University collaborations in Brazilian regions: spatial network analysis

Márcia Siqueira Rapini (CEDEPLAR-UFMG);

Tulio Chiarini (INT/MCTI);

Alexandre Queiroz Stein (CEDEPLAR - UFMG)

Resumo:

Neste artigo, propomos analisar as colaborações realizadas pelas universidades brasileiras nas diferentes regiões. As universidades desempenham papel fundamental nos Sistemas Nacionais de Inovação, fornecendo conhecimento, pesquisa e capital humano. Utilizando o Censo 2016 do Diretório de Grupos de Pesquisa do Conselho Nacional de Pesquisa Científica e Tecnológica (CNPq), analisamos 28.181 colaborações dos grupos de pesquisa com diferentes parceiros a partir de metodologia de redes. As análises evidenciam a existência de diferenças importantes quanto aos parceiros locais, sugerindo a necessidade de ampliar o foco das políticas de CT&I que têm sido voltadas às colaborações com empresas. O foco nas colaborações universidade–empresa reforça as desigualdades entre as regiões brasileiras e limita o papel da universidade no desenvolvimento local, em especial no contexto de um país marcado por disparidades regionais historicamente desenvolvidas.

Palavras-chave:

Colaboração de universidades; grupos de pesquisa; metodologia de redes; regiões; Brasil

Código JEL:

O38; O39

Área Temática:

Redes de inovação – alianças de P&D, interações universidade-empresa, outras redes

Espaço reservado para organização do congresso.

1.   Introduction

Since the 1980s universities are being suggested to be more connected to society in order to contribute to economic growth, by supporting and fostering the propensity of technology-intensive sectors to innovate, through technology transfer, collaborations with profit-seeking companies and the creation of startups and spin-offs (ETZKOWITZ, 1983; GEUNA, 2001; KLOFSTEN et al., 2018; PERKMANN et al., 2013). In fact, some scholars call for an "entrepreneurial" role of universities, creating and commercializing new technologies (BERCOVITZ; FELDMANN, 2006). This agenda has been stimulated by innovation policies worldwide emulating the U.S. Bayh-Dole Act of 1980 which fostered technology transfer from publicly funded research in universities to firms (MOWERY; SAMPAT, 2004). As a consequence, many scholars and policy makers have proclaimed that universities should follow the "entrepreneurial agenda" (DALMARCO; HULSINK; BLOIS, 2018).

Brazilian policy makers replicated this agenda approving, in the beginning of the 2000s, the so-called Innovation Law (*Lei da Inovação*) whose aim is to encouraged universities to comply with the normative "entrepreneurial agenda". Notwithstanding those efforts, results are still incipient, as Brazilian profit-seeking companies demand little knowledge from universities which, on their turn, interact more with other universities in what is considered "academic collaborations".

Even if the concept of the entrepreneurial university was based on its orientation towards knowledge for the sake of solving specific challenges confronting society (AUDRETSCH, 2014), the focus on the "entrepreneurial" role of universities was mainly devoted to university–industry collaborations, disregarding – or putting at a secondary category at best – the collaborations with other partners (GEUNA; MUSCIO, 2009). As a critique on "entrepreneurial agenda" emphasis, a sort of "developmental" role of universities has been defended by some scholars, especially in the context of developing countries (AROCENA; GÖRANSSON; SUTZ, 2015; BRUNDENIUS; LUNDVALL; SUTZ, 2008; GÖRANSSON; MAHARAJH; SCHMOCH, 2009). These authors enlighten universities' collaborations in a broad perspective, giving emphasis on how universities can co-deliver social innovations (AROCENA; SUTZ, 2021; BAYUO; CHAMINADE; GÖRANSSON, 2020; MCKELVEY; ZARING, 2018) and promote social, economic and cultural development (GÖRANSSON; MAHARAJH; SCHMOCH, 2009).

In this paper we present the developmental role of Brazilian universities, showing their collaborations beyond university–industry relations by geographic regions. We show that there are important differences in university collaboration in Brazilian regions regarding local partners. Brazil is a huge continental country with geographical and territorial inequalities, showing diversity among its regions also regarding knowledge demand. Consequently, the focus on university collaboration with firms limits the contribution of university for development reinforcing regional inequalities.

The article is organized into five sections, including this introduction and some concluding remarks. In the second section, we present a brief review of the literature on the role of universities in National Innovation Systems stressing the Latina American and Brazilian debate. Section three address the methodology used to construct our dataset. We make use of secondary data provided by the Research Groups Directory of the Brazilian National Technological and Scientific Research Council (CNPq) which is responsible for gathering information about the research groups (*Grupos de Pesquisa*). We focus our analysis on 2016, which is the last Census year available. In section four, we present descriptive analysis based in spatial network analysis focusing on universities collaborations and in then we discuss regional level disparities. Finally, in section five, we conclude the article, reflecting on the importance to adapt science, technology and innovation (ST&I) policies in the light of regional disparities.

2.   University role and collaborations in National Innovation Systems

We can cite at least three authors whose contributions consolidated the traditional "canonic" National Innovation System (NIS) approach. Their seminal inputs came from cases of developed countries: Freeman (1987, 1995), for instance, analyzed Japan, highlighting its historical dimensions; while Nelson (1993) investigated the case of the US and focused on the role of explicit policies and scientific-technological institutions; finally, Lundvall (1992) inspected the case of Scandinavia, accentuating the role of collaborations, mainly between producers and users.

With those contributions, universities gained a paramount role in being the source of knowledge

and providing competences through training and scientific research. There is an ample and rich literature that describes them as an important part of the capitalist system as they can increase the country's knowledge stock and its innovative opportunities (MAZZOLENI; NELSON, 2006; NELSON, 1990). Consequently, most studies using the NIS framework end up focusing on university–industry collaborations and their challenges to foster innovation and technological upgrading. Relevant work has been done and systematized elsewhere (D'ESTE; PATEL, 2007; ETZKOWITZ, 1983; GEUNA; MUSCIO, 2009; MASCARENHAS; FERREIRA; MARQUES, 2018; PERKMANN et al., 2013; PETERS; ETZKOWITZ, 1990; SJÖÖ; HELLSTRÖM, 2019)

The previous perspective has influenced many scholars in the developing world who attempted to use straightforward the NIS approach. Consequently, the main focus remained the university collaboration with profit-seeking firms – as in Argentina (ARZA; VAZQUEZ, 2010), China (HOU et al., 2020), Iran (SALAMZADEH; FARSI; SALAMZADEH, 2013), Mexico (DE FUENTES; DUTRÉNIT, 2012), Nigeria (OYELARAN-OYEYINKA; ADEBOWALE, 2012) and Turkey (GÖKSIDAN; ERDIL; ÇAKMUR, 2018), just to cite a few.

In most developing countries universities do not have the same role played by their peers in more developed industrial economies (KRUSS; VISSER, 2017). Most of those countries are not knowledge-based and innovation-driven, thus science is rarely used for the development of radically new products and processes once there is little knowledge demand from production despite the existence, in many countries, of highly qualified scientists and well-equipped research laboratories (RODRIK, 2008). Consequently, universities are somehow disconnected from industrial needs (AROCENA; SUTZ, 2005)

That being said, the analytical tools commonly proposed by NIS approach and used in more developed countries, e.g. university–industry collaboration, fail in less developed countries where "the productive structure and the scientific and technological infrastructure alienate from each other" (AROCENA; GÖRANSSON; SUTZ, 2018, p. 78) and where we find "disconnected universities", focused more on consulting (AROCENA; SUTZ, 2005). As in most of these countries market demand for scientific and technological knowledge is weak, an innovation-driven and learning society is absent.

In an attempt to build more genuine visions to capture local specificities, broadening the theoretical-conceptual framework including new analytical dimensions, many Latin American researchers debated on the conceptualization of the NIS approach and on its characterization and usefulness to both interpret and promote development processes (DUTRÉNIT; SUTZ, 2013; CASSIOLATO; LASTRES, 2002). As a consequence, their perspective privileges regional aspects – instead of national ones – considering different development processes of each region in terms of its historical, structural and productive dynamics.

Regarding the university role in NIS, Arocena et al. (2015) stressed their potential to contribute to solve social, cultural and environmental claiming, contributing to economic and social development. Universities are not only relevant knowledge producers for industrial needs, but they have also the potential to contribute to boost social policies to "build the system" (AROCENA, et. al. 2018). Universities committed to the development process are "developmental universities" (AROCENA; GÖRANSSON; SUTZ, 2015).

In Brazil, the university role in brazilian National Systems of Innovation were predominantly investigated by its collaboration with firms (SUZIGAN; ALBUQUERQUE; CARIO, 2011; FERNANDES, et. al., 2010), also in regional perspective (GARCIA, et. al, 2018). Some authors already stressed that university collaboration in Brazil were reduced to the ones with firm collaboration (DAGNINO, 2007; SERRA; ROLIM; BASTOS, 2018; SILVA, 2012).

In an attempt to enlarge this vision some studies carried out in considered a very broad perspective of universities' collaboration within the NIS (LASTRES et al., 2019; MARCELLINO; RAPINI; CHIARINI, 2019). They stress that a relevant part of university-society relationships remain below the radar when the debate focuses on university-industry interactions. Other studies focused in some areas or regions. Tatsch, Ruffoni, and Botellho (2016) analyzed university collaborations in the health sector finding that they are broad in scope and entangle different partners as hospitals, other universities, and various types of productive sector organizations. D. S. Silva (2020), on her turn, showed the importance of considering other partners rather than just profit-seeking firms when analyzing universities collaborations to foster economic development in the Northeast of Brazil, one of the least developed regions in the country.

As presented in the Introduction, our study presents university collaborations that go beyond those

with firms. Moreover, we consider the Latin American critique on NIS and take into account that Brazil is a continental country with large regional asymmetry, especially regarding science and technology infrastructure and innovative and productive capabilities. Consequently, we propose to take a closer look at university collaboration with distinct partners considering Brazilian regions.

3. Methodology

The analysis proposed in this paper is based on principles of a deductive reasoning approach, starting out with a general premise that universities play a key role in NIS by providing knowledge and competences through training and research, therefore, collaborating with distinct partners. Based on that premise, we use a descriptive method with spatial network analyses to show universities' collaborations in Brazil considering regional differences, as the country has non-neglected regional asymmetries, especially regarding S&T infrastructure and innovative and productive capabilities.

3.1 Database

The Brazilian National Council for Scientific and Technological Development (*Conselho Nacional de Desenvolvimento Científico e Tecnológico* – CNPq) is a fifty-year-old organization of the Brazilian Ministry of Science, Technology and Innovations (*Ministério da Ciência, Tecnologia e Inovações* – MCTI) responsible for distributing research grants to the Brazilian scientific communities. CNPq created in the 1990s the Directory of Research Groups (*Diretório dos Grupos de Pesquisa*) which is a database that gathers biennially information about research activities in Brazil using the "research group" as the unity of analysis. The directory provides a proxy for studying research activities in the country and, since 2002, collaborations with partners were introduced in the questionnaire[1]. Therefore, the database supplies the record details about Brazilian university collaborations in general[2]. Being them the unit of analysis, the university collaboration data allows us to identify all collaborations, and to characterize them according to geographic region, partners' typology and location. In order to provide answers to questions presented previously we use microdata of year 2016 as it is the last Directory of Research Groups Census available.

Aiming at systematizing research groups' collaborations according to partners' characteristics, our first step was to classify the partners into seven categories. As follows:

1) government (including local and state governments);
2) universities (including colleges and research institutes);
3) trade unions (including the S-System[3]);

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[1] The Directory proposes 14 types of possible interactions; however, there is not any sort of intensity scale. Each research group leader can list at most the three most frequent types of interactions. University research groups relations with external partners can be classified in nine different types and the inverse, that is, interactions from external research groups with university research groups can be of four kinds. The different types of Modes of Interaction are: 1) Consultancy; 2) Non-routine engineering (including prototype development and pilot plants and equipment development); 3) Software development; 4) Supply of inputs and materials not linked to joint projects; 5) Scientific research (for immediate use of results); 6) Scientific research (not for immediate use of results); 7) Technology transference; 8) Training (including "on the job"); and 9) Others. Modes numbered 2, 3, 4, 7 and 8 indicate interactions with possible bilateral exchange of knowledge and information between research groups and partners. Although in this present paper we do not use these characteristics about the interactions, they are a potential information to qualify the analysis in future studies.

[2] We would like to make a caveat once our database has important limitations. Firstly, adherence to the Directory is voluntary and spontaneous, although researchers are highly encouraged to participate, mainly because the updated information is a precondition for access to public funding and scientific research. It should be emphasized that interactions with society is not a criterion used by governmental agencies to evaluate the performance of the research, which may explain their expressive underestimation.

[3] The S-System is a joint system of social contributions paid by companies: National Service of Rural Apprenticeship – SENAR; National Service of Trade Apprenticeship – SENAC; National Trade Social Service – SESC; National Service of Cooperativism Apprenticeship – SESCOOP; National Service of Industrial Apprenticeship – SENAI; Industry Social Service – SESI; Social Service of Transportation – SEST; National Service of Transportation Apprenticeship – SENAT; and Brazilian Service of Micro and Small Size Companies

4) companies (including public enterprises and majority-owned foreign affiliates located in Brazil);

5) cooperatives;

6) hospitals (excluding university hospitals, which were included in "universities" category); and,

7) others (including banks, financial institutions, foundations and other foreign institutions with offices based in Brazil like the United Nations' agencies).

Collaborations with foreign partners – which represent 13% of total collaborations – are not considered in our study once it is out of scope.

Secondly, we harmonized different names and ways of writing the names of one partner once there are imprecise information, for example due to misspelling. We had to take another important decision regarding all different units and branches of one partner belonging to the same corporation. For instance, there are collaborations between a research group and "3M do Brasil – Matriz" located in São Paulo State (Southeast region) and another between a research group and "3M Manaus", located in Amazonas State (North region). Both partners are obviously subsidiaries of "3M" and belong to the same group; however, we consider them as distinct partners. This choice is justified once our focus is also on local and regional collaborations. Therefore, if we considered the subsidiaries as the same partner, it would bring a non-neglected bias, because they would have to be accounted in the same municipality and consequently in the same region, which it is not true in many cases. We considered three criteria to differentiate partners: their names, municipalities and categories. Two partners are accounted as not being the same if they have at least one of these three criteria different.

Our final database comprises information of over 28 thousand collaborations between 11,888 research groups and over 5 thousand partners.

3.2 Networks and collaboration distance

In order to build a more accurate idea about the spatial and regional dimension of the collaborations, we developed undirected networks. We consider each of the 11,888 research groups and the 5,886 partners as nodes connected by the 28,181 collaborations, which were considered as the network edges (connections). We identify five possible networks (Figure 1)[4]:

a) university–society network;

b) university–industry network;

c) university–university network;

d) university–government network;

e) university–other partners' network.

The first network is built with research groups and all partners (represented in Figure 1 by letter "A"). We call it "university–society network". The "university–industry network" (letter "B" depicted in Figure 1) represents the research groups' relations with profit-seeking companies, therefore the nodes in this case are only research groups or companies.

Support – SEBRAE).

[4] Network "A" (university–society) can be visualized as a main graph and the others as subgraphs where just the interest nodes and connections were kept.
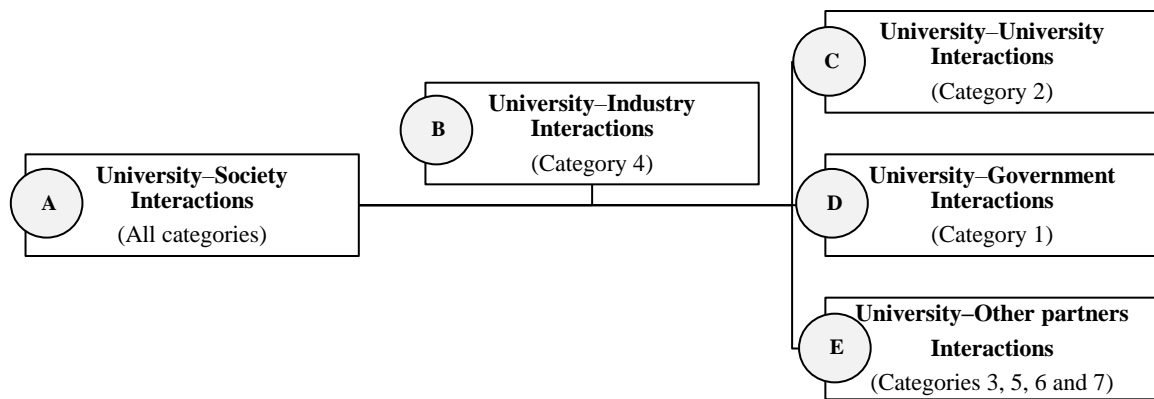
Figure 1 – University networks

Source: Authors' own.

In the third network – marked by letter "C" in Figure 1 – we consider only academic relations, therefore, we call it "university–university network". Collaborations with government is represented by "university–government network" ("D"), as they are especially important in developing country context (SCHWARTZMAN, 2009). Finally, the last network, to our concern, is under studied and it represents the university collaborations with omitted groups and we call them "other partners": domestic associations, domestic cooperatives, foundations, domestic hospitals and international agencies located in Brazil. This last network is represented by letter "E" in Figure 1 and we name it "university–other partners' network".

In all networks, as the collaborations are always between a research group and a partner, there are neither "research group–research group" nor "partner–partner" connections, that is, edges connecting nodes of the same type. Finally, to bring up the spatial element for the networks we set the Euclidean distance from the municipality seat of the research group to the municipality seat of the partner as an edge weight. In other words, we set the distance in kilometers as the intensity of the connections.

We consider only network nodes that correspond to research groups to compute network measures. It is possible to calculate several measures from a network that allows us to understand the network topology. In our case, we used the measures of degree and weighted degrees of nodes. The degree of a node measures the number of adjacent edges of that node, which means the number of connections that this node has to other nodes. The weighted degree measures the number of adjacent edges of a node considering its weight, which means the sum of the weights of a node's connections. In our case, as each edge represents a collaboration and the weight of each edge is the distance between the municipality of the research group and the municipality of the partner, the degree of a node shows the number of collaborations a research group made, while the weighted degree shows the sum of the distances of its collaborations, as presented in Figure 2[5].

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5   To see more about undirected networks and measures of degree and weighted degree, consult Newman (2018) or Jackson (2010).
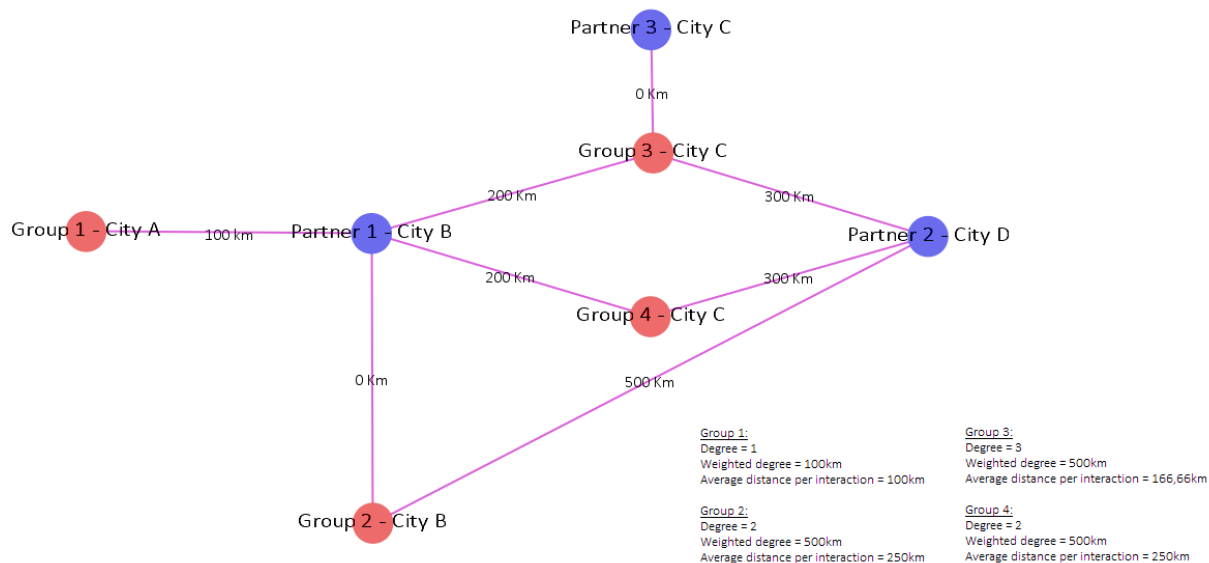
Figure 2 – Example of network structure and measures, 2016

Source: Authors' own.

In essence, in this paper the first measure is the number of collaborations of each group (node degree), the second is the sum of the distances of the collaborations of each research group (node weighted degree) and the last is the average distance per collaboration. These measures allow us to see in section 4 the differences between the research groups of each Brazilian region.

4. Descriptive data analysis

The simple counting of collaborations and partners, which is the most basic descriptive data, already brings the central argument of the paper and confirm its importance: a relevant part of universities' collaborations is not with firms. Companies represent nearly half of total partners (51%) while university–industry collaborations represent only 18% of total (Figure 3). A relevant part of universities' collaborations – 82% of total collaborations – are between universities and other partners as universities, government, trade unions, hospitals, cooperatives, etc.
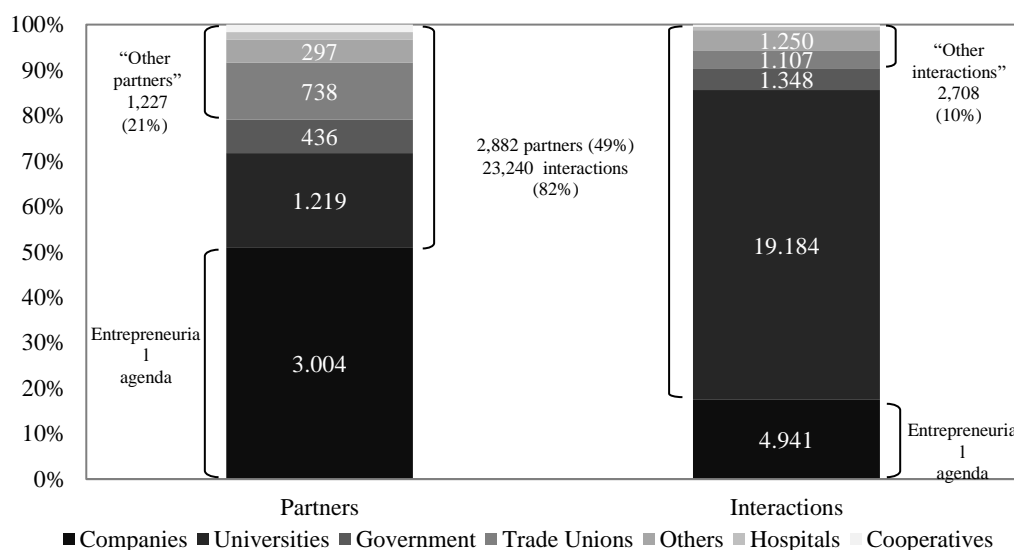

Figure 3 – Types of partners and collaborations, 2016
Source: Authors' own. Data sourced from CNPq. Note: total partners = 5,886; total collaborations = 28.181

Those partners do not represent a homogeneous group, as it is shown on Table 1. Within that group two partners are more frequent: universities and government which represent respectively 20.71% and 7.41% of total partners, and 68% and 4.7% of total collaborations. The "collaborations-by-partner" ratio is especially high, showing 15.7 collaborations by partner on average. These figures reinforce that academic cooperation (university–university relations) are intense in Brazil and that government is a potential user of knowledge produced by universities in developing countries, as in showed in university–government collaboration. In Brazil, Schwartzman (2009) demonstrates that the major buyer and user of scientific and technological research is not necessarily the private productive sector, but the public sector.

Table 1 – Partners and collaborations

Networks	Partners' Category	Partners		Collaborations		"Collaborations-by-partner" ratio
		N. (a)	%	N. (b)	%	(b)/(a)
University–Industry	Companies	3,004	51.04	4,941	17.53	1.6
University–University	Universities	1,219	20.71	19,184	68.07	15.7
University–Government	Government	436	7.41	1,348	4.78	3.1
University–Other partners	Other partners	1,227	20.85	2,708	9.61	2.2
	Trade Unions	738	12.54	1,107	3.93	1.5
	Hospitals	95	1.61	204	0.72	2.1
	Cooperatives	97	1.65	147	0.52	1.5
	Others*	297	5.05	1,250	4.44	4.2
University–Society	Total partners	5,886	100	28,181	100	4.8

Source: Authors' own. Data sourced from CNPq. Note: (*) Foundations; and international agencies located in Brazil.

Notwithstanding that, other 20% of total partners embrace 10% of total collaborations. These "other partners" are trade unions, hospitals (excluding the ones belonging to universities' structures), cooperatives and international agencies based in Brazil. The first interesting thing to note is that other partners' collaborations-by-partner ratio is 2.2 which is higher than companies' ratio (1.6) (Table 1). Therefore, we can say that "Other partners" are more interactive than partners that are companies.

4.1   Heterogeneous economies, different partners

As we presented previously, university collaborates with a great number of different partners. In this section we will show how those kinds of collaborations are more important in regions outside the country's economic center, meaning that neglecting their role in development tend to make room for more regional inequalities.

First, looking at research groups and partners spatial distribution by municipalities we can observe that while research groups are spread throughout the regions, partners are more concentrated in Southeast and South regions (Figure 4). The number of research groups divided partner is bigger in North (3.08), Northeast (2.20) and Central-West (2.11), than in Southeast (1.92) and South (1,84). We can also notice that partners are located but not restricted to the capitals in South and Southeast. There are considerable partners in the countryside – as in Campinas, Ribeirão Preto, Uberlândia, Londrina, Santa Maria etc. For the other regions, partners are mainly located in big cities, especially in capitals such as Salvador, Recife, Fortaleza, Belém and Manaus, reinforcing that the Brazilian urban structure is asymmetrical and marked by strong polarization of few large cities and by fragile medium-sized cities (RUIZ, 2005).

This pattern reinforces that S&T dynamics in Brazil differ regionally. In fact, intellectual and research assets are concentrated in the South and Southeast regions of the country (ALBUQUERQUE et al., 2002; ARAÚJO; GARCIA, 2019; CHIARINI et al., 2014; SANTOS; CALIARI, 2012; SIDONE; HADDAD; MENA-CHALCO, 2016), mainly in four states: São Paulo, Minas Gerais, Rio de Janeiro and Rio Grande do Sul (CHIARINI et al., 2014).
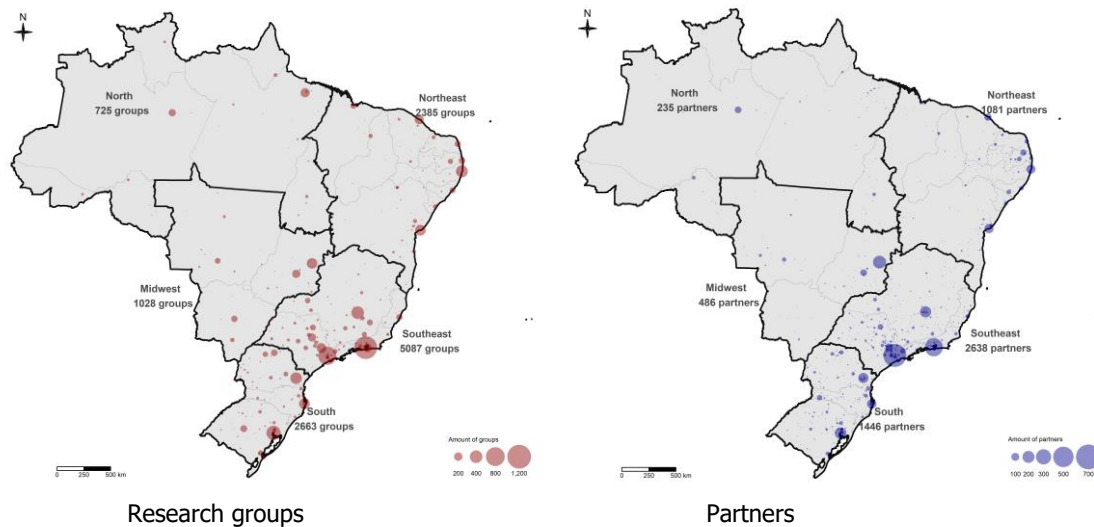
Research groups   Partners

Figure 4 – Research groups and partners per municipality, 2016

Source: Authors' own. Data sourced from CNPq. Note: total research groups = 11,888; total partners = 5,886.

As we can see in Table 2, not only the number of partners are different between regions, but also the composition of the partners. Companies are 56.25% and 57.26% of the partners on the Southeast and South, respectively, while they represent just 32.30%, 38.30 and 41.17% of the partners located on the Center-West, North and Northeast. In these last three regions, government represents a more important percentage of the partners comparing to the South and Southeast. Besides, we must highlight that universities represents an important percentage of northern and northeastern partners and that "Other partners" (mainly trade unions) are a significant share of the partners, especially for Center-West and North.

These data are completely coherent with the fact that South and Southeast regions concentrate the biggest number of firms in Brazil, a more complex e technological productive structure, highest levels of industrial productivity and a better transportation infrastructure (RUIZ; DOMINGUES, 2008; SOBRINHO; AZZONI, 2015), which is related to more university-industry relations. In other words, the partners composition reflects the economic conditions of each region.

Table 2 – Partners by regions

Partner category	N		NE		SE		S		CW	
	N.	%	N.	%	N.	%	N.	%	N.	%
Companies	90	38.30	445	41.17	1.484	56.25	828	57.26	157	32.30
Universities	58	24.68	293	27.10	516	19.56	251	17.36	101	20.78
Government	28	11.91	99	9.16	151	5.72	72	4.98	86	17.70
Other partners	59	25.11	244	22.57	487	18.46	295	20.40	142	29.22
Trade Unions	32	13.62	145	13.41	311	11.79	167	11.55	83	17.08
Hospitals	0	-	24	2.22	39	1.48	28	1.94	4	0.82
Cooperatives	10	4.26	17	1.57	13	0.49	45	3.11	12	2.47
Others*	17	7.23	58	5.37	124	4.70	55	3.80	43	8.85
Total	235	100	1,081	100	2,638	100	1,446	100	486	100

Source: Authors' own. Data sourced from CNPq. Note: (*) Foundations; and international agencies located in Brazil. Total collaborations = 28,181.

4.2   Different partners, different collaborations

Given the heterogeneous composition of partners between regions and that for each kind of partner is possible to identify different intensities of collaborations, when turning the analysis to the research groups and, by consequence, to the collaborations, we can observe different importance of each network according to the regions.

In Table 3 we show collaborations classified by location of research groups' regions. The first

thing we note is that most part of collaborations are concentrated in South and Southeast Brazil (68.20% of total), as expected. Table 3 also shows a different pattern as compared to the one observed in developed countries that universities collaborations are more located in the same region (FITJA; GJELSVIK, 2017; MUSCIO, 2006; ESTE; IAMMARINO, 2010; FRITSCH, 2005; VILLANI; LECHNER, 2020). Secondly, university–university collaborations are at least 60% of all collaborations for all regions, achieving 74.25% on Center-West.

Table 3 – Collaborations by groups' regions

Partner	N		NE		SE		S		CW	
Category	N.	%	N.	%	N.	%	N.	%	N.	%
Companies	191	12.60	678	13.18	2,457	19.10	1,384	21.77	231	10.05
Universities	1,099	72.49	3,640	70.75	8,721	67.79	4,017	63.20	1,707	74.25
Government	72	4.75	286	5.56	561	4.36	285	4.48	144	6.26
Other partners	154	10.16	541	10.52	1,126	8.75	670	10.54	217	9.44
Trade Unions	58	3.83	228	4.43	433	3.37	290	4.56	98	4.26
Hospitals	6	0.40	38	0.74	105	0.82	52	0.82	3	0.13
Cooperatives	18	1.19	14	0.27	19	0.15	81	1.27	15	0.65
Others*	72	4.75	261	5.07	569	4.42	247	3.89	101	4.39
Total	1,516	100	5,145	100	12,865	100	6,356	100	2,299	100

Source: Authors' own. Data sourced from CNPq. Note: (*) Foundations and international agencies located in Brazil. Total collaborations = 28,181.

Third, and most importantly, collaborations with government and "other partners" represent a bigger share of total collaborations in the North, Northeast than they represent in the Southeast and South. This importance is reinforced once we notice that collaborations with "other partners" alone represent 10.16% in the North while collaborations with companies represent 12.60%, which are almost the same. A very similar pattern can be seen in the Northeast. In the South and Southeast, "other partners" collaborations represent less than half of collaborations with companies. In the case of the Center-West, the difference between collaborations with companies and collaborations with "other partners" are just 0.61%. This view takes us to reinforce the argument that it is not possible to understand the role of universities for development just looking at their collaborations with companies. Moreover, given the reduced importance of the university–industry collaborations in the peripherical regions, policy making regionally blinded guided just by strengthening university–industry collaboration can lead to an increase of regional disparities.

4.3   Spatial differences on the networks by region

These differences in the pattern of collaborations according to regions took us to explore the differences of the networks composed by research groups and partners of different regions. Here we focus on analyzing the spatial features of this networks, which allow us to understand the specifics of each network at each region and have insights about the reasons behind these differences.

First, Figure 5 shows the percentage of collaborations that happen inside the research group region and state, respectively. We can notice that collaborations of the "university-other partners" network more frequently happen between research groups and partners from the same region. On the other side, collaborations of the "universities-government" network tend to have the smallest percentage of collaborations happening inside the region (expect for Center-West), which is explained by the high number of collaborations between the universities and the Federal Government, which is located in Brasília on the Center-West. This also explain why 92% of university-government collaborations happen within the Center-West region.
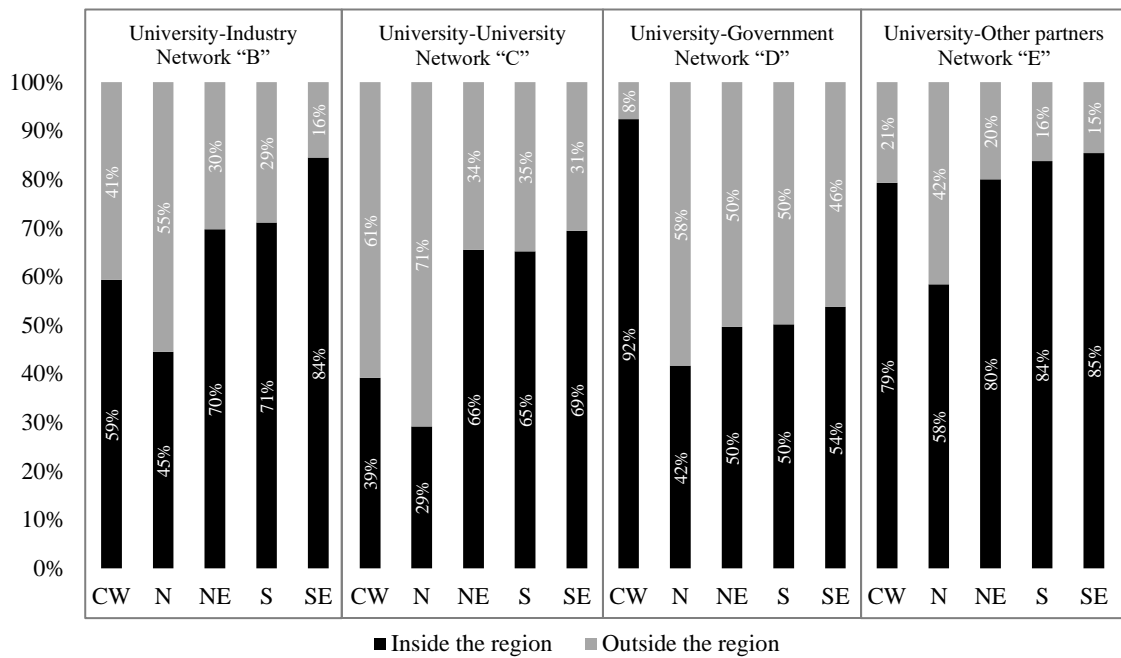
Figure 5 – Collaborations' percentage inside and outside each region, by type of network, 2016

Source: Authors' own. Data sourced from CNPq.

It is important to call attention here that Figure 5 shows that university–other partners network as being more locally concentrated than other networks, especially for the Center-west and North regions. We can also see that, as expected, both South and Southeast regions have university – industry locally concentrated as well.

When considering the Southeast and South regions we have already noticed from Tables 2 and 3 that for both regions, universities have interacted the most with profit seeking firms and other universities (university–industry and university–university relations). Observing the percentage of university–industry collaborations from these regions that happen with partners from the same region, we can point that South and Southeast regions are "self-sufficient". Surprisingly, the Northeast shows a similar pattern for university–industry collaborations. However, looking at the data it seems to be difficult for Center-West and North research groups to collaborate with companies from the same region (see the maps in the Appendix for an illustration), consequently, as may be no local demand, research groups of these regions look collaborate with companies from South and Southeast regions.

From this perspective, it is possible to understand why "university–other partners" network is important in peripherical regions and tend to play an important role in connecting university with society, because, as previously mentioned these regions are less dynamics in industrial terms demanding little knowledge from local universities. In these regions, knowledge demand come from other groups, in some cases not market-driven, but with the potential to contribute to solve local challenges.

4.4 Spatial Network indicators: centralities and distances

In order to expand our analysis about the spatial characteristics of networks and also bring more robustness for our argument about the importance of university-other partners network for local development, in this section we present some indicators of network centrality which allow us to verify how interactive the research groups are. At the same time, they allow us to check the average distance per collaboration.

When considering the collaborations between research groups and all partners (network "A", i.e., university–society), it is possible to check that Southeastern and Southern research groups have more collaborations per group (2.53 and 2.39 collaborations on average, respectively), have smaller sum of collaborations distances (1,120 and 1,234 km per group on average) and present collaborations of shorter distance (443 and 517 km per collaboration on average) (Table 4). In the following order, research groups

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from Central-West, Northeast and North have fewer collaborations, further distances of collaborations per group on average and further distance per collaborations. These figures indicate that research groups from Brazilian South and Southeast regions are able to easily interact locally, while partners from groups from North, Northeast and Central-West are located further away. This picture shows the weak local knowledge demand inside regions, leading to seek more distant partners and collaborations.

Table 4 – Research groups' statistics obtained from the networks "A" and "B", average values

	Network "A"			Network "B"		
	University–Society			University–Industry		
	Number of collaborations[1]	Distance Traveled[2] (km)	Distance by collaboration[3] (km)	Number of collaborations[1]	Distance Traveled[2] (km)	Distance by collaboration[3] (km)
N	2.09	2,925	1,399	1.68	1,911	1,140
NE	2.16	1,605	744	1.80	1,196	665
SE	2.53	1,120	443	2.25	689	307
S	2.39	1,234	517	2.06	733	355
CW	2.24	1,601	716	1.56	775	497

Source: Authors' own. Data sourced from CNPq, 2016. Note: ([1]) Average degree; ([2]) Average weighted degree; and ([3]) Sum of all research groups nodes' weighted degrees divided by the sum of all research groups nodes' degrees

Table 5 – Research groups' statistics obtained from the networks "C" and "D", average values

	Network "C"			Network "D"		
	University–University			University–Government		
	Number of collaborations[1]	Distance Traveled[2] (km)	Distance by collaboration[3] (km)	Number of collaborations[1]	Distance Traveled[2] (km)	Distance by collaboration[3] (km)
N	1.89	2,929	1,548	1.24	1,256	1,012
NE	1.94	1,561	807	1.28	949	740
SE	2.25	1,139	506	1.25	534	426
S	2.05	1,241	604	1.34	884	661
CW	2.08	1,726	830	1.30	335	258

Source: Authors' own. Data sourced from CNPq, 2016. Note: ([1]) Average degree; ([2]) Average weighted degree; and ([3]) Sum of all research groups nodes' weighted degrees divided by the sum of all research groups nodes' degrees

The results considering collaborations with profit-seeking companies (network "B", i.e., university–industry) and exclusively between universities (network "C", i.e., university–university relations) show a similar pattern, with groups from Southeast and South region being more interactive, closer to each other and shorter distance per collaboration (Tables 5). The only difference is that groups from Northeast and North have more collaborations than the Central-West region for university–industry network (1.80; 1.68; and 1.56, respectively). These results are expected as Brazilian industrial sector is more dynamic and denser in Southeast and South regions. Consequently, the industrial partners of research groups located in the North and Northeast are further, located in other regions.

University collaborations with government (i.e., network "D") show almost no differences between regions regarding the average number of collaborations, but show differences regarding distance. North, Northeast and South regions present bigger figures, what is partially explained by their distance from federal government (Brasilia, Central-West) that gather many other institutions from Brazilian Innovation System. Within regions, partners are the ones related to local and state government institutions.

Considering network "E" (i.e., university–other partners collaborations), depicted in Table 6, we can firstly observe that for all regions, universities interact with relatively closer actors if compared to other networks. A second observation regards the average number of collaborations with other partners: North and Northeast research groups present higher averages than Southeast and Central-West groups, showing the knowledge demand from local or regional nonprofit partners. A third important observation is that all regions present shorter average collaboration distance for university–other partners relations than the distance of university-industry collaborations, but this reduction is more intense in the Northeast, Center-west and North, respectively, pointing more localized collaborations.

The previous data show that there are different patterns of collaborations between university and society and that the emphasis in those exclusively with profit-seeking companies fostered by Brazilian

Innovation Law (*Lei da Inovação*) and by the "entrepreneurial agenda" disregard other partners and collaborations that are especially important in some regions, especially collaborations with other partners. In the next section we will analyze in more detail these partners and their cooperation.

Table 6 – Research groups' statistics obtained from the network "E", average values

	Number of collaborations[1]	Distance Traveled[2] (km)	Distance by collaboration[3] (km) (A)	(A) / University–Industry network distance by collaboration
	Network "E"			
	University–Other partners			
N	1.33	1,107	834	0.7315
NE	1.32	555	421	0.6330
SE	1.27	324	255	0.8306
S	1.35	363	268	0.7549
CW	1.28	453	353	0.7102

Source: Authors' own. Data sourced from CNPq, 2016. Note: ([1]) Average degree; ([2]) Average weighted degree; and ([3]) Sum of all research groups nodes' weighted degrees divided by the sum of all research groups nodes' degrees

Final Remarks

This paper analyses universities collaborations in Brazilian regions, using a database of over 28 thousand collaborations constructed from the Census 2016 of Directory of Research Groups. We demonstrated that universities' collaborations are broader than most studies on the topic suppose so, especially those that focus on university–industry collaborations. Although those studies provide relevant insights for policy makers, they have been recurrently focusing on technology transfer channels and university contribution to spin-offs and high-tech companies, leaving aside a set of partners and actions with potential impact for local development, especially in peripherical NIS.

Our data shows that universities are one of the most connected actors in Brazilian NIS. Profit seeking firms are relevant partners, but not the only one. Academic collaboration – between universities and research institutes – are also considerable, as the ones with government institutions. Research groups also collaborate with other partners – trade unions, cooperatives, foundations, association, among other – and these ones are more locally concentrated. So, universities can also reach social knowledge demand, contributing to build an Inclusive Innovation System (AROCENA; GÖRANSSON; SUTZ, 2015).

Another relevant pattern we detected regards regional analyzes. The data converged with the conventional results about the concentration of Brazilian scientific and technological infrastructure. For historical reasons, both South and Southeast regions concentrate the greatest numbers of research groups and collaborations with society. Furthermore, these regions seem to be denser in terms of university–industry relationships. Still, the patterns of intraregional and interregional collaborations indicate that university–society collaborations in these regions are more endogenous since research groups in these regions interact more with partners in the same regions than with partners from the North, Northeast and Central-West regions. All this evidence suggest that, while South and Southeast regions have a more endogenous dynamics of university–society collaboration, universities in the North, Northeast and Central-West are demanded by partners from other regions, since the local knowledge demand is weak.

The data also shows the importance to design policy and programs to university collaboration with other partners – beyond firms, that are already contemplated in Brazilian Innovation Law. The Centro de Desenvolvimento Regional (CDR) Program from MEC and MCTI and Local Productive Arrangement (APLs) Policies are examples in this direction. Our data shows that university-firm collaboration Programs reinforces Brazilian regional inequalities. So, a sort of compensatory policy able to change the concentrating dynamics promoted by Brazilian Innovation Law are necessary in less dynamic Brazilian regions.

Arocena et al. (2015) emphasized the importance of policies to identify and bring up social demand by connecting them with high quality available research and transforming research results into effective innovations that contribute to solving social, cultural and environmental claiming. As a consequence, the main role of universities should be their contribution to economic and social development, safeguarding a certain level of autonomy. Arocena et al. (2015) still defend this perspective as a response to the contradictory demands placed on universities. The system must combine abilities to meet, in the short

term, the needs of society with some degree of autonomy and long-term commitment and should also promote innovation combining it with social and global equality and justice. In this sense, cooperation among universities and other types of societal agents, such as governments, unions and cooperatives can be an important step forward the democratization of knowledge and its benefits. But for that the reward system should incentive academic engagement with communities and non-academic collective actors (Arocena, et. al, 2018).

In this way the propositions by Dutrénit and Vera-Cruz (2016) and Arocena and Sutz (2016) related do changes on innovation policies in Latin America are useful. Industrial and innovation policy commonly assume the existence of a spillover process from firms to society which are absent. So, Brazilian innovation policy should expand the relationship between innovation and development, including mission-oriented issues related to equity, poverty, sustainability, health, inclusion.

By unveiling some formerly implicit issues about the way universities are inserted in a peripheral NIS, the identified partners are undoubtedly relevant for academic and policy debate. However, further research is still necessary in order to enlarge the evidences presented in this article, as it is the first attempt to show empirical data related to the university developmental role. A special investigation on research groups focused on "Social Sciences" and "Humanities", for instance, should be relevant to infer their role in complying with societal and environmental needs. Finally, analyzes on the types of collaboration associated with different regions, areas of knowledge or types of partner may also be useful to public policy not only to influence universities to interplay in innovation processes but also to engage in social innovation.

University collaboration in Brazilian regions: spatial network analysis

Abstract: In this article, we propose to analyze the collaborations carried out by Brazilian universities in the different regions. Universities play a fundamental role in the National Innovation Systems, providing knowledge, research and human capital. Using the 2016 Census of the Research Groups Directory of the National Council for Scientific and Technological Research (CNPq), we analyzed 28,181 collaborations of research groups with different partners using spatial network methodology. The analyzes show the existence of important differences in relation to local partners, suggesting the need to broaden the focus of ST&I policies that have been focused on collaborations with companies. The focus on university-company collaborations reinforces inequalities between Brazilian regions and limits the role of the university in local development, especially in the context of a country marked by regional disparities.

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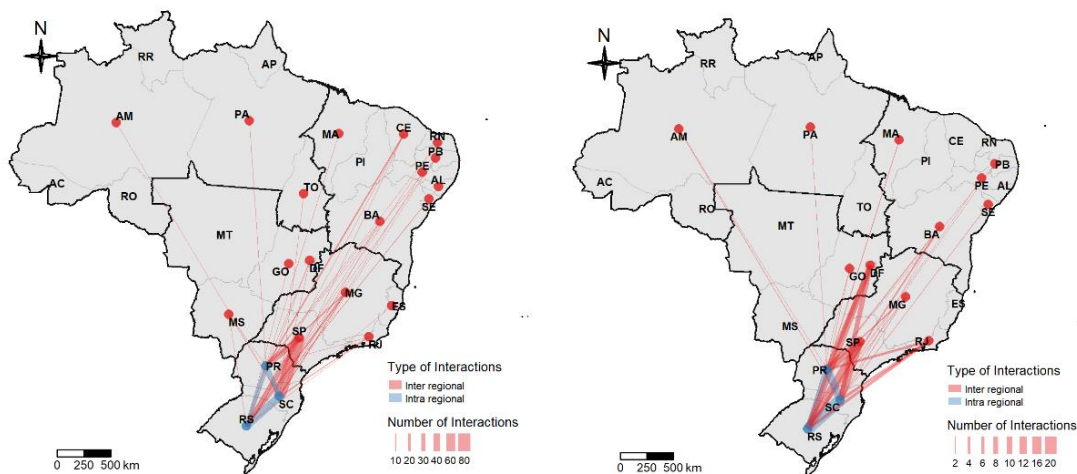## Appendix – Geospatial networks aggregated by state
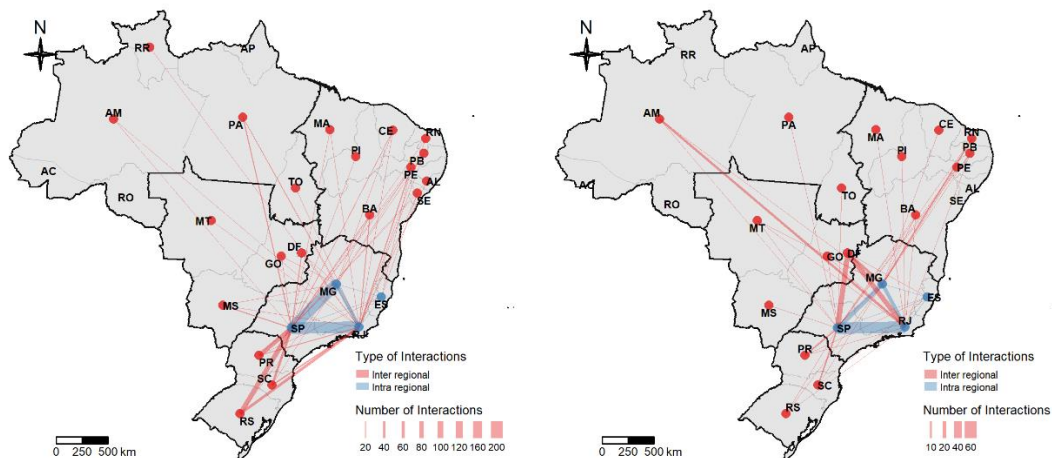
University–Industry collaborations (network "B")

University–Other partners collaborations (network "E")

Figure A1 – Southeastern research groups' collaborations by type of network, aggregated by state, 2016

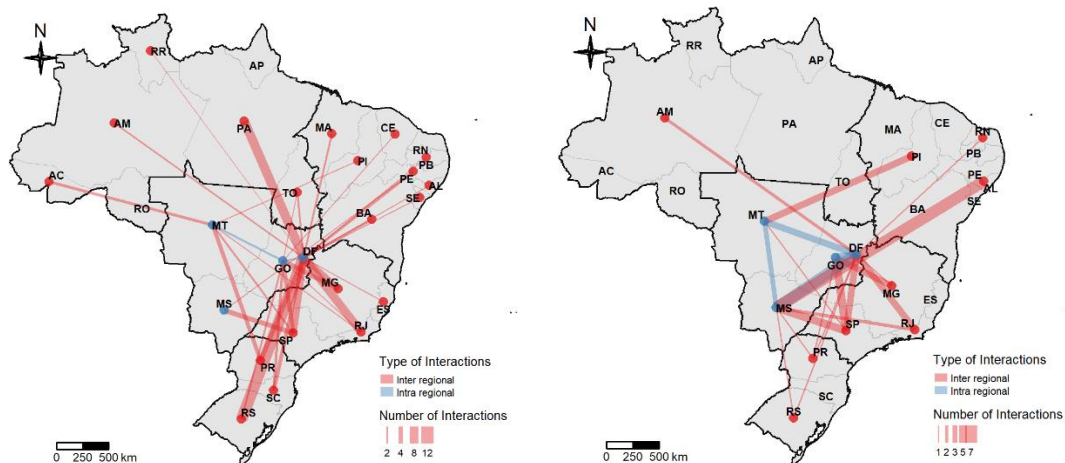Source: Authors' own. Data sourced from CNPq.

University–Industry collaborations (network "B")

University–Other partners collaborations (network "E")

Figure A2 – Southern research groups' collaborations by type of network, aggregated by state, 2016
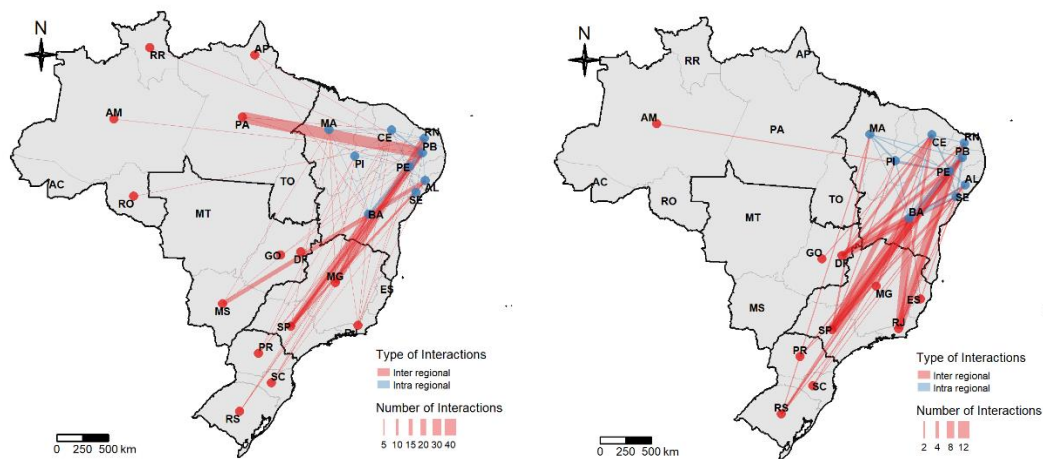
Source: Authors' own. Data sourced from CNPq.

University–Industry collaborations (network "B")   University–Other partners collaborations (network "E")

Figure A3 – Central-west research groups' collaborations by type of network, aggregated by state, 2016

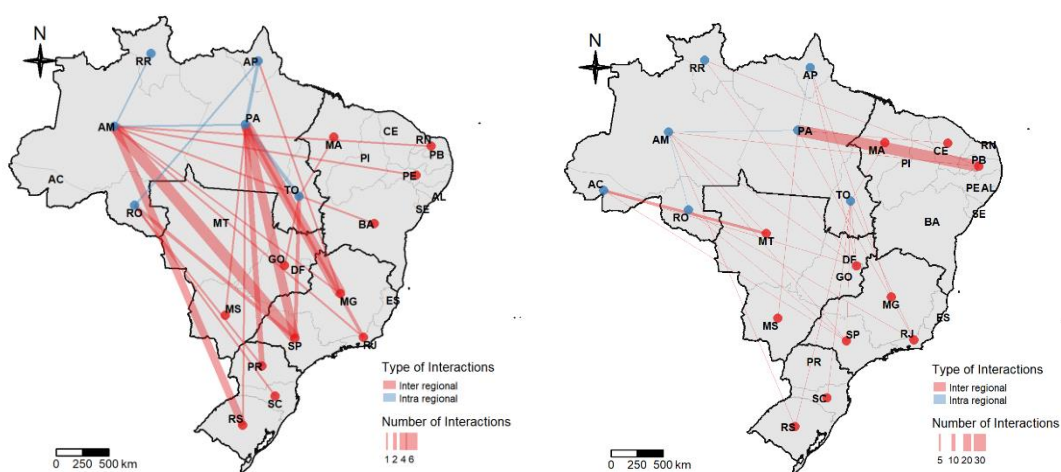Source: Authors' own. Data sourced from CNPq.

University–Industry collaborations (network "B")   University– Other partners collaborations (network "E")

Figure A4 – Northeast research groups' collaborations by type of network, aggregated by state, 2016

Source: Authors' own. Data sourced from CNPq.

University–Industry collaborations (network "B")   University– Other partners collaborations (network "E")

Figure A5 – North research groups' collaborations by type of network, aggregated by state, 2016

Source: Authors' own. Data sourced from CNPq.