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Abstract

The article identifies how Research and Development (R&D) collaborations in startups can influence digital innovation in Brazilian manufactures. A qualitative multiple case study was performed with startups incubated at the Federation of Industries of Paraná (FIEP), through semi-structured interviews to the Chief Executive Officer (CEOs) and case document's, applying the content analysis. The results indicate that the sources of knowledge of the startups and the collaboration with companies, universities, government development agencies and incubators, characterize the actions in the ecosystem of open innovation. It has been found that the complexity of the innovation ecosystem of startups is a strategic asset, and the nature of the collaborations is informal, coupled with a stage of maturity considered low in startups. This study contributes to highlight the nature, dynamics and progress of startup collaborations in the development of digital transformation, and the challenges for the leverage of Industry 4.0 in Brazil.

Keywords: Startups; Digital Transformation; Industry 4.0; Collaboration.

1. INTRODUCTION

The acceleration of technological transformations in a dynamic and competitive organizational context emphasizes the need to develop competences that promote innovation. The technological revolutions teach that competitiveness depends more on the development and effective use of technology to create value than the simple adoption of new technologies (Sousa, 2017). Thus, the isolated use of new digital technologies is not enough for the organization to transform and remain competitive. It is necessary the development of social and managerial aspects, through a structure, leadership and digital and collaborative organizational culture, that internalize these technological changes (Westerman et al., 2011), as well as the development and qualification of the employees. These need to enhance cognitive and analytical skills to adapt to these changes (Schumacher et al., 2016). It is also necessary to use a network of collaborations internal and external from the organization to understand, develop and make correct use of these technologies (Bechtold et al., 2014; PWC, 2016).

The implications of technological change in the industrial world are summarized in the Industry 4.0 concept (Bücker et al., 2016). The systematic review by Liao et al. (2017) evidenced the growth of discussions on academic research and industrial organizational practice since the first announcement at the Hannover Fair in 2011. Industry 4.0 is permeated by the use of digital technologies that allow data collection and analysis the internal and external environment of the factories and their transformation into pertinent and disseminated information in real time, allowing a better decision-making, faster and more predictable (FIRJAN, 2016, PWC, 2016 and Schlaepfer et al., 2015).

Industry 4.0 is not only a technological challenge but also has organizational implications (Schuh et al., 2016), providing opportunities to: (i) develop a more flexible, agile management and develop an open and collaborative culture for the development and use (ii) build and strengthen collaborative networks with various partners, such as government agencies, research and higher education institutions, consulting firms, non-profit institutions, and startups, for the dissemination and development of disruptive technologies, and (iii) developing new capabilities of people seen as transformation agents (PWC, 2016; Schuh et al., 2016; Schlaepfer et al., 2015).

This research aims to verify the role of the network of startups collaborations incubated in the International Innovation Center (C2i) of the Federation of Industries of the State of Paraná (FIEP) in the digital innovation in Brazilian manufactures. This study is justified by the relevance of digital technologies for the competitiveness of organizations (CNI, 2016). Industry 4.0 lacks scientific organizational studies that explore in detail strategic, social and managerial aspects. This study aims to clarify them through the lens of collaboration networks for innovation. Since such networks are multidisciplinary in nature, they can help in gaining a more holistic understanding of these aspects. There is also a lack of empirical and theoretical Brazilian and international studies on how companies can develop collaborations in R&D to assist in the development and application of digital technologies (Camarinha-Matos et al., 2017). This study explores R&D collaborations addressed as one of the foundations of Industry 4.0. Empirical results can bring contributions to the practitioners of this industry and clarifications for the literature of open innovation and technology in companies.

2. MATERIALS AND METHODS

This exploratory study has a qualitative approach and research strategy Multicaso (Yin, 2013; Eisenhardt, 1989) of Brazilian startups incubated and accelerated by FIEP C2i. In this research, C2i is the incubator of startups active in the development and commercialization of digital technologies, whose customers and/or collaborating beneficiaries are the industries of Paraná.

The case study is a suitable strategy for this work since it empirically investigates a contemporary phenomenon in its real-life context and the boundaries between the phenomenon (collaborations in R&D) and the context (Industry 4.0) are not clearly defined (Yin, 2013).

The nature, dynamics, characteristics and implications of the partnerships of the startups under analysis as well as the descriptions of the digital technologies developed by them are confronted with the theoretical approaches of the literature review. Four startups were analyzed in depth, which allowed an exhaustive and comparative evaluation. These are: *i) Lince IT Solutions, ii) Tru Work Consulting and Systems Development, iii) Strike XII Industrial Automation; and iv) Alpha Technologies Corporation*.

Secondary data were collected via relevant documents available on the websites of these startups in order to collect business details, such as their history, mission and vision, descriptions of the solutions developed and their benefits to customers. Also, semi-structured interviews were elaborated with the help of a script based on the research objective and literature review.

The elaboration of this script facilitated in the confrontation of each relevant result of the cases with the literature. With the appropriate authorizations of the interviewees all the interviews were recorded and transcribed, however their names were preserved. Each interview had an average duration of seventy minutes, and the data collection period occurred between December 2017 and April 2018.

Because the unit of analysis is the R&D projects of these startups, data were collected from its CEOs and/or founders viewed as key respondents, having in-depth knowledge about their respective businesses, and working with R&D projects tied to Industry 4.0 and its developments.

After transcribing the interviews, the content analysis technique was applied (Bardin, 2002), using the Atlas.ti software. A total of 44 codes were established for content analysis, of which 21 codes were extracted from the interview script and 23 from the data, that is, from the coding of the transcript of the interviews. These 23 codes are relevant to better specify the literature on R&D collaborations in the context of Brazilian digital transformation, respecting the specificities of the cases under analysis. The 44 codes were employed in 280 citations.

The reports of the four interviewees as well as the institutional information on the websites of the respective startups were triangulated in Atlas.ti. In this confrontation it was noticed that the data are aligned: each data supports or corroborates the other. There were no significant differences in content between the data. This software allowed the elaboration of networks that demonstrate the relationships between the created codes (Figures 1 and 2).

3. DISCUSSION

In the technological field, startups are dedicated to meet the demands of developing technologies in the Brazilian market, with solutions tailored to the needs of the industry. In cases it is verified that there is a "standard" digital solution developed by the startup itself, however this solution must be adapted to attend specific companies.

3.1 The case of Strike XII

Startup Strike XII develops digital solutions for traceability of people, objects, machinery and other assets through the use of RFID sensors. This solution enables, in general, a better asset management in the factory. From the solution developed by Strike, the data obtained by RFID sensors are "imported" from the physical to digital domain, via gateway, to a visualization layer. In this layer, the manager and other users have access to a dashboard, which demonstrates the status of manufacturing aspects. By means of these data collected by the sensors it is possible to base the decision making consistently. The incorporation of digital solutions by companies is motivated by the government's requirement for factories to have control over internal processes. This drives the business of startups like Strike XII as a market opportunity. The manager of this startup reported the importance of implementing these intelligent monitoring sensors, not only for governmental requirements, but also for the benefit of control and avoiding operational risks.

3.2 The Truwork case

Startup Truwork develops artificial intelligence solutions. It focuses on replacing workers in the quality testing industry for a robotic solution. By automating factories, production can be performed at night and on weekends, without the presence of employees, leading to reductions in operating expenses, higher quality of product testing, and agility in production. Like Strike XII, Truwork is focused on developing technologies for tracking people and assets. For Truwork, their solutions can deliver gains in performance and risk reduction.

3.3 The Alpha case

Startup Alpha exclusively develops the gateway for the IoT architecture, applied in companies belonging to the Industry 4.0 concept. The gateway is a software that reads the data collected by intelligent sensors in the factory and transports them to another IoT layer for data storage: the so-called Cloud Computing. The large volume and diversity of manufacturing data (Big Data), after being stored in the cloud, are directed to a visualization layer so that managers and other users can have access to decision making with data backup processed in real time.

3.4 The case of Lince

Startup Lince develops intelligent robots for the industry, with the purpose of optimizing and streamlining the production process and, in the hospital branch, to ensure the traceability of medicines to the respective patients. For Strike XII, the use of digital solutions brings competitive advantages to companies, but also brings social challenges, such as the substitution of operational labor for the automation of production lines

(PWC, 2016; Schwab, 2017). The manager of this startup emphasizes that solutions in IoT and other disruptive technologies create new jobs. New job opportunities require more cognitive capabilities to analyze the Big Data collected by sensors. Therefore, factory workers need to be trained to adapt to these digital technologies (Schumacher et al., 2016; Schuh et al., 2016).

The way the technologies are developed and adapted to the national market is linked to actions of open innovation. As the startups analyzed capture ideas, knowledge and technologies externally to develop their digital solutions, open innovation actions are outside in (Gassmann, Enkel, 2004). The complexity and diversity present in the ecosystem of these startups is a facilitator for outside-in actions in startups. The product-base adaptations developed by the startups come from their access and contact with the market. It is based on problems and needs found in the market or exposed by the industry itself that startups improve their solutions to meet the specificities of this market.

3.4 Digital Maturity Stage

The technologies developed are also linked to the maturity stage of the interviewed startups. They all existed before being incubated by FIEP. However, they faced difficulties in accessing the business market, with weak partnerships, poor infrastructure, lack of capacity and limited growth. Startups were motivated to become part of C2i in order to accelerate their business. For all the interviewees, the FIEP incubator is perceived as an accelerator and not only as an incubator.

Strike XII and Truwork achieved a higher maturity level compared to the other two startups, with more diversity of clients. Lince and Alpha are more premature, in terms of organizational structure, training, billing solutions, and in terms of customer diversity and signed partnerships. Strike XII was one of the pioneers in Brazil when developing solutions in IoT in 2011. The founder of Truwork believes that its startup has already been "positioned as a more mature model".

Unlike Strike XII and Truwork, the Alpha Company did no training and mentoring meetings with C2i as it was still at an early stage in incubation. However, in other respects, this startup has a more advanced stage while teaching in lectures their own technologies and their benefits to industry. Lince is newly incubated and its incubation period is only six months. They have not yet billed with any customers. Due to the fact that its interviewed partner had obtained training before being incubated, he does not feel the need to obtain it, at least for the time being, benefits that FIEP offers regarding training courses.

All the startups interviewed still do not have any patent registrations or licenses for the developed solutions, which shows that they may be exposed to risks: their solutions can be copied by potential competitors.

It is observed a relationship between startup maturity stage and incubation benefits. The more mature and complex the startup is in terms of the number of employees, its ecosystem, the number of technologies already marketed and sold, the more the startup will get and take ownership of the benefits that C2i can offer.

3.5 Organizational Practices and Know-how

The maturity stage is also related to the informal organizational structure of startups. Since the incubation period is recent and the number of employees is small (between two and four employees in each startup),

organizational practices are informal, regarding the training, customer relationships, and technology transfer to customers. At Truwork and Strike XII, the only more explicit formality with some partner companies and clients is via a confidentiality agreement that characterizes a formal technology transfer. This agreement provides protection for the business partner.

The more startup develops expertise and know-how with digital technologies and the market, the broader will be its network of partnerships and the greater the diversity of customers. Consequently, the more complex will be its innovation ecosystem. It can also be inferred from reports that the more immature and weak the startup is, in terms of skills, partnerships, customer numbers and billing, the more difficulties it will encounter in order to survive. With this, the lower will be its competence and strength to sell its solution to potential customers, and the lower will be its condition of establishing partnerships.

3.6 Management of collaborations

The maturity of the startups leads to an informal management of collaborations with companies, universities and other startups incubated. This informality is an aspect that characterizes this ecosystem of innovation. For startups (except Lince) this informality is seen as a weak point to be developed. For Lince, this nature of partnership management is seen in a positive and necessary way, because with informality in relationships, the benefits of these relationships occur in a more agile and more practical way, without bureaucracies.

Emphasis is given to aspects that characterize the informal management of collaborations: (i) lack of decision-making criteria to collaborate - few criteria are adopted by startups, and informally; (ii) lack of Key Performance Indicators (KPIs) that leads to insufficient and weak actions of partnerships evaluations; (iii) the need for knowledge management actions - the sharing of information, ideas or skills between startup and its partners, occur informally through exchanges of interpersonal conversations or, at most, small formalization occurs via e-mails; and (iv) few planning actions in some partnerships of some startups that conflict with the informality of collaborations. In Strike XII and Truwork, there are some planning actions, but without rigidity:

> "We usually have a timeline for these partnerships. It is not so formal because we end up adopting an agile methodology of development, which is not so controlling, so it is something more relaxed than a project control like classical management. But we're building a kind of roadmap. "(**Truwork Interviewee**).

Without KPIs, startups lack information about the partners' perception of satisfaction about the results achieved by the partnerships. This lack of monitoring exposes fragility in the management of collaborations and reinforces the low maturity stage of startups. Strike XII did not even consider creating KPIs to monitor partnerships. Truwork recognizes this weak point and is aware that if they have KPIs they could optimize collaborative efforts and target the lack of KPIs to the still low level of maturity. The existing instruments were adopted by the C2i incubator to monitor the performance status of each incubate. In order to comply with the CERNE method - Center of Reference for Support to New Developments - that evaluates the level

of maturity of incubators in Brazil, C2i uses KPIs to monitor and evaluate their incubations. The CERNE method is directly coupled with C2i monitoring.

There is a lack of practices regarding knowledge management, such as storage, dissemination and reuse of the knowledge obtained in the collaborations. Due to the small number of employees and reduced or non-existent revenues, startups still do not have the conditions, although they wish, to adopt knowledge management actions.

3.7 Collaborations in the Digital Innovation Ecosystem

The digital innovation ecosystem is considered a strategic asset, since the various collaborations of the startups assist them in the development, dissemination and commercialization of digital solutions. This relevance to the network of collaborations corroborates with the research from Camarinha-Matos et al. (2017), Bechtold et al. (2014), Sniderman et al. (2016), Schuh et al. (2016) and PWC (2016). The collaborations also promote improvements in terms of managerial skills, and consequently, in the growth of startups. The collaborations considered most relevant to the interviewees are with small and large industrial companies and with C2i that offers benefits to their incubators**.**

In the reports of Truwork and Alpha, the innovation ecosystem of the city of Curitiba called "Vale do Pinhão", or Pinhão Valley, which has FIEP support, is relevant for digital innovation. The City Hall supports the Pinhão Valley with systematic actions, as a integral part of the city plan. In the physical space of this ecosystem, these startups can get access to the market, meet companies with shortages, which will be inputs for startups to develop digital technologies to supply them. From this ecosystem, it awakens in the startups the motivation to develop and commercialize new digital technologies, besides having access to potential clients of the industry and obtaining new knowledge coming from other startups. Also, the Pinhão Valley provides the exposure of knowledge to the other interested actors who participate in the space. Informal collaborations with other startups were noticed in Lince and Alpha.

> "[...] at FIEP with the others incubated, we have complementary knowledge ... a person has more knowledge in cloud development, which we also need ... he uses technology X, we can go there and he teaches us how to use it". (**Interviewee from Lince**).

All interviewees consider collaboration with C2i as necessary and beneficial for incubator development and acceleration. C2i offers startups the freedom to develop their technologies and partnerships and to manage them in a way that startups consider best:

> "[...] FIEP gives us all the support we need, without getting stuck in anything." (**Interviewee from Lince**).

Among the benefits that the C2i incubator offers to startups, some are highlighted by the respondents: (i) direct access to the market; (ii) disclosure of solutions via pitching events; (iii) obtaining training, lectures and courses, which are part of the mentoring offered by C2i, and other events for or about the industry. These achievements are considered as external sources of training; (vi) C2i monitoring, since the startups

do not have their own mechanisms for this. This monitoring takes, if necessary, the incubator to offer mentoring and training for those startups that have performed poorly in some aspect of management.

All startups believe that when they are physically incubated in the C2i, leaders of large Brazilian manufactures who visit the space of the incubator give them greater visibility. From access to the industrial market through FIEP, visiting industries can become future customers or partners of the startups. Startups take advantage of this visit to make their pitching that means they have the opportunity to receive feedback from the big companies in the industry that expose their needs and problems. Thus, startups can adapt their solutions to suit the need of these companies:

> [...] the fact of interacting with some companies, especially through corridor pitching at FIEP, allows us to see new applications for our base product. "(**Truwork interviewee**).

For those interviewed, C2i offers satisfactory support in relation to direct access to industries, guides the market niche to be focused by each incubated, and quality of monitoring with the incubated ones. However, for the interviewees, C2i does not (yet) offer access to financial capital and technological support. C2i gives its incubators freedom to develop their own technological frameworks. Figure 1 represents the network related to the digital innovation ecosystem of the startups.

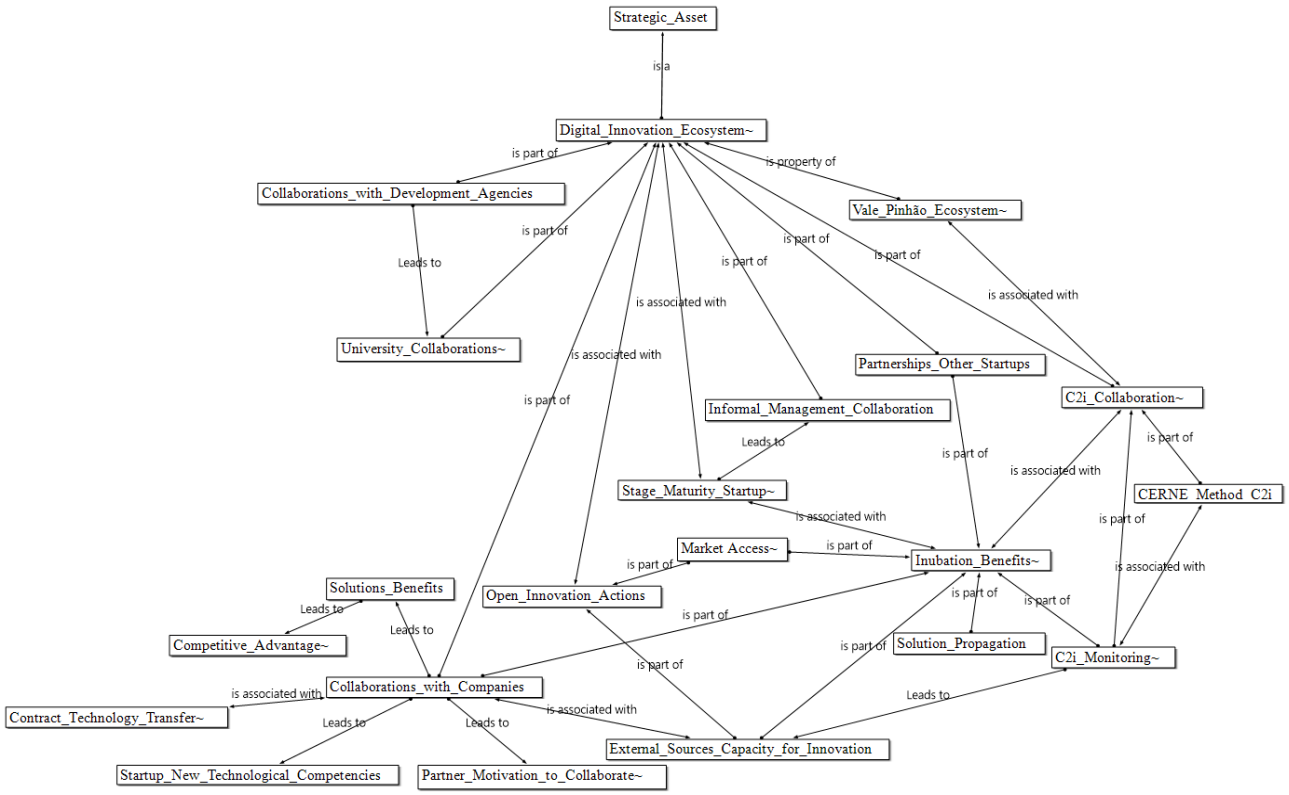

Figure 1. Relationships of the Digital Innovation Ecosystem of the Startups
Source: Own elaboration, with the aid of Atlas.ti software.

Collaborations with government development agencies were noted in Lince's reports. The project with financial assistance from CNPq - National Council for Scientific and Technological Development -

encourages the startup to develop partnerships with students from the stricto sensu programs of Universities in the State of Paraná, which have helped to develop the intelligent robot. Lince reported a positive and profitable collaboration with masters of the Federal University of Paraná (UTFPR), where the startup received support not only from students for the development of their robot, but also from the good quality of the physical structure of that university.

Strike XII also received grant support from a CNPq project in 2012, which was crucial for it to gain the financial means to develop its IoT solution.

3.8 Difficulties Identified in Startups in Industry 4.0

By the perception of the interviewees, many are the challenges of the Industry 4.0 concept in Brazil. These difficulties are related to (i) the search for suppliers abroad; (ii) external sources of training and innovation; (iii) lack of funding partner; (iv) startup maturity stage; (v) difficulties in collaborating with universities; (vi) cultural differences between startups and large companies which in its turn makes it difficult to establish partnerships with corporations; (vii) challenges not only for small and medium sized companies, but also for large Brazilian companies to understand and enter phase 4.0; (viii) the need for startups to teach companies about the concepts of the 4th industrial revolution and its benefits; (ix) the digital innovation ecosystem. It is worth stressing that this last aspect conflicts with the "Difficulties of Industry 4.0", since the ecosystem is one of the driving forces for companies to understand and use digital technologies.

> [...] there is a lack of awareness of many companies in the industry and cooperatives in Brazil regarding the basic knowledge of digital solutions. The lack of market awareness about what is behind the Industry 4.0 concept means that companies cannot see the value of digital solutions and the competitive advantages they can bring". (**Interviewee from Strike XII**).

The lack of market awareness awakens the need for startups to develop digital solutions to promote events to disseminate to the market the concepts and characteristics of Industry 4.0 and how they can contribute to this new industrial paradigm. This need to teach reinforces the country's initial stage of digitization.

> [...] Brazilian businessmen are not yet prepared for this transformation". (**Interviewees of Strike XII, Truwork and Alpha**).

Figure 2 illustrates the difficulties faced by interviewees. Many of the findings outlined in the network are corroborated by research highlighting the managerial and social challenges surrounding the concept of industry 4.0 in Brazil and internationally (Schwab, 2017, Zancul, 2017, CNI, 2016).

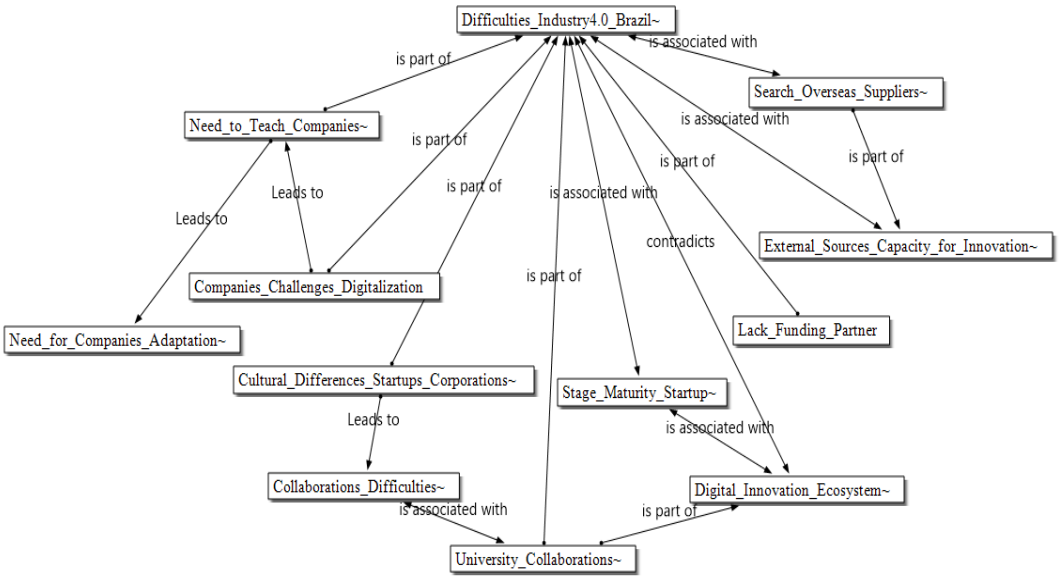

Figure 2. Relationship of Industry Difficulties 4.0 in Brazil by Startups
Source: Own elaboration, with the aid of Atlas.ti software.

Raising awareness of the business environment in the Digital Age has been a challenge. The startups analyzed believe that there is a need for companies not only to incorporate digital solutions, but also to adapt their structures, cultures, business processes to make them more flexible, agile, open and digital-driven.

For these startups, the change is more complex and comprehensive, since it needs to include social and managerial aspects of these companies so that Industry 4.0 is effective in them (Westerman et al., 2011, PWC, 2016, Sniderman et al., 2016, Camarinha- Matos et al., 2017; Schwab, 2017; Xu et al., 2018).

Another factor that hinders the organizations' adherence to Industry 4.0 in Brazil is hierarchical, bureaucratic and embedded structures, which lead to slowness in decision processes, delays in authorizations, and payments to third parties. Truwork had a negative experience in these aspects with a potential customer of the automotive sector in Brazil:

> [...] the large company that does not have the same speed as the startup has, nor flexibility due to its own structure ... the processes of these companies are slower". (**Truwork interview**).

The difficulty of insertion of Industry 4.0 can also be seen in the obstacles promoted by the federal government, both in the lack of investments in technology and in the high import rates of the technological components.

Mainly because of the lack of an industrial policy for digital transformation, startups tend to seek more and more sources of technological capacity outside the country (CNI, 2016). As for the difficulties in collaborating with the universities, the interviewees report a lack of vision of some of them on digitization.

Lince had a negative experience trying to collaborate with a university in Paraná to develop its intelligent robot for the industry:

> [...] some higher education institutions research, produce their academic articles, divulge their ideas and solutions, but they did not see a product". (**Interviewee of Lince**).

4. Conclusion

This research identified how the ecosystem of collaborations in R&D of startups incubated in C2i can influence the digital innovation in Brazilian manufactures. The findings in Figures 1 and 2 demonstrate the achievement of this goal. The development of a strategy of collaboration in R&D with startups has been presented, at least in the Brazilian context, as a facilitator for companies to move towards digitalization, even though it is permeated by (still) informal practices. Brazil has been promoting efforts for innovative entrepreneurship to collaborate in the development of digital innovations in the country, but in the perceptions of the analyzed startups, these are timid efforts. The research suggests that Brazil is still unprepared for the large-scale adoption of the Industry 4.0 concept, in view of the educational and cultural aspects of large Brazilian companies, as well as the lack of financial resources to invest in a digital industrial policy.

As for the contributions to the practice, the research showed that Brazil needs to be aware of the challenges and gaps in order to face them so that the use of Industry 4.0 is effective. The network of collaborations to promote technological innovation is at the center of the digitization and thus the innovation ecosystem needs to be considered as an important - though certainly not the only - enabler for industrial transformation.

As to the contribution to the literature, this research identified the nature, dynamics, complexity and level of relevance of collaborations in R & D in an emerging context: Industry 4.0. The research results highlighted the relevance of obtaining external sources of knowledge and technology for business innovation, strengthening the theoretical approach of open innovation contextualized in the Digital Age. This study, therefore, does not allow generalizations without enough future studies being carried out in other startups, and with other organizational actors directly involved in the concept of Industry 4.0.

It is suggested, as future research, to consolidate or debate the results of this research, in order to characterize and analyze the collaborations in R&D for digital innovation, in a qualitative way, in other institutions and with other actors. It would be equally interesting to do comparative case studies between Brazilian manufactures and manufactures from developed countries that have a digital industrial policy like Germany, Japan, the USA and South Korea, to compare their ecosystems of digital innovation.

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