Innovation, entrepreneurship and networks: the case of the Incubator of the University of Campinas (INCAMP)

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Abstract

Purpose: The Technology Business Incubator literature stresses that networks are deemed essential for innovation and entrepreneurship to take place. As such, different authors have studied networks at incubators, specially investigating the resources acquired by the entrepreneurs and types of ties established. Nevertheless, only a few authors have analyzed network formation and the influence of network features in innovation activities taken by the entrepreneurs. Our paper tries to fill this void by investigating how innovation networks are formed at Technology Business Incubators and how the network features affect these activities.

Study design: Our approach is a case study in which we analyze the network of entrepreneurs incubated at the University of Campinas Incubator (INCAMP). We have conducted interviews with entrepreneurs, incubator managers and policy makers. Furthermore, we have analyzed our data using an analytical framework set to investigate network features.

Findings: We have found that there are four mechanisms that can lead to network formation at incubators: i) institutional mechanisms; ii) social relations; iii) institutional association; and iv) public policies. Additionally, we show that the strength of ties is related to the type of resources circulating; the level of openness of the network can improve innovation activities; and the lack of ties cause delay to the innovation process.

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Originality**:** We apply a novel analytical framework, once developed to analyze Technology Policy, that can help identify features and shortcoming of the networks and, thus, assist incubator managers to create strategies to overcome these issues.

Keywords: Innovation; Technology Incubator; Entrepreneurship; Networks.

Introduction

Entrepreneurship and innovation are two of the drivers of capitalism that can lead to wealth and job creation (Huggins and Thompson, 2015). Due to the centrality of these activities to the economy, different strands of societies (e.g., businessmen, academics and politicians) foster initiatives aimed at promoting them (Lamine *et al.*, 2018). A common initiative is the creation of Business Incubators (BI), small infrastructures designed to support different types of entrepreneurship (Barbero *et al.*, 2014).

Given the range of types of entrepreneurship (e.g., social, traditional, green and technology), there are also different types of incubation schemes to support each of them (Etzkowitz, 2002). Among these, one of the most appealing is the Technology-based Business Incubator because of the nature of technological entrepreneurship: an activity based on knowledge to generate innovation and which has a high economic impact when successful (Prodan, 2007).

The activities designed for the entrepreneurs at Technology BI present a rationale that innovation and entrepreneurship are two collective activities (Soetano and Jack, 2013). In other words, it is understood that incubated entrepreneurs need to find partners that help them with the innovation and entrepreneurial process (Bruneel *et al.*, 2015), thus forming networks - a set of formal and informal collaborations in which economic activities are embedded (Costa, 2019).

However, networks do not always generate positive outcomes. Depending on their features, such as the strength of the ties or the level of openness of the network, they can either be conducive or

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detrimental for innovation and entrepreneurship to take place (Granovetter, 1983; Powell and Grodal, 2005). In this sense, it is fundamental that networks present a mix range of features that are conducive and capable of potentializing economic activities (Powell and Grodal, 2005; Saxenian, 1994).

In the BI literature, networks have been widely studied. Some studies have explored network formation (Pettersen *et al.*, 2016); others have analyzed whether and how networks have contributed for entrepreneurs to innovate (Sa and Lee, 2012); and others have tried to map the resources sought by the entrepreneurs (Soetano and Jack, 2011). However, there is a lack of understanding regarding how networks are formed at Technology BIs and how the features of the networks directly affect the activities the entrepreneurs need to take in order to innovate.

To answer these questions, we resort to a qualitative approach to investigate the networks of entrepreneurs that were incubated or that had recently graduated at the University of Campinas Incubator (INCAMP) in the year of 2018. The University of Campinas is a top ranked public research university in the Southeast of Brazil (QS Top Universities, 2019), and may enable its incubated companies to have access to frontier knowledge.

The methodology of this paper can be divided into three parts: i) in-depth interview with the entrepreneurs, the incubator manager of INCAMP and policy makers; ii) analysis of the data using a Social Network Analysis framework developed by Costa (2012); and iii) data plotting using a network software.

We use a novel analytical framework, once developed to investigate networks of a Technology Policy, to identify network formation, features and shortcomings at a Technology BI. Therefore, our study contributes to the literature by systematizing mechanisms of network formation; but also by providing a framework that can help identify features and shortcoming and, thus, that can assist policy makers and incubators managers in the creation of plans that might support entrepreneurs to overcome barriers related to innovation.

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The paper is outlined in 6 parts: in addition to the introduction and conclusion, there is a literature review section on Innovation Systems and Entrepreneurship Ecosystem, Networks and Business Incubator; a section to present INCAMP and the profile of the entrepreneurs and their companies; a methodology section; and a section to present and discuss the results.

Literature Review

Innovation System and Entrepreneurial Ecosystem

Technological entrepreneurship bears some similarity with technological innovation due to the nature of these two activities that require a diversity of actors, skills, competences, and resources to come to life (Prodan, 2007; Venkataraman, 2004). From a conceptual point of view, various authors have drawn upon the frameworks of Innovation Systems and Entrepreneurial Ecosystems to analyze those activities (Asheim and Gertler, 2005; Freeman, 1998; Rucker Schaeffer *et al.*, 2018).

From the perspective of Innovation Systems, innovation is not only conducted and reliant on companies, it is also a process that requires different institutions and actors. Therefore, different institutions (e.g., universities, research laboratories, investors, banks, producers and consumers) trade and exchange resources in the form of capital, knowledge, information and qualified workers. To enable innovation, the State is expected to maintain a favorable and cogent code of laws that facilitate university-company cooperation; and to fund academic academic research that can be involved in different stages of economic exploitation of research outcomes (Atkinson, 2014; Freeman, 1988; Godin, 2009; Nelson, 1993). As a subset of Innovation Systems, innovation networks provide a set of relationships dealing with market transaction and learning relationships that emerge from distribution, production and consumption activities (Lundvall, 1992; Queiroz, 2006); and monetary relationships with commercial agents that finance

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innovation activities (Mazzucato, 2014) which require complementary social relationships that facilitate the exchange of knowledge, trust and off-market resources (Borgatti *et al.*, 2009).

The Innovation System framework takes a geographical perspective (national, regional and local) (Asheim and Gertler, 2005; Nelson, 1993), a sectoral perspective (Malerba, 2004) or a technological perspective (Makard *et al.*, 2015). In countries with extensive territorial dimensions, which is the case of Brazil, where regions display different economic and institutional trajectories, and governmental capacity, it is desirable to analyze innovation dynamics from a regional perspective. In this sense, Asheim and Gertler (2005) propose a typology with three types of Regional Innovation System (RIS): i) Territorially Embedded Regional Innovation Systems; ii) Regionally Networked Innovation Systems; and iii) Regionalized National Innovation Systems. Regarding the second type, which fits the experience of the innovation dynamics of companies localized in Campinas, learning usually takes place in a localized and interactive form among firms. In addition, there is the institutional support infrastructure of a specific region which usually occurs due to public policy interventions to increase actors' collaborations and capacity for innovation (i.e., network formation).

The Innovation System framework is centrally bound to analyze innovation, thus treating marginally other activities, such as entrepreneurship (Audretsch and Belitski, 2017). To complement this approach, the Entrepreneurial Ecosystem is created to serve as an analytical framework to analyze the individual action of economic agents willing to take risks to start-up an enterprise; and the context where entrepreneurship is carried out (Alvedalen and Boschma, 2017; Audretsch and Belitski, 2017; Autio *et al.*, 2014; Inácio Júnior *et al*., 2016; Stam, 2015).

Entrepreneurial Ecosystems are idiosyncratic regional spaces that present different features and levels of development. However, despite these differences, there are general strategies that can be taken in order to foster entrepreneurship. One of these strategies is to set part of activities of the universities to the market, creating different schemes in which academics can economically exploit the result of their research, such as the creation of spin-offs and R&D partnerships

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agreements with companies (Noveli and Segatto, 2012; Rucker Schaeffer *et al.*, 2018). Another strategy is through network formation in which different organizations can help entrepreneurs to obtain resources they lack and develop capacities to carry out activities related to the performance of their enterprises (Hayter, 2016; Spiegel, 2017). In this sense, organizations, such as universities and incubators, could act as network brokers for the entrepreneurs.

The Innovation System and the Entrepreneurship Ecosystem carry essential dimensions for the analysis of data. Firstly, both frameworks allow to analyze entrepreneurship and innovation in a regionally bound space; and secondly they deem networks as essential for economic activities. In the next subsection, we discuss this latter element, highlighting how the features of networks can affect the dynamics of innovation and entrepreneurship.

Innovation and Entrepreneurial networks

It is widely debated in the sociology literature that economic agents mainly transact with other agents whom they already know or whose information on credibility can be obtained from reliable sources (Granovetter, 1983). In turn, this debate has led to the argument that economic activities are embedded in networks that breed social capital and trust shared among agents (Burt, 1992; Granovetter, 1993).

For economic activities which present high levels of uncertainty, such as innovation and entrepreneurship, networks have become even more essential (Engel *et al.*, 2017). Due to the rise of the pace and complexity of these two activities, entrepreneurs and firms have to cope with new competencies and resources to succeed in economic competition (Spender *et al.*, 2017). As a consequence, network formation between them and actors from the Innovation System and Entrepreneurial Ecosystem has been advanced (Powell and Grodal, 2005; Reis *et al.*, 2018).

However, networks may not generate expected outcomes in terms of economic competition since intrinsic features to them, such as network structure or the actor position, can act as barriers to

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the transmission of resources (Burt *et al.*, 2013; Granovetter, 1983). Departing from the argument of Granovetter (1983) on the strength of the ties, different authors claim that strong ties allow the transmission of resources that depend on relationships based in trust, friendship or face-to-face; on the other hand, weak ties allow the flow of resources that happen because of some opportunity and do not depend on high level of trust (Ahrweiler and Keane, 2013; Costa, 2012). In this sense, it is important that a network contains both strong and weak ties to diversify the resources; as it is pointed out by Saxenian (1994) who states that, in the Silicon Valley, relationships based on mutual trust allow specific information or industrial secrets to circulate; while general information circulate among people with a low level of interaction.

Besides the strength of the ties, another feature of the network which can be conducive or detrimental to economic activities is the level of openness of networks: whether closed or open. A network is considered closed when it is composed by only one cluster in which all the nodes interact with each other. As a result, the resources flowing will be the same, leading to a network sclerosis[3] (Burt, 1992). On the contrary, a network is open when it contains different clusters in which an actor from one cluster interacts with another actor from a different cluster. Thus, allowing actors to access a diverse set of activities and establish partnerships that expand the collection of resources and competences they possess (Powell and Grodal, 2005).

The position of an actor on the networks also influences the dynamics of resources flowing through them. For instance, actors who act as network brokers, bridging opportunities to establish potential relationships (i.e., structural holes), or that are centrally located on the network are capable of controlling the circulation of resources and obtain them in a shorter time when compared to actors who are peripherally located (Burt et al., 2013). In turn, for economic activities, actors controlling the resources flows tend to have a greater advantage in market competition than their competitors (Chiu, 2008).

[3]An example of how closed networks led to network sclerosis is the case of the steel industry in Ruhr, Germany, where relations among the steel producers were so consolidated and homogeneous that they barely looked for external information or different strategies to conduct their business. As a consequence of the low level of network openness, there was the decline of this economic sector in the region (Grabher, 1993).

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Finally, given the content of the networks, some authors propose to break them down into small subnetworks. This is the case of Costa (2019) who argues that innovation and entrepreneurial networks are composed of four subnetworks: i) business; ii) skills; iii) technological; and iv) financial. Each subnetwork has its own features and resources to differentiate them, as it can be observed in Table 1.

Table I - Entrepreneurial and innovation subnetworks

Subnetwork	Features	Resources
Business	Organizations that ● Facilitate interaction with clients and competitors ● Support entrepreneurs to obtain public funding ● Support entrepreneurs to get information about different markets ● Provide spaces for corporate facilities ● Assist entrepreneurs with management issues	● Physical infrastructure ● Client feedback ● Information of different shades (e.g., administrative, commercial and marketing) ● Financial resources
Skills	● Organizations conducting student training in Science and Technology activities ● Research foundations ● Government Programs to support Research and Development (R&D) in firms	● Scientific and technological Knowledge ● Financial resources ● Human Resources ● Technologies
Technological	● Organizations that perform R&D for their own commercialization or for rendering services to companies	● Technological Knowledge ● Technological Information ● Technologies
Financial	● Organizations that provide financial support to entrepreneurs	● Financial resources ● Loans ● Refundable and non-refundable subsidies ● Financial incentives

Source: own elaboration based in Costa (2012).

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In summary, the discussion conducted in this subsection leads to the main argument that the features of the networks directly affect the performance of economic activities. Each feature discussed (e.g., the strength of the tie, the level of openness of the network, the position of an actor on the network or the subnetworks) will serve as indicators to analyze the data collected.

Business incubators

Strands of society from different regions of the world establish policies, based on the Innovation Systems and the Entrepreneurial Ecosystem frameworks, to foster networks (Asheim and Gertler, 2005; Freeman, 1998; Rucker Schaeffer *et al.*, 2018). One such policy is the creation of Business Incubators - infrastructures built in different locations (e.g., universities, companies and public organizations) to support entrepreneurial activities (Isenberg, 2010; Soetano and Jack, 2011). In round figures, there are 7000 Business Incubators in the world and, among them, 2000 technology incubators (UNFCCC, 2018).

The main rationale underlying the creation of Business Incubators in the world is that market failures limit entrepreneurial activities since many entrepreneurs do not have enough resources, either financial or administrative competences, to turn their ideas into new companies (Aernoudt, 2004; Bollingtof and Ulhoi, 2005). In addition to that, entrepreneurs face high costs to obtain market information. In this sense, incubators are built as mechanisms to help entrepreneurs access infrastructures and resources (Ikebuaku and Dindabo, 2017), but also to reduce market failures (Barbero *et al.*, 2014).

To support the growth and survival of new technology firms, different types of incubators schemes are set in place. Since the creation of the first Business Incubator in the 1980s, there have been advanced three incubation models, with minor variations, in different incubators in the world (Bruneel *et al.*, 2012):

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- The first-generation model emphasizes the provision of physical infrastructures. Based on the economy of scale argument, incubators are set to provide basic infrastructure and services (e.g., water, electricity, telephone and internet), so that entrepreneurs can reduce fixed costs and use facilities that would be difficult to access otherwise, such as conference call rooms and reception. However, this model presents a major issue: it is not designed to support entrepreneurs to develop competences they need to run their business.
- The second-generation model focuses on the offer of business support, such as mentoring and training. To overcome the void of the first-generation model, a second one was idealized to provide mentoring programs to assist entrepreneurs with technical, business and administrative issues. But the second model also presents a shortcoming: there are no programs to support entrepreneurs to seek and obtain resources they need for their activities.
- The third-generation model foresees network formation as a mechanism for entrepreneurs to acquire and access services and resources for their innovation activities. In this model, incubator managers and staff act as network brokers: through their social networks and events, they help entrepreneurs to find potential partners, such as consumers, suppliers and investors.

Leveraging resources for incubated companies has become a central mission for the incubator management. However, different authors argue that these resources gathered by the incubator staff are marginally important to the entrepreneurs. For instance, Pettersen et al. (2016) observed that external and internal networks fostered by the management team of an incubator in Norway did not provide the incubates with critical, idiosyncratic (non-general) resources, only general one. Instead, the authors claim that the entrepreneurs' personal networks are central to obtain idiosyncratic resources for activities conducted throughout the life cycle of the firms. In the same vein, Sa and Lee (2012) discovered that companies from a Canadian incubator benefit only partially from the networks established by the incubator management.

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In the incubator literature, authors mainly analyze the external and internal networks emerged from purposive actions or social experiences of the entrepreneurs or the incubator team. Nevertheless, they marginally systematize the drivers that lead to network formation (Sa and Lee, 2012; Patton *et al.*, 2009; Soetano and Jack, 2011). In this sense, these authors mention that previous social experiences of the entrepreneurs or social events created by the incubator are drivers to network formation, but they do not delve into the dynamics of these drivers or if there are more drivers that explain the creation of new networks. Thus, we also aim to investigate and systematize some of the drivers that lead to network formation.

In the next section, we present our research scope and methodology used to investigate how networks are formed at a Technology Business Incubator and how the features of these networks affect the activities entrepreneurs need to take to innovate.

Methodology and Research scope

INCAMP and the 7 companies

Since its foundation in the 1960s, the University of Campinas (UNICAMP) has had a strategy to maintain close interaction with companies. At first, the university set part of its activities oriented to local industry demands, especially those from strategic sectors, such as Oil and Gas, Telecommunications or Aerospace (Dagnino and Velho, 1988). Then, in the beginning of the 21st century, the university expanded its strategy to promote technological entrepreneurship by creating support mechanisms, such as the Innovation Agency (Inova), a Science and Technology Park, and a technology Business Incubator (INCAMP) (Gimenez *et al.*, 2016).

In 2001, INCAMP was established as a mechanism to support technological entrepreneurship and promote relationships between the university and organizations from the national (Brazil), regional (São Paulo State) and local (Campinas) innovation system and the entrepreneurial ecosystem (Campinas) (Gimenez *et al.*, 2016). At the incubator, there are two types of services offered: the pre-incubation and the incubation stages. The first stage is a 12-month-program

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which is oriented to entrepreneurs who wish to develop new business. In this sense, the incubator staff offers know-how on starting-up a company, assistance to develop new business ideas, and lectures on how to write business plans. On the other hand, the incubator stage covers a period up to 36 months (3 years),and focuses on supporting entrepreneurs in product and service development and business management. At the incubation stage, management offers subsidized infrastructures, mentoring programs alongside the Brazilian Micro and Small Enterprises Support Service (Sebrae), and supervision on obtaining public financing to entrepreneurs (Inova, 2018).

Throughout the 19 years of INCAMP, 28 technology-based companies from different sectors have successfully completed the incubation stage; and, at the time of data collection, 9 companies were incubated and 4 were in the pre-incubation stage. Most of these companies are owned by former students from UNICAMP who have identified economic opportunities to transfer their research into new products and services. Additionally, a significant number of these companies are in sectors with a strong engineering knowledge base (INCAMP, 2020).

Out of 34 the companies which were involved with INCAMP incubation[4], we have interviewed 7 entrepreneurs: 5 who were in the incubation period and 2 that have recently graduated. To give a glimpse of the companies profiles, we have summarized the general features of our sample in Table 2: i) company sector; ii) foundation year; iii) status (incubated or graduated); iv) technological intensity level according to the Oslo Manual (2005); v) academic background of the entrepreneurs; and vi) previous association with UNICAMP.

Table II – Profile of the enterprises and entrepreneurs

Enterprises					Entrepreneurs	
Enterprise	Sector	Foundatio	Status	Technological	Academic	Studied at

[4] In 2018, when we conducted our interviews, there 25 graduated companies and 9 incubated.

ISBN 978-65-87175-10-2

		n Year		Intensity	background	UNICAMP
1	Environmental engineering (engineering)	2017	Incubated	Medium-high technology	Chemical Engineering	Yes
2	Health information	2016	Incubated	Medium-high technology	Physical Education and Biotechnology	No, but the entrepreneur is a researcher at one of the university institutes
3	Numerical and computational technology (engineering)	2015	Incubated	Medium-low technology	Chemical Engineering	Yes
4	Qualitative research	2015	Incubated	Low-technology	Business management	Yes
5	Robotics and Artificial Intelligence (Engineering)	2016	Incubated	High-technology	Telecommunication Engineering and Electrical Engineering	Yes
6	Internet of things and Telemetry (engineering)	2015	Graduated	Medium-high technology	Electronic Engineering and Telecommunication	Yes
7	Trend research (fashion)	2011	Graduated	Low-technology	Social Sciences	Yes

Source: own elaboration (2018).

Methods

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Our research seeks to understand how networks are formed at Technology Business Incubators and how these networks affect activities entrepreneurs need to take to innovate. In this sense, to conduct the research, we opted for a case study type since we "investigate a contemporary phenomenon (the case) in-depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2014: 16). Additionally, we have followed methodological procedures in three stages: i) conduction of 10 interviews with 7 entrepreneurs, the incubator manager, and 2 specialists in entrepreneurial and innovation policy making; ii) analysis of the data collected using a Social Network Analysis framework developed by Costa (2012, 2019); and plotting the data into network representation using Gephi, a network analysis and visualization software.

Initially, we developed a semi-structured questionnaire that indicated actors and institutions from different levels of innovation systems (national, regional and local) and the entrepreneurial ecosystem of Campinas in order for the entrepreneurs to indicate with whom they maintain relations that support them conduct innovation activities (e.g., innovation project, technological development and product commercialization). At first, nine entrepreneurs were contacted and invited to participate in the research; however, only five entrepreneurs responded positively to our contact (calls or emails). Thus, to strengthen the scope of our research, we invited two other entrepreneurs who have recently graduated from the incubation process. The interviews occurred during the period of August to December of 2018 and they all lasted an average of one hour.

Furthermore, to have an overview of Business Incubators in Brazil and INCAMP, we also interviewed two specialists in innovative environments and the manager of INCAMP during the first semester of 2018. The two specialists have worked for Science, Technology and Innovation state agencies in Brazil, such as the Research Foundation of the São Paulo State (FAPESP) and the innovation agency of Goiás State; thus they were able to answer a semi-structured questionnaire on the state of art of Business Incubators in the country. Additionally, the manager of INCAMP answered a semi-structured questionnaire on the activities fostered by the incubator

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to support entrepreneurs; the general nature of the incubates' networks; and shortcomings of the incubation stage.

Once the data collection was concluded, data was analyzed using four indicators that support the understanding of features of the network (Costa, 2012): i) the tightness of ties; ii) the structure of networks; iii) the consistency of subnetworks; and iv) the openness level of networks:

- The tightness of ties indicator was constructed having the work of Granovetter (1983) on strong and weak ties as a reference. This indicator covers two categories: tightly connected and loosely connected ties. The former bears features of strong ties, such as trust, affiliation, collective identity or availability and accessibility of knowledge. On the other hand the latter bears features of weak ties, for instance, the presence of opportunities or costs.
- The network structure indicator was designed to capture how well related is the actor on the network. In this sense, the reference behind this indicator is the work of Burt on how the position of an actor on the network can control the circulation of resources (Burt, 1992; Burt et al., 2013). This indicator has two categories: fragmented and well-knit. The network is fragmented when the number of ties is low, which demonstrates the isolation of an actor. On the opposite side, the network is well-knit when there are large numbers of tightly connected and loosely connected ties.
- The consistency of the subnetwork indicator was built to show whether the actors and organizations sought by entrepreneurs can provide the resources they need. Additionally, it helps to understand the performance of these actors and organizations that support entrepreneurs directly or indirectly. To indicate consistency of the subnetworks (Business, Skills, Technological and Financial), it is recommended to analyze the sought resources, according to the Oslo Manual (2005), by entrepreneurs when they establish external relations: i) access to open information; ii) knowledge acquisition; iii) technology acquisition; iv) access to new sources of funding; v) access to commercial information; and vi) innovation cooperation (see Table 3).

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- The level of openness of the network indicator was set to investigate the importance of variegated resources from different contexts to ensure the maintenance of economic activities (Granovetter, 1983; Burt, 1992; Grabher, 1993). This indicator can either be closed or open. Networks are considered closed when actors and organizations with whom entrepreneurs related are located in the same region as them. On the contrary, networks are open when entrepreneurs maintain relationships with actors from other regions (which include different states and countries).

Concomitantly the data analysis using the four indicators, we have also used Gephi, a network analysis and visualization software program to transform the data into network representation. We have chosen to use some features to characterize the network. For instance, we use some colors to represent the subnetworks: green (business) purple (skills), yellow (technology) and brown (financial). We also use the size of ties to represent tightly connected ties (denser ties) and loosely connected ties (thin lines). Finally, some ties are directed, indicating unilateral relations; and others are undirected, signaling mutual relations.

Table III - Consistency of subnetworks

Sub-network	Type of sub-network actor	General aims by sub-network	Features indicating consistency
Business	I. Industrial association II. Competitors III. Customers IV. Suppliers V. Consultancy firms VI. Incubators VII.	I. Foster and support interactions among firms and between firms and customers II. Support for research funding applications III. Access to information on national and international markets IV. Provision of facilities or knowledge for software development, training and workshops V. Support the design of business plans and training on organizational matters VI. Incubation programs	I. Access to open information source II. Acquisition of knowledge III. Acquisition of technology IV. Access to new sources of financing V. Access to commercial information VI. Innovation co-operation VII.
Skills	I. Universities II. Continued education organizations III. Research councils IV. Research foundation	I. Educational training in different levels, such as undergraduate, Masters, Doctoral and Postdoctoral and continued education II. Support new knowledge creation through basic or applied research funding programmes III. Support new knowledge creation through funding programmes for development activities IV.	I. Access to open information source II. Acquisition of knowledge III. Acquisition of technology IV. Innovation co-operation

ISBN 978-65-87175-10-2

Technology	I. Research Organizations II. Development organizations	I. Perform basic or applied research for, among other, the commercialization by the private sector II. Development activities for, among others, the commercialization by the private sector III.	I. Acquisition of knowledge II. Acquisition of technology III. Innovation co-operation
Financial	I. Private and public banking II. Public funding organizations III. Venture capitalists IV. Government authorities	I. Grants or loans for firm-level basic or applied research and development activities II. Venture capital for start-ups III. Tax incentives for firm-level innovation activities IV. Creation of technological parks or incubation programmes V.	I. Acquisition of knowledge II. Acquisition of technology III. Access to new sources of financing

Source: Adapted from Costa (2012, p. 142).

Results

The network investigated (Image 1) has 33 nodes and 50 ties. Out of this, there are 31 ties with organizations from the business subnetwork; 15 ties with organizations from the skill subnetwork; 3 ties with organizations from technological subnetwork; and 1 tie with actors from the financial subnetwork. Additionally, there are 30 tightly connected ties and 20 loosely connected ties.

Image I - Innovation and Entrepreneurial network

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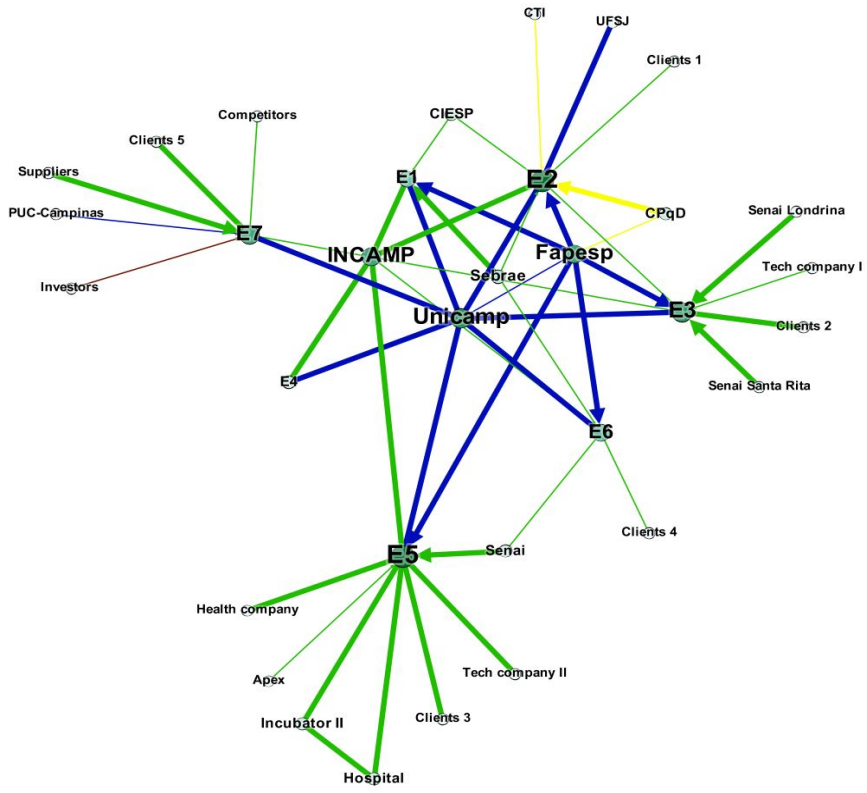

Business
Skills
Technology
Financial

Source: Own elaboration (2018).

The network is mainly composed of ties from the business and skills subnetworks. In this sense, the higher measures of the business subnetwork are 9 ties with nonprofit private organizations (Sebrae, Senai and CIESP), 8 ties with two incubators (INCAMP and Incubator II which belongs to a Hospital in the city of Sao Paulo), and 5 ties with clients. The skill subnetwork bears 10 ties with top-ranked Brazilian universities (UNICAMP, PUC-Campinas and UFSJ) and 5 ties with the Sao Paulo State Research Foundation (FAPESP, acronym in Portuguese).

Besides the number and types of the ties, there are also the topographic metric characterization metrics of the network collected from the statistical table of Gephi. The diameter is 4; the radius is 2; the density is 0,095; the average degree is 3,030; and the average path length is 2.8333.

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The entrepreneurs of the network analyzed have established ties with 26 different actors or institutions from different regions of the world. Out of this figure, there are 12 ties (46%) with institutions and actors from the Campinas Region; 3 ties (11%) with institutions and actors from the city of Sao Paulo; 8 ties (30%) with institutions and actors from other regions of Brazil; and 3 ties (11%) with institutions and actors from the United States. Thus, because there are more ties with organizations outside of Campinas, the network is considered to be open.

At a first glance, the network appears to be well-knit with all entrepreneurs connected through two organizations: UNICAMP and INCAMP. However, as it will be discussed in the next sections, the network displays signs of fragmentation mainly caused by the lack of technological and financial ties.

As terms of output, the network has generated 7 different innovations (products, processes or services, and 2 technologies are under development. In Table 4, we summarize the new technologies and whether they have been launched to be considered innovations.

Table IV - Outputs of the network

Enterprise	Innovations and new technologies	Has it been launched?
1	● Reactors for air decontamination in industries and houses	● Still underdevelopment
2	● Virtual reality software for physical therapy	● Still underdevelopment
3	● Thermal analysis ● Computational fluid dynamics analysis	● Yes
4	● Qualitative research	● Yes
5	● Facial recognition software	● Yes
6	● Intelligent parking system ● Ultrasonic hydrometer with embedded telemetry	● Yes

ISBN 978-65-87175-10-2

7	• Trend research	• Yes

Source: Own elaboration (2018).

Discussion

Network formation

The data analysis for the creation of each tie allowed the identification of four main different mechanisms that favor network formation at INCAMP: i) institutional mechanisms; ii) social relations; iii) institutional association; and iv) public policy.

Institutional mechanisms correspond to the activities taken by the incubator management to promote external and internal networks. In line with the work of Bruneel et al. (2012), we have also observed that entrepreneurs obtain resources to conduct innovation endeavors with the help of INCAMP that fosters i) peer group meetings; ii) mentoring via Sebrae; and iii) social events.

The peer group meetings are periodically gatherings organized by the incubator management to bring the incubated entrepreneurs to discuss aspects related to their enterprises. At these meetings, entrepreneurs form social bonds and share experiences in the conduction of enterprises with their peers, such as forms to obtain financial mechanisms or to launch products into an international market. These meetings therefore are set to create internal networks between the incubates; however, the resources circulating through these channels are general, and the entrepreneurs do not advance any type of relations among them to perform innovation activities, as it can be observed by the lack of direct ties connecting them.

Mentoring is also an institutional mechanism advanced by the management team to foster networks. Different from the usual type of mentoring in which the incubator's employees help entrepreneurs with technical, business and administrative issues (Bruneel et al., 2012), INCAMP’s management team invites consultants from Sebrae, a SME support agency, to help

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entrepreneurs to overcome problems faced daily in their enterprises. Even when the consultants do not have the right expertise to offer, they access their personal networks to find an expert that can help. However, the resources offered by Sebrae are considered general by the entrepreneurs, which is reflected by the loosely connected ties between the support agency and them.

The last institutional mechanism fostered by the Incubator management is the social events organized to create connections in the network. At these events, the management organizes pitch practices for the entrepreneurs to present their technologies to an audience, which includes entrepreneurship experts and potential investors; and meetings with representatives of multinational companies located in Campinas. In a sense, these two meetings are set for the incubated entrepreneurs and actors from the Innovation system and Entrepreneurial Ecosystem of Campinas to be aware of each other. Notwithstanding, the entrepreneurs have barely mentioned any tie emerging from these meetings. The only case is the loosely-connected tie between the entrepreneur of E7 and investors, in which the entrepreneur did not receive financial support; but feedback to improve the activities of the company.

Overall, the experience of INCAMP in fostering networks shows that its actions are limited and do not lead to a substantial creation of ties. Thus, our results are in line with the work of Pettersen *et al.* (2016) and Sa and Lee (2002) in which the incubator management plays a narrow role as network brokers for the entrepreneurs and that resources circulating through these ties are mainly general.

Entrepreneurs' social relations are also a mechanism that favors network formation at INCAMP, and the most important. The majority of the entrepreneurs has relied on their personal networks to conduct part of the activities related to innovation, for instance, the entrepreneur of E1 has had the help of her supervisor from UNICAMP to design and develop an innovation project, or the entrepreneur of E2 counted on a friend from UFSJ, a public university, to support him in developing software. Accordingly, we can notice that innovation activities are embedded in social networks as argued by Granovetter (1983).

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Furthermore, some of the nodes from the entrepreneurs' personal networks have acted as network brokers building bridges over structural holes (Burt et al., 2013). In particular, the entrepreneurs' graduate advisors and professors who have not only supported the entrepreneurs with technological aspects of innovation, but also have connected them with potential clients, partners and financial opportunities. As three examples, a professor from UNICAMP's Physics Institute has assisted the entrepreneur of E2 with both the development of the innovation project and the raise of public funding sources; Professors from UNICAMP have helped to build bridges between academia and the business sector, in the opinion of the entrepreneur of E5; and the entrepreneur of E1's advisor knows potential clients who are interested in her business area and product.

The key role the entrepreneurs' social network plays can be observed by the tightly connected ties the entrepreneurs have with UNICAMP. As all of the entrepreneurs have studied or worked at this university, they all had mentioned that their colleagues and professors have a substantial role in their entrepreneurial endeavors, especially by providing critical resources for the innovation activities (Pettersen et al. 2016). Therefore, social relations stand as a relevant mechanism to provide critical resources the entrepreneurs need to innovate.

Institutional association also leads to network formation. Being associated with the incubator and UNICAMP breeds trust and credibility. In turn, actors and organizations of the innovation systems and entrepreneurial ecosystem tend to be inclined to establish ties with the entrepreneurs. For example, clients of E3 have opted to hire the services of the company as they knew they could trust the company because of its affiliation. Thus, having the stamp of UNICAMP and INCAMP is a form to validate the business of the entrepreneurs and make them potential partners.

Public policy is also a mechanism that favors network formation. In different innovation systems and entrepreneurial ecosystems, governments establish policies oriented to foster collaborative

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innovation activities at technology-based small companies (Asheim and Gertler, 2005; Stam, 2015). As many of these companies are located in incubators, network formation at these infrastructures is advanced by these policies.

Some of the entrepreneurs at INCAMP have benefited from two innovation public policies: the Innovative Research in Small Business Program (PIPE) and the EMBRAPII-SENAI project. The first policy is advanced by the Sao Paulo Government's Research Foundation (FAPESP) which provides non-repayable funds to entrepreneurs of small companies who propose to conduct technological research. The second is a federal government's policy in which the government covers ⅓ the costs of innovation projects of small companies and fosters collaborations between these companies and technology institutions.

Similar to the social relations mechanisms in which the entrepreneurs obtain critical resources, public policies also are important for them to acquire these resources. Image 1 illustrates that entrepreneurs who have obtained the PIPE or the EMBRAPII-SENAI project point that they maintain tightly-connected ties with FAPESP and CPqD, a technology institution involved in the latter project. Therefore, signaling the critical nature of the resources they have obtained from these two institutions.

In sum, the four network formation mechanisms at INCAMP are essential for the entrepreneurs to establish new ties and to obtain resources to conduct their activities; but may have some limited effect. While social relations and public policy play an important role for the entrepreneurs to obtain critical resources; the efforts of the incubator management to construct new ties are limited and may only generate general resources.

In the next subsection, we delve into how the features of the networks may affect the activities entrepreneurs take to innovate.

Network features

ISBN 978-65-87175-10-2

Departing from the work of Burt et al. (2013), Granovetter (1983), and Powell and Grodal (2005) who argue that different features influence the functioning of economic activities embedded in networks, we have applied the 4 network indicators (Pamplona da Costa, 2012) to analyze the network features of the entrepreneurs who are advancing innovation activities. Our results from the empirical data analysis support the arguments proposed by these authors on the network features.

The image 1 illustrates the predominance of tightly connected ties over loosely connected ties, meaning the majority of the entrepreneurs' ties have trust, affiliation, collective identity or availability and accessibility of knowledge as common grounds. In this sense, there are more critical resources circulating through the network and, as a consequence, the innovation activities of the entrepreneurs can be advanced. For instance, the entrepreneur of E5 has mentioned that a tightly connected tie with a multinational tech company allowed him to obtain a set of technologies necessary to improve his own product.

Nevertheless, despite the small number in the network, the loosely connected ties also play a critical role in providing general resources for the entrepreneurs. Many of them seize these ties to obtain new information on what is happening in the entrepreneurial ecosystem (the ties with CIESP), or to improve management-related activities (ties with Sebrae). As such, these resources offer a glimpse of novelty to the innovation activities the entrepreneurs conduct, corroborating therefore to the argument of Granovetter (1983) on the strength of weak ties.

Overall, tightly and loosely connected ties allow resources that have different roles for the entrepreneurs to circulate in the network. As each type of resource (critical or general) displays different functions, it is paramount that a network contains both types of ties to improve the innovation activities of the entrepreneurs.

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At first sight, the network seems to be in an intermediate state towards a well-knit structure, which means that the entrepreneurs are well connected. However, a closer examination of the network representation reveals that there are missing connections, mainly with institutions and actors from the technological and financial subnetworks.

The lack of ties with technological subnetworks does not pose a major problem as many of the entrepreneurs access UNICAMP's facilities to research and develop their technologies. On the other hand, the lack of financial ties can be problematic. The majority of the incubated entrepreneurs at INCAMP have obtained limited public grants from FAPESP to conduct R&D. Nevertheless, the entrepreneurs need more financial resources to continue performing R&D and other activities, such as marketing; but they face shortcomings to obtain extra financial resources from investors or banks. As a consequence, many of them have mentioned that there were delays in the innovation process, especially during the development phase when there were occasions they lacked financial resources to acquire inputs.

The structure indicator also points out to the centrality (Burt *et al.*, 2013) of three institutions in the network: INCAMP, FAPESP and UNICAMP. These institutions stand out as major sources of information on entrepreneurship, knowledge and financial resources, respectively, to the entrepreneurs. Additionally, as regarded in the Innovation System Literature (Atkinson, 2014; Freeman, 1988; Godin 2009; Nelson, 1993), having these institutions playing different but complementary roles are conducive to technology entrepreneurship as they allow entrepreneurs to seize opportunities to transform their research into economically viable products and services.

The consistency of the subnetwork indicator points out that the four subnetworks networks are strongly consistent. This means that the resources sought by the entrepreneurs matched with the resources provided by actors and institutions from the Innovation Systems and Entrepreneurial Ecosystem. However, there are small inconsistencies in the skill subnetwork as some of the entrepreneurs have stated that they had looked for commercial information and access to new sources of funding with nodes from this subnetwork.

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The openness level of the network is open, but to an intermediary degree: slightly more than half of the resources are obtained outside the Campinas Region, including from other countries; and the rest in this region.

Accessing resources outside the Campinas region can be beneficial to the entrepreneurs as there are entries of new inputs circulating through their network. As argued by Burt (1992) and Powell and Grodal (2005), network diversification allows the freshness in economic activities and therefore helps to avoid network sclerosis. In the network analyzed, there are some ties that provide a sense of freshness to the entrepreneurs. One of these, as already discussed, is the ties with FAPESP, which gives R&D grants. Another case is the links with multinationals located outside the Campinas Region. For instance, the entrepreneur of E5 asserted that, in addition to being incubated at INCAMP, he incubated his company in a North America health multinational company incubator, and this had enabled the company to access the North American market more easily. In addition, the directors from this multinational have helped with the company's business plan, supporting the adaptation of his technology for other markets niches. As such, it is important that entrepreneurs maintain ties with nodes outside their region.

In general, the network features analyzed influence the functioning of innovation activities in three different manners. At first, the strength of tie is directly related to the type of resources circulating through the network. While loosely connected ties allow entrepreneurs to obtain general resources; tightly connected ties allow them to acquire critical resources that fit more to the necessities of their own innovation process. Furthermore, the lack of ties causes delays in the innovation process. Finally, obtaining resources from different regions can give freshness to the innovation activities conducted by the entrepreneurs.

Conclusion

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Our results show that social relations, institutional mechanisms, institutional association and public policies play a major role for the entrepreneurs incubated at INCAMP to form networks. Through these networks, entrepreneurs gather resources that support them to develop innovation-related activities, such as technological development and product commercialization. Additionally, we have shown that network features affect the dynamics of these activities. Using four social network analysis indicators, we have identified that the openness level of the investigated network enables entrepreneurs to obtain resources that strengthen their initiatives; tightly connected and loosely connected ties allow critical and general resources to circulate; and the lack of financial ties cause delays of the innovation process.

Understanding network formation and how network features affect innovation-related activities at Technology Business Incubators is relevant for incubator management and policy makers to develop strategies to support technology entrepreneurship. We have observed in our case study that while institutional mechanisms have a limited role in fostering substantial networks for the entrepreneurs, social relations and public policies are significant to offer critical resources. In this sense, the incubator management should reflect on whether their current mechanisms to advance networks are effective. Additionally, as public policies can have a decisive role for the entrepreneurs, policy makers could design policies that aim to increase innovation activities bearing network formation.

The analytical framework applied in this paper offers different tools to analyze the innovation networks and how their features affect innovation-related activities. As such, it gives an overview of the networks on the strength of the ties, the consistency of the subnetworks, the level of openness and the structure. Grasping these features can support the incubator management to identify shortcomings and propose mechanisms to lessen them. Nevertheless, there is no optimal fit for the networks. We have argued that innovation networks should bear a mix of ties of different strengths, and with nodes from different regions and subnetworks. However, the entrepreneurs and the incubator management from different parts of the world should modulate the networks to meet their own necessities.

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Our paper presents some shortcomings. One limitation is the low number of interviews since the 4 entrepreneurs incubated at INCAMP did not reply to our emails nor our calls. Therefore, we were not able to identify the full picture of the innovation network complexities, only some directions. However, it is fundamental to stress that we were able to gather general aspects of the innovation network from the interview with the incubator manager. A second limitation is regard to the network formation mechanisms. Depending on the regions and the incubation model adopted by the incubator, some of these mechanisms may be particular to certain cases. Notwithstanding, this limitation does not weaken our work as we argue that systematizing network formation mechanisms is paramount to provide better support to the entrepreneurs.

For future studies, we propose to apply the analytical framework used in this paper with entrepreneurs located at incubators with different economical, geographical and institutional contexts, and compare with our results.

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