Are Brazilian innovation systems innovative? Regional and sectorial decompositions of triple-helix synergies

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Abstract

A knowledge-based economy adds innovation as another dynamic to a political economy. Whereas a political economy is institutionalized -for example, in a nation state- the knowledge base is volatile although it leaves footprints behind by transforming the institutional layers. This transformation into new options can be measured as redundancy using the Triple-Helix indicator. The balance between historical entropy generation and the knowledge-based generation of options can be measured in terms of positive and negative contributions to the prevailing uncertainty. At what scale and in which sectors is synergy among geographical, technological, and organizational distributions of firms evident? Using mutual information in the three dimensions as an indicator, we analyse a dataset of more than 16 million firms in Brazil and compute synergy within and across states and sectors in this country in terms of bits of information. The results suggest that no synergy is generated at the national level. The political economy of the country has not (yet) been transformed into a national innovation system. At state level, synergies vary according to geographical levels and sectors due to the specifics of the states. Above-average values were found for some states in the South and Southeast Regions. Also, the political capital, Brasilia, has resulted to have no impact in the innovation system of Brazil.

Keywords

Innovation systems; Triple helix; Universities; Government; Industry; Synergies; Geography; Technology; Brazil.

1. Introduction

A number of models have been created over the last decades to explain the feedbacks among technological developments, the generation of innovations, and economic development resulting from these activities. Are innovation systems national, regional, sectorial, supra-regional? In the 1960s-1970s, government programs and projects in Latin America drew on Jorge Sabato's triangle model which proposed to promote innovation at the national level. The approach was based on the multiple and coordinated action of three key elements represented by the geometry of a triangle: government, productive structure and scientific-technological infrastructure, with the government playing a leading role in coordinating the actions of universities and the productive sector (**Sabato**; **Botana**, 1970). Although the role of the knowledge base was envisaged, the model eventually served "import substitution" as a national strategy endowed with technological capacities. Technological development remained unexplained (cf. **Nelson**; **Winter**, 1977; 1982).

Lundvall (1999) proposed to distinguish between national business systems (NBS) and national systems of innovation (NSI). The concept of national business systems is related to the constituent elements of the national system with its structural interconnections. The differences between countries are explained by the organization of the firm and the firm's behavior, due to differences in culture and formal institutions. The central aspect of this approach, however, remains the coordination of economic activities and governance, and therefore political economy.

There are three main differences between the NBS and NIS models:

(i) while NBS considers economic coordination and governance, NIS defines innovation;

(ii) NBS seeks to explain the motivations of companies and how they organize themselves whereas NIS investigates the functioning of the national economy and its performance in terms of economic development;

(iii) Different ways of using the term "system": NBS regards a system as a combination of elements in different patterns; NIS emphasizes the processes in which agents interact (**Lundvall**, 1999).

Initially, the NIS approach was based on experiences in Europe and North America, but more recently several studies have drawn on data from Latin America, African and Asian countries. NIS has been used in different contexts in developed and developing countries, considering that the main elements provide a flexible and conceptual, methodological and analytical framework. Differences among NIS in developed and developing countries have been explained in relation to four dimensions:

(i) orientations based on different needs,

(ii) the key actors and respective incentives systems are different,

(iii) institutional frameworks are less formalized in developing countries and

(iv) existing rules are also less enforceable (**Altenburg**, 2011).

University-industry-government relations are key elements of the dynamics and processes in innovation systems (**Etzkowitz**; **Leydesdorff**, 1995; 2000). In addition to an institutional network model, "triple helix" models assume that three functions are combined: wealth generation, novelty production, and governmental control. The institutional arrangements are not *sui generis*, but co-evolving with the generation of synergies in these (functional) relations.

Mutual information between geographical, organizational, and technological distributions of the firms in a region, helps to measure the interactions between the triple helix organizations. Such information measures the increase or decrease of uncertainty in the ties among the stakeholders. This methodology evaluates the difference between the information (I) generated in the relationships versus redundancy (R), which is generated through the repetitions and overlaps in the interactions between the variables analyzed (**Leydesdorff**, 2003; **Park** *et al.*, 2005; **Leydesdorff**; **Sun** 2009; **Park**; **Leydesdorff**, 2010; **Ye** *et al.*, 2013; cf. **Ulanowicz**, 1986, p. 143. The three dimensions considered are: firms, as industrial production players, university, as the main knowledge producer and Government as the main institutional stakeholder, corresponding to the 3 subsystems in an innovation system (**Edquist**, 1997).

The triple helix model explains social and economic development as occurring through interactions among universities, industries, and governments. The model can be applied to national, regional, and local environments. The complexity of a triple helix model is a result of the local trajectories observed in each region or country (**Leydesdorff**; **Etzkowitz**, 1996). A continuous process of interactions emerges at the interfaces among geographical scales, technological capacities, and organization (firms), causing an overlay of negotiations and exchanges. New options for innovations are generated in the overlaps, due to the interactions between the helixes. The triple-helix indicator enables us to measure and explain the synergy in university-industry-government relations based on the overlays of information communicated in an innovation system (**Leydesdorff**; **Fritsch**, 2006).

The objective of this study is to analyze the synergy among geographical, technological, and organizational distributions of firms in Brazil at different scales, levels. The paper is organized into the following sections, in addition to this introduction. The next section presents a review of the Brazilian innovation system. Section 3 exhibits the literature underpinning triple helix model developed to measure innovation systems. Section 4 explains the methodology that oriented the research and the main descriptive statistics of the data. Section 5 describes the results in both geographical and technological perspectives. Finally, we offer some concluding remarks about innovation performance in Brazil.

2. Is there a Brazilian innovation system?

In Brazil, a double pattern of behavior related to innovation has been observed. On the one hand, the country has achieved success in the development of some technologies, such as deep-water oil exploration carried out by *Petrobras*, the production of airplanes for regional flights, by *Embraer*, and the growth of productivity in agriculture and livestock, led by *Embrapa*. State-owned enterprises have taken part in these successful endeavors, with privatized ones appearing on the scene recently. On the other hand, the country has not built a mature innovation system with diversified interactions between research institutions and the productive sector.

Brazil is an interesting case due to the fact that other studies using different methodologies considered Brazil's innovation system as "immature" (**Albuquerque**, 2000; 2008). An immature innovation system was defined by **Albuquerque** (2000) in the following terms:

1) a large share of specific individuals in patenting activities;
2) little firm ïnvolvement in innovative activities;
3) lack of continuity in patenting activity,
4) low sophistication of inter-firm technological division, showing sectors with technological advances and other less developed ones,
5) declining role of the machinery sector, which is important for the catching up process,
6) foreign companies established in the country develop incremental innovations,
7) patents registered in Brazil are not considered very innovative by international offices.

Corroborating this analysis, the Brazilian patent ranking indicates that between 2014 and 2019, nineteen of the twenty-five largest patent depositors of products and services were from higher education institutions (*INPI*, 2021), highlighting the absence of companies to lead this process. Also, in this sense, the study by **Pacheco** (2019) considered the Brazilian innovation system "weak" due to the federal government's failure to prioritize the innovation agenda. The efforts undertaken are considered by this author as limited and disconnected from the country's general strategy.

Brazil is one of the BRICS member countries, and is also classified by the *World Bank* as an upper-middle-income country with a GDP (gross domestic product) of US$ 1,445 trillion (2020), with the economy gradually emerging after four years of recession. The country's imports last year amounted to US$ 276,032 billion, while total exports were US$ 243,739 billion.

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https://data.worldbank.org/indicator/NE.EXP.GNFS.CD?locations=BR

However, twelve of Brazil's fifteen major export products are commodities and represent 71% of the country's total exports (**Canuto** *et al.*, 2013). As a consequence of this mix of products, the country has the ability to produce and export products associated with a high level of inequality (**Hartmann** *et al.*, 2017). According to the *Economic Complexity Index Brazil* is the 37th most complex economy, which corresponds with a problematic economic context (**Oreiro** *et al.*, 2020). The total population is 231 million (*OECD*, 2018) and the country remains one of the most unequal in the world where half of the population receives 10% of total household incomes, while another half holds 90% (*OECD*, 2018).

3. Operationalization

University-industry-government relations shape an ecosystem of bi and trilateral relations which can promote innovative production, prosperity for the territory and a legal framework within the innovation system. For this reason, the quality and intensity of the relationships maintained become crucial (**Leydesdorff**, 2006). In the words of **Lengyel** and **Leydesdorff** (2011, p. 6),

> "the triple helix model enables one to distinguish knowledge functions in innovation systems in addition to the two main dimensions of a political economy".

The knowledge-based economy is built on the relationships between the drivers of a political economy in terms of knowledge creation, knowledge transfer and knowledge control (**Nelson**; **Winter**, 1982; **Whitley**, 1984; 2001).

Different studies have analyzed the reduction of uncertainty at the systems level in Europe, using the triple helix indicator of synergy in the knowledge base of an economy. Examples include the Netherlands (**Leydesdorff** *et al.*, 2006), Sweden (**Leydesdorff**; **Strand**, 2013), Germany (**Leydesdorff**; **Fritsch**, 2006), Hungary (**Lengyel**; **Leydesdorff**, 2011), Norway (**Strand**; **Leydesdorff**, 2013), Spain (**Leydesdorff**; **Porto-Gómez**, 2019), and the USA (**Leydesdorff** *et al.*, 2019).

The novelty of the present study on Brazil lies in its focus on the entire economy, built around the sectorial classification made with *NACE* codes (*Nomenclature statistique des Activités économiques dans la Communauté Européenne*). While previous articles focus solely on knowledge intensive activities, this study takes into account not only high-tech innovation activities but also the medium-low and less knowledge-intensive services being performed. In this way, we might be able to gain a clearer picture of the Brazilian regions, depending on their strength.

We use three variables and their interactions to measure the performance and synergy:

(1) the geographical situation of the firms through post codes, in order to pinpoint the region;
(2) the *NACE* code in order to clarify the technological knowledge base of the firm; and
(3) the firm size by number of employees, as a measure of organizational structure.

Technology will be represented by the sector classification (*NACE Rev. 2*), organizations by the respective company sizes in terms of the number of employees, and the geographical dimension by the zip codes extracted from the address information.

4. Methodology

The (Shannon-type) information in three dimensions can be decomposed into groups as follows (**Leydesdorff**; **Strand**, 2013, p. 1895; **Theil**, 1972):

$$T = T_0 + \sum_G \frac{n_G}{N} T_G$$

where,

- T_0 is the inter-territorial uncertainty,
- T_G is the uncertainty on the geographical scale G,
- N_G is the number of firms on the specific geographical scale G,
- N is the total number of firms in the analysis.

A negative value of T_0 can be considered an indication of additional synergies at higher geographical levels.

4.1. Data and descriptive statistics

The dataset was downloaded from the *Orbis* database of *Bureau van Dijk* on November 13, 2018, using the strings: "All active companies and Companies with unknown situation combined (with a Boolean AND) with "World Region/Country/Region is country: Brazil" the total number of retrieved Brazilian companies was 21,296,980. The data were downloaded in 22 batches of 100,000 records. From this total, 15,957,292 records contained complete information on the three dimensions for the analyses: that is, zip codes, *NACE* codes and number of employees.

The geographical dimension presented in Table 1 provides the distribution of firms across the Brazilian states. There is an unequal distribution of firms across Brazilian states. The companies are concentrated in the Southeast Region. The states with the largest number of firms are São Paulo (28.4% of all firms in the sample), followed by Minas Gerais with 10.4% and Rio de Janeiro with 8.7%.

Table 1. Distribution of sampled firms across the Brazilian states.

State name	Number of firms	%	GDP trillion US$ (2018)[1]	% GDP
Acre	175,794	1.10%	4,196	0.21%
Alagoas	154,878	0.97%	14,893	0.77%
Amazonas	60,493	0.38%	27,401	1.42%
Amapá	75,068	0.47%	4,597	0.23%
Bahia	901,861	5.65%	78,349	4.10%
Ceará	509,953	3.20%	42,671	2.25%
Distrito Federal	46,961	0.29%	69,745	3.63%
Espírito Santo	348,477	2.19%	37,503	1.95%
Goiás	204,879	1.28%	53,559	2.70%
Maranhao	281,592	1.76%	26,873	1.40%
Minas Gerais	1,673,231	10.49%	168,293	8.70%
Mato Grosso do Sul	222,567	1.39%	29,278	1.52%
Mato Grosso	341,745	2.14%	37,619	1.96%
Pará	539,330	3.38%	44,169	2.30%
Paraíba	207,302	1.30%	17,619	0.91%
Pernambuco	505,102	3.17%	51,007	2.70%
Piauí	158,183	0.99%	13,788	0.71%
Paraná	1,084,840	6.80%	120,437	6.28%
Rio de Janeiro	1,399,610	8.77%	207,702	11.00%
Rio Grande do Norte	198,789	1.25%	18,330	0.95%
Rondônia	195,700	1.23%	12,293	0.64%
Roraima	75,984	0.48%	3,659	0.20%
Rio Grande do Sul	1,075,389	6.74%	125,163	6.52%
Santa Catarina	723,142	4.53%	81,626	4.25%
Sergipe	101,901	0.64%	11,500	0.60%
São Paulo	4,537,365	28.44%	605,037	31.60%
Tocantins	157,156	0.98%	9,792	0.50%
Total	15,957,292	100%	1,917	100%

Source: based on *Orbis data*, 2018, [1]IBGE (2020).

The second dimension shown in Table 2 is technology. We use the economic activity based on the four-digit sector classifications from the *NACE, the industry standard classification system used in the European Union. The current version is revision 2 and was established by Regulation (EC) No. 1893/2006. It is the European* implementation of the *UN International Standard Industrial Classification* (*ISIC*), revision 4, and allows comparison of companies according to the type of technology used by them.

The sector-based analysis focuses on the sectors of high-tech manufacturing (HTM), medium-high-tech manufaturing (MHTM) and knowledge-intensive services (KIS). Brazil has adopted the *National Classification of Economic Activities* (*CNAE*) in the production of economic statistics, which is derived from the *UN* classification *ISIC*, revision 4, enabling the use of *NACE* classification to make comparisons possible with results from previous studies on other countries. The *NACE* classification for Brazilian companies was carried out by *Orbis*.

Table 2. *NACE* classifications (Rev. 2) of high and medium-tech manufacturing industries and knowledge services. Sources: *Eurostat/OECD* (2011); cf **Laafia** (2002, p. 7) and **Leydesdorff** *et al.*, (2006, p. 186).

Manufacturing	Services
High-tech manufacturing (HTM) 24.4 Manufacture of pharmaceuticals, medicinal chemicals and botanical products 30 Manufacture of office machinery and computers 32 Manufacture of radio, television and communication equipment and apparatus 33 Manufacture of medical, precision and optical instruments, watches and clocks 35.3 Manufacture of aircraft and spacecraft **Medium-high-tech manufacturing (MHTM)** 24 Manufacture of chemicals and chemical products excluding excluding 24.4 Manufacture of pharmaceuticals, medicinal chemicals and botanical products 29 Manufacture of machinery and equipment N.E.C. 31 Manufacture of electrical machinery and apparatus N.E.C. 34 Manufacture of motor vehicles, trailers and semi-trailers 35 Manufacture of other transport equipment excluding 35.1 Building and repairing of ships and excluding 35.3 Manufacture of aircraft and spacecraft	**Knowledge-intensive services (KIS)** 61 Water transport 62 Air transport 64 Post and telecommunications 65 to 67 Financial intermediation 70 to 74 Real estate, renting and business activities 80 Education 85 Health and social work 92 Recreational, cultural and sporting activities Of these sectors, 59 to 63, and 72 are considered high-tech services.

Table 3 shows the distribution by number of employees. The majority of the companies are small: 58.6% have from 2 to 4 employees and 33.1% from 5 to 9 employees.

5. Findings

The country is divided into 27 states, which vary greatly in terms of size, population, geographical characteristics, GPD, economic activities and number and size of companies. Considering the analysis conducted decomposed by states, we present some of the main characteristics of each one in Table 1. The purpose is to strengthen understanding of the results obtained on synergy between the companies.

Figure 1 shows a map of Brazil with the states coloured according to their respective contribution to synergy generation in Brazil's innovation system.

Table 3. Size distribution of the firms in the sample by number of employees.

Number of employees	Number of companies	Percentage
None	0	0.0%
0-1	0	0.0%
2-4	9,218,577	57.774%
5-9	5,394,428	33.805%
10-19	658,251	4.124%
20-49	552,443	3.462%
50-99	94,690	0.593%
100-199	19,098	0.120%
200-499	12,137	0.076%
500-749	61	0.0004%
750-999	4,234	0,027%
≥1000	3,373	0,021%
Total	16,261,721	100%

Source: based on *Orbis data*, 2018.

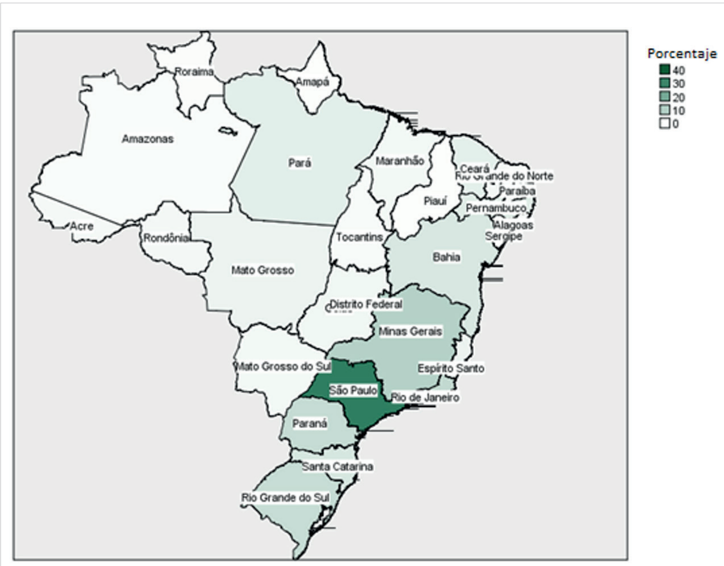

Figure 1. Synergy generation at the level of 27 states in Brazil (NUTS2).
Source: based on *Orbis* data, 2018; using *SPSS* for the mapping.

The analyses of the results are divided into two levels: 1) the geographical perspective showing the synergy levels in the different states (NUTS 1), provinces (NUTS 2, and municipalities (NUTS 3); and 2) synergy levels in the states considering the technological activities of the firms in the sample.

5.1. Decomposition at the geographical level of states

Figure 1 shows a map of Brazil with the coloured states (NUTS2) to visualise their contribution to the generation of synergy at the national level. The total synergy of Brazil is T= - 113 mbits. 50.5% comes from economic activities in 4 states: São Paulo (-25.1114243 mbits or 22.2%), Minas Gerais (-12.99 mbits or 11.48%), Paraná (10.0360304 mbits or 8.87%) and Rio de Janeiro (8.99 mbits or 7.95%).

The differentiation between the states observed in Table 1 in terms of GDP and number of companies is reflected in the synergy between companies. The five states with the largest share of the country's GDP in 2018 are São Paulo (31. 9%), Rio de Janeiro (11%), Minas Gerais (9 %), Rio Grande do Sul (6. 6%) and Paraná (6. 3%).

The states of São Paulo, Minas Gerais and Rio de Janeiro are located in the Southeast Region and Rio Grande do Sul and Paraná in the South Region, indicating that innovation activity is more densely concentrated in those regions revealing economic inequality characteristics. Table 4 shows the main products in terms of economic value of these five states.

Table 4. Main products of the states with higher GDP and synergy (Source: *IBGE*, 2020).

States	High-tech manufacturing (HTM)	Medium high-tech manufaturing (MHTM)	Knowledge-intensive services (KIS)	Others
São Paulo	Airplanes, mobile phones and smartphones	Cars and parts and accessories	Largest financial centre in Latin America and where most national and international airlines are based	Relevant production of petroleum refining for fuel production, agricultural production of sugarcane and ethanol
Rio de Janeiro	-	Cars,parts and accessories, steel industry products	Specialized services for petroleum extraction and aircraft maintenance	It is the largest producer of petroleum in the country and also has refineries
Minas Gerais	-	Coils and steel plates	-	Mining (iron, niobium, gold),pig iron, fuel alcohol, meat production, rations for animal feed, fertilizers
Rio Grande do Sul	-	Cars and parts and accessories	-	Agricultural products (rice, tobacco), diesel fuel, rations for animal feed, fertilizers
Paraná	-	Cars	-	Petroleum, rations for animal feed, fertilizers

São Paulo is also the state with the largest population in the country, including a higher rate of urban population. The largest Brazilian universities and research centers are located in these states, in the cities of São Paulo (*University of São Paulo*), Campinas (*University of Campinas*) and São Carlos (*Federal University of São Carlos*). A considerable number of spin-offs are based in these cities, along with a high rate of PhDs residing there. The highest rate of R&D investment originating from state governments is also in this state. The average monthly salary is in the highest bracket observed in the country (400 dollars), although there is internal inequality in the distribution.

The main economic sectors in the Brazilian states mentioned in Table 1 whose GDP corresponds proportionally to less than 1% of the country's GDP include agriculture, livestock and agricultural processing: Acre, Alagoas, Amapá and Roraima. The states in this group that show other economic activities are Paraíba (textile industry, footwear and manufacture of non-metallic mineral products – cement), Amapá and Rondônia with gold and tin mining, respectively, and Sergipe (oil extraction).

5.2. Decomposition at the technological level

We decommposed the data into three different technological sectors: high-tech manufacturing, medium high-tech manufacturing, and high-tech knowledge-intensive services. Analysis was also carried out to identify each of the 27 Brazilian states' contribution to total synergy. The results are presented in Table 5. Figure 2 shows the total synergy and decreasing contributions of states. Figure 2 shows the generation of synergy by regions and (states) in descending order subdivided by each sector. The 10 states displayed, are the ones with the highest contribution. São Paulo is the leading state for innovation in Brazil, in the four groups of HTM, MHTM, HTKIS and KIS sectors.

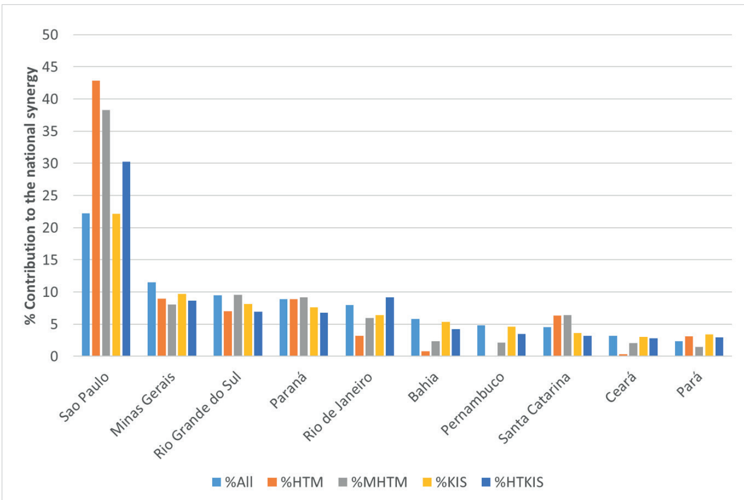

Figure 2. Contribution to national synergy. State levels.
Source: *Orbis* data.

Table 5. Synergy contribution for all 27 states and their respective economic sectors.

Federal states (a)		All sectors			High tech manufacturing				Medium-high tech manufacturing			Knowledge-intensive services			
		N of firms (b)	ΔT (mbit) (c)	% (d)	N of firms (e)	ΔT (mbit) (f)	Synergy (g)	% (h)	N (i)	ΔT (mbit) (j)	% (k)	N (l)	ΔT (mbit) (m)	Synergy (n)	% (o)
	Brazil	15,957,292	-113	100		-629,839	-629,839	100	76,477	-758,559	100	2,181,007	-202,204	-202,204	100
1	Acre	175,794	-1,1823934	1,045481	19	1,197855	0	0	471	-2,63462	0,35	18,975	-1,88065	-1,88065	0,930074
2	Alagoas	154,878	-1,14551394	1,012872	20	2,153378	0	0	396	-1,9105	0,25	17,741	-1,81105	-1,81105	0,895655
3	Amazonas	60,493	-0,66243415	0,585729	20	1,308926	0	0	88	-0,03952	0,01	19,709	-1,33696	-1,33696	0,661194
4	Amapá	75,068	-0,53461297	0,472709	3	0	0	0	209	-0,31002	0,04	6,847	-0,85084	-0,85084	0,420784
5	Bahia	901,861	-6,5648188	5,804662	218	-4,86508	-4,86508	0,772432	2,706	-17,6721	2,33	105,524	-10,8631	-10,8631	5,372351
6	Ceará	509,953	-3,60458867	3,187204	133	-2,0685	-2,0685	0,328418	2,316	-15,4491	2,04	53,631	-6,16542	-6,16542	3,049111
7	Distrito Federal	46,961	-0,34989234	0,309377	5	0	0	0	91	-0,08144	0,01	4,271	-0,49581	-0,49581	0,245201
8	Espírito Santo	348,477	-2,1866814	1,933480	78	-1,68697	-1,68697	0,267841	1,312	-7,45812	0,98	42,105	-3,88223	-3,88223	1,919955
9	Goiás	204,879	-1,92582611	1,702830	137	-0,63063	-0,63063	0,100126	1,485	-12,1284	1,60	29,009	-3,24273	-3,24273	1,603694
10	Maranhão	281,592	-1,58080918	1,397763	29	1,036982	0	0	590	-2,71377	0,36	29,875	-3,01955	-3,01955	1,493317
11	Minas Gerais	1,673,231	-12,9944568	11,489800	990	-56,437	-56,437	8,960537	7,291	-61,4073	8,10	220,154	-19,5854	-19,5854	9,685952
12	Mato Grosso do Sul	222,567	-1,72704575	1,527067	36	1,023815	0	0	661	-5,1514	0,68	25,548	-2,92628	-2,92628	1,447193
13	Mato Grosso	341,745	-2,65703323	2,349369	50	-0,08793	-0,08793	0,013961	1,220	-9,16467	1,21	38,143	-4,18102	-4,18102	2,067723
14	Pará	539,330	-2,68824462	2,376966	347	-19,6604	-19,6604	3,121492	1,635	-11,0909	1,46	61,093	-6,94257	-6,94257	3,433450
15	Paraíba	207,302	-1,30466216	1,153592	49	1,598913	0	0	733	-3,20171	0,42	22,394	-2,0493	-2,0493	1,013480
16	Pernambuco	505,102	-5,50371897	4,866430	137	3,896228	0	0	2,036	-16,428	2,17	65,825	-9,33074	-9,33074	4,614517
17	Piauí	158,183	-0,56569838	0,500195	21	2,284935	0	0	374	-1,3554	0,18	16,518	-1,6486	-1,6486	0,815318
18	Paraná	1,084,840	-10,0360304	8,873933	797	-55,831	-55,831	8,864320	7,434	-69,8901	9,21	140,575	-15,3773	-15,3773	7,604867
19	Rio de Janeiro	1,399,610	-8,99700673	7,955221	510	-20,143	-20,143	3,198121	4,402	-45,1463	5,95	232,414	-12,9227	-12,9227	6,390925
20	Rio Grande do Norte	198,789	-1,27215666	1,124850	38	0,760363	0	0	675	-4,16316	0,55	24,518	-1,90754	-1,90754	0,943372
21	Rondônia	195,700	-1,67029474	1,476887	93	-1,84425	-1,84425	0,292813	978	-7,78521	1,03	22,776	-3,07319	-3,07319	1,519847
22	Roraima	75,984	-0,72563895	0,641615	25	1,385841	0	0	125	-0,57058	0,08	13,047	-1,51357	-1,51357	0,748537
23	Rio Grande do Sul	1,075,389	-10,7514673	9,506528	719	-44,1559	-44,1559	7,010667	7,503	-72,5133	9,56	146,920	-16,4781	-16,4781	8,149244
24	Santa Catarina	723,142	-5,11843412	4,525758	532	-39,8123	-39,8123	6,321022	5,908	-48,5664	6,40	95,844	-7,33631	-7,33631	3,628173
25	Sergipe	101,901	-0,98783229	0,873449	23	0,727327	0	0	325	-1,29843	0,17	13,386	-1,82452	-1,82452	0,902315
26	São Paulo	4,537,365	-25,1114243	22,203710	3196	-270,088	-270,088	42,882080	24,851	-290,679	38,32	685,010	-44,8181	-44,8181	22,164780
27	Tocantins	157,156	-1,24691059	1,102528	18	1,319743	0	0	383	-2,4555	0,32	16,230	-2,0019	-2,0019	0,990040
			-113			-498,617	-498,617	79,16572	76,198	-711,265	93,77		-187,466	-187,466	92,711070

Source: based on *Orbis* data, 2018

In the high-tech manufacturing sectors the results for the states with the largest share of synergy are similar to those found for Brazil's overall economy. The largest share of synergy can be observed in the state of São Paulo: 42.9% of Brazil's total synergy, while Minas Gerais and Paraná contribute 8.9% and 8.9% respectively (check Table 3).

Several Brazilian states registered zero synergy in high-tech manufacturing, the majority of which are located in the North and Northeast Regions, the poorest in the country. The North Region, which comprises most of the Amazon Forest, has the lowest population density in the country, weak infrastructure (roads, telephony, electricity) and lower levels of per capita income. This region consists of seven states, five of which register zero synergy in high-tech manufacturing: Acre, Amazonas, Amapá, Roraima and Tocantins. These same states individually contribute less than 1% to the national GDP according to data presented in Table 1. The *Manaus Free Trade Zone* was installed in 1967 with the purpose of creating an industrial, commercial and agricultural center endowed with economic conditions that allow its development. In view of local factors and the great distance between the state of Amazonas and the consumer centres for their products, international companies were set up that produce televisions and communication equipment, among others. In the Northeast Region, made up of nine states, eight also have zero values for synergy in high-tech manufacturing. Of this total, five states contribute individually less than 1% of the national GDP as reported in Table 1: Alagoas, Paraiba, Piauí, Rio Grande do Norte and Sergipe. Other states with the same pattern are from the Midwest Region: Distrito Federal, Mato Grosso do Sul. None of these states contribute to the dynamics of the high-tech sector.

The greatest amount of medium-high tech manufacturing continues to take place in the same states with the largest high-tech manufacturing sector, as shown in Table 5. However, among the ten highest states, three from the Northeast Region are included (Bahia, Pernambuco and Ceará). In the last decades public policies have been developed, to boost the economy by offering incentives to companies setting up in the region.

In the case of high-tech knowledge-intensive services, the leading states are São Paulo (ΔT= -44.8 mbit), Minas Gerais (ΔT=-19.5 mbit) and Rio Grande do Sul (ΔT=-16.5 ΔT mbit). The comparison among the ten top states enables us to see that states from different regions have been developing these economic activities by taking advantage of the opportunities created by new technologies, like Bahia, Pernambuco and Ceará (Northeast), Pará (North), Santa Catarina (South).

The synergy values are significantly correlated to the numbers of firms in *all* states and sectors. The *N* of firms variess as the independent variable among the states and sectors. These results suggest that the numbers of firms and not the technological capacities are crucial for the synergy generated at each scale. Table 6, here below, shows the correlations between the number of firms and the synergy generation across Brazilian states. At the 4-digit level, the first eigenvector in this matrix accounts for almost all (97.5%) of the variance. In sum: we found no significant differences among the states in terms of distributions HTM, MHTM, KIS, HTKIS.

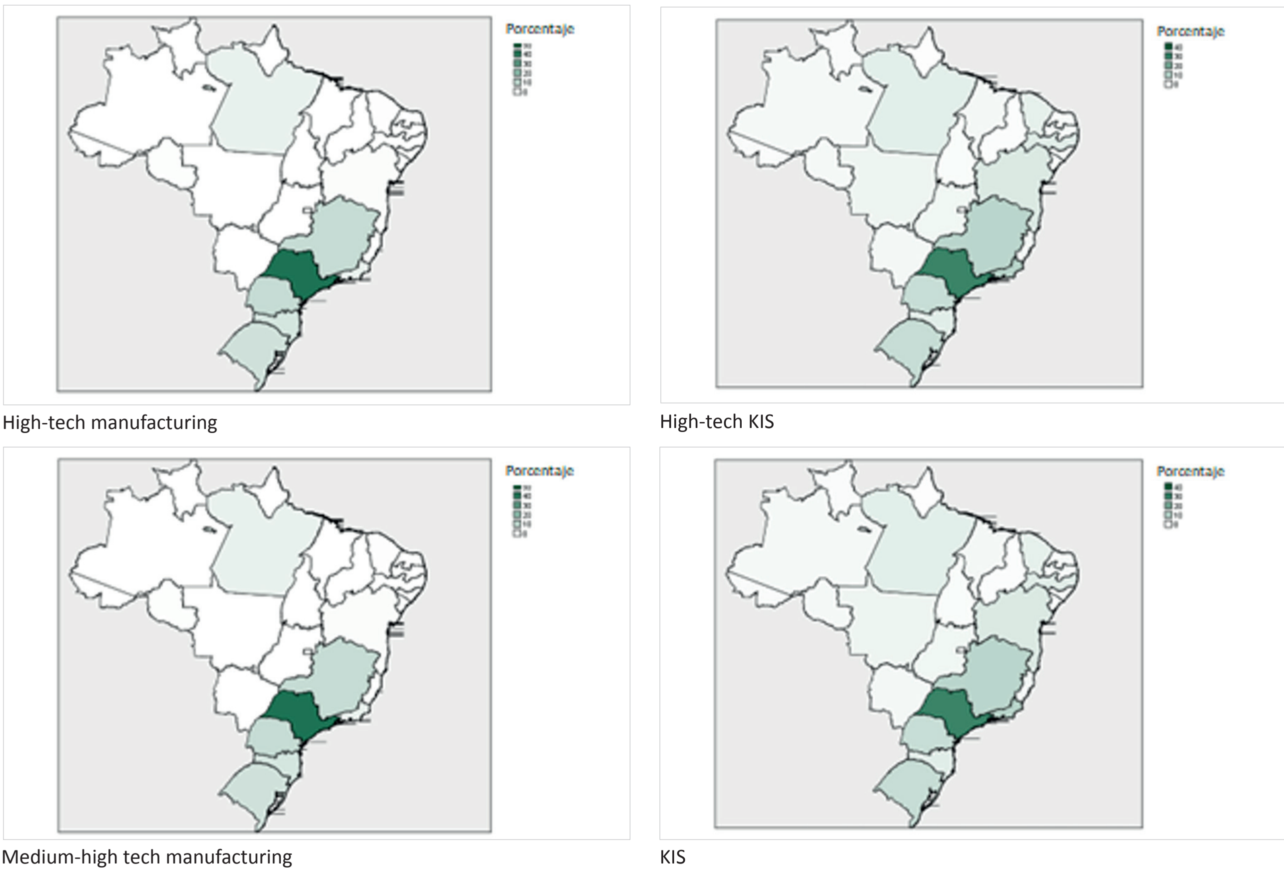

Figure 3. Synergy generation at the level of 27 regions in Brazil (NUTS2) separated by different sectors: HTM, MHTM, HTK, KIS.
Source: based on *Orbis* data, using *SPSS* for the mapping.

Table 6. Correlations between the number of firms and synergy generation in Brazilian states and relevant sectors

		Perc_All	Perc_HTM	perc_MHTM	perc_KIS	perc_HTKIS	N_All
Perc_All	Pearson Correlation	1	.908**	.940**	.993**	.958**	.971**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	27	27	27	27	27	27
Perc_HTM	Pearson Correlation	.908**	1	.991**	.938**	.968**	.960**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	27	27	27	27	27	27
perc_MHTM	Pearson Correlation	.940**	.991**	1	.961**	.982**	.974**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	27	27	27	27	27	27
perc_KIS	Pearson Correlation	.993**	.938**	.961**	1	.977**	.985**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	27	27	27	27	27	27
perc_HTKIS	Pearson Correlation	.958**	.968**	.982**	.977**	1	.994**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	27	27	27	27	27	27
N_All	Pearson Correlation	.971**	.960**	.974**	.985**	.994**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	27	27	27	27	27	27

** Correlation is significant at the 0.01 level (2-tailed).

6. Discussion and conclusions

The four sectors which were distinguished by the OECD as typical for knowledge-based economic developments –(*i*) high-tech manufacturing, (*ii*) medium-high tech, (*iii*) knowledge-intensive services, and (*iv*) th subset of high-tech among these services– are not different in their contribution to the synergy in the Brazilian innovation system. When we drew the geographical maps for the four sectors, they were to our surprise virtually identical. The Pearson correlations among the distributions across the states are all larger than .9 and significant at the 0.01 level. In other words, differences in technological capacities among the sectors do not make any difference for the innovativeness of states or sectors. The knowledge-based part of the Brazilian economy is a layer which is not interacting with the remaining of the economy. The latter is a political and not a knowledge-based economy.

Two further findings arise from these results with relevance for the development of a Brazilian Innovation System.

Southeast belt around São Paulo

When comparing the results in the geographical distributions of Brazil –no matter for which sector–the synergy for the whole country are concentrated in São Paulo (22,16%), and the bordering states to São Paulo: Minas Gerais (9,68%), Rio de Janeiro (6,39%), Paraná (7,6%), and Rio Grande do Sul (8,14%). Such a strong regional effect was also found in the analysis of other nations, such as the United Sates (**Leydesdorff** *et al.*, 2019) and Spain (**Leydesdorff**; **Porto-Gómez**, 2019). In the USA, synergy was, concentrated in the north-east (around New York) and in Spain around the metropoles of Barcelona and Madrid. However, in Brazil, the remainder of the country does not participate in the knowledge-based economy. We find an absence of innovation and high-tech manufacturing in the 82% of the states of Brazil, although these states contribute 33,6% of the Brazilian GPD 2018. The states that do not participate in the knowledge-based economy are the ones with low economic development (**Haddad**, 1999; **Morais**; **Swart**; **Jordaan**, 2018), high levels of poverty and deprived productive structures. In the absence of radically new policies, these conditions will negatively affect the future growth of those states. They will not be viable in the future.

A capital without influence

Brazilian capital is Brasilia since 1960, which is located in the state Distrito Federal. Before this date, the capital was Rio de Janeiro, which maintains high levels of economic development. The relocation of the capital city to Brasilia followed a strategy to promote the economic development of the inner regions, although this plan was not achieved and Brasilia has not evolved (**Madaleno**, 1996; **Ishenda**; **Guoqing**, 2019). The absence of a network of triple-helix relations and the priority of public services in Brasilia are visible in our results. Brasilia has the lowest contributions to synergy development (0.24%) in all the sectors. Accordingly, the number of firms is also lower than for any other state in our data: 0.31% of the companies in Brazil are located in Brasilia. The Brazilian economy is based on firms responding to the needs of the public needs (*Codeplan*, 2020). This penumbra of firms earns from the political process with legal and illegal means. Considered as a political capital and not an economic capital, Brasilia has not been able to attract economic activities and has therefore not been able to promote new technological developments. This configuration is comparable with the absence of sectors other than government services to firms in Rome as the administrative capital of Italy (**Leydesdorff**; **Cucco**, 2019). In Italy, the north of the country around the Emilia-Romagna belt[1], completely overtakes the national synergy, compared to a lowest contribution of Lazio; that is, the region in which Rome is located.

Our results suggest that at the national level no synergy is generated. The Brazilian economy is anchored in agrobusiness and mineral extraction (**Petras**, 2013), with a small number of states developing economic activities with more advanced technological levels. In short periods, plans to stimulate technological development based on industrialization and knowledge-based services have been adopted, but these were primarily stimulating for the southeast and south regions of the country (**Santana** *et al.*, 2019). Precisely, in the states where 60% of the synergy can already be found. The large regional disparities in economic development, wage levels, educational and health levels, have made the North, Northeast and part of the Mid-west very marginal to the national synergy. Some of these regions have synergy values equal to zero or below 1%.

The largest contribution in terms of innovation is for the state of São Paulo, which alone contributes 22,16% of the synergy. In comparative terms it is the state with the highest values for HTM, MHT, KIS and MTKIS. In this sense, getting back to the aim of this study, we can confirm that Brazil lacks a national innovation system with interactions among geographical, technological, and organizational distributions generating innovations. A normative consequence arising from this work should points to the need to reframe the productive structure of Brazil, in order to invest in more knowledge advanced sectors, and not only in the southeastern states but also in north and center ones.

A limitation of this study is the measurement at a certain moment in time. The *Orbis* dataset employed does not offer historical series, so we have not been able to perform panel data in order to make comparisons between different political regimes such as the military dictatorship of the 70s and 80s, and the democratic period thereafter. Our data, however, is pre-Covid (2018). Covid has probably worsened the situation. It would be interesting to compare the situation in 2018 with 2008 in order to develop a historical perspective. However, data needed for this type of studies is available only during the last decade or so.

The second interest area would be in the region of São Paulo. Considering the relevance for the whole Brazilian economy, we should better understand the regional innovation system, as it was made for the Californian economy in the analysis performed by **Leydesdorff** *et al.* (2019). From an economic development perspective, we recognized that more efforts have been made in analyzing triple-helix approaches in economically advanced countries, mainly in Europe, but also in North America. Considering the lack of roads and transport connectivity between Brazil and its neighbors (**Jaimurzina** *et al.*, 2015; **Vecchio** *et al.*, 2020), one can also consider a broader perspective and analyze Brazil in its Latin-American context; for example, of *MercoSur*.

7. Note

1. The Italian case, does not correspond to the relocation of the capital but to a geographical distribution of a political capital (Rome) and an economical capital (Milano).

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