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Profile of partnerships between the Instituto Nacional de Tecnologia and innovation players: a study of scientific collaborations

Perfil das parcerias entre o Instituto Nacional de Tecnologia e os atores da inovação: um estudo das colaborações científicas

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Abstract

This study analyzes the collaborative relationship based on the scientific production of a Brazilian public technological research institute, the National Institute of Technology, using the Scopus and Web of Science databases. It is a scientometric study where the analyses were conducted based on collaborations with organizations with which National Institute of Technology published scientific articles, involving different actors in innovation, categorized as Scientific, Technological, and Innovation institutions, companies, and government, following the "Triple Helix" innovation model. Out of the 923 retrieved documents, 654 were articles, with 543 published in collaboration and 111 solely authored by National Institute of Technology. The research identified that the majority of collaborations occurred with scientific institutions classified as educational. Interactions with state-run and private companies from various industry sectors were also identified, and in a smaller number with government institutions. The geographical aspect was also explored, mapping partnerships by region and federal unit. The Southeast region had the highest number of collaborations, with a significant presence in the state of Rio de Janeiro and São Paulo.

Keywords: Co-authorship. Innovation. Research institute. Scientific article. Scientometrics.

Resumo

Este estudo analisa o perfil de relações colaborativas com base na produção científica de um instituto de pesquisa tecnológica público brasileiro, o Instituto Nacional de Tecnologia, utilizando as bases de dados Scopus e Web of Science. Trata-se de um estudo cientométrico realizado a partir das colaborações identificadas nos artigos científicos publicados pelo Instituto Nacional

de Tecnologia com outras instituições, classificadas como Instituto de Ciência e Tecnologia, empresa ou governo, conforme a classificação dos principais atores do modelo de inovação da "Hélice Tríplice". Dos 923 documentos recuperados, 654 eram artigos, sendo 543 publicados em colaboração e 111 de autoria exclusiva do Instituto Nacional de Tecnologia. A pesquisa identificou que a maioria das colaborações ocorreu com instituições científicas classificadas como ensino. Também foram identificadas interações com empresas públicas e privadas de diversos setores industriais, e em menor número com agências do governo. Explora-se também o aspecto geográfico, mapeando parcerias por região e unidade federativa. A região Sudeste teve o maior número de colaborações, com destaque para os estados do Rio de Janeiro e São Paulo.

Palavras-chave: *Coautoria. Inovação. Instituto de pesquisa. Artigos científicos. Cientometria.*

Introduction

With the rapid transformations the contemporary world is undergoing, previously innovative technologies quickly become obsolete, and the pursuit to adapt to new markets and for constant innovation becomes a necessity and a great challenge. These challenges are even greater in countries like Brazil, where competitiveness is strong only in activities linked to commodities with a large scale of production and low added value, which do not have significant weight in the generation of innovations (Morceiro; Guilhoto, 2019).

Understanding how a network of players working in a collaborative system operates is a fundamental resource to overcome the innovation challenges and build a collaborative innovation system (Khademi; Lampela; Smyrnios, 2021). These systems encompasses a network of organizations within an economic framework that engage in the generation, dissemination, and utilization of scientific and technological knowledge, alongside the organizations tasked with coordinating and supporting these processes. Etzkowitz and Leydesdorff (1995) were trailblazers in using the "Triple Helix" model to depict a sophisticated innovation system comprising academic institutions, government institutions, and industrial organizations.

Knowing the collaborations between companies and institutions can provide important information that allows institutes to better direct their efforts to intensify their relationships with other actors in the innovation system. The importance of exploring scientific production information as one of the pillars for managing both institutional strategic knowledge and technological innovation, being a great competitive advantage for an organization (Borschiver; Silva, 2016).This study explores the collaborative relationship of the scientific production of a state-run technology-based research institute in Brazil, the *Instituto Nacional de Tecnologia* (INT, National Institute of Technology), affiliated with the *Ministério da Ciência, Tecnologia e Inovação* (MCTI, Ministry of Science, Technology and Innovation), found in the Scopus and Web of Science (WoS) databases.

The choice of INT is justified because since its creation, it has held a relevant position as a government center for analysis and technological research, catering to the needs of the productive sector (Castro; Schwartzman, 2008), as well as to create, transfer, adapt, and update technology, in support of the Brazilian industry (Motoyama, 2004). Through the research, services, technology transfer, and by supporting innovation in partnership with government agencies, businesses, and teaching and research institutions, both state-run and private, i.e., with the main players of the innovation system, the institution currently focuses its activities in three areas: Materials Science and Engineering, Chemistry and Chemical Engineering, and Process and Product Engineering.

In Brazil, scientific-technological research was only institutionalized in the 20th century, when the few or almost non-existent research initiatives took place outside of universities, in institutes and museums that had been created for this purpose (Meis; Leta, 1996). It was in this scenario that, in 1921, the then Fuels and Minerals Experimental Station, today INT, was officially created. In these one hundred years, the INT has undergone two changes in its institutional name (Institute of Technology – 1933) and ties with ministries (Ministry of Agriculture, Industry and Commerce – 1921, Ministry of Agriculture – 1933, Ministry of Labor Industry and Commerce – 1934, Ministry of Industry and Commerce – 1961, Ministry of Science and Technology – 1986, Ministry of Science, Technology, Innovation and Communications – 2016).

In the search for bibliometric studies on collaboration in scientific publications among Brazilian institutions, only one study on the *Instituto Nacional da Mata Atlântica* (INMA, National Institute of Atlantic Forest) (Freitas; Rosas; Mendes, 2020) was found. The INMA is a research unit affiliated with MCTI; however, the collaboration categorization proposed in this study (Triple Helix - University-Industry-Government) was not utilized. To validate this information, a new search was conducted individually considering the 16 institutions affiliated with MCTI, and once again, only the aforementioned study was retrieved.

The literature available in the technical-scientific memory of the INT shows that the institute's scientific production has been explored in three studies with different focuses and limitations, two of which aimed to conduct historical surveys rather than analyze outcomes or interactions. In the first, conducted by the now extinct *Instituto Brasileiro de Bibliografia e Documentação* (Brazilian Institute of Bibliography and Documentation) (currently *Instituto Brasileiro de Informação em Ciência e Tecnologia* – IBICT) (Instituto Nacional de Tecnologia, 1970), data were collected manually based on queries made of the INT's document collection, and resulted in the mapping of approximately 1,550 titles, among technical publications and scientific studies done from 1922 to 1978 (Castro; Schwartzman, 2008).

Another study, conducted between 1979 and 1981 (Castro; Schwartzman, 2008), aimed both to catalog the almost 60 years of history of the INT, and to analyze two sets of data, the first of which based on the same technical and scientific publications addressed in the study cited above, while the second on documents dated from 1953 and belonging to the INT's central archive.

In 1992, the master's thesis of Silva (1996) analyzed the different forms of scientific communication INT researchers used in the period ranging from 1983 to 1989, via bibliographic production, and based on institutional documents that recorded the researchers' publications.

None of the studies cited above focused on the institute's interactions with other organizations, nor did they use any technique based on retrieving information from indexed databases, bibliometrics or data science. The purpose of this study is to fill this gap and ascertain the existing profiles of collaboration.

This study explores these interactions based on co-authorship of scientific articles published among the main players of the innovation system and the INT, based on the "Triple Helix" concept, which addresses academia-industry-government relations (Etzkowitz; Leydesdorff, 1995) and is featured in the National Strategy for Science, Technology, and Innovation (Ministério da Ciência, Tecnologia, Inovações e Comunicações, 2016).

The aim was to address the following questions: What is the proportion of articles published by INT in collaboration with other Institute of Science and Technology (ISTs), companies, or the government? Which institutions have produced the most articles in collaboration with INT during the analyzed period? Which institutions have had the highest number of articles produced in

collaboration with INT? What are the geographic locations of the institutions that have produced articles in collaboration with INT?

To this end, the article comprises 4 sections, including this introduction. In the second section, the data collection methodology. Results and discussions related to the environment of scientific collaboration appear in the third section. Finally, the fourth section contains the final considerations, which points out the contributions the study made and its limitations, in addition to perspectives for future research.

Methodological Procedures

Retrieval of Scientific Information

Scientific information was retrieved from the WoS and Scopus databases in December 2020.

The AF-ID (60012366) affiliation code, which is the Institutional standardization within this database, was used for retrieval in Scopus. In addition to using the affiliation code, a search strategy was developed to retrieve documents whose name variations did not appear in the existing standardization. Since the name "National Institute of Technology" is used in several countries, such as Japan, India, and Argentina, among others, the search strategy that was developed to exclude terms that refer to other National Institutes of Technology.

Since the INT does not have a standardized institution name, the previously developed search strategy was used to retrieve information from WoS. After applying the search strategy ((ALL = ("Inst Nacl Tecnol" OR "Instituto Nacional De Tecnologia" or "National Institute Of Technology" or "Natl. Inst. of Technol.") NOT ALL = ("Instituto Nacional de Tecnologia Industrial" OR "Instituto Nacional de Tecnologia Agropecuária")), which were the two institutes that appeared the most but were not the institute being studied, a filter was applied to limit the results to Brazil, eliminating records from National Institutes of Technology in other countries. Finally, all records were manually verified.

Data Cleaning and Standardization

A manual data check was performed to test for false positives. To remove duplicates, the software R, version 4.0.3, and the Bibliometrix package, version 3.0.2, were used (Aria; Cuccurullo, 2017) with code changes, which considered the title of the scientific document and the year of scientific publication to identify duplicities.

To standardize the large number of variations in an institution's name, manual standardization was done using the acronym for Brazilian institutions, while for foreign ones an abbreviation of their names. When laboratories, departments, and institutes, among others, were stated, the name of the hierarchically superior institution was considered.

Methodological Choices

As the focus of the study is on research collaborations, this is defined as activities to investigate basic and applied scientific phenomena, where the research result includes at least two authors affiliated to different institutions (Carayannis; Laget, 2004).

The period from 1934 (first scientific publication retrieved) to 2021 was divided into four 22-year periods to monitor the evolution of data over time, namely 1934 to 1955, 1956 to 1977, 1978 to 1999, and 2000 to 2021.

To analyze the collaboration relationships in the period, the institutions were categorized into Institute of Science and Technology (IST), Company, or Government, and subcategorized into IST – education or research; Company – state-run or private; and Government – regulatory body, development agency, or state body. This categorization followed these criteria: (a) IST – institutions whose main activity was education and/or research. As Brazilian public universities are engaged in both functions, it was decided to categorize them as Education, and the same was done for colleges, high schools, and technical schools. Meanwhile, Science and Technology institutes that did not have education as their main activity were classified as Research; (b) Company – institutions that conducted business activities with commercial purposes, subcategorized into state-run and private. Those who also conducted research activities were categorized here, as it was understood that this would be a secondary activity done to support the main one, and (c) Government – state-run institutions subcategorized into regulatory institutions, state institutions, and funding agencies.

The analyses show the number of articles prepared in collaboration with other institutions, based on variables related to the institutions, to player categories, and the geographic location of the Brazilian states. When analyzing articles, the first time each field occurs is counted, and, when analyzing collaborations, the sum in which each variable appears in the analyzed whole, to broaden the view of their amount, since every time that field occurs per article is counted. Since the study focuses on the INT and its collaborations, we allocated the article and collaboration count in the tables excluding the INT, to get a better view of the relationships established with other institutions.

For a better understanding of the collaboration count, Table 1 shows a fictitious article with the variables this study covers. In it, article Alpha has 5 authors (i, ii, iii, iv, and v) from 4 different institutions (A, B, C, and D). When analyzing affiliations, 4 institutions will be computed, while each institution computes 1 article in the ranking. As for the collaboration count, all occurrences are computed, i.e., institution A would get 2 occurrences and be represented as follows: 1 (article) / 2 (collaboration occurrence). The same logic is applied to the country, state, category, and subcategory variables.

To facilitate visualization and interpretation, cuts were made in at least 5 articles in collaboration, in the ranking of institutions in the IST category.

Table 1 – Example of the fields analyzed in this study.

Article	Autors	Afiliation	Country	State	Category	Subcategory
	i	A	Brazil	SP	S&T - Instituitions	Research
	ii	B	Brazil	RJ	Government	Regulatory body
Alfa	iii	C	Brazil	MG	S&T - Instituitions	Education
	iv	A	Brazil	SP	S&T - Instituitions	Research
	v	D	France	-	S&T - Instituitions	Research
Article	Autors	Afiliation	Country	State	Category	Subcategory
Alfa		A, B, C, D	Brazil e France	SP, RJ, MG	S&T - Instituitions Government	Research, Regulatory body & Education

Source: Prepared by the author (2022).

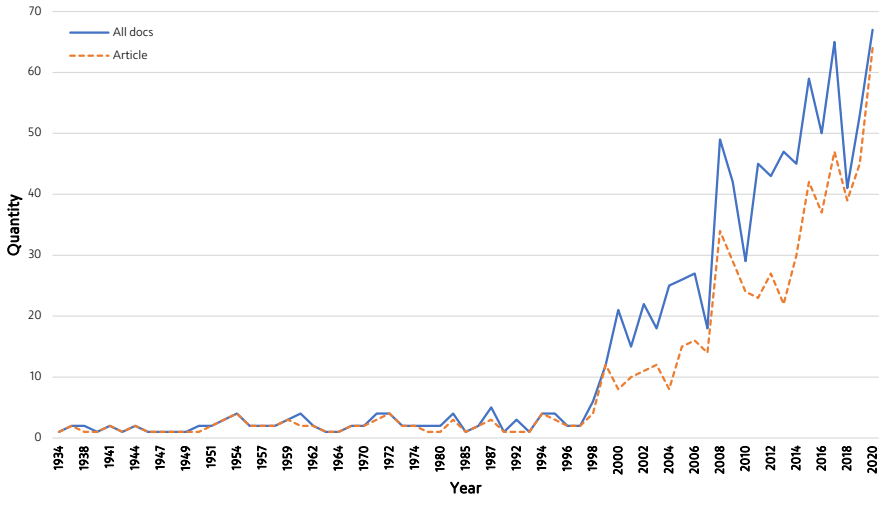
Results and Discussion

A total of 923 scientific documents were retrieved and divided into seven categories. On the collection date, the WoS database had 43 categories (Web of Science, 2020), while Scopus (Elsevier, 2020) only 11, so it was necessary to standardize document types. To do so, we considered "Conferences" as the sum of "*Meeting Abstract*" and "*Conference Paper*", Editorial as the sum of "*Editorial Materials*" and "*Editorial*," "*Proceedings Papers*" are journal articles previously presented at Conferences (Gonzalez-Albo; Bordons, 2011). The "Articles" category is the sum of "*Article in press*", *"Article early access*", *"Proceedings paper*", and *"Article review*", while books is the sum of books and book chapters.

The "Article" document type was the form of scientific communication that the INT used most in the analyzed period, accounting for 70.8% of the total number of documents, followed by "Conferences," coming in at 23.9%. These two types of scientific documents account for 94.7% of the total, while the five other types, "Book, Editorial, "Letter", "Erratum" e "Note", for less than 2%. Of the 654 articles published, the INT has 111 articles with sole authorship and/or with intra-institutional partnerships, and 543 articles produced in collaboration.

The first article retrieved was from 1934, and it had a single author. The first article produced in a collaboration between the INT and the School of Engineering of the University of Brazil, today the Federal University of Rio de Janeiro, was identified in 1941.

Figure 1 shows the evolution of all INT scientific documents, and its articles are shown separately; their sum per period appears at the bottom of the graph, the last period being the most productive. The growth curve begins in 1999, when for the first time more than 10 publications are identified, and almost all publications are articles only. Since data collection took place in 2020, we omitted the two articles approved for publication in 2021, as the graph would not correctly represent that year.



	1st Period	2nd Period	3rd Period	4th Period	Sum
All Docs	26	31	51	809	921*
Article	24	30	41	559	654

* A few years of Conferences has not been identified

Figure 1 – Evolution in the number of articles over time.
Source: Prparede by the author (2022).

It can be noted that the number of articles retrieved until 1998, although stable, represents a small amount of publications cataloged in the indexed databases. To understand the landscape of this period (1921-1998), one must keep in mind that the INT was created to conduct technological research to serve the productive sector, possibly not prioritizing publishing its results in articles in specialized scientific journals, but, rather, other types of documents, such as technical reports, for example, as previously mentioned in the work of the extinct Brazilian Institute of Bibliography and Documentation. This may be why the Institute behaved contrary to the world trend, in which research institutions showed an upward curve in terms of scientific production from 1960 onwards (Biojone, 2003).

It was only from 1998 that there was an increase in the number of publications, in line with what is seen in the literature, which correlates this growth with the increase in Brazilian graduate programs. It is also important to consider that this performance is the outcome of a careful scientific production evaluation model used by Capes and by other funding institutions, which tends to prioritize publication in high-impact journals with international visibility (Leta, 2011).

The document type "articles" was selected to allow for a better understanding of the INT's interactions with other institutions, as it has the largest number of document types used in the institute's scientific communications, for being a full and completed study that is submitted to a peer review process, and for being an institutional performance indicator.

Overview of the Collaborations

To get an overview of the players who produced scientific articles in collaboration with the INT (543), the institutions with which the authors state affiliation were analyzed in terms of the number of articles and occurrences of collaborations (Table 2). Due to the joint collaborations among the subcategories, for example, in a same article there are collaborations between the teaching and research subcategories, the sum of articles in these subcategories does not match the total of the IST category. They will only be the same when there are no collaborations among the subcategories, as in the case of the subcategories within government.

Table 2 – Number of articles and collaborations in categories and subcategories.

Category	S&T Instituitions		Companies		Government		
Articles (# 543)	530		53		20		
Collaboration Occurrence	1179		54		20		
Subcategory	Education	Research	State-run company	Private	Funding Agencies	Regulatory body	State Agency
Articles	510	108	26	27	2	17	1
Collaboration Occurrence	1055	124	26	28	2	17	1

Source: Prepared by the author (2022).

A total of 530 articles categorized as IST were identified, and in them 1179 collaborations among ISTs. In the company category, there were 53 articles with 54 collaborations, while in the government one there were 20 articles, none of which with more than one collaboration with other government institutions, so the occurrence of collaborations was also 20.Institutions classified as IST stood out compared to the others, with 530 articles, or 97.6% of the analyzed articles; companies collaborate with 9.4% of the articles, while government institutions with 3.7% of them.

In subcategories, meanwhile, in S&T, we have 510 articles with at least one teaching institution, or 96.2% of the total of these articles, and 1055 occurrences of collaborations with

teaching institutions. In Research, there were 108 articles done in collaboration with at least one research institution, which represents 20.4% of the total number of articles within the S&T category, which has 124 occurrences of collaborations among research institutions. This scenario can be justified based on the fact that educational institutions attribute greater importance to publishing their results in scientific articles because they are often evaluated in accordance with the number and quality of this type of publication that they have (Barata, 2019).

The number of articles published with government-owned companies represents 49.0% (26) of the total number of articles in collaboration with authors affiliated with a state-run company. Private companies represent 51.0% (27) in the category.

In the "Triple Helix" theory, the primary role of the government is not to actively engage in R&D activities, but rather to encourage interaction among other actors through funding and other initiatives that contribute to the conception and implementation of innovation projects (Etzkowitz; Zhou, 2017), a smaller number of collaborative articles was expected. There were two studies in the funding agencies subcategory in the Government category. Considering these institutions provide financial support to other institutions rather than having educational or research as their main lines of activity, these two statements may represent a filing error. As for regulatory bodies, collaborations were identified in 85% (17) of the publications.

Two pieces of information were analyzed before checking the ranking of institutions: The maximum number of partner institutions, without repetition per article, and the number of different institutions, both verified by period. As for partner institutions, there was an increase in collaborations within an article over the years, as a maximum of 2 were found in the first period, 3 in the second, 4 in the third, and 8 in the fourth. The number of different institutions also increased significantly per period, with 3 in the first period, 9 in the second, 16 in the third, and 215 in the last period, totaling 229 different institutions, 14 of which repeated over the periods, which indicates older collaborations.

Collaboration Ranking – IST

The ranking of institutions with at least 5 collaborative articles in the IST category (Table 3), indicates that the seven that most collaborated with the INT in the last period are Brazilian, the first four of which being based in Rio de Janeiro and located less than 25 km from the Institute: *Universidade Federal do Rio de Janeiro* (UFRJ, Federal University of Rio de Janeiro), *Universidade Federal Fluminense* (UFF, Fluminense Federal University), *Instituto Militar de Engenharia* (IME, Military Institute of Engineering), and the *Universidade do Estado do Rio de Janeiro* (UERJ, State University of Rio de Janeiro). The *Pontifícia Universidade Católica* (PUC, Pontifical Catholic University), fifth in the ranking, had 40 articles, 95% of which also written at the Rio de Janeiro campus. In the third period, the only institution with more than 5 articles in collaboration was UFRJ, with 18 articles and 27 occurrences of collaboration.

The INT is one of the few institutions affiliated with MCTI that does not have a graduate program. As "Brazilian science is entirely in the hands of graduate programs" (Leta, 2012, p. 51), it is possible that this is one of the reasons why the institute seeks closer ties with educational institutions as a strategy to boost research in its areas of expertise.

Table 3 – Ranking of partner institutions in the IST category with at least 5 articles in collaboration.

Rank	IAA *	Country	Num. Articles / Occurrence	Subcat.	Rank	IAA*	Country	Num. Articles / Occurrence	Subcat.
Period: 2000 a 2021									
1	UFRJ	Brazil	181 / 246	Educ.	16	DCTA	Brazil	8 / 8	Res.
2	UFF	Brazil	107 / 130	Educ.	16	UFSC	Brazil	8 / 9	Educ.
3	IME	Brazil	74 / 75	Educ.	16	UP	France	8 / 10	Educ.
4	UERJ	Brazil	41 / 43	Educ.	17	CNPEM	Brazil	7 / 7	Res.
5	PUC	Brazil	40 / 42	Educ.	17	UFRRJ	Brazil	7 / 7	Educ.
6	UFU	Brazil	28 / 28	Educ.	17	Unifei	Brazil	7 / 10	Educ.
7	UFSCar	Brazil	22 / 25	Educ.	18	CNEN	Brazil	6 / 6	Res.
7	UK	EUA	22 / 22	Educ.	18	UFJF	Brazil	6 /6	Educ.
8	Unicamp	Brazil	18 / 20	Educ.	18	UFMG	Brazil	6 / 6	Educ.
9	USP	Brazil	16 / 16	Educ.	18	UFPB	Brazil	6 / 8	Educ.
10	CEFET	Brazil	15 / 15	Educ.	18	UFPE	Brazil	6 / 8	Educ.
11	Fiocruz	Brazil	15 / 20	Res.	18	UFS	Brazil	6 / 6	Educ.
12	UFRGS	Brazil	12 / 18	Educ.	18	Estácio	Brazil	6 / 6	Educ.
13	OU	EUA	11 / 11	Educ.	18	UTSA	EUA	6 / 11	Educ.
14	UDL	France	10 / 10	Educ.	19	CETEM	Brazil	5 / 5	Res.
15	UFBA	Brazil	9 / 11	Educ.	19	MAST	Brazil	5 / 5	Educ.
16	CNRS	France	8 / 8	Res.	19	UNESP	Brazil	5 / 6	Educ.
16	CSIC	Spain	8 / 8	Res.	19	UA	Portugal	5 / 5	Educ.
Period: 1978 a 1999									
1	UFRJ	Brazil	18 / 27	Educ.					

Note: *IAA: Institution abbreviation or acronym; Educ.: Education; Res.: Research. CEFET – Centro Federal de Educação Tecnológica; CETEM – Centro de Tecnologia Mineral; CNEN – Comissão Nacional de Energia Nuclear; CNPEM – Centro Nacional de Pesquisa em Energia e Materiais; CNRS – Centre National de la Recherche Scientifique; CSIC – Consejo Superior de Investigaciones Científicas; DCTA – Departamento de Ciência e Tecnologia Aeroespacial; Estácio – Universidade Estácio de Sá; Fiocruz – Fundação Oswaldo Cruz; IME – Instituto Militar de Engenharia; MAST – Museu de Astronomia e Ciências Afins; OU – University of Oklahoma; PUC – Pontifícia Universidade Católica; UA – Universidade de Aveiro; UDL – Université de Lyon; UERJ – Universidade do Estado do Rio de Janeiro; UFBA – Universidade Federal da Bahia; UFF – Universidade Federal Fluminense; UFJF – Universidade Federal de Juiz de Fora; UFMG – Universidade Federal de Minas Gerais; UFPB – Universidade Federal da Paraíba; UFPE – Universidade Federal de Pernambuco; UFRGS – Universidade Federal do Rio Grande do Sul; UFRJ – Universidade Federal do Rio de Janeiro; UFRRJ – Universidade Federal Rural do Rio de Janeiro; UFS – Universidade Federal de Sergipe; UFSC – Universidade Federal de Santa Catarina; UFSCar – Universidade Federal de São Carlos; UFU – Universidade Federal de Uberlândia; UK – University of Kentucky; UNESP – Universidade Estadual Paulista; Unicamp – Universidade Estadual de Campinas; Unifei – Universidade Federal de Itajubá; UP – Universidade do Porto; USP – Universidade de São Paulo; UTSA – University of Texas at San Antonio.
Source: Prepared by the author (2022).

Of the 14 institutions collaborating in more than one period, for the first, third, and fourth periods we have UFRJ and Universidade de São Paulo (USP, University of São Paulo) which are the oldest partnerships, and UFF, being the only institution with uninterrupted partnerships in the second, third, and fourth periods. Among the partner institutions with the most collaborations, 8 were from abroad, of which 3 from the United States, 3 from France, 1 from Spain, and 1 from Portugal.

Collaboration Ranking – Companies

In the company category, the ranking of articles and collaborations (Table 4) by period points to three top companies: *Petróleo Brasileiro S. A.* (Petrobrás), a publicly traded company, with 18 articles (34.0% of the articles with companies); the *Empresa Brasileira de Pesquisa Agropecuária* (Embrapa, Brazilian Agricultural Research Corporation), a state-run company, with 7 articles (13.2%), and the *Serviço Nacional de Aprendizagem Industrial* (SENAI, National Learning Service Industrial), a non-profit private institution focused on education, with 6 articles (11.3%).

Table 4 – Ranking of partner Institutions in the Company category.

Period	Rank	Companies	Country	Num. Articles / Occurrence	Subcategory
	1	Petrobras	Brazil	18 / 18	public
	2	Embrapa	Brazil	07 / 07	public
	3	SENAI	Brazil	6 / 6	private
	4	CDPI	Brazil	4 / 5	private
	5	Create Health Clinic	United Kingdom	2 / 2	private
	6	3 Tentos	Brazil	1 / 1	private
	6	Braskem sa	Brazil	1 / 1	private
	6	Consultora	Brazil	1 / 1	private
	6	Eco Sust Develop Ltda	Brazil	1 / 1	private
2000 a 2021	6	Enersol Consulting Eng	Australia	1 / 1	private
	6	Ipiranga	Brazil	1 / 1	private
	6	Lab Paulo Loureiro	Brazil	1 / 1	private
	6	Oxiteno	Brazil	1 / 1	private
	6	Peróxidos do Brasil	Brazil	1 / 1	private
	6	PMI	Brazil	1 / 1	private
	6	Protip Medical	France	1 / 1	private
	6	Redetec	Brazil	1 / 1	public
	6	UTC Eng	Brazil	1 / 1	private
	6	Waters Corp	Brazil	1 / 1	private
1978 a 1999	6	Esso Bra Petr SA	Brazil	1 / 1	private
1955 a 1977	6	Radiation Research Corp	United State	1 / 1	private

Source: Prepared by the author (2022).

The fourth and fifth in the ranking - Diagnostic Image Clinic (CDPI) and the *Create Health Clinic* from the United Kingdom – also stand out for having two articles in collaboration; the other companies have no collaborations with other companies, unlike what is seen in the IST category. It is noticeable that the vast majority, 17 of 21, are Brazilian companies, with emphasis on Petrobrás, an oil company with a legal obligation to have expenses qualified as R, D&I in the form of projects or programs conducted in Brazil. When analyzing the companies' legal regime, it is seen that most are private, with 18 companies (85.7%), while 3 are state-owned (3%): Petrobrás, Embrapa, and Redetec – a non-profit association that encourages innovation in the state of Rio de Janeiro, but the number of articles published is similar, *i.e.*, 27 for private and 26 for state-owned corporations.

It is noted that the INT relates to companies from different market segments, such as a group of companies focused on oil exploration, refining, and distribution: Petrobrás, Esso, and Ipiranga, with 37.8% of the articles, and others operating out of the chemicals area, such as Braskem, Oxiteno, and Peroxidos do Brasil, with 5.7% of the articles. These are areas of knowledge that have always predominated at the institute. In collaborations with state-run companies, no articles were identified in which a same company appeared more than once, whereas only one article was identified in collaboration with private companies in which CDPI appeared twice.

The majority of the companies that collaborated with INT were foreign multinational corporations established in Brazil; however, the collaboration is primarily concentrated with Petrobrás (34%). This difference is due, among other factors, to the mandatory investment in R&D, as well as the former relationship between INT and Petrobrás, which actively participated in

discussions related to the definition of policies and strategies in the oil sector in Brazil and supported the creation of the company (Instituto Nacional de Tecnologia, 2005).

Several authors have recognized the positive association between company partnership activities and their long-term innovation performance (Breschi; Malerba, 2005; Chen; Lin, 2017; Edquist, 2011). These networks are mainly made up of innovative companies in addition to government agencies, universities, research centers and financial agents (Gardet; Mothe, 2011; Pyka; Kuppers, 2003).

It should be noted that (with only one exception) collaborations with private companies were restricted to the partner company only, that is, only one company appears as a collaborator in each article, quite different from the profile seen in collaborations between the INT and other ISTs. This profile was expected since a company's ability to innovate depends on its capacity to absorb new knowledge, which is often achieved through its relationship with universities and research institutes (Nagane; Sumikura, 2020).

Collaboration with the productive sector in scientific publications may also be related to regional proximity, as well as the characteristics of the available research infrastructure, which can be a motivating factor in certain sectors that require high investment (De Negri; Cavalcante; Alves, 2013). As in Brazil, it can be inferred that collaborations with state-owned technology-based ISTs, such as the INT are an integral part of the competitive strategy in the companies' innovation environment, allowing them to develop new skills and competencies, which in turn can help promote national innovation (De Faria; Lima; Santos, 2010).

The Brazilian government has been actively promoting this form of collaboration, by bringing closer together ISTs and the productive sector, by implementing financial instruments to support innovation, whether through fiscal incentives such as the Lei do Bem (Law of Good), or capital investment, contribute to fostering technological development and the innovation process (Santana *et al.*, 2019)para o período de 2005-2014. Para avaliar a concentração regional do financiamento à inovação foram construídos três indicadores, tomando como base a quantidade de empresas beneficiadas (ICFq, for example the creation of *Empresa Brasileira de Pesquisa e Inovação Industrial* (Brazilian Company for Industrial Research and Innovation), through partnerships among industry, academia, and the government.

Collaboration Ranking – Government

In the Government category (Table 5), the 20 articles done in collaboration occur in the second and fourth periods. Three of the five subcategories are regulatory agencies and represent 85.0% of the articles in this category. Inmetro stands out with 13 of the 20 published articles (65.0%), but it is important to note that despite its status as a regulatory agency (Government), it was born within the INT and instituted in the 1970s. All institutions in this subcategory appear only once per article, so the number of articles is equal to the number of collaboration occurrences. The only international partnership identified was with the *International Atomic Energy Agency*, a regulatory agency headquartered in Austria.

Collaborations with Other Institutions – Brazil

Activities that involve the generation, dissemination, and transmission of scientific knowledge are spatially distributed. To analyze scientific collaborations, which include those with other institutions in different regions of Brazil, it is very important to consider the geographic

perspective in scientometric analyses to identify patterns of spatial interaction of the scientific activity (Ponds; Oort; Frenken, 2009). Of the 543 articles prepared in collaboration with the INT, 989 collaboration occurrences were identified, with a sum of 629 articles distributed in the states, represented in Table 6 , which shows the results of collaborations by state and region for the selected periods. Of the 27 Brazilian states, collaborations were established with 18, or 66.7% of the existing states.

Table 5 – Ranking of partner Institutions in the Government category.

Period	Rank	Government	Country	Num. Articles / Occurrence	Subcategory
2000 a 2021	1	INMETRO	Brazil	13 / 13	Regulatory Body
	2	ANP	Brazil	3 / 3	Regulatory Body
	3	CNPQ	Brazil	2 / 2	Funding Agencies
	4	Secr. Desenv. Tec. Inov.	Brazil	1 / 1	State Agency
1955 a 1977	4	IAEA	Austria	1 / 1	Regulatory Body

Note: ANP – Agência Nacional do Petróleo, Gás Natural e Biocombustíveis; CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico; IAEA – International Atomic Energy Agency; INMETRO – Instituto Nacional de Metrologia, Qualidade e Tecnologia; Secr. Desenv. Tec. Inov. – Secretaria de Desenvolvimento Tecnológico e Inovação.
Source: Prepared by the author (2022).

Table 6 – Partnerships with Brazilian states.

Region	State	Num. Articles / Occurrence				
		1934 a 1955	1956 a 1977	1978 a 1999	2000 a 2021	Sum
Southeast	Rio de Janeiro*	1 / 1	3 / 3	20 / 30	385 / 669	409 / 703
	São Paulo	1 / 1	1 / 1	5 / 5	71 / 95	78 / 102
	Minas Gerais				49 / 60	49 / 60
Sum		2 / 2	4 / 4	25 / 35	505 / 824	536 / 865
Northeast	Paraíba				8 / 13	8 / 13
	Pernambuco				8 / 13	8 / 13
	Maranhão				5 / 6	5 / 6
	Rio Grande do Norte				5 / 5	5 / 5
	Bahia				14 / 19	14 / 19
	Ceará				1 / 1	1 / 1
	Piauí				1 / 1	1 / 1
	Alagoas				3 / 3	3 / 3
Sum					45 / 61	45 / 61
South	Rio Grande do Sul				18 / 26	18 / 26
	Paraná				9 / 15	9 / 15
	Santa Catarina				9 / 10	9 / 10
Sum					36 / 51	36 / 51
Central West	Distrito Federal				4 / 4	4 / 4
	Goiás				3 / 3	3 / 3
Sum					7 / 7	7 / 7
North	Acre				1 / 1	1 / 1
	Pará				4 / 4	4 / 4
Sum					5 / 5	5 / 5
Total Sum		2 / 2	4 / 4	25 / 35	598 / 948	629 / 989

Note: *For the calculation was used Rio de Janeiro excluding one or multiple-authors papers from INT alone.
Source: Prepared by the author (2022).

Partnerships with Rio de Janeiro (the INT's home state) accounted for 75.3% of the articles in collaboration. In the first period, the Institute collaborated with a single institution outside its state of origin, the USP, while in the second period again with a single institution in the state of São Paulo, Universidade Paulista Júlio Mesquita Filho (UNESP). It was only from the fourth period that collaborations outside the state of Rio de Janeiro began to stand out. Several factors have contributed to the increase in scientific collaborations among actors from different regions, like the significant decline in the real cost of travel and communication, combined with increased availability and easy access (Katz; Martin, 1997). These factors likely contributed to the increase in collaborations during the analyzed period.

When creating a ranking of the five states with the most articles in partnership with the INT, the following stand out: Rio de Janeiro (409), São Paulo (78), Minas Gerais (49), Rio Grande do Sul (18), and Bahia (14). It is believed that this concentration of collaborations with the state of Rio de Janeiro is partly justified by geographic proximity, which, for example, facilitates laboratory infrastructure sharing and interaction among researchers. In addition, the INT has researchers who have stated in their articles their affiliation with other research institutions such as INT/UFRJ and INT/IME, for example.

Analyzing the number of articles drafted in collaboration by region, from largest to smallest, we have: Southeast (536 / 86,9 %), Northeast (45 / 6,4%), South (36 / 5,4%), Midwest (7), and North (5). These results are aligned with what is commonly pointed out in analyses of Brazilian scientific production, which is spatially concentrated in a few states, with the southeastern region standing out quantitatively and with low occurrence of collaborations with the Midwest and North regions (Sidone; Haddad; Mena-Chalco, 2016; Smith; Sotala, 2011).

In the Southeast region, of the 4 states, collaborations were found with the states of Rio de Janeiro, São Paulo, and Minas Gerais. Of the 9 states in the Northeast, only Sergipe had no collaborations. Collaborations were found with all 4 states in the South region. Of the 4 states in the Midwest, collaborations were found only with Goiás and the Federal District, and of the 7 states in the North region, the Institute partnered with only two: Acre and Pará.

Conclusion

This study presents a scientometric methodology that allows exploring collaboration relationships among institutions based on the analysis of the publication of scientific papers. In addition, exposing the data and analysis of the results of a Brazilian technology-based state-run research institute, contributes to the debate on collaborations in research and development among the main players of innovation.

The results reflect the multidisciplinary nature of the institution, with a great diversity of education and research ISTs in its relationships. Regarding the proportion of articles published in collaboration, the vast majority of publications occurred between INT and other IST´s, followed by companies, and lastly the government. A more detailed analysis identified that the greatest emphasis was on articles developed in conjunction with research institutions that also engaged in teaching activities, followed by research institutions, and then state-run and private companies, respectively. There were collaborations with government organizations, but with little representation.

In terms of international collaborations, there are also some international partners, including renowned universities and research centers, mainly in the USA and Europe, demonstrating the institution's efforts in the internationalization process.

In regional terms, the majority of collaborations were from institutions based in the Southeast region. The increase in partner institutions (Brazilian and foreign) in the last two decades is evidence of the Brazilian government's effort (public policies, investment in research and development, human and financial resources, etc.) to expand the institution's collaborations in order to promote science, technology, and innovation in the country.

Although studying from a single institution favors specific conclusions, it is believed to be relevant to use the same methodology to analyze scientific articles from multiple institutions, such as those affiliated with MCTI, thus obtaining an even broader overview of relationships.

This study has the limitation of disregarding articles that were not included in the databases that were used. A few other limitations were found, which are related to the structure of the data in the databases and may impact scientific publication co-authorship results. Examples of this include inconsistencies in how the data are presented, an unidentified co-author's institutional affiliation, and acronyms of unidentified companies.

To understand the institution's relationship through the knowledge area, deepening analyses with a qualitative focus and mapping cluster was identified as an opportunity for further research. There is also the opportunity to conduct a patent analysis of the institution to investigate whether collaborations in scientific articles and patent filings are related.

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