

Collaborative network of SMEs innovation projects: influence of scientific and technological institutions

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Abstract: Public funding for Small and Medium Enterprises (SMEs) innovation projects in collaboration with Scientific and Technological Institutions is still incipient in less developed Global South regions. Within the context mentioned above, our objective is to show a network analysis of Industry-University-Research Institute (IUR) interactions promoted by a government program, identifying its structure and dynamics and the influences played by these organisational actors. The results point out that the program presents effectiveness in establishing the IUR interaction network. Moreover, the network presents a scale-free structure, strong clustering and short distances between the actors. Universities lead as the most central actors, followed by research institutes. Despite the growth of the network with the significant entry of new SMEs, there is no evidence that this evolution contributes to improving its network metrics. The conclusions suggest that the network structure and dynamics may imply greater redundancy in the innovation process while allowing greater speed in the flow of knowledge and wider dissemination of knowledge among actors. The hubs (four central universities) in the network suggests an influence as generators and disseminators of knowledge and facilitators of interaction, but they can also limit the dynamics of the search for innovation in the network.

Keywords: triple helix; industry-university-research institute interactions; social network analysis; innovation networks; government funding

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1 Introduction

Innovation has been studied as a key factor in the development of countries and regions (Leydesdorff, 2012; Leydesdorff & Etzkowitz, 1996; Mazzucato & Semieniuk, 2017). Continental countries, such as Brazil, tend to present different levels of development in their different regions, linked to their production matrixes and their environmental characteristics that historically can create an economic dependence on traditional and less innovative sectors in less developed regions (Beramendi & Rogers, 2021; Cardozo & Martins, 2020). Furthermore, especially in the less developed regions of the Global South, innovation processes are still incipient and depend on regional and local dynamics and political incentives to improve the innovative environment (Ndabeni, Rogerson & Booyens, 2016; Pinho & Fernandes, 2015).

In this context, in northeastern Brazil, the State of Ceará, inserted in a semiarid and poorly developed territory in the Global South, has been seeking to diversify its production matrix with industrial policies. More recent policies are geared towards alignment with the perspective of the ability to create innovation. Thus, since 2015 the State of Ceará has developed, through its agency to promote scientific and technological development, a systematic program for funding innovation projects of local Small and Medium Enterprises (SMEs) in collaboration with Scientific and Technological Institutions (STIs), even without robust data from the region.

Nevertheless, such programs have support in the literature, as innovation as a complex process submits isolated actors to increased

obstacles, as opposed to obtaining benefits when involved in collaboration (Barrie, Zawdie & João, 2019; Bertello et al., 2022; Brem & Radziwon, 2017; DeBresson & Amesse, 1991; Faccin, Balestrin & Bortolaso, 2016; Franco, Câmara & Parente, 2017).

In this perspective, many studies are concerned with interactions between actors in innovation networks formed spontaneously or with networks as an instrument of sectoral policies (Franco, Câmara & Parente, 2017; Hernández & González, 2017; Mahmoudzadeh & Alborzi, 2017; Schütz et al., 2018). Furthermore, as pointed out by Brem and Radziwon (2017), those networks used to support actors' performance in the development of national and regional innovation, opening space for studies with scope in local projects with the participation of SMEs. Analysing the literature, we found a lack of studies on the interactions between actors in networks formed from public funding for innovation in local SMEs. Thus, from this gap, the study of Industry-University-Research Institute (IUR) interactions in networks derived from innovation projects of SMEs (in this research, they are organisational actors that represent the industry helix) financed by a government agency program is considered relevant, and this is the research scenario.

In this context, universities and research institutes (RIs) are organisational actors that play an important role in the innovation process in partnership with SMEs. IUR interaction network partnerships are based on the Triple Helix (TH) theory, making it possible to investigate them from this theoretical perspective, considering these three spheres of independent actors in the innovation system (Zhang, Chen & Fu, 2019). It is also possible and seeks to undertake in this research a

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combined investigation involving the TH approach with the use of the lenses of the Social Network Analysis (SNA). This combination is used as a conceptual and empirical basis in the referred research scenario.

Thus, we formulated the following research question: what are the structure and dynamics of networks and the influences of organisational actors in a network of IUR interactions in SMEs innovation projects financed by government agency program? Network metrics are calculated for the selected project networks in the program over time - 2015 to 2018.

The projects analyzed were proposed by SMEs, which they are responsible for executing in partnership with universities and research institutes. The interactions of SMEs with other organizations (others enterprises that also submit projects to the government agency's program and others organizations supporting innovation) are also observed.

This study aims to contribute to this theme, first, by offering an empirical longitudinal study on the structure and dynamics of IUR networks, combining the TH and SNA approaches in the context of innovation projects, with only a few researches that made this combination in the context innovation, as Barrie, Zawdie and João (2019) and Chen and Lin (2017). Second, by disaggregating STIs into "Universities" and "RIs", especially when most research does not approach RIs as independent actors, ignoring or treating them as affiliated to the university (Chen et al., 2020; Zhang, Chen & Fu, 2019).

After this introduction, the paper continues with Section 2, presenting a literature review on the SNA lens and TH approach. Section 3 presents the methodology, while Section 4 presents the results, and Section 5 discusses the findings. Finally, in Section 6, the conclusions with the implications of the research are expressed.

2 Theoretical underpinning

2.1 Social Network Analysis lens on innovation

SNA makes it possible to design and interpret relationships, looking for patterns and implications, in addition to considering the actors and their actions as a dependent, the generation of resource flows, the network structure influenced by actions and the relational pattern defining the structures of the social environment (Wasserman & Faust, 1994). With this, a broad description of networks is sought, focusing on the elements that make up its structure (actor and link) and indicating structural models for forming ties.

For example, in the scale-free model, there is a preferential attachment as the network expands continuously with the inclusion of new actors, with a greater chance of them connecting to the hubs (Barabási, 2009). Another model of network evolution could indicate structural holes (Burt, 1992), with the creation of small-world networks, combining many local connections and some more distant ones (Watts & Strogatz, 1998). Regardless of perspective, there is considerable agreement in the analysis of innovation networks as to the greater chance of actors to connect with others with whom they have related in the past or with actors similar to former partners (Van der Valk & Gijsbers, 2010).

It is also widely accepted that the network structure and its properties may be able to influence the performance of the network (Angelini et al., 2017; Barabási, 2009; Burt, 1992; Mahmoudzadeh & Alborzi, 2017; Watts & Strogatz, 1988), it is possible to observe the actors of the networks through configuration mechanisms such as centrality (Freeman, 1979; Wasserman & Faust, 1994).

In this sense, SNA is useful for understanding structural and positioning patterns, describing the influence on structures and development of innovation networks (Van der Valk & Gijsbers, 2010). This approach provided relevant contributions to innovation studies (DeBresson & Amesse, 1991) in the way the idea of an innovation network is related to the collective nature of the innovation process in contemporary societies (Castells, 2010). Moreover, the network's superior performance constitutes a collective property inherent in the relationships between actors (Burt, 1992).

2.2 Triple Helix approach to innovation networks

Partnerships in networks contribute to promoting superior performance in innovation, especially given the obstacles faced by organisations to innovate (Barrie, Zawdie & João, 2019; Brem & Radziwon, 2017; DeBresson & Amesse, 1991; Faccin, Balestrin & Bortolaso, 2016; Franco, Câmara & Parente, 2017; Mazzucato & Semieniuk, 2017). In this sense, the theoretical approach of TH is a fundamental milestone for the analytical exploration of University-Industry-Government (UIG) partnerships (Etzkowitz & Leydesdorff, 2000; Etzkowitz & Zhou, 2018; Leydesdorff & Etzkowitz, 1996). With the popularity of TH in examining the structure of the innovation system, this theory moves from an analytical concept to a normative one, with strength in the study of innovation and political action from the local to the multinational level (Galvao et al., 2019).

Given that the establishment of partnerships between enterprises and STIs in innovation projects consists of a good strategy (Awasthy et al., 2020; Parolin et al., 2020; Schütz et al., 2018), policymakers increasingly adopt incentive instruments (Edler & Fagerberg, 2017; Mazzucato & Semieniuk, 2017; Wang, 2018). With the provision of resources, support and guidance, the role of governments function as a mechanism to facilitate these collaborative relationships (Bertello et al., 2022; Brem & Radziwon, 2017; Li et al., 2018; Wang, 2018; Zhang, Chen & Fu, 2019). In addition, participation in public support programs contributes enterprises to expand their collaborative networks and innovation activities (Douglas & Radicic, 2022; Nakara, Messegem & Ramaroson, 2021).

Cooperation in innovation projects allows, in addition to expanding access to resources, improvements in the teams' capacities, which are perpetuated even after the execution of the projects (Faccin, Balestrin & Bortolaso, 2016; Parolin et al., 2020). This cooperation makes it possible to generate benefits for both companies by accessing researchers and research infrastructure, obtaining a scientific seal to the results of the partnerships and improving the image due to the links with the STIs (Chen & Lin, 2017; Parolin et al., 2020; Schütz et al., 2018), as for STIs, by gaining opportunities to show the results of

their work and to attract new resources for related projects (Brem & Radziwon, 2017; Parolin et al., 2020). However, despite the potential benefits and multiple incentives, there may be obstacles to such collaboration, such as issues related to intellectual property (Awasthy et al., 2020; Schütz et al., 2018).

The TH model supports the construction of relationships in the system, which are the strategic focus to promote development (Leydesdorff, 2012; Li et al., 2018). TH provides a generic and flexible method for investigating non-linear relationships or synergies between actors in a dynamic perspective (Galvao et al., 2019; Zhang, Chen & Fu, 2019). Although its initial focus is UIG relations, their derivations (Arranz et al., 2020; Galvao et al., 2019; Leydesdorff, 2012; Schütz et al., 2018) and their use to support studies of IUR interactions in the fields of innovation (Barrie, Zawdie & João, 2019; Chen & Lin, 2017) and scientific collaboration (Chen et al., 2020; Zhang, Chen & Fu, 2019) make it possible to seek to understand networks of IUR interactions in innovation projects from the perspective of TH.

3 Methodology

3.1 Research context

The research object consists of the organisational partnerships derived from the list of members of the SMEs innovation project teams. All projects selected in a government agency financing program – *Inovafit Program*, from the Support Foundation for Scientific and Technological Development (FUNCAP), linked to the State Government of Ceará, in northeastern Brazil, were considered.

Ceará is a poorly developed state inserted in a semiarid region from Global South, with low industrialisation and historically dedicated to producing some commodities, but which has been instituting in recent years a policy of technological incentive, having as an important action the financing of innovation involving SMEs-STIs collaboration. Compared to some countries, this state has a population similar to Sweden, a territorial extension slightly higher than England and a Human Development Index equivalent to the Philippines.

The choice of this case is due to the fact that few states have their own funding programs for innovation projects, through their research support agencies (called FAPs – Fundação de Apoio à Pesquisa). All states in the country have their own FAP, but most of them act exclusively or predominantly in the funding of academic research developed by universities, neglecting innovation research in enterprises. Most of the FAPs are very dependent on partnership with the national government. The policy to support innovation projects carried out by enterprises is very incipient in the country. The state of Ceará is one of the prominent in this policy in the Northeast region, as well as in the rest of the country. In richer states, such as São Paulo, Rio de Janeiro, Minas Gerais and Rio Grande do Sul, this policy is more frequent, unlike what is observed in poorer states.

The program started in 2015, with editions taking place every year to funding local SME projects' execution. FUNCAP developed the program in two independent phases: i) Phase 1 (up to six months),

for research on technical feasibility and development of a Minimum Viable Product (MVP), with a volume of resources equal to US\$ 821,018 (or R\$ 3,000,000) for contracting projects with a value up to US\$ 27,367 (or R\$ 100,000); ii) Phase 2 (up to 24 months), to develop the project itself, starting with the presentation of an MVP and having to present a commercialisation business plan, with US\$ 2,736,727 (or R\$ 10,000,000) being made available for contracting projects with a value up to US\$ 109,469 (or R\$ 400,000). The values in US dollars refer to the average exchange rate (R\$/US\$) equal to 3,654 for the year 2018 - the last year considered in the analysis. The SMEs participating in Phase 2 may or may not have benefited from Phase 1. In both phases, the SMEs' counterparts (minimum 10% of the project value) are required.

3.2 Data collection

We carried documentary research out at FUNCAP between 2018 and 2019 to collect project data in the first four years of the program - 2015 to 2018. We follow preparing an adjacent matrix for each year with the organisational partnerships obtained from the projects and observing the areas of innovation, with four major sectors being defined: health and biotechnology, water and agribusiness, information and communication technology (ICT), civil construction. The selected SMEs express organisational partnerships and the set of partners in the projects, divided into universities and RIs, considered separately (Chen et al., 2020; Zhang, Chen & Fu, 2019), unselected SMEs (that have links with the selected SMEs, then make up the network) and still other organisations (enterprises not participating in the program but working with innovation, as well as innovation support organisations).

We only consider projects proposed by SMEs and selected by the funding agency, which indicates that the project has been carried out. The interactions established by SMEs, based on team bonds, are used to design the network. All projects have been completed.

We extract data from the list of team members, observing the professional/academic bonds from consulting the curricula of the members on the CNPq Lattes Platform (for the submission of projects, it was required to update the curricula). In this case, we paid attention to the coincidence between the project submission periods and professional/academic bonds. Thus, we design a prescribed network of organisational actors based on the bonds of project members, similar to other studies on innovation networks, such as Franco, Câmara and Parente (2017) and Hernández and González (2017).

3.3 Data analysis

SNA was undertaken with the selected projects, considering that these projects' selection and financing enable an effective partnership in their execution. From the IUR interaction network calculations and drawings, it was possible to point out the involvement of different TH structure organisational actors and their influences on the network. Network expansion was considered in the period from 2015 to 2018. This perspective makes it possible to obtain insights regarding the dynamics of the network's evolution. With each project as a reference, undirected and unweighted connections were assumed, such as

Mahmoudzadeh and Alborzi (2017). These choices are due to the premise that knowledge is not directed in only one direction and the difficulty of giving weight to the participation of members of the project teams.

The interaction matrices were analysed using Gephi. The network obtained is of the one-mode and whole mode type (Wasserman & Faust, 1994), as it exhibits connections between actors within a limited group - selected projects. To analyse this type of network, according to Cherven (2015) and Wasserman and Faust (1994), one can make use of metrics of three types.

- i. Network properties (network level):
 - a) Density – the intensity of connections between actors;
 - b) Average degree – summarising the degree of all actors, expressing the average number of links per actor;
 - c) Average path-length – the shortest average path between two actors in the network;
 - d) Diameter – the shortest distance between the two most distant actors in the network, representing their linear size.
- ii. Structural positions of the actors (actor level):
 - a) Degree centrality – number of connections by an actor;
 - b) Betweenness centrality – representing the link in the connection between different pairs of actors;
 - c) Closeness centrality – measuring the average distance of a specific actor in relation to the other actors.

- iii. Groups of actors (Meso level):

- a) Average clustering coefficient – the probability that a pair of actors connected to a third actor will also constitute links with each other;
- b) Modularity – statistics that unite a set of actors based on characteristics shared on the network;
- c) Communities – modular classes of actors with similar characteristics;
- d) Connected components – number of physically separated groups.

4 Results

4.1 Actors and areas in the interaction network

The most common partners of the SMEs in the projects are the STIs, emphasising the universities. STIs participate in the projects three times more than other organisations, even though they present more remarkable growth in the network (Table 1). In addition to the STIs having greater participation, they are also the most competitive because while they establish partnerships in 2/3 of the projects submitted to the program, they are present in 3/4 of the selected projects. It is also worth mentioning the high frequency of unselected SMEs, showing great interaction between enterprises. On average, 60% of the selected SMEs have links with other enterprises in the network (including unselected SMEs and enterprises that make up the other organisations category).

Table 1: Participation of actors and project areas

Actors and areas	2015	2016	2017	2018	Average participation	Variation in the period
Total actors	105	148	207	229	100%	118%
Selected SMEs	37	52	80	90	37%	143%
Unselected SMEs	21	35	43	49	21%	133%
Universities	23	30	43	46	21%	100%
Research institutes	14	16	20	20	11%	43%
Other organisations	10	15	21	24	10%	140%
Total projects	37	59	90	112	100%	203%
Health and biotechnology	12	18	22	27	28%	125%
Water and agribusiness	7	13	22	28	22%	300%
Information and communication technology	6	10	15	19	17%	217%
Civil construction	4	6	11	12	11%	200%
Other areas	8	12	20	26	22%	225%

As for the distribution of the areas where innovation is proposed, health and biotechnology projects and water and agribusiness projects demonstrate high participation in the network, emphasising the latter's strong growth.

Health and biotechnology projects address, for example, from antibody research for veterinary cancer treatment to the production of products based on natural extracts and probiotics to combat viruses that attack shrimp farming. Water and agribusiness projects address from integrated systems for irrigation depth control to vegetarian cheese production research. While in information and communication technology area it is possible to find projects that address the creation of platforms for business management. In the construction area, we can find projects to create an intelligent construction system for slabs for buildings. In other areas are varied projects, such as the production of solar cookers and the manufacture of compact mechanized composter.

In general, universities have a strong presence in all areas covered by the projects, while some RIs are more focused on water and

agribusiness or health and biotechnology. The greater number of projects in relation to the number of selected SMEs is due to the possibility of an enterprise proposing a project in a different area than the one proposed in the previous year. Approximately 1/5 of these SMEs having selected projects in more than one year of the program.

4.2 Structural level of the network

The metrics throughout the evolution of the network (Table 2) demonstrate an increase in the number of links (137%) greater than in the number of actors (118%), in addition to demonstrating that the network becomes larger and more dispersed (less dense) while having the highest average connections (highest average degree). Despite the reduced density and the reasonable average degree, the network structure contributes to the actors preserving connections with small average path lengths, allowing that a pair of actors can communicate within a short distance of two steps. Another statistic that demonstrates this condition is the diameter, which points out that the shortest distance that knowledge can be shared between more distant actors is equivalent to five steps.

Table 2: Structural evolution of the network

Metrics	2015	2016	2017	2018
Actors	105	149	207	229
Links	358	565	747	850
Density	0,066	0,052	0,035	0,033
Average degree	6,838	7,635	7,227	7,432
Average path length	2,250	2,209	2,244	2,241
Diameter	5	5	5	5
Average clustering coefficient	0,768	0,769	0,787	0,781
Modularity	0,397	0,404	0,421	0,429
Communities	4	5	6	7
Components	1	1	2	2

As for the metrics associated with the group, the clustering coefficient is high and practically does not change. On average, actors enjoy more than 3/4 of the connections available in the neighbourhood. The network has a maximum of two components, also showing high clustering. While modularity, resulting from an optimisation process, shows an increase with the evolution of the network, accompanied by an increase in the number of communities.

4.3 Centrality and formation of communities

In the top 10 of the centralities (Table 3), it is possible to observe great amplitude in the degree and the betweenness, corroborating the existence of hubs in the scale-free patterns. This result suggests a concentration of high connectivity and high power to control knowledge flows in one or a few universities, contrasting with less amplitude in the power of reaching the network, indicating a lower level of difficulty in accessing the knowledge generated.

Table 3: Top 10 values of centrality metrics in the 2018 network

Actors	Degree	Actors	Betweenness	Actors	Closeness
UFC	171	UFC	0,580	UFC	0,804
IFCE	97	IFCE	0,191	IFCE	0,630
UNIFOR	90	UNIFOR	0,166	UNIFOR	0,618
UECE	58	UECE	0,059	UECE	0,564
SENAI ^(RI)	26	Inovaeduc ^(SME)	0,026	SEBRAE ^(O)	0,518
SEBRAE ^(O)	22	SENAI ^(RI)	0,025	SENAI ^(RI)	0,516
ITIC ^(RI)	20	INOVAGRI ^(RI)	0,013	ITIC ^(RI)	0,513
EMBRAPA ^(RI)	18	CENTEC	0,012	EMBRAPA ^(RI)	0,510
UniEstácio	18	ITIC ^(RI)	0,010	UniEstácio	0,510
CLAEQ ^(RI)	16	SEBRAE ^(O)	0,010	CLAEQ ^(RI)	0,508

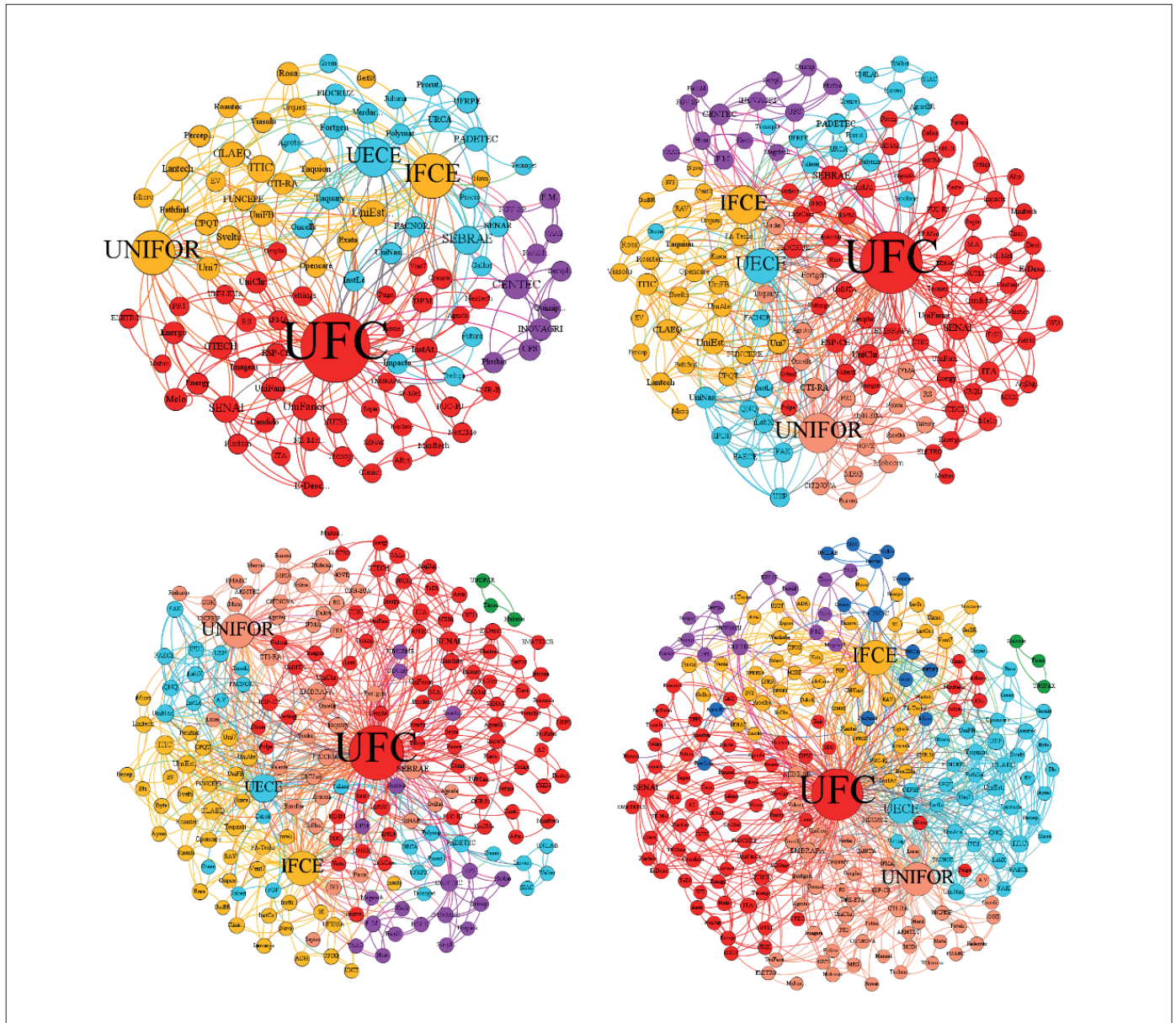
Note: All actors are universities, except RI (research institute), O (other organisation), and SME.

This greater centrality of universities can be seen throughout the evolution of the network when the four main universities more than double the number of their connections. This growth is not seen in any of the other actors in the top 10. Compared to hubs, it is interesting to identify those other universities, RIs, and civil society organisation (make

up the category of other organisations) that play a less strategic role in terms of centrality but important for the projects developed by SMEs.

In the verification of communities, it is possible to perceive more explicit clusterings, observing some patterns and changes during the evolution of the network (Figure 1).

Figure 1: Evolution of the network, according to degree centrality and communities



Notes: Different node colours indicate community, and node size indicates degree centrality. Right to left and top to bottom networks 2015, 2016, 2017 and 2018.

First, the four main universities (UFC, UECE, UNIFOR and IFCE), as “hubs” and working on projects in different areas, lead separate communities in almost the entire period. Second, a community led by a university and a research institute (CENTEC and INOVAGRI, respectively), with

a greater focus on water and agribusiness projects, is persistent throughout the period. Third, in the last network, a set of actors with network characteristics more similar to the UECE form a separate group, led by PADETEC, with a greater focus on health and biotechnology projects.

5 Discussions

The program seems to influence stimulating the consolidation of the IUR interaction network, based on the permanent promotion of SMEs projects in partnership with STIs, with many of these SMEs maintaining the same partners throughout the evolution of the network. This behaviour in establishing relationships over time is aligned within studies of innovation networks (Van der Valk & Gijssbers, 2010), suggesting that government support for collaboration in innovation can lead to the formation and success of networks, which need to be encouraged by politics (Awasthy et al., 2020; Brem & Radziwon, 2017; Zhang, Chen & Fu, 2019). The mutual knowledge between SMEs and STIs, which can be gained through collaboration in projects, favors a greater affinity of the goals and objectives of these different organizational actors during innovation work (Bertello et al., 2022; Douglas & Radicic, 2022). In addition, in less developed regions of the Global South, emphasis should be placed on innovation as a continuous practice (Ndabeni, Rogerson & Booyens, 2016), a function stimulated by the systematic financing of projects by the government agency program.

It is important that the resources made available by the program finance only the innovation activities of SME projects and are not used for other expenses (Bertello 2022). For this, the program defines criteria for the application of resources, leaving out expenses not related to research and development within the project, such as rent expenses, remuneration of administrative staff and payment of fees, taxes or interest.

The strong knowledge base installed in STIs can justify the preference of SMEs to establish partnerships with these actors, as also pointed out by Arranz et al. (2020), Awasthy et al., (2020), Brem and Radziwon (2017), Chen et al. (2020), Franco, Câmara and Parente (2017), Schütz et al. (2018) and Zhang, Chen and Fu (2019). However, partnerships between SMEs are also significant in the studied network. This result reveals that the cooperation that interests SMEs in the network is not restricted to STIs only, as also evidenced by Acevedo and Díaz-Molina (2021), Barrie, Zawdie and João (2019), Chen and Lin (2017) and Hernández and González (2017). Such collaborations occur in several project areas, with the government agency supporting a relatively balanced set of technologies, or as suggested by Mazzucato and Semieniuk (2017), not choosing a single “winning” area. In IUR interactions, STIs can use their diversification of knowledge sources to benefit from their insertion in the network, avoid redundancy, and strengthen their key position in the innovation process in different areas (Schütz et al., 2018).

As for metrics throughout the network evolution, it is possible to identify greater communication efficiency in the network, as suggested by Angelini et al. (2017) and Chen et al. (2020), as small distances are established that separate the actors. The network also presents a high and constant clustering over time, showing an intense level of beneficitation of the actors with the relations in the neighbourhood, which may indicate, according to Muller and Peres (2019), greater chances of participating in knowledge flows with other actors in the

group or greater redundancy of knowledge exchanged in the group. The greatest strength in concentrating links, intermediating knowledge flows and reaching actors in the network of some universities and RIs demonstrates consolidating, especially in universities, influences as knowledge generators, facilitators of interaction and disseminators of knowledge, which is according to evidence by Arranz et al. (2020), Barrie, Zawdie and João (2019), Chen and Lin (2017) and Schütz et al. (2018). In comparison with other emerging countries in the Global South, Brazilian enterprises use universities a lot as one of the main sources of information for developing new projects (Pinho & Fernandes, 2015), which is confirmed in this research.

While in the formation of communities and the strong influence of universities to lead groups, it is possible to identify that RIs also present this characteristic at certain times. These findings show different influences of actors in building communities in IUR relations, justifying the separation of STIs, as suggested by Chen et al. (2020) and Zhang, Chen and Fu (2019). The evolution of the network corroborates the scale-free structure (Barabási, 2009), with the continuous expansion of the network, primarily due to the entry of new SMEs, and with the SMEs' preferential attachment in establishing a connection with the hubs (main universities).

All these issues that involve the roles of organizational actors, especially SMEs and STIs, and the structure and dynamics of innovation network they are inserted in express some characteristics of the case studied and possible effects on the local innovation environment.

The importance of universities in the relationships established by enterprises elevates these actors to a key position in contributing to the development of local innovation by SMEs. Universities are responsible for intensifying interactions (links) and increasing agglomeration in the network, leading knowledge generation groups. This capacity of universities is widely reported in several studies (Arranz et al., 2020; Awasthy et al., 2020; Barrie, Zawdie & João, 2019; Brem & Radziwon, 2017; Chen et al., 2020; Chen & Lin, 2017; Franco, Câmara & Parente 2017; Pinho & Fernandes, 2015; Schütz et al., 2018; Zhang, Chen & Fu, 2019).

In addition, public funding policy serves as a catalyst for the process of creating or expanding collaborative interactions between SMEs and STIs (Awasthy et al., 2020; Brem & Radziwon, 2017; Chen & Lin, 2017; Faccin, Balestrin & Bortolaso, 2016; Parolin et al., 2020; Schütz et al., 2018). It is possible that this type of policy, properly designed, generates this greater interaction between the actors in the different innovation environments of a region. The presence of hubs can lead to the creation of redundant knowledge, which can be mitigated with the idea of leaving the SMEs that form the network, with universities as collaborators. The focus of the program is the SMEs innovation projects. This statement is even more valid when a region needs the public incentive for the development of innovation by enterprises, particularly SMEs.

The findings of the case studied are particular to a design of the financing program for innovation projects in a less developed region of the

Brazilian Northeast. Care must be taken with possible extrapolations to other cases with similar policy, both in other regions of the world and in the country itself, which has continental dimensions and is very heterogeneous.

6 Conclusions

The article shows the IUR interactions in innovation projects of local SMEs financed by a government agency program in a context of a less developed region of the Global South. Contributes to the scarce empirical studies that use an approach based on the TH structure combined with SNA in innovation and that independently deal with universities and RIs, in addition to the focus on local SMEs projects. The research results may suggest some implications, as seen below.

The structure and evolution of the network and the positioning of the actors indicate different influences played in the IUR interaction network. Universities are positioned as the most central and contribute to creating a more connected and clustered network, driving a scale-free configuration. While the RIs have a secondary play in the generation and flow of knowledge. The analyses carried out show that the helix of STIs deserves to be divided into universities and RIs. The centrality of universities is predominant, even though they are considered isolated. According to the extended TH model, the research also shows a civil society organisation (other organisations) with some positioning relevance, suggesting that other helix exist and have their importance in the system.

The program promotes the creation of a collaborative network between SMEs and STIs. From the evidenced structural pattern (scale-free), it is possible to suggest that the network leads to a continuous concentration of power in the hubs (four universities), allowing a more redundant knowledge flow. Also, a network configuration over time does not show to improve the speed and distribution of the knowledge flow because, together with the high centrality of the hubs, there is no reduction in distances between the actors and no greater clustering. Understanding the structure and properties of the network is important because policies to encourage collaboration can have more beneficial results than action simply focused on financial support, especially in regions of the Global South with limited funding.

STIs are relevant for establishing partnerships by SMEs, with relationships between them also relatively important. Thus, a wide range of opportunities is offered for SMEs to develop projects in partnership, which may increase innovative capacities and greater visibility in the network. Despite the preferential attachment of SMEs to universities, due to their capacity and scientific reputation, RIs also have an important presence. The technical work capacity of the RIs is strongly directed to the market, which may explain the interest of SMEs. That said, the implications suggest that SMEs may have some incentive to seek partnerships with actors outside the most central core in search of building less redundant knowledge, even if they lose some participation in the largest flow of knowledge of the network, with origins in hubs and their surroundings.

As limitations of the research, the short data series is pointed out, implying a reduction in the possibilities of longitudinal analysis, since the networks may take longer to demonstrate relevant changes, as well as the use of only documentary data, which makes it impossible to view networks of emerging groups during project execution. As a suggestion for advancing the theme, we can mention the study of the effects generated by the financing policy on the performance of SMEs, as well as the analysis on the perspective of multiple helices. First, because the government or civil society funds many RIs; second, because it is possible to have an environmental spectrum in the form of a shaded helix that drives the search for innovation in emerging sectors to overcome limitations imposed by the vulnerability of the natural and socio-economic conditions of a less developed semiarid region in the Global South.

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