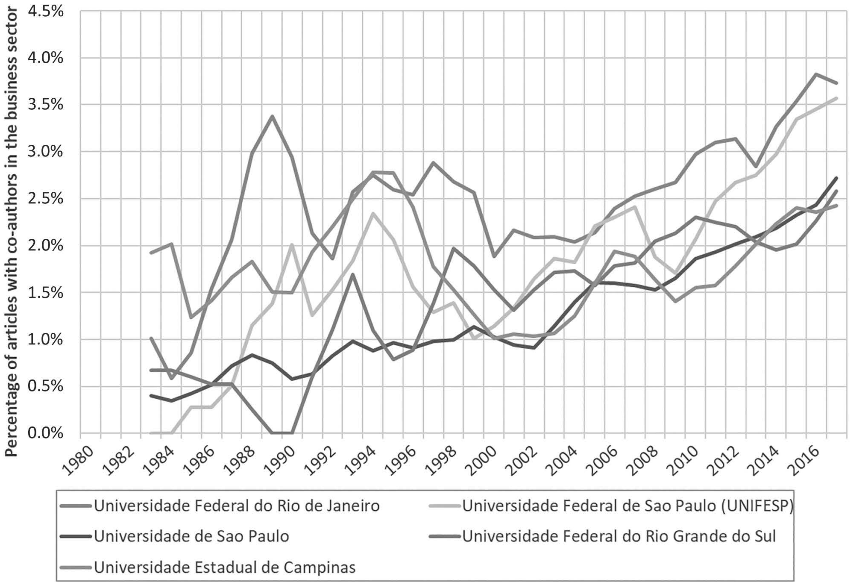

Figure 5.7 Evolution of university/business co-authorship rates (as a percentage of total publications) for the five universities in Brazil that have the largest number of articles co-authored with the business sector

Figure 5.8 compares rates of university/business co-authorship for selected universities in Brazil and selected universities in the United States. The data indicate that even in a country with a strong tradition of university/industry research collaboration, such as the United States, there is wide variation in this indicator.

At 11%, MIT has the highest business co-authorship percentage in this set, while the rate for Texas Tech University (TTU)[20] is just 4%. The rate for the Brazilian universities ranges from 1.7% (UNESP) to 4.4% (ITA).

It is clear from Figure 5.8 that business co-authorship at universities in Brazil lags behind that observed for U.S. universities. The increase in co-authorship rates in recent years suggests that Brazilian universities will catch up in due time, but it is important to take note here of some differences between the environment in which universities operate in Brazil and the environment for universities in the United States. The main difference, in our view, is the fact that Brazil's business sector employed 59,364 researchers in 2014,[21] while the figure for the United States in the same year was close to 960,000 (in full-time equivalent positions or FTEs).[22] Thus, the number of potential co-authors from industry in the United States is 16 times larger than in Brazil.

A characteristic that distinguishes UFRJ from the other Brazilian universities included in our comparison is its very high rate of collaboration with Petrobras. For the period 2015–17, co-authorship with Petrobrás accounted for 14% of

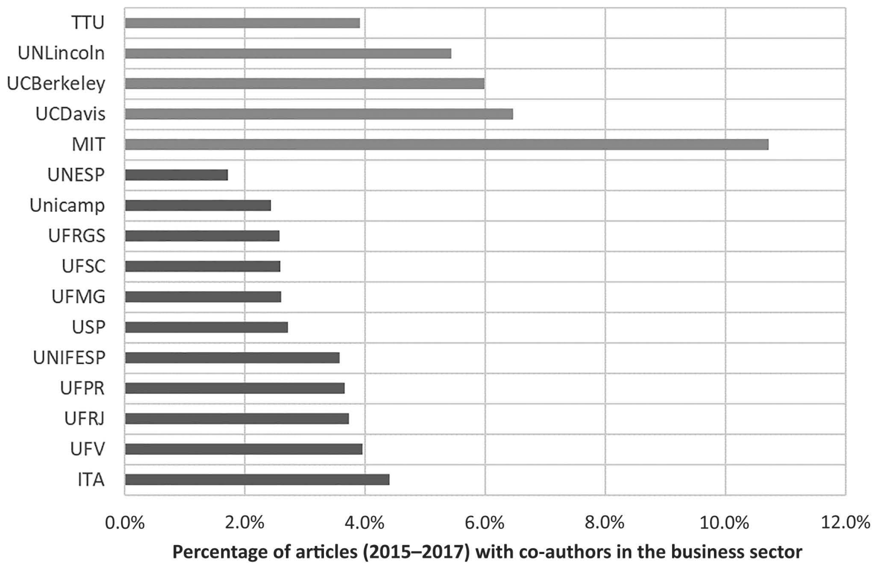

Figure 5.8 Comparison of university/business co-authorship rate for the ten universities in Brazil that have the largest number of articles co-authored with the business sector, and for some U.S. universities over the period 2015–17

Source: Measurements described in this chapter for all the universities shown.

the total articles with business-sector co-authorship from all universities in our analysis. For UFRJ, this percentage was 34%. This result is not surprising considering the geographic proximity of CENPES (the Petrobras research center) to the UFRJ campus and the effective work of COPPE-UFRJ in developing research partnerships.

Main business-sector collaborators in university research

Petrobrás appears as the main corporate co-author, which is to be expected considering that the company sponsors numerous R&D activities in Brazil and also has a strong program for interacting with universities, as mandated by federal legislation.

Pharmaceutical companies also appear prominently in Table 5.3. This industry has played a larger role in university collaborations in the last 20 years, as the number of articles published by Brazilian researchers in the field of health sciences has increased.

Among the 40 companies shown in Table 5.3, 15 are Brazilian. Vale ranks seventh and has recently been expanding its research collaborations, especially since the organization of the Instituto Tecnológico Vale in 2012. Eletrobrás ranks ninth in the list, and Fibria appears as 11th. Other companies in the pulp and paper sector have joined Fibria, such as Suzano (ranked 34th in Table 5.3) and companies associated with IPEF (Instituto de Pesquisas e Estudos Florestais, or

Table 5.3 The 40 companies with the most co-authored articles with university researchers in Brazil (2011–17)

Rk	*Name*	*Qty*	*Rk*	*Name*	*Qty*
1	Petrobras	1,050	21	Eli Lilly	47
2	Novartis	174	22	Syngenta	47
3	Pfizer	118	23	Novo Nordisk	45
4	Roche	94	24	Amgen	42
5	GSK	94	25	Dow Agrosciences	42
6	IBM	93	26	Itaipu	40
7	Vale/ITV	84	27	Bristol-Myers	39
8	Merck	78	28	Genzyme	38
9	Eletrobras	72	29	Whirlpool/Embraco	38
10	AstraZeneca	72	30	Fundecitrus	36
11	Fibria	70	31	Ericsson	36
12	Westat	64	32	Genentech	34
13	Janssen	57	33	IPEF	33
14	Embraer	56	34	Suzano	31
15	Bayer	55	35	CEMIG	31
16	Monsanto	54	36	AT&T	30
17	Agilent	52	37	Furnas	26
18	Braskem	51	38	Microsoft	26
19	Boehringer Ingelheim	49	39	Apis Flora	26
20	Sanofi	49	40	Votorantim	25

Forest Science and Research Institute), a private institute created by a consortium of pulp and paper companies. Embraer ranks 14th and has been increasing its co-authorship activity recently. Apis Flora, initiated in 1982, is an interesting case: a small company with a strong R&D program that has benefited from a number of FAPESP's Small Business Innovative Research grants.

The prominence of foreign companies in the list reflects the small number of Brazilian companies with advanced R&D activities. It also shows that universities in Brazil have capabilities to contribute to industrial R&D, and these capabilities seem to have been noticed more by foreign companies than by Brazilian ones. This conclusion is consistent with other indicators such as patents registered by the business sector, or the number of researchers working for companies in Brazil.

Patent portfolios, intensity of industry and university co-titleship in patents, and licensing

Patents are a primary tool for measuring innovation, both at universities and, more broadly, at the country level. Increasing patenting activity at universities has been a central goal of many of the innovation policies implemented in Brazil over the past two decades. Patents are also useful instruments for facilitating university/industry interactions, whether through joint ownership of title or through licensing of university-owned patents. This section focuses on patenting activity as an indicator of the quantity and/or quality of university/industry research collaboration.

Quantity of patents filed is the indicator that has been most often used to demonstrate universities' contributions to innovation. Most universities value this number highly and are proud of their growing patent portfolio. Many established innovation agencies at Brazilian universities (which function much like technology transfer offices at U.S. universities) have done effective work with their faculty to develop a culture for valuing intellectual property rights, with reasonable results – so much so that in recent years, universities figure among the largest patent filers in Brazil. In more developed economies, by contrast, industry is often a larger filer of patents.

Table 5.4 shows patents filings relative to faculty size for selected Brazilian and U.S. universities. Consistent with results obtained by Pacheco (see Note 4), we find that the number of patents filed per 100 faculty members at Brazilian universities lags behind the rate for prominent U.S. universities. However, a cautionary note is in order with respect to the difficulty of determining the actual workforce size to be used in the denominator, since U.S. universities normally have more public support for hiring research associates (a similar difficulty is discussed in the "Business-sponsored research" section with respect to estimating the institutional funds directed to research activities).

In light of this caveat, it seems preferable to compare quantity of patents filed to university R&D expenditures. Figure 5.9 shows these data for 2016. Using R&D expenditures avoids the problems associated with counting personnel.

Table 5.4 Patents filed and articles published per 100 faculty for universities in Brazil and the United States in 2016

University	*New patents filed*	*Articles* *WoS*	*Faculty*	*Patents filed per 100 faculty*	*Articles per 100 faculty*
CalTech	355	3,372	300	118,3	1,124
MIT	470	7,109	1,040	45,2	684
Stanford U.	288	9,420	2,219	13,0	425
Harvard U.	314	41,424	2,459	12,8	1,685
U. Nebraska, Lincoln	174	2,053	1,699	10,2	121
U. California	1,329	39,502	22,110	6,0	179
Boston U.	122	4,054	3,870	3,2	105
Unicamp	62	3,072	1,910	3,2	161
U. Massachusetts	133	4,670	5,712	2,3	82
UFPR	53	1,567	2,411	2,2	65
U. Central Florida	49	1,412	2,481	2,0	57
UFMG	70	2,275	3,465	2,0	66
TTU	29	1,638	1,740	1,7	94
USP	60	9,524	5,845	1,0	163
UFSCAR	13	1,139	1,437	0,9	79
UNESP	30	3,836	3,631	0,8	106
UFRJ	15	2,855	4,066	0,4	70

Source: AUTM Database for U.S. universities' patents; websites of universities for faculty; INPI for Brazilian universities' patents; Incites for articles.

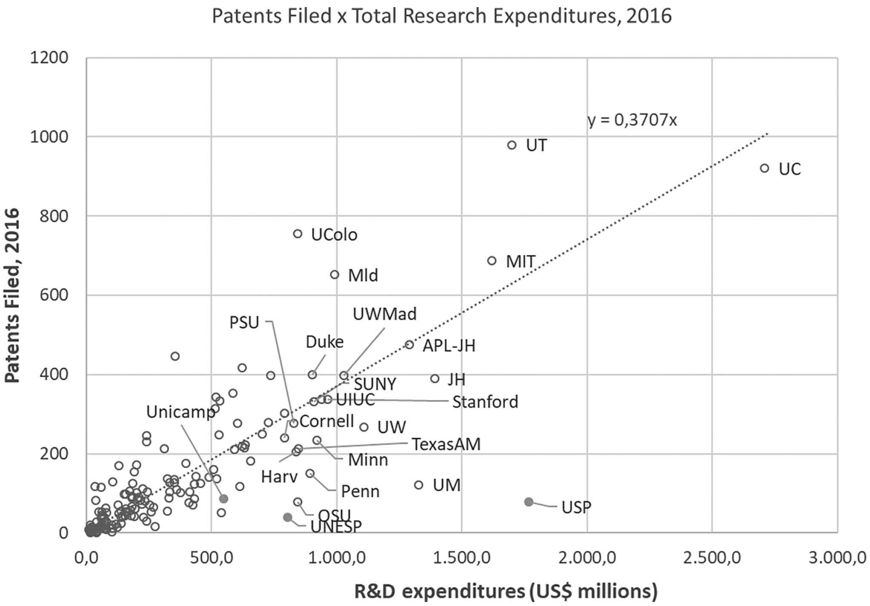

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Figure 5.9 Patents filed versus R&D expenditures for 160 universities in the United States

Source: AUTM Annual Report, 2016, and for USP and Unicamp; UT: U. of Texas system; UC: U. of California system.

We find that patents do not come cheap: the graph shows that U.S. universities file, on average, one patent for every US$2.7 million in R&D expenditures. The data points for Unicamp and USP suggest a much lower rate of patent filings relative to R&D expenditures, at 40% and 12% of the average for U.S. universities (indicated by the trend line in the graph), respectively.

While quantity of patents filed is a basic indicator of the potential for transferring technology innovations from the university to the business sector, another relevant indicator is the number of patents in which the university shares title with a business or company. This indicator must be regarded with care, as the practice at many Brazilian universities has been to release title to patents in exchange for benefits obtained through joint research with industry partners as a way to avoid the complex process of licensing technology from public organizations. Not having title to the intellectual property does not mean the university cannot receive benefits from licensing or selling a patent – these benefits are usually written into agreements between universities and industry partners.

In principle, information about joint title to patents can be obtained from INPI (Instituto Nacional Da Propriedade Industrial, or National Institute of Industrial Property) or other databases, but most universities do not value this indicator. An internal publication by INPI examined this indicator for selected Brazilian universities from 2004 to 2008.[23] It finds that Unicamp filed 272 patents during this period; in 43 of these filings, Unicamp shared title with another entity. Among these entities, 15 were companies. USP filed 257 patents, of which 113 had shared title; 14 companies were among the entities with which USP shared title. UFMG filed 154 patents and shared title with seven companies during this period, while UFRJ filed 141 patents and shared title with six companies.

A third indicator related to intellectual property is the percentage of patents licensed and the amount of revenues obtained through licensing. This issue is widely misperceived in Brazil, where many in government and academia have the mistaken impression that most U.S. universities make great amounts of money from licensing intellectual property. Figure 5.10 shows that about half the U.S. universities that participated in the Association of University Technology Managers (AUTM) survey for 2016 earned gross revenues from licensing that were less than 1% of their R&D expenditures that year, 70% earned revenues below 2%, and only three universities (out of 164) obtained revenues above 20% of their R&D expenditures. Note that the AUTM data refer to gross revenue, indicating that income from licensing is even more meager if we consider net revenues. Data on licensing revenues are not available for Brazilian universities, with the exception of Unicamp, which publishes this information in its Statistical Yearbook. For 2015 and 2016, Unicamp's licensing revenues amounted to 0.2% and 0.1% of the university's R&D.

Even if licensing revenues are relatively small, this does not mean that university efforts to file and license patents are irrelevant. Transferring technology through licensing is one of the many ways universities contribute to the economy, and it complements other actions. The mistake would be to assume that

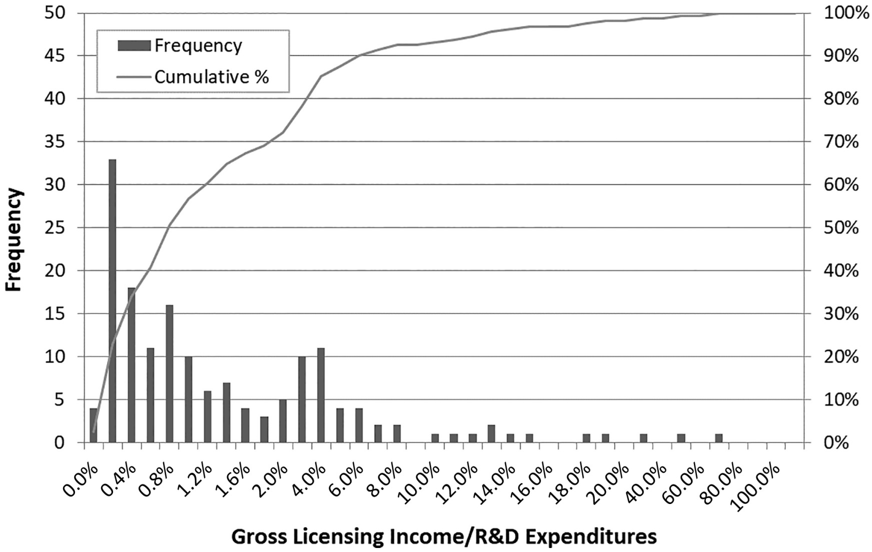

Figure 5.10 Distribution of the ratio (gross licensing income/R&D expenditures) for 164 universities in the U.S. in 2016

Source: AUTM Annual Report.

licensing revenues could substitute for the investment of public funds to support research. The 2016 CNI Report cites (p. 18) the conclusion of John Fraser, an ex-president of AUTM, on this matter: "no longer is licensing income seen as a comprehensive indicator of success."

University-related startup companies

Number of startups launched by university students, faculty, or staff is another useful indicator for certain aspects of university/industry research collaboration. While joint research, with business-sector co-funding, covers most cases of collaboration with medium-size and large companies, startup formation focuses on interactions and opportunities that involve small businesses.

In Brazil, few universities keep information on startups that originated from the university. Unicamp maintains the most complete database;[24] using this database, Figure 5.11 displays the total number of startups launched from Unicamp for every year since 1974.

Figure 5.12 shows the distribution of these startups across industry sectors; it indicates that most startup activity was in the fields of information technology and engineering. Each year Unicamp surveys the companies in its database. Several results from 2016 underscore the economic benefits university startups provide:

1 In 2016, companies that originated from Unicamp sustained 28,000 jobs.
2 These companies together generated annual revenues of R$3 billion.
3 More than a quarter (26%) of the surveyed companies had an office abroad.

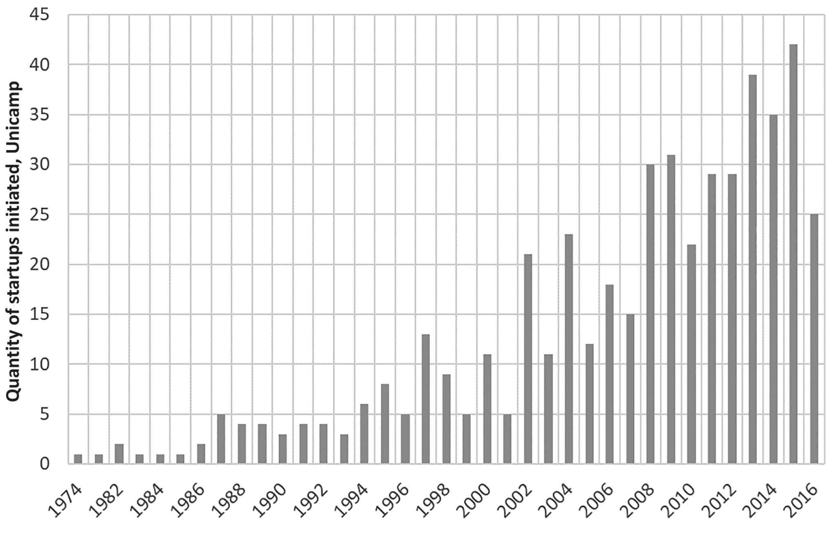

Figure 5.11 Quantity of startups initiated by students and faculty from Unicamp, by year

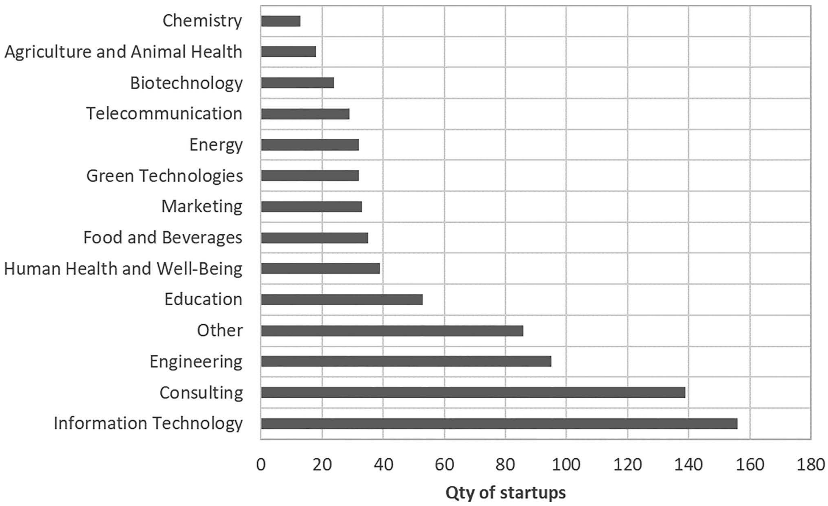

Figure 5.12 Unicamp startups by sector

Source: Agência de Inovação da Unicamp, 2017.

Figure 5.13 compares the data from Unicamp with startup activity for U.S. universities, using data from the AUTM survey. The figure correlates the number of startups generated at a university in a given year with R&D expenditures the same year. This is not intended to imply that all startups arise from research performed in the same year; rather, R&D expenditures are used as a proxy for innovative activity and research vitality at each institution.

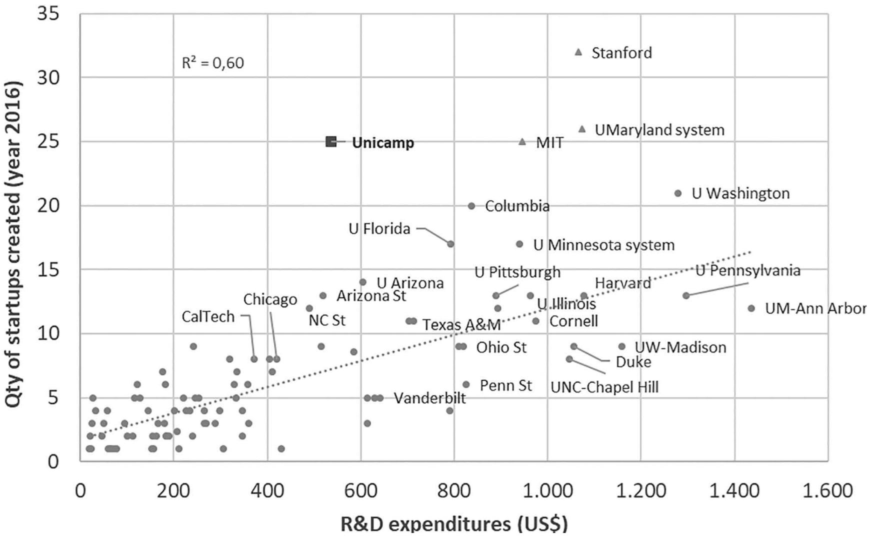

Figure 5.13 Number of startups launched plotted against R&D expenditures for Unicamp and U.S. universities; base year is 2016

Source: AUTM database and Unicamp's Statistical Yearbook.

Interestingly, Unicamp fares quite well in this comparison to U.S. universities. Its performance with respect to startup formation may be boosted by the fact that Brazilian universities, so far, have not required students or professors to share title or royalties from companies they may start as a result of their work at the university. In other respects, however, such as business growth over time, startup performance in Brazil is not yet as robust as in the United States. Part of this weakness might reflect the shortcomings of the venture capital environment in Brazil. In 2017, the venture capital market in the United States mobilized more than US$70 billion[25] compared to R$8.3 billion in Brazil.[26]

Conclusion

This chapter has outlined indicators that may be helpful in assessing the evolution of university/industry research collaboration in Brazil, and the effectiveness of public policy instruments created to facilitate and foster this type of collaboration. Additional indicators beyond those discussed here should also be considered. Our chief aim in this chapter has been to demonstrate that the data are available to apply these indicators and benchmark them. Additionally, our findings suggest that there are parts of the science and technology system in Brazil in which the role of university/industry research collaboration is already more than "incipient," but is well established and increasing over time.

Nonetheless, the data presented here point to important hurdles to be considered:

1 A large fraction of the industry researchers who are co-authoring with researchers at Brazilian universities are employed by companies that are not Brazilian and do not even sponsor any R&D in Brazil. This suggests that many Brazilian universities have the state-of-the art, internationally competitive research capacity to attract the interest of foreign partners. At the same time, few Brazilian companies are using Brazilian universities' research capacity. We address some possible reasons for this, but it suffices to say that the protectionist strategy that has dominated Brazilian economic policy for decades may be cutting many Brazilian companies off from global value chains and reducing their capacity for, or interest in, pursuing advanced innovative R&D.
2 The size of the Brazilian business sector's R&D enterprise is small when compared to that of developed countries. A single point noted in the "Comparing rates of business co-authorship at Brazilian universities" section of this chapter is telling: the business sector in Brazil employs one-sixteenth the number of researchers employed by the business sector in the United States. This disparity limits the potential for fruitful university/business interactions by reducing the Brazilian business sector's capacity to absorb innovative advances and engage with university researchers.
3 The harm done to Petrobras by government policies enacted before 2015 also reduced the effectiveness of one of the country's important instruments for developing tech-based companies, particularly suppliers in the oil sector. Together with the economic troubles that have led to Brazil's current overarching difficulties, serious damage was done to the capability of the government and the private sector to invest in R&D.
4 Most universities still handle the role of developing business-sector partnerships in an amateurish way. Institutional support for researchers interested in developing collaborations is weak in most cases. This leads individual researchers to try and work out contracting and juridical issues on their own, which is unfortunate since help from professionals experienced in these areas could speed up negotiations. This lack of expertise leads to frequent complaints, among researchers and in the national debate, about "excessive bureaucracy" and the like. Contracting, in general and especially in contexts where the public interest must be protected, necessitates some measure of bureaucracy, but these details should be managed by professionals and not by scientists who should be focused on conducting research and supervising students. Those universities in Brazil that have the professional capacity to support collaborative activities are forging ahead rather well and using the available opportunities.

Applying learning from useful indicators can stimulate the organizations that are part of Brazil's science and technology system to consider the implications of current policies and design better initiatives. This will tend to foster continuity in national efforts to address technology transfer challenges and encourage criticism and suggestions for improvement from the academic and business research communities. It will also inform the national debate, leading to higher-quality proposals for reforming existing policies. Evidence-based policymaking might prove more effective and deliver superior results than the traditional practice of "policymaking by anecdote" that has so frequently characterized Brazil's approach in the past. Targets could be set, indicators tracked, and policies adjusted to obtain stated objectives.

What Brazil clearly *cannot* afford, on the other hand, is to use no indicators of university/industry research collaboration at all to provide a real, objective check on progress in this critical area of science and technology policy.

Notes

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2 "Industria e Ensino", O Estado de São Paulo, August 4, 1968, p. 6.
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4 Pacheco, C., 2016, "Inovação: o papel da cooperação universidade-empresa", CNI, Brasília, 2016.
5 Adam Smith, "The Wealth of Nations", Book 1, Chapter 1 (www.bibliomania.com/NonFiction/Smith/Wealth/index.html).
6 IBGE's innovation surveys were done in 2000, 2005, 2008, 2011, and 2014. See www.ibge.gov.br/estatisticas-novoportal/multidominio/ciencia-tecnologia-e-inovacao/9141-pesquisa-de-inovacao.html.
7 Pinho M. and Fernandes, A. Table 5.5, adapted by the author in Albuquerque, E., Suzigan, W., Kruss, G., Lee, K, "Developing National Systems of Innovation: University-Industry Interactions in the Global South". Edward Elgar Publishing, IDRC, January 30, 2015 (available in open access at www.idrc.ca/en/book/developing-national-systems-innovation-university-industry-interactions-global-south).
8 E. Mansfield, "Contributions of new technology to the economy", in Technology, R&D and the Economy, ed. Bruce Smith e Claude Barfield. P. 125 (The Brookings Institutions, Washington, DC (1996).
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11 Cohen, W. M., and Levinthal, D.A. (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* 35(1), pp. 128–52.
12 Jewett, F.B., "Industrial research with some notes concerning its scope in the Bell Telephone System", Presentation at the 3333d Meeting of the American Institute of Electrical Engineers, Philadelphia, PA, October 8, 1917.
13 Unicamp, www.aeplan.unicamp.br/anuario/anuario.php.
14 https://ncsesdata.nsf.gov/profiles/site.
15 http://data.worldbank.org/indicator/PA.NUS.PPP?locations=BR.

16 Data for USP and Unicamp were obtained following the specifications of the OECD Frascatti Manual, which specifies that the fraction of total institutional costs ascribed to R&D activities follow an estimate of the time dedicated by faculty and staff to these activities. This determination involves difficulties that are well recognized internationally and is highlighted in the OECD Frascatti Manual where the suggestions for the estimation procedure are the subject of a special Annex. One of the recommendations suggests that the estimation of the costs and personnel dedicated to R&D in higher-education institutions should be based on surveys of the time dedicated to each faculty activity or, if such surveys are not available, on other ways to assess the fraction of R&D in the total costs of higher education. The estimates for Unicamp and USP are described in detail in Part A of Chapter 3 of FAPESP's publication on S&T Indicators, 2010. http://fapesp.br/indicadores/2010/volume1/cap3-Parte-A.pdf.
17 It might be argued that hospitals and museums contribute to the R&D activities at a university, so the estimates obtained following the algorithm described must be considered a lower bound.
18 Data recently announced by Unicamp for the year 2017 point to a recovery, raising the business/government fraction to 23% (www.inova.unicamp.br/noticia/correio-popular-noticia-balanco-das-parcerias-firmadas-pela-unicamp/).
19 While this work was being finished we obtained data for ITA: between 2010 and 2017 the ratio of business-to-government-agency R&D funding was between 42% and 88%. In 2017 the percentage was 87%.
20 TTU and University of Nebraska Lincoln were chosen here as FAPESP has developed research collaborations with these universities and held a FAPESP Week symposium at both campuses in 2017. Both are strongly research-intensive universities, albeit located at a distance from high-technology hubs in Massachusetts or California.
21 MCTIC, Indicadores de C&T&I, www.mctic.gov.br/mctic/opencms/indicadores/detalhe/Recursos_Humanos/RH_3.1.2.html.
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