Benchmarking University-Industry Research Collaboration in Brazil

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> 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. (Charles Babbage, 1832)

Summary

University-Industry research collaboration has been a pillar of science, technology and innovation policy in Brazil for a long time. However, surprisingly enough, there are very few cases of indicators developed to assess the state of the relationship. In most discussions policy makers and researchers start by stating that "university industry research collaboration is incipient" and conclude that it is necessary to use more government money to foster it. Rarely measures of success have been established, beyond counting the value of funds spent in fostering.

In this article we propose three non-original (but rarely explored in Brazil) indicators that might allow for a more effective follow-up of the policies. These are: (a) the value of expenditures by the business sector to support research in universities; (b) the quantity and intensity of university-business (U-B) co-authorship in scientific articles; and (c) the quantity of start-ups created by students and faculty of universities. These are reasonably simple indicators that can be identified and followed by each university and by governmental agencies, allowing for a measure of success (or lack thereof) of the established policies.

We exemplify the proposed indicators using: (a) data from USP and Unicamp for the business sector expenditures, demonstrating that as a percentage of the governmental funding for research the business funding percentage is competitive with the numbers found in the USA and other developed countries; (b) data for co-authorship mined in the Web of Science that shows that in the state of São Paulo the intensity of U-B co-authorship is 20% below that found in Spain or in EU-28, 67% that found in the USA and 50% of the value found in France or Germany; (c) data about the size of the patent portfolio, the joint title to patents and licensing revenues; and (d) data for the number of start-ups created annually with data for Unicamp, showing that the number of start-ups created by students and faculty each year is very competitive with that found in universities in the USA with similar, or even higher, R&D expenditures.

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1 Introduction

University-Industry Research Collaboration (U-IRC) has been an important part of science, technology, and innovation policy in many regions as it is believed that more intense interactions might assist in driving business sector competitivity. The subject has been on the agenda for many years, including in Brazil: in 1968 the Brazilian National Confederation of Industry (CNI) released a statement on industry-university interactions[1] in which it was defended that:

> "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 pratctical applications. For this very reason, research represents one of the motivations for its intimate and permanent association with the University."

U-IRC has been studied by several authors. For the case of developing countries, seeking economic catching-up, Mazzoleni and Nelson[2] argue that

> "Universities and public research organizations are key institutions supporting this process of catching up".

However, agreeing on the relevance of university-business interactions is one matter, but finding how to make it work for development is another problem. The same authors state[2]:

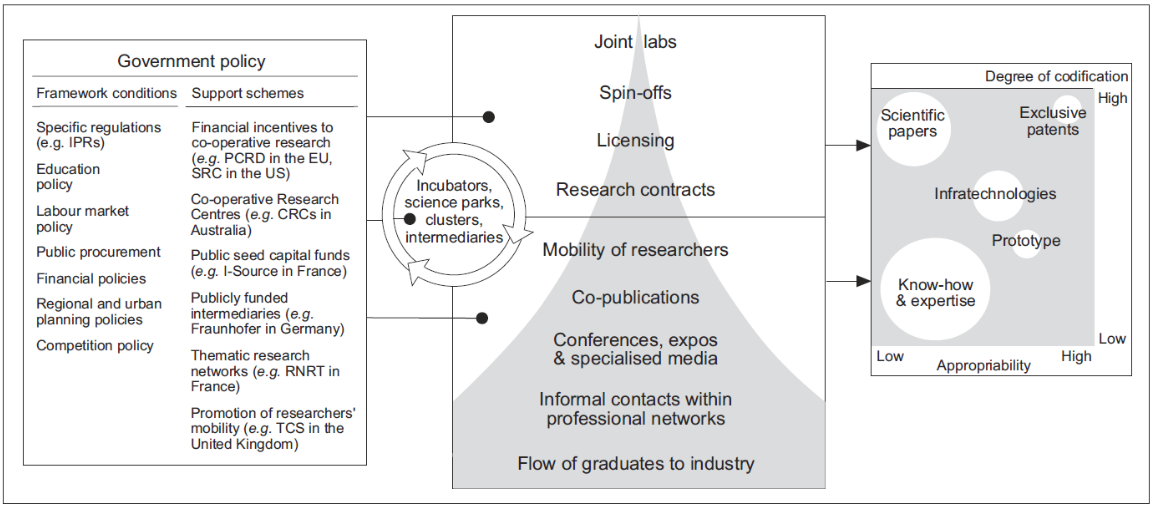
> "Successful public research programs of other countries can and should serve as broad guides for countries trying to establish their own programs, but as indicators of principles to follow, not as templates. There is first of all the problem that it is very difficult to identify just what features 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".

The complexity of the interaction processes between universities and the business sector is well illustrated in Figure 1.

The complexity in the interaction mechanisms *per se,* is compounded by the fact that the process of innovation is not governed solely by knowledge or its sharing, but by many other characteristics of countries or regions such as intellectual property legislation, public-private interaction regulations, economic and financial environment, propensity to reach international markets, and others. Still, business sector surveys tend, frequently, to rank the relevance of universities and business sector

[1] "Industria e Ensino", O Estado de São Paulo, August 4, 1968, p. 06.
[2] Mazzoleni, R., Nelson, R.R., "Public research institutions and economic catch-up", Research Policy 36 (2007) 1512–1528.

interactions highly. For the case of Brazil this is highlighted in a recent report by CNI[3] (written by Carlos A. Pacheco).



Source: OECD.

Figure 1. Formal mechanisms that might be involved in university-business interaction in research. (Source: OECD 2002, Benchmarking Industry-Science Relationships, p. 23)

Adam Smith alluded to that in his “An Inquiry into the Nature and Causes of the Wealth of Nations[4]”, where he described succinctly the process by which “improvements in machinery” were reached, stating a role for the users of machines, for the makers of machines (these two classes would be the business ssector) and for the “philosophers or men of speculation” (those would be the present day equivalent to 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 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 ssector innovation. In Brazil’s IBGE PINTEC university interactions come repeatedly among the 5 or ten most important sources of ideas for industry. A recent study by Pinho and Fernandes[5] finds (Table 1) that

[3] CNI, 2016, “Inovação: o papel da cooperação universidade-empresa”, Brasília, 2016.
[4] Adam Smith, "The Wealth of Nations", Book 1, Chapter 1 (http://www.bibliomania.com/NonFiction/Smith/Wealth/index.html)
[5] 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 https://www.idrc.ca/en/book/developing-national-systems-innovation-university-industry-interactions-global-south).

among the countries studied, in Brazil the relevance attributed by firms to Public research institutes and Universities is the highest, ranking 2nd and 3rd, while, for example, in the U.S. firms ranked Universities as 6th and in China 9th. The authors state that:

> "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."

Table 1. Sources of information used by firms for innovation (Source: Albuquerque et al.[5], Table 5.5, adapted by the author of this article)

Sources	India		China		Malaysia		Mexico		Brazil		So.Africa		USA	
	%	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

A note of caution about U-IRC comes from Mansfield who addressed the role of the U-B interactions[6], demonstrating that, if universities have a contribution to the innovation creation process, they cannot act alone so that the role of the business sector is paramount. He found that academic research made an essential and immediate contribution to less than 10% of the new products or processes introduced by companies in the United States. In other words, 9 out of 10 innovations are born within company walls. Mansfield stated,

> ". . . of the new products or processes that could not have been developed without the aid of academic research, very few were invented at universities; on the contrary, the majority were invented as by-products of the new theoretical and empirical discoveries, as well as the new types of instrumentation employed in the making of those discoveries, that came out of academic research, rather than being invented specifically through such research itself. This seems unlikely to change. The successful development of products or processes

[6] 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).

> demands an intimate knowledge of market details and production techniques, as well as the ability to recognize and weigh the technical and commercial risks, a skill that comes only with direct experience in the company. This expertise does not exist within universities, and it is unrealistic to expect that it will arise there."

This finding is especially relevant in developing countries, in which many times the business sector and the government fall prey to the illusion (or, worse, delusion?) that university research will substitute for non-existent business R&D, through a magical process of "technology transfer" from scientists and engineers in universities to accountants and lawyers in industry. The CNI report[3] mentioned above is explicit in this matter:

> "The literature emphasizes that, to a large extent, this performance (of industry in interacting effectively with universities) depends on what is called "absortive capacity" of the business ssector itself, to be understood as the hability to recognize the value of the new information, assimilate it, ans apply it for commercial ends. This capacity requires the previous existence of some knowledge and of teams dedicated to R&D, especially as the science content of the new knowledge required for innovation increases (Cohen & Levinthal, 1990)."

Interestingly enough, 99 years before, Jewett[7], the first diretor of Bell Laboratories, described his view on "absortive capacity":

> "But 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. Any failure in the supply of men or any failure to advance the bounds of knowledge by pure scientific research will result inevitably in a strict limitation of industrial research."

1.1 Some indicators relevant for assessing U-IRC

Multiple indicators can be thought of to assist in assessing the state of university-business interactions.

For the present discussion we chose to analyze three indicators of U-IRC:

a) Value of expenditures of a university with industry funds for sponsored research.

b) Intensity of industry researcher's co-authorship in scientific articles published by universities.

[7] Jewett, F.B., "Industrial research with some notes concerning its scope in the Bell Telephone System", Presentation at the 333d Meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 8, 1917.

c) Patent portfolio, intensity of industry and universities co-titleship in patents, and licensing.

d) Quantity of start-ups created by students and faculty from a university.

2 Business sponsored research

One way to assess the intensity of U-IRC is to try and measure the amount of money transferred from industry to universities yearly to support sponsored research activities. In most universities contracts for sponsored research with industry are coveted, as a source, not only of funds to complement funds from governmental sources, but of new challenges for the academic research environment. Collaborative research also has an important role in training students and post-docs, especially in applied fields. In the U.S. and Europe universities have Offices of Sponsored Research, that assit the investigators in identifying and developing opportunities for joint research projects with industry. In Brazil most research oriented universities 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 governmental funds and also because they can be used for paying additional salary to some of the investigators associated with the contracted project. Governmental organizations, such as FINEP, FAPESP, EMBRAPII 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 U-IRC has been fostered in Brazil, there are very few measurements of its intensity or impact. The research funding agencies tend to have data about the yearly value spent in collaborative projects, but few universities publish openly their data on the value of the research contracts with industry. In the state of São Paulo, only the State University of Campinas (Unicamp) presents this data as a time series in its Statistical Yearbook[8].

For this work we used the data published by Unicamp, which is publicly accessible and covers the period from 1995 to 2017, and we also obtained a specially built time series from USP, covering the period from 2006 to 2015. In both cases the data includes only research contracts, and not funds donated for other purposes.

For the universities in the U.S. we used data published by NSF in their National Center for Science and Engineering Statistics (NCES)[9], which presents selected data for individual institutions on doctorates, graduate students, funding and expenditures from four NCSES surveys, including 2,014 universities and colleges. We also referred to the MIT Report of the Treasurer for 2016 and 2010, which are available at MIT's website.

To compare the data, we converted the nominal values the Purchase Power Parity (PPP) exchange rate, published by the World Bank[10].

[8] UNICAMP, https://www.aeplan.unicamp.br/anuario/anuario.php
[9] https://ncsesdata.nsf.gov/profiles/site
[10] http://data.worldbank.org/indicator/PA.NUS.PPP?locations=BR

Table 2 summarizes the data, using as examples the values for years 2010 and 2015.

Table 2. Descriptive data for the years 2010 and 2015 for MIT, All U.S. universities covered on NCES, Unicamp, and USP.(Sources: see text)

	MIT		All U.S. Univ in NCES		Unicamp		USP	
Em US$	2010	2015	2010	2015	2010	2015	2010	2015
Total revenues	2.663,1	3.290,8	-	-	1.295,1	1.129,9	2.507,4	2.498,0
Research expenditures	677,1	930,7	61.253,7	68.667,8	723,3	647,0	1.931,9	1.970,1
Governmental	458,0	489,1	41.327,7	41.689,3	178,1	164,5	532,1	518,4
Institutional funds	102,9	92,6	11.940,5	16.711,7	509,8	459,4	1.332,7	1.398,1
Business	68,9	150,0	3.197,6	4.000,6	35,4	23,1	67,1	53,6
Nonprofit organizations	12,5	98,4	3.740,1	4.237,0				
All other sources	34,9	100,7	1.047,8	2.029,2				
HERD/Total Revenues	25,4%	28,3%	-	-	55,9%	57,3%	77,0%	78,9%
Business/Gov Funding Agencies %	15,0%	30,7%	7,7%	9,6%	19,9%	14,1%	12,6%	10,3%
Business/Total revenues %	2,6%	4,6%	-	-	2,7%	2,0%	2,7%	2,1%
Faculty	1.025	1.021			1.750	1.867	5.865	5982
Undergraduate students	4.299	4.527			17.083	19.001	57.300	58.828
Graduate students	6.267	6.804			14.571	15.651	31.662	36.819
PhDs awarded	582	606			826	993	2.338	2.939

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

Before analyzing the data shown in Table 2, we must comment on a discrepancy resulting from the way the data is calculated for the institutions displayed. This refers to the line "Institutional Funds", where it can be seen that the values for Unicamp and for USP are substantially larger than the values for MIT. The data for Unicamp is approximately 5 times higher that that of MIT, while USP's is 14 times. The reason for this disparity seems to be due to the use of different ways to estimate the value of institutional funds devoted to R&D. The data for USP and Unicamp is obtained following the specifications of the OECD Frascatti Manual, which determines that a fraction of the total costs of the institution must be ascribed to the R&D activities following an estimate of the time dedicated by faculty and staff to these activities. This determination involves difficulties well recognized internationally, and is highlighted in the OECD Frascatti Manual where the suggestions for the procedures for this estimation are the subject of a special Annex[11]. 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 viable, on other ways to assess the fraction of R&D in the total costs of higher education[12]. The estimations for Unicamp and USP are described in

[11] OECD, Manual Frascatti (Ed 2002), Annex 2, p. 158.

[12] OECD, Manual Frascatti (Ed 2002), Annex 2, p. 158. "Time-use surveys or, if these are not possible, other methods of estimating shares of R&D (R&D coefficients) in total activities in the higher education sector are a necessary basis for statistics."

detail in the Part A of Chapter 3 of FAPESP's publication on S&T Indicators, 2010[13]. To summarize, the estimation is done by considering that faculty is paid a full time additional to work in research, besides teaching undergraduate classes. The total cost of the institution dedicated to R&D is calculated considering this full time additional salary and its impacts in the other costs of the institution. Before the calculation the costs of hospitals, museums and retirement pay are subtracted from the total as these do not relate to R&D[14].

In the case of MIT we could not find the details about the way the institutional funds are attributed.

Considering the discrepancy discussed above, we found it more meaningful to use, for the comparison of business research contracts intensity estimation, a calculation of the ratio between the expenditures covered with business contracts and the expenditures covered with governmental contracts. This is the data shown in the line "Business/Gov Funding Agencies %" of Table 2.

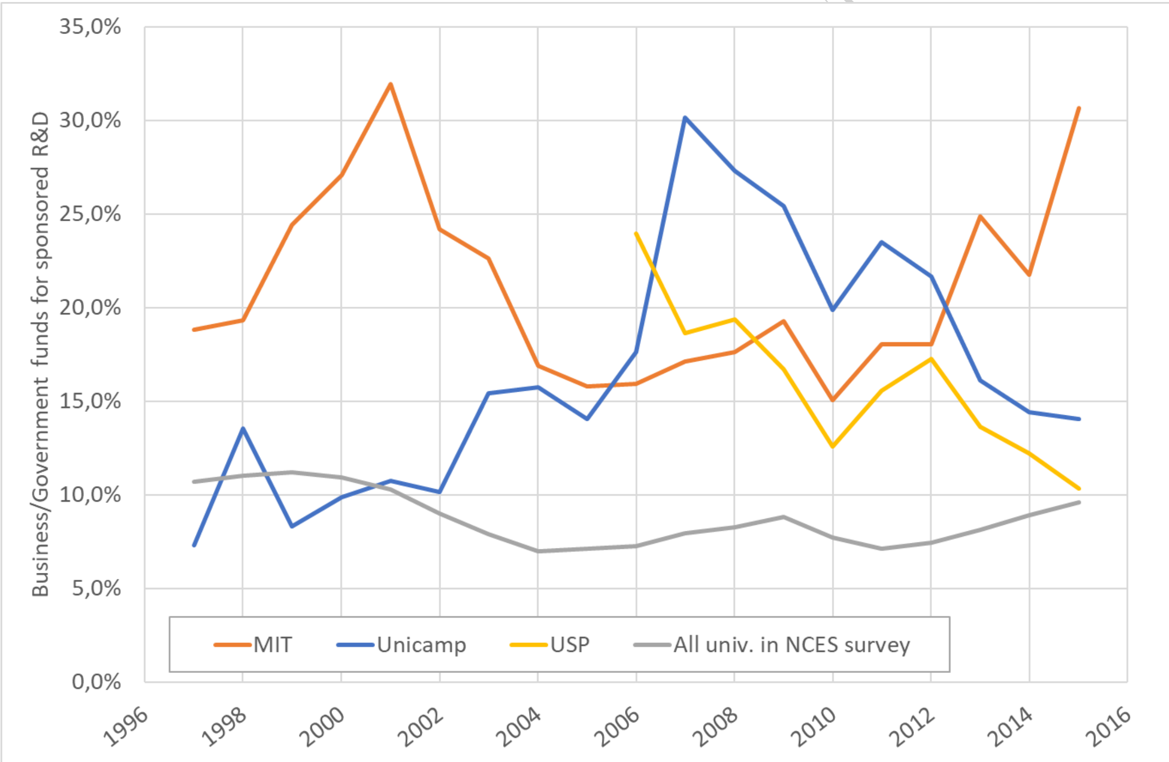


Figure 2. Ratio of business to governmental agencies funds spent in research at MIT, Unicamp, USP, and at the set of U.S. universities included in NSF's NCES database.

Figure 2 shows the time series for each entity (or set of entities), according to the availability of the data. Features worth mentioning are:

a) Both for Unicamp and USP the ratio of business to government (B/G) lies above the average for the set of U.S. entities.

[13] http://fapesp.br/indicadores/2010/volume1/cap3-Parte-A.pdf

[14] It might be argued that hospitals and museums contribute to the R&D activities in a university, so that the estimation obtained following the algorithm described must be considered as a lower bound.

b) For Unicamp B/G ranges from 10% to 30%, from 10997 to 2015, while for USP the range is from 25% to 10% in the period from 2006 to 2015.

c) For the years between 2006 and 2012 the B/G ratio for Unicamp was higher than that of MIT.

d) Starting in 2010 there was a steep rise in the B/G ratio for MIT, reaching 31% in 2015.

e) For both USP and Unicamp the B/G ratio has been decreasing since 2007, a decline that seems to have worsened after 2012, but that can be understood considering the economy and political troubles that have been afflicting Brazil since then.

Before concluding this section, it is worth mentioning that USP and Unicamp are among the strongest research universities in Brazil so that the fact that they display indicators for the intensity of university-industry contracts higher than the average for U.S. universities and in the same range of intensity found at MIT should be generalized with care, or not at all. It is very likely that some research oriented universities in Brazil have university- industry interaction at a level similar to that shown, for USP and Unicamp, in Figure 2. Entities as ITA, UFSCAR, UFRJ, UFSC and UFMG come to mind, for which unfortunately there is no available data at present.

4 Co-authorship in scientific articles

An indicator for U-IRC which is widely available and covers numerous institutions would be the number (and percentage of the total number) of articles in which researchers from a given university are coauthors together with researchers from the business sector. The analysis presented here uses data from the Web of Science, obtained through searches performed at the normal WoS interface available to researchers.

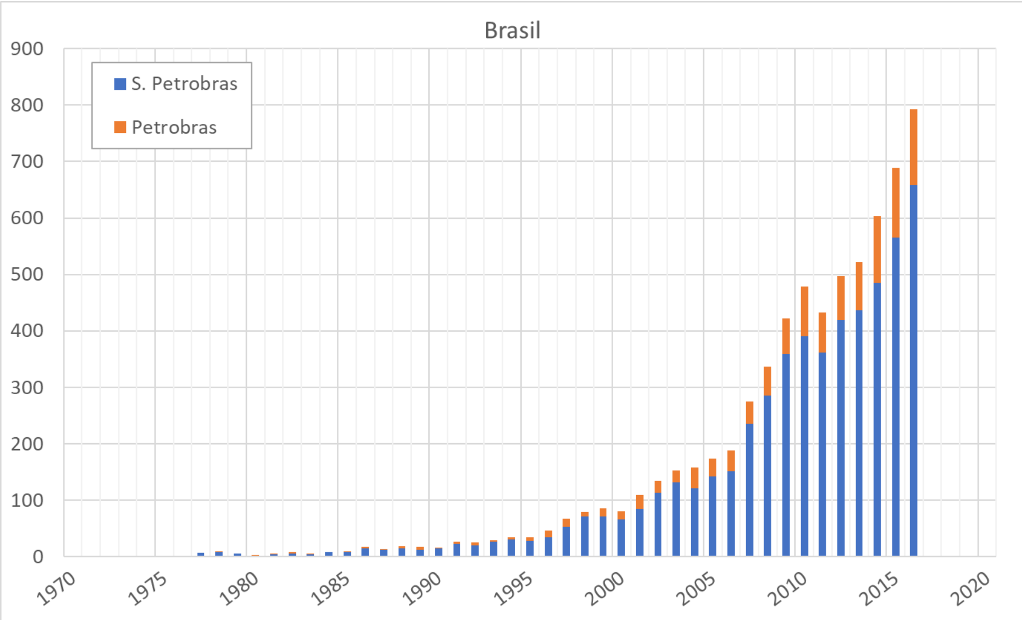


Figure 3. Quantity of articles, by year, with authors in universities in Brazil and coauthors in the business sector. We included a separate mark for the number in each year with coauthors from Petrobrás to make it clear that, although relevant, the set is not dominated by these.

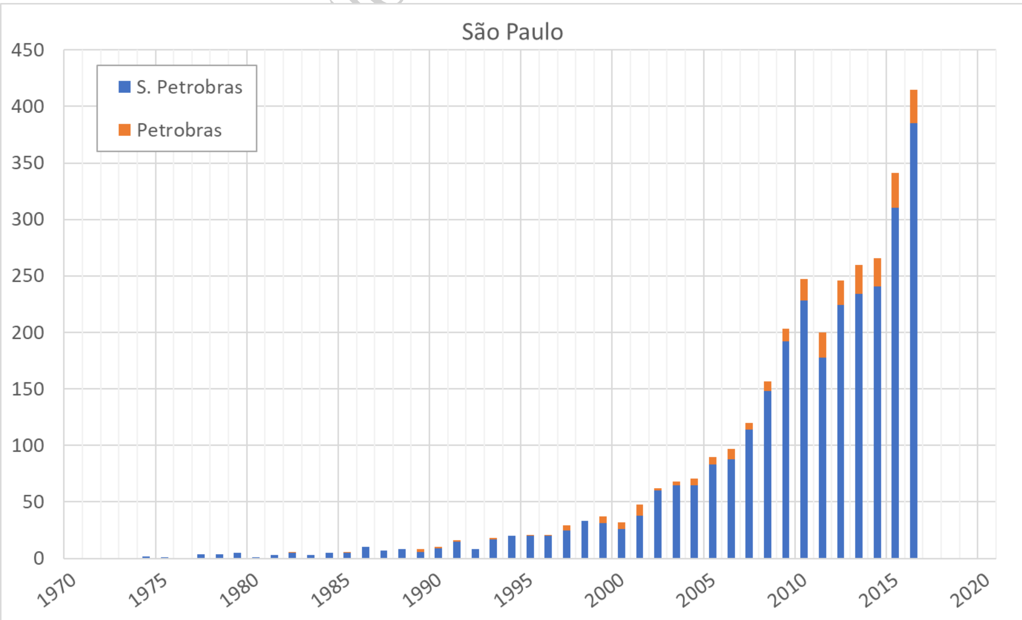


Figure 4. Same as in Figure 3, but for universities in the state of São Paulo. Note that the contribution of co-authorship with Petrobras is smaller than that visible for Brazil.

Figure 3 shows the evolution of the quantity of articles with coauthors in the business sector and in universities highlighting the quantity in co-authorship with researchers at Petrobras. Figure 4 shows the same indicator, but for the case of universities in the state of São Paulo. While for the case of Brazil the contribution of Petrobras ranges from 16% to 20% in recent years, for the case of the state of São Paulo this range narrows to be from 7% to 9%. The growth is exponential, as seen in Figure 5.

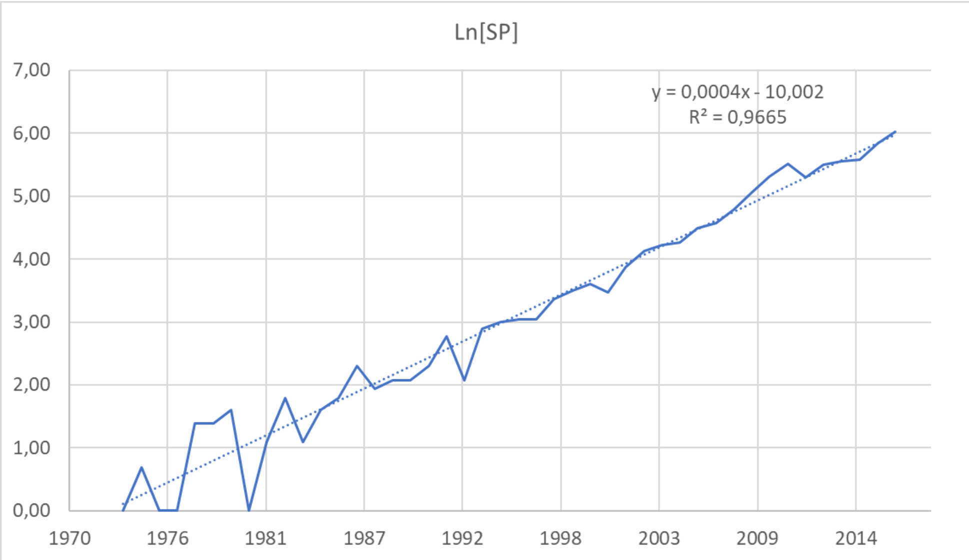


Figure 5. Logarithmic plot of the data in Figure 4, showing the exponential characteristic of the growth rate.

While the growth seen in Figure 3 and Figure 4 is interesting, it is also relevant that the fraction of the articles with university and business (U-B) co-authors in the total scientific production of Brazil and São Paulo is also growing (Figure 6).

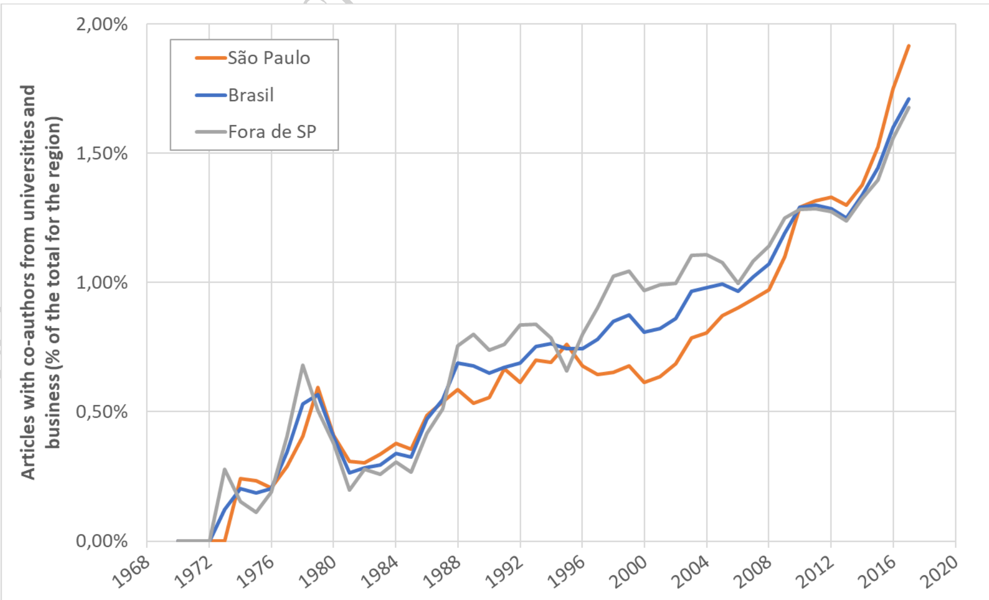


Figure 6. Fraction of the total scientific production in Brazil, São Paulo, and Brazil outside São Paulo that have co-authors from universities and business (the data was averaged over a rolling 3-years window to facilitate the visibility of the figure).

There seem to be three periods with different behavior in the evolution of U-B co-authorships in Brazil: first, from 1974 to 1987 the behavior in São Paulo was hardly distinguishable from the behavior outside

São Paulo. From 1988 to 2010 the universities outside the state of São Paulo had more co-authorships than the universities in São Paulo. Then, after 2012 the incidence of U-B co-authorships in the state of São Paulo took the lead.

Even though there is an encouraging growth, an international comparison demonstrates that there is ample room to grow. Brazil, China and the State of São Paulo are at 1,5% - 1.9%, while more developed countries have percentages between 2.4% and 4.4%.

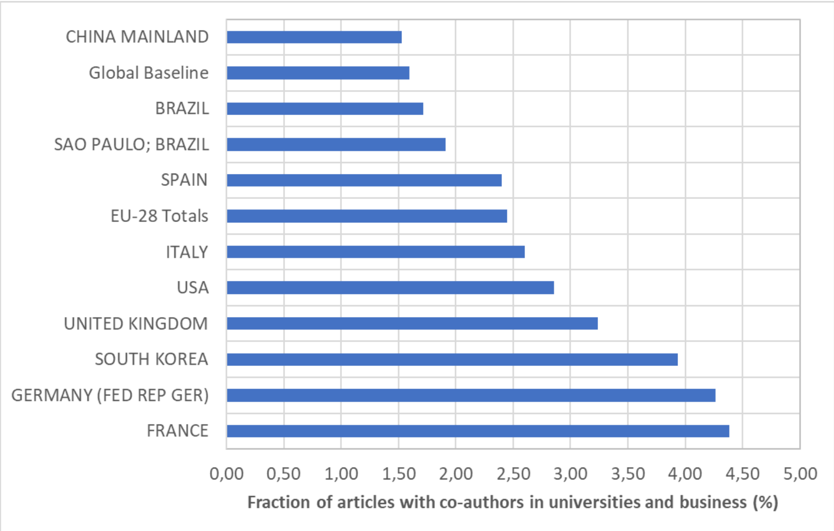


Figure 7. Fraction of articles with co-authors from universities and the business sector in a set of countries and regions (Source: For Brazil and São Paulo, author's measurements in the Web of Science; for the other regions: Clarivate's Incites).

The percentage of U-B co-authorships for the universities in the state of São Paulo, in 2017, at 1,9%, was 20% below that found in Spain or in the Europe of 28 countries, 67% of that occurring in the USA, and less than 50% of that in France or Germany.

4.1 U-B co-authorship – a view by university

Figure 8 shows how the U-B co-authorship percentage has been evolving for some research-intensive universities in Brazil. ITA has the highest ratio, around 4%, with a steep climb after 2007, even though over a small total number of publications (188 items in 2016). UFRJ displays also a strong growth after 2013, almost doubling its percentage in only four years. USP displays a solid continued increase for the last several years, with a more intense growth in the last two years.

Figure 9 shows a comparison of the U-B co-authorship rate for some universities in Brazil and some universities in the USA. The data shown indicates that even in a country with a strong tradition of university-industry research collaboration such as the USA, there is a range of behavior in this indicator.

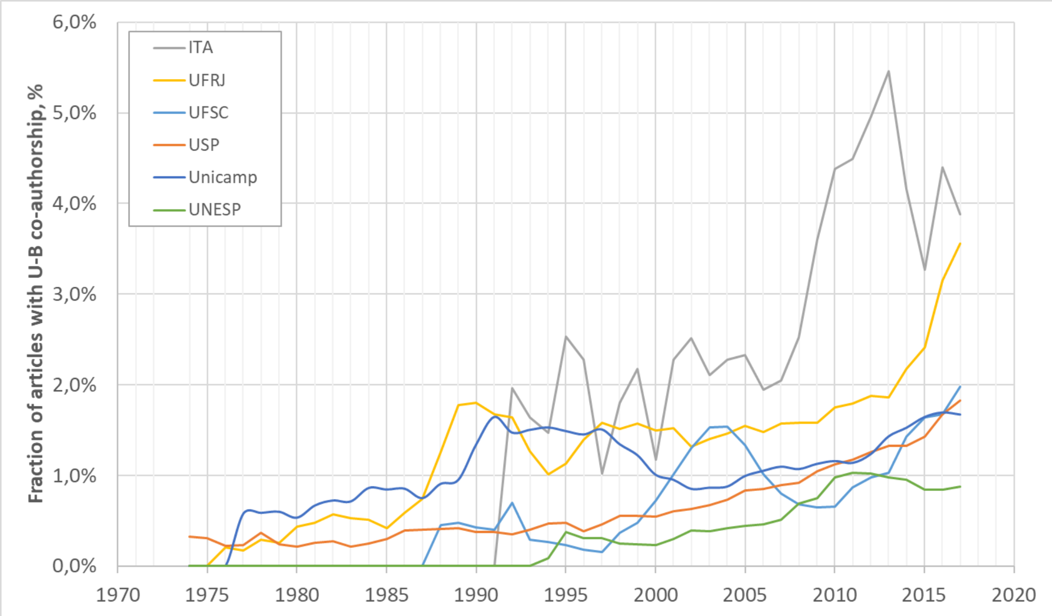


Figure 8. Evolution of the U-B co-authorship fraction of the total publications from some universities in Brazil.

MIT is the strongest in this set, with a U-B co-authorship percentage of 4,8% while Texas Tech University (TTU)[15] has an intensity of 1%. The Brazilian universities range from 0,9% (UNESP) to 3.8% (ITA).

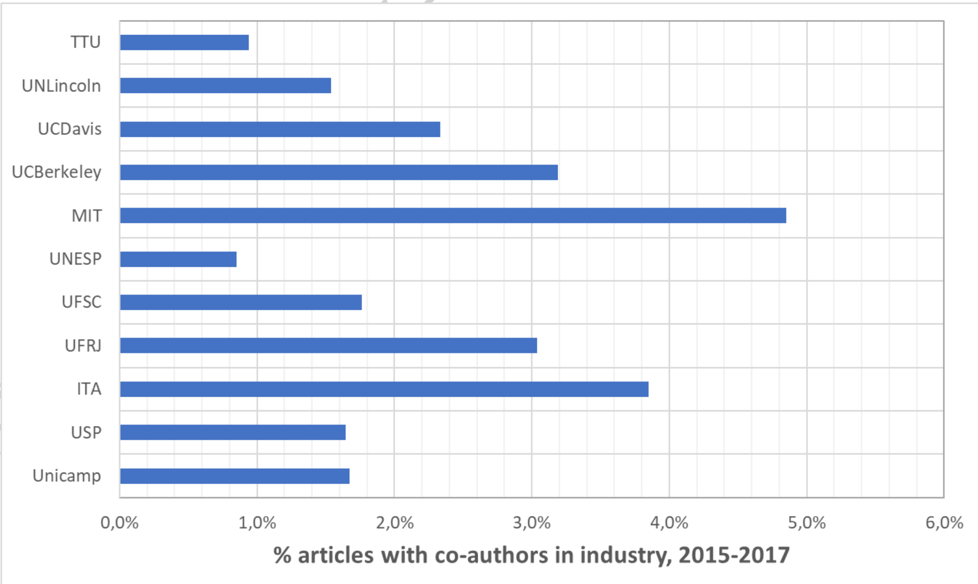


Figure 9. Comparison of U-B co-authorship rate for some universities in Brazil and some universities in the USA, considering the period 2015-17.

A characteristic that differs for the case of UFRJ and the other Brazilian universities used in the comparison is that for UFRJ the weight of collaborations with Petrobras is very high. This is to be

[15] TTU and University of Nebraska Lincoln were chosen here as FAPESP has developed research collaborations there and held a FAPESP Week symposium in both campuses in 2017. Both are strong research intensive universities albeit located at a distance from high technology hubs like Massachusetts or California.

expected, considering the geographic proximity between CENPES, the Petrobras research center and the UFRJ campus, plus the effective work of COPPE-UFRJ in developing research partnerships.

4.2 Most frequent co-authoring companies

The methodology used for this study uncovered 1,148 companies as co-authors to university researchers in Brazil[16]. The ones with more than 40 articles in the sample are shown in Table 3.

Table 3. Companies with more than 40 co-authored articles with universities in Brazil (1974-2017).

Organization name	Quantity
PETROBRAS	1262
NOVARTIS	258
ROCHE HOLDING	216
MERCK COMPANY	187
PFIZER	168
INTERNATIONAL BUSINESS MACHINES IBM	145
BRISTOL MYERS SQUIBB BRAZIL	134
GLAXOSMITHKLINE	130
BRASKEM	113
AT T	101
ASTRAZENECA	93
WESTAT	92
EMBRAER	88
FUNDO DE DEFESA DA CITRICULTURA	86
ELI LILLY COMPANY	82
FIBRIA	81
MONSANTO BRASIL LTDA	81
SYNGENTA PROTECAO CULT LTDA	74
BOEHRINGER INGELHEIM	73
BAYER AG	62
HEWLETT PACKARD BRASIL LTDA	61
SANOFI AVENTIS	58
JOHNSON JOHNSON	57
ITAIPU BINAC	58
ELETROBRAS	53
NOVO NORDISK	53
SUZANO PAPEL E CELULOSE	49
AGILENT TECHNOL BRASIL LTDA	46
AMGEN BRASIL	46
DOW AGROSCI BRASIL	43
ERICSSON	43
DUPONT BRASIL	42
SIEMENS AG	41
USIMINAS	40
GENENTECH	40

[16] By mid-January, 2018 a report by Clarivate Analitycs was published under the title “Research in Brazil A report for CAPES by Clarivate Analytics”. This report has data for university-industry co-authorship in Brazil for the period 2011-2015 with the observation: “This could be partly due to how corporations are defined in the Web of Science, which may miss the domestic SMEs that the Brazilian government has been so keen to support.” The data shown here does not suffer from this deficiency as it was searched independently with a methodology that allowed for the consideration of more than one thousand companies as co-authors. First we obtained all articles with authors in Brazil. Then we obtained the list of organizations with co-authors in each article and classified the organizations to identify the ones belonging in the business sector.

5 Patent portfolio, intensity of industry and universities co-titleship in patents, and licensing

Patents are useful instruments for facilitating university-industry interactions, be it through joint ownership of title or through licensing. For this reason, it makes sense to consider some data related to patenting activity as indicators of quantity and/or quality of U-IRC.

The most used indicator in Brazil so far has been the quantity of patents. Most universities treasure this number and are proud of their growing patent portfolio. Many established Innovation Agencies (which have functions associated in the U.S. with Technology Transfer Offices) and 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, as opposed to what is seen in more developed economies where industry appears higher in this kind of ranking.

Carlos Pacheco[3] has analyzed the ratio of the number of patents filed for to the size of faculty in some Brazilian universities, and compared these to data obtained for universities in the U.S. (Table 4). He found that this ratio for Brazilian universities lags that found in the U.S. However, he cautions the reader about the difficulty of considering the actual workforce to be used in the denominator, as universities in the U.S. normally have more public support for hiring research associates (this is a similar difficulty as the one we discussed in section 2 for estimating the institutional funds ascribed to research activities).

Table 4. Patents filed per Faculty and Articles published per Faculty for some universities in Brazil and in the U.S. (Source: CNI, 2016, "Inovação: o papel da cooperação universidade-empresa", Brasília, 2016).

University	Patents Filed/Faculty	Articles/Faculty
University of California	4,4	182,8
Harvard	5,2	806,0
MIT	45,3	589,5
CalTech	64,0	1061,7
Stanford (***)	13,1	359,1
UFMG	2,0	74,4
UNICAMP	3,0	152,7
UFPR	2,0	52,7
USP	0,7	136,4
UNESP	1,0	99,3

Using the caveat discussed above, it is possible to compare the quantity of patents filed (2016) with the R&D expenditures for the university (2016) (Figure 10). Patents do not come cheap: the graph allows one to estimate that U.S. universities file a patent for each US$ 2,7 million spent in R&D. The data point for Unicamp indicates that this university is at 40% of the trend line, while USP is at 12%.

While the quantity of patents filed is a basic indicator of the potential for transferring technology to the business sector, another relevant indicator is the quantity of patents in which the university shares title with industry. This indicator must be seen with care, as the practice in many universities is to release title to patents obtained in joint research with industry to avoid the complex process required for the licensing of technology from public organizations. Not having title to the IP does not mean the university cannot receive benefits accrued from licensing or selling of the patent – these are usually written into an agreement between university and industry.

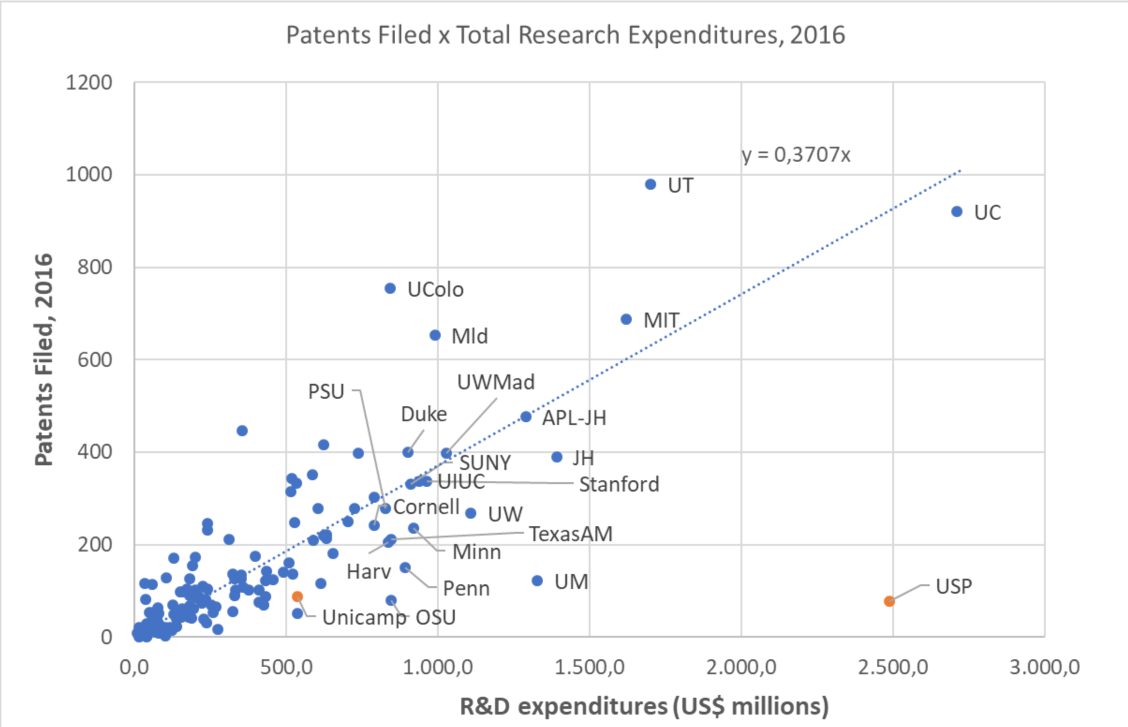


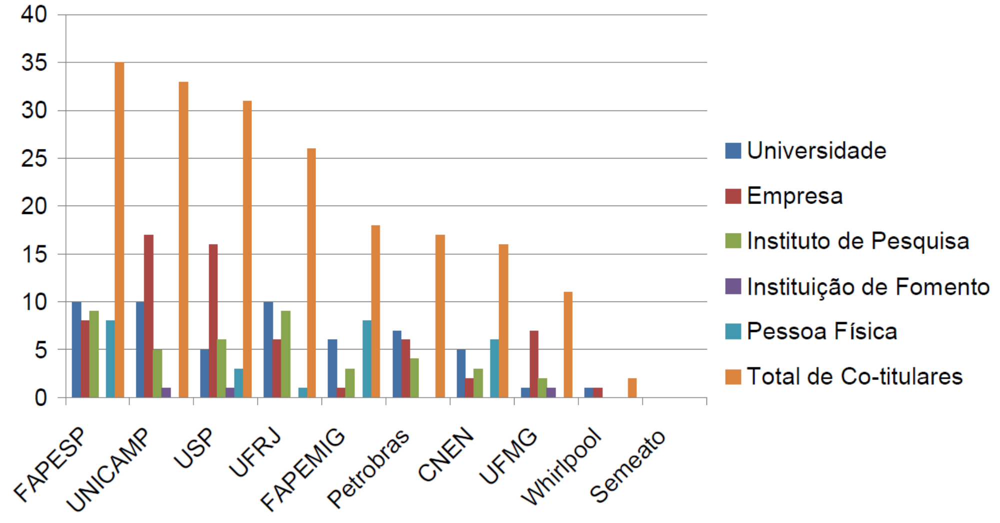
Figure 10. Patents Filed versus R&D expenditures for 160 universities in the U.S. (Source: AUTM Annual Report, 2016) and for USP and Unicamp.

In principle the information about joint titleship to patents can be obtained from INPI orother databases, but most universities do not value this indicator too much. An internal publication by INPI illustrated this indicator for some Brazilian universities for the period 2004-2008[17] and the results related to industry co-titleship are shown in Figure 11. For USP and Unicamp, in the period covered, close to half of the patents with shared title were with industry.

A third indicator related to intellectual property is the value of revenues obtained through licensing. There is a lot of misunderstanding in Brazil about this, with a general supposition in universities and in government that most universities in the U.S. make great amounts of money from licensing IP. The data in Figure 12 shows that about 50% of the universities that participated in the AUTM survey obtain from licensing a gross revenue which is less than 1% of their yearly R&D expenditures, 70% obtained revenues below 2% of the R&D expenditure, and only three universities (out of 164) obtained, in the year in question (2016), a ratio higher than 20%. Note that the data refers to the gross revenue, indicating an even meager situation if we consider net revenues. For the Brazilian universities we do not have

[17] INPI, "Principais Titulares de Pedidos de Patente no Brasil, com Prioridade Brasileira,

data about licensing revenues, except for Unicamp, which publishes this information in their Statistical Yearbook. For 2015 and 2016 the licensing revenues were 0,2% and 0,1% of the R&D expenditures.



Fonte: Base SINPI/INPI. Acesso em: set. 2010; Dados institucionais disponíveis nos *websites* dos titulares.

Figure 11. Joint title to patents filed at INPI from 2004 to 2008 for some Brazilian organizations.

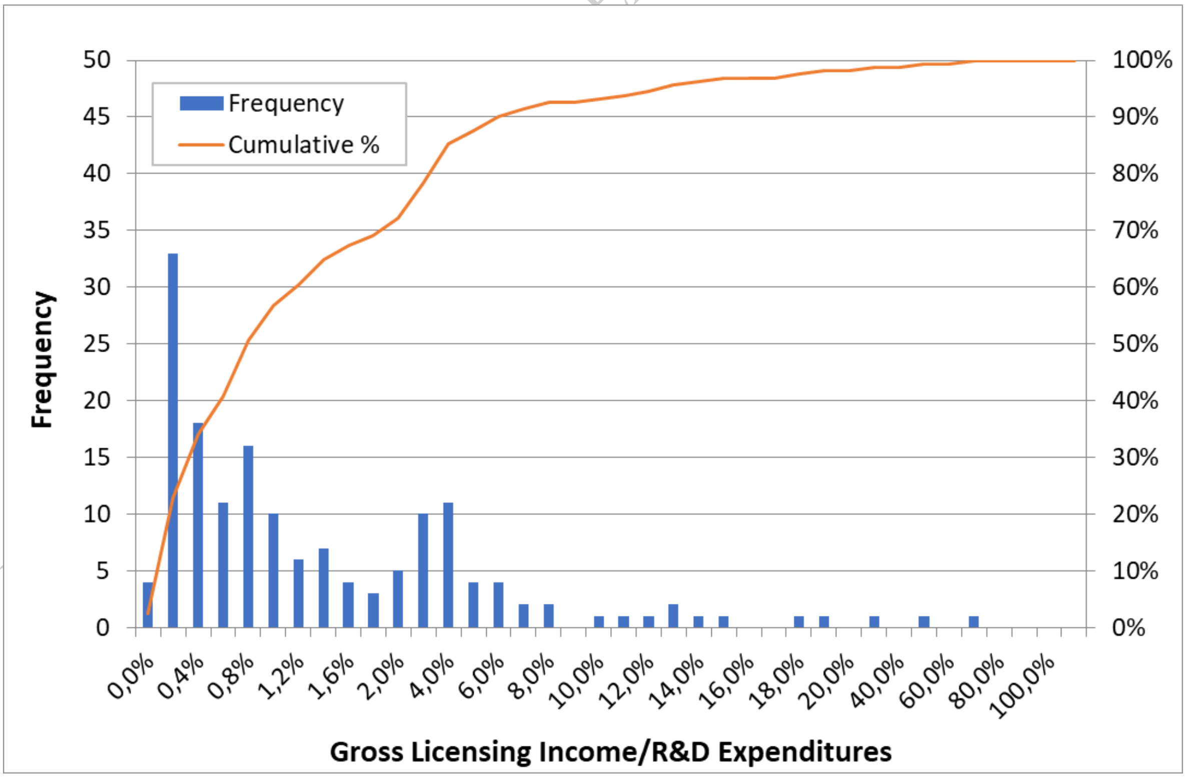


Figure 12. Distribution of the ratio (Gross Licensing Income/R&D Expenditures) for 164 universities in the U.S. in 2016 (Source: AUTM Annual Report).

Even if the licensing revenues are relatively small, this does not mean filing patents and licensingthem is irrelevant. Transferring technology through licensing is one of the many contributions of universities to the economy, and this adds to other actions. The mistake would be to consider that licensing revenues would substitute for public revenues to support research. The recent CNI Report[3] refers to this matter, citing that according to John Fraser of AUTM *"no longer is licensing income seen as a comprehensive indicator of success".*

6 University related start-up companies

The number of startups created by students, faculty, or staff from universities is also a useful indicator about certain aspects of U-IRC. While joint research, with business sector co-funding, covers mostly the case of collaboration with medium and large companies, startup creation lets an eye on the small business side of the interaction.

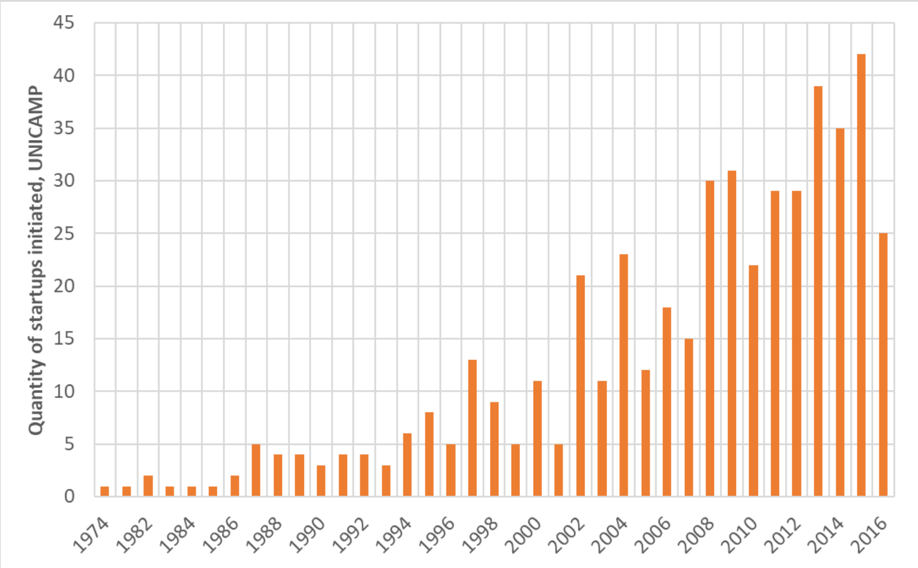


Figure 13. Quantity of startups initiated by students and faculty from Unicamp, by year.

In Brazil few universities have a database of related startups. The most complete one is that of the State University of Campinas (Unicamp)[18] from which the data in Figure 13, displaying the number of startups created yearly, since 1974.

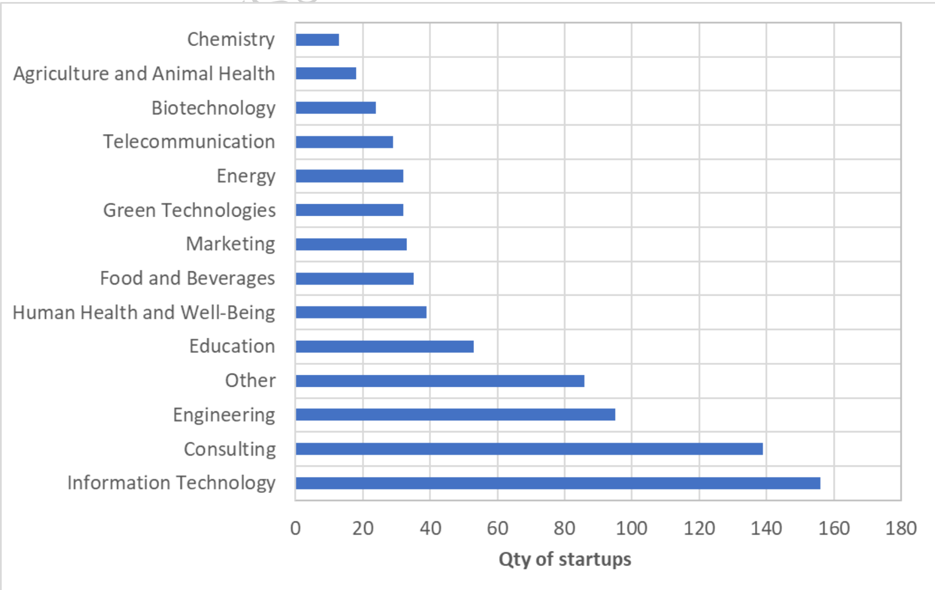


Figure 14. Unicamp's startups by sector. (Source: Agência de Inovação da Unicamp, 2017)

18 https://docs.google.com/forms/d/e/1FAIpQLSepaQDACAOMhCetBEIgxiUYdhv_3jCYPrExZbcaoXJ1fAj8YQ/closedform

Figure 14 shows the distribution of those startups across industry sectors, demonstrating a dominance in IT and Engineering.

Each year the university surveys the companies in its database establishing for example that, in 2016:

a) The companies originating from Unicamp sustained 28,000 jobs.

b) The companies' revenues were R$ 3 billion.

c) 26% of the surveyed companies had an office abroad.

A comparison of the data from Unicamp with that for universities in the USA is shown in Figure 15, using data from the AUTM database. The figure correlates the number of startups generated in a given year with the R&D expenditures at the university in the same year. This does not mean that all startups arise from research performed in the same year, the value spent in R&D is used in the figure as a proxy of the vitality and breadth of the academic environment in each organization.

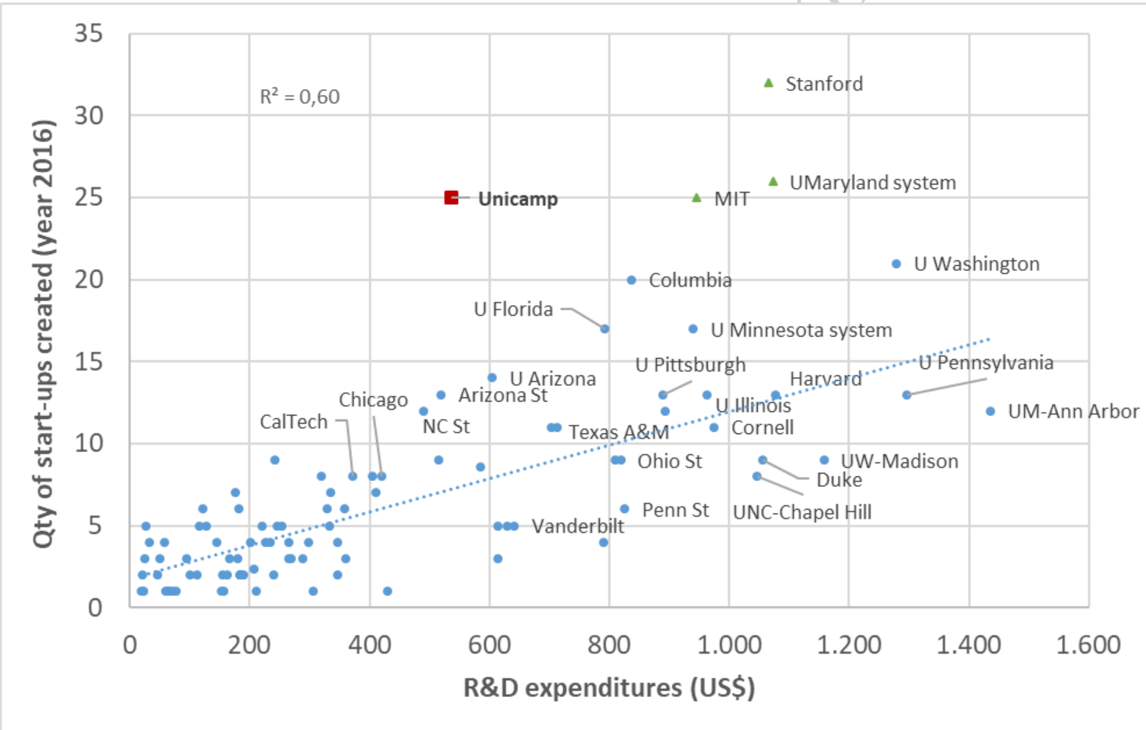


Figure 15. Quantity of start-ups created plotted against the university's R&D expenditures. Base year is 2016. (Source: AUTM database and Unicamp's Statistical Yearbook).

Interestingly, Unicamp fares well in the comparison about the quantity of startups generated. However, in other aspects, such as the growth of each of these startups in time the results, though reasonable as described above, are not yet as remarkable as seen in universities in the USA. Part of the issue might be related to the weakness of the venture capital environment in Brazil. A single number illustrates the disparity: in 2017 the VC market in the USA mobilized more than US$ 70 billion[19].

[19] PwC and CB Insights, Money Tree Report Q4, 2017. P. 76. https://gcase.files.wordpress.com/2018/01/cb-insights-moneytree-q4-2017.pdf

7 Conclusion

We have discussed some indicators that might be helpful to assess the evolution of U-IRC in Brazil, creating the possibility of assessing the instruments of public policy created with the objective of facilitation and fostering U-IRC. We have illustrated each indicator with data obtained for universities in Brazil and in the U.S. Indicators beyond those exemplified here should also be considered. The illustrations aim mostly at demonstrating that it is possible to determine the indicators and the benchmarks.

Additionally, the indicators discussed show that there are certain parts of the S&T system for which U-IRC is much more than "incipent".

The use of adequate indicators will stimulate the organizations that are part of the S&T system to consider them in their initiatives, which fosters the continuity of the initiatives and allows for criticism and suggestions for improvement that may come from the community. It will also inform the national debate, leading to higher quality proposals of policies to be enacted. Evidence based policy might help the policy makers act in a more effective way than traditional practice of "anedoctal" based policy that is so frequent in the debate in Brazil. Targets could be set, the indicators tracked and the policy adjusted to obtain the stated objectives.

What Brazil cannot afford anymore is not to use any indicator to assess this important part of its S&T policy.