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ANDREI MIKHAILOV

UNIVERSITY-INDUSTRY COLLABORATION, INNOVATION CAPABILITY AND FIRM PERFORMANCE IN BRAZIL: the role of resources and channels

Porto Alegre
2023

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Tese apresentada como requisito parcial para obtenção do título de Doutor em Administração, pelo Programa de Pós-Graduação em Administração da Universidade do Vale do Rio dos Sinos (UNISINOS).

Orientadora: Prof.ª Dra. Janaina Ruffoni

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Dedico este trabalho aos meus amados pais, Andrei Mikhailov e Irina Mikhailova, por amor incondicional e suporte.

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“If you can’t measure it, you can’t manage it” , Robert S. Kaplan and David P. Norton

ABSTRACT

The university-industry (U-I) collaboration is an essential factor for industrial innovation. The investigation of UIC outcomes from the firms' perspective has attracted scholars' attention in the last few years. Firms that collaborate with universities may benefit from access to valuable resources, such as access to state-of-art scientific knowledge and human resources, patents, new methods, and university infrastructure and technical equipment. In turn, access to resources is vital for building innovation capability, which is essential for innovation performance. However, the studies that analyzed the benefits of U-I collaboration for the firms underexplored the capabilities issue. Hence, the following research question is proposed: **which are the most benefic universities' resources and U-I collaboration channels to the innovation capability and performance of manufacturing firms?** In 2021, the researcher applied a survey with 176 Brazilian industrial firms that collaborated with universities. To measure firms' innovation capability, it was used Zawislak's (2012) model. This model splits innovation capability into four capabilities: management, transactions, operations, and development. The data was analyzed through the structural equation modeling (SEM) and multiple regression techniques. The results showed that the use of universities' resources for product and process innovation based on *knowledge infrastructure* is more benefic for firms' innovation capability and performances than *applied science*. Specifically, the use of *research results*, *laboratories and physical infrastructure*, *new designs* and *instruments and equipment* are the most benefic resource types for innovation capability. In turn, the use of U-I collaboration channels based on *knowledge transfer* to conduct firms' innovation activities is more benefic for innovation capability and performance than *innovation networks*. Specifically, *technology licensing*, *publications and reports*, and *training*, are among the most benefic U-I collaboration channels for improving firms' innovation capability. The contributions of the present dissertation are two-fold. First, the present study contributes to the literature by analyzing the impact of U-I collaboration on firm innovation capability and performance within a holistic approach. In this sense, it combines the measuring of the influence of the use of different universities' resources and U-I collaboration channels on the firms.

Second, the study contributes to the literature by suggesting options for improving firms' innovation capability.

Keywords: innovation; university-industry collaboration; innovation capability; emerging country; Brazil

RESUMO

A interação universidade-empresa (U-E) é um fator essencial para a inovação industrial. A investigação dos resultados da UIC sob a perspectiva das empresas tem atraído a atenção de estudiosos nos últimos anos. As empresas que colaboram com universidades podem se beneficiar do acesso a recursos valiosos, como acesso a conhecimento científico e recursos humanos de ponta, patentes, novos métodos e infraestrutura universitária e equipamentos técnicos. Por sua vez, o acesso aos recursos é vital para a construção da capacidade de inovação, que é essencial para o desempenho da inovação. No entanto, os estudos que analisaram os benefícios da colaboração U-I para as empresas pouco exploraram a questão das capacidades. Assim, a seguinte questão de pesquisa é proposta: quais são os recursos das universidades e os canais de interação U-E mais benéficos para a capacidade de inovação e desempenho inovativo das empresas industriais? Em 2021, foi aplicada *survey* com 176 empresas industriais brasileiras que colaboraram com universidades. Para medir a capacidade de inovação das empresas, foi utilizado o modelo de Zawislak (2012). Esse modelo divide a capacidade de inovação em quatro capacidades: gestão, transação, operação e desenvolvimento. Os dados foram analisados por meio das técnicas de modelagem de equações estruturais (SEM) e regressão múltipla. Os resultados mostraram que o uso de recursos das universidades para inovação de produtos e processos baseados na *infraestrutura de conhecimento* é mais benéfico para a capacidade de inovação e desempenho das empresas do que a *ciência aplicada*. Especificamente, o uso de *resultados de pesquisa*, *laboratórios e infraestrutura física*, *novos designs* e *instrumentos e equipamentos* são os tipos de recursos mais benéficos para a capacidade de inovação. Por sua vez, o uso de canais de interação U-E baseados na *transferência de conhecimento* para conduzir as atividades de inovação das empresas é mais benéfico para a capacidade e desempenho de inovação do que as *redes de inovação*. Especificamente, *tecnologia licenciada*, *publicações e relatórios* e *treinamentos* estão entre os canais de interação U-E mais benéficos para melhorar a capacidade de inovação das empresas. A presente tese apresenta duas contribuições teóricas. Em primeiro lugar, o presente estudo contribui para a literatura analisando o impacto da interação U-E na capacidade e desempenho de inovação da empresa dentro de uma abordagem holística. Nesse sentido, combina a mensuração da influência do uso de recursos de diferentes universidades e canais de interação U-E sobre as empresas. Em segundo lugar, o estudo contribui para a literatura ao sugerir opções para melhorar a capacidade de inovação das empresas.

Palavras-chave: inovação; interação Universidade-empresa; capacidade de inovação; Brasil

SUMMARY

1 INTRODUCTION

The University-Industry (U-I) collaboration has attracted the attention of innovation scholars for many decades (Bonaccorsi & Piccaluga, 1994; Bastos, Sengik & Tello-Gamarra, 2021). Many of the world's most innovative economies comprise the world's top-ranked universities (Etzkowitz & Zhou, 2017). During the XXI century, there was an increasing diffusion of the entrepreneurial university approach (Etzkowitz & Zhou, 2017) and pressures from the government and society toward more active engagement of universities in collaborations aiming for innovation (Hulsink et al., 2014). This scenario turned the debate on the role of U-I collaboration in providing benefits to the firms even more relevant for the academic and practitioners' community (Baba, Shichijo & Sendita, 2009).

To this date, different empirical studies were conducted aiming to explore the benefits obtained by the firms from the collaboration with universities (Apa et al., 2021; Fitjar & Rodriguez-Pose, 2011). The empirical literature has been using different approaches to measure U-I collaborations per se and the benefits obtained by the firms from these collaborations. For instance, part of the studies in the field analyzed the increase in technological and innovation performances of the firms due to U-I collaboration (Eom & Lee, 2010; Fitjar & Rodrigues-Pose, 2011). Other studies focused on the financial benefits of U-I collaboration. The impact of U-I collaboration on a firm's longevity and survival rates was also addressed by a few articles. (Bandera & Thomas, 2019).

However, the benefits of collaboration with universities go beyond the above-mentioned outcomes. Collaboration with universities allows the firms to obtain valuable scientific knowledge, qualified human resources, access to physical facilities, laboratories, and instruments as well as applied knowledge embedded in the forms of new production techniques and prototypes and designs (Bishop et al., 2011; Puffal et al., 2021). It also contributes to the firm`s learning abilities and technological capabilities (Bishop et al., 2011; De Fuentes & Dutrenit, 2012), and the firm's knowledge base. Therefore, it acts as a catalyzer for the enhancement of the firm's ability to innovate (Zollo & Winter; 2002). Hence, it is argued that U-I collaboration may contribute to the firm's innovation capability. However, despite the importance of the university for the firm's innovation capability and the relationship between U-I collaboration and innovation capability, this topic lacks empirical exploration.

The approaches to quantify the U-I collaboration, their intensity and/or importance for the firm's innovation activities also differed among studies. Part of the studies treated U-I collaboration as a set of different types of technologies or transfer channels (Puffal et al., 2021; Outro). Other papers interpreted that the most appropriate way to measure U-I collaboration is through the analysis of the content of transfer, that is, by focusing on the university's resources used by the firms (Zawislak & Dalmarco, 2011). Still, academic scholars who aimed to measure collaboration benefits for the firms have been using a one-sided rather than holistic view of the U-I collaboration in a quantitative study. That is because these studies had been choosing between two main measurement approaches to U-I collaboration. Particularly, either university resources' or collaboration channels' perspective is one-sided, as both collaboration channels and transferred resources are natural elements of any U-I collaboration.

Overall, until now no study had properly addressed the relationship between U-I collaboration including both university resources and collaboration channels and the firm's innovation capability and performance. Previous studies suggested that different types of U-I collaboration may impact the firm differently (Apa et al., 2021; Mikhailov et al., 2020). Hence, it is proposed the following research question: which are the most benefic U-I collaboration channels and university resources to the innovation capability and performance of manufacturing firms?

The present thesis addressed two research gaps. The first one comprises a holistic view of the relationship between collaboration with universities, the firms' innovation capability and the firms' performance. The second gap relates to the options available to the firms that aim to improve their innovation capability and performance. The manufacturing industry was selected for three reasons. First, manufacturing sectors share features such as high investment in capital goods, quality control systems, and safety measures. Therefore, it increases the comparability of the companies that composed the sample. Second, industrial firms are important drivers of regional and national innovation systems' competitiveness (Reynolds & Uygun, 2018), making this sector strategic for national innovation. Third, Brazilian manufacturing firms still lack productivity and innovativeness in comparison to their counterparts from developed economies (PINTEC, 2017). Therefore, collaboration with universities may represent an opportunity to become more competitive.

The study used a survey method applied with Brazilian manufacturing firms that collaborated with universities. The population of industrial companies was identified through the DGP-CNPq research groups census 2016, which is the Brazilian periodical census of research groups. The present dissertation used Zawislak's et al. (2012) innovation capability model and U-I collaboration typologies based on PINTEC (2016) and BR Survey (2009). Zawislak's et al. (2012) innovation capabilities model has been applied by empirical studies conducted in Brazil and published in peer-reviewed journals (Alves et al., 2017; Ostermann et al., 2021; Reichert et al., 2016). The data was analyzed through structural equation modeling and multiple regression techniques.

1.1 Objectives

1.1.1 Main objective

To identify the most benefic U-I collaboration channels and university resources for building manufacturing firms' innovation capability and performance.

1.1.2 Specific objectives

1) To describe the main characteristics of U-I collaboration and innovation capability in Brazilian manufacturing firms that collaborated with universities.
2) To compare the benefits of different university's resources and identify the most benefic for firms' innovation capability and performance.
3) To compare the benefits of different U-I collaboration channels and identify the most benefic university resources for firms' innovation capability and performance.
4) To deepen the general understanding of the impact of U-I collaboration on firms' innovation capability and performance

1.2 Relevance of the study and contributions.

The contributions of the present dissertation are two-fold. First, it contributes to the knowledge of the impacts of U-I collaborations on firms' innovation capability and performance by using a holistic exploration of the cause-effect between U-I collaboration and firms' innovation capabilities. This holistic view is achieved by analyzing the effect of U-I collaboration beyond firm performance, as well as using two different U-I collaboration measurement scales. This contribution also resides in the necessity to extend the knowledge on the impacts of universities (Etzkowitz & Zhou, 2017; O'Shea et al., 2007; Wang et al., 2013).

Second, the dissertation contributes to the knowledge concerning the available options for the manufacturing firms to improve their innovation capability through the external collaborations. The importance of building innovation capability resides in the fact that it is a crucial determinant of sustained innovation performance (Guan & Ma, 2003; Zawislak et al., 2012). Improvement of innovation capability allows the firms to better adapt to add more value to their products and services, adapt to changing external environments and obtain superior financial and innovation performance (Reichert et al., 2016; Zollo & Winter, 2002). This capability is particularly important for Brazilian manufacturing firms, as it still lacks innovativeness (PINTEC, 2017).

1.3 Structure of the dissertation

The dissertation is organized as follows. In chapter 2, there is a description of the state of the art of U-I collaborations' scientific knowledge. Chapter 3 comprises innovation capabilities literature. The method is described in Chapter 4. Chapter 5 presents the results and discussion. Conclusion was made in Chapter 6. Lastly, the references are listed.

1. UNIVERSITY-INDUSTRY COLLABORATION

The first universities, such as, for instance, the University of Paris, had a single teaching mission. Later, with the advent of the Industrial Revolution and the expansion of scientific research, a second role was added to the institution, which deals with conducting scientific research (Etzkowitz & Leydesdorff, 1998; Etzkowitz & Leydesdorff, 2000). This model in which the university presents two missions: teaching and scientific research, is known as Humboldtian university, implemented in Germany in the nineteenth century (Etzkowitz, 2017).

During the late XX and beginning of the XXI century, the understanding that universities must act as active innovation actors gained a spread among innovation scholars (Bramwell & Wolfe, 2008; Etzkowitz & Zhou, 2017; Kimatu, 2016). This perception has been influenced by the diffusion of a “Triple Helix” approach, which states that in addition to teaching and research activities, the modern university must encompass the so-called “Third Mission”, that is, pro-active interaction with the private and public sector (Etzkowitz & Leydesdorff, 1998; Etzkowitz & Zhou, 2017; Guerrero & Urbano, 2017).

From the policy side, the Bayh-Dole act (1980) and the reduction of public investment in research (Mowery & Sampat, 2004) stimulated the university to collaborate with private firms to obtain additional resources and investment. Pressures from society have also motivated universities to provide greater returns for society (Hulsink, Dons, Lans & Blok, 2014; MacKenzie & Zhang, 2014; Reihlen & Wenzlaff, 2014). In Brazil, innovation law was an important initiative for establishing partnerships between universities and industries (Dalmarco, Hulsink & Blois, 2018), therefore generating a necessity for U-I collaboration.

In academic literature, the concept of U-I collaboration refers to partnerships between universities and industries in search of scientific knowledge, qualified human resources, access to laboratories and instruments, and innovation (Bonaccorsi & Piccaluga, 1994). Firms collaborate with universities for different reasons. They obtain state-of-art scientific and technological knowledge (Bonaccorsi & Piccaluga, 1994; Meyer-Krahmer & Schmoch, 1998; Puffal, 2014), use physical facilities such as laboratories (Santoro, 2000), conduct tests of their products and services, and gain certification (Silva Neto et al., 2013), outsource research projects or conduct joint research (Bonaccorsi & Piccaluga, 1994), improve companies’ image (Santoro, 2000;

Van Weele, Van Rijnsoever & Nauta, 2017), and reduce costs (Bonaccorsi & Piccaluga, 1994; Puffal, 2014; Van Weele et al., 2017). To find common patterns inside different collaborations and encourage U-I collaboration scientific investigation, scholars proposed different U-I collaboration typologies.

Estrutura nova.

2.1 Reasons, challenges, and benefits of U-I collaboration

Lore ipsilum..

2.2 U-I collaboration typologies

Most typologies use different criteria for U-I collaborations classification and different names and labels for a given relation. However, U-I collaboration typologies can be divided into three groups (Table 1). The first group comprehends typologies proposed by academic scholars through literature reviews and theoretical discussion. The second group is composed of empirical typologies created within the national scientific and innovation surveys. The third group includes typologies applied by empirical studies.

Table 1.

U-I collaborations typology types

Typology characteristics	References
Typologies created through literature review and theoretical discussion	Bonaccorsi and Piccaluga (1994), Cunha and Fracasso (1999), D'Este and Patel (2007), Meyer-Krahmer and Schmoch (1998), Santoro (2000), Schaeffer et al. (2017), Schartinger et al. (2002).
Typologies used by scientific, innovation, and U-I collaborations national surveys	BR Survey (2009), DGP-CNPq Research Group Census (2004, 2006, 2008, 2010, 2014, 2016).
Typologies applied by empirical studies that measured outcomes of U-I collaboration for the companies	Apa et al. (2020), Arza et al. (2010), Brehm and Lundin (2012), Dezi, Santoro and Monge et al. (2018), Povoa and Rapini (2010), Puffal (2014).

Source: elaborated by the author

Thus, typologies created by theoretical studies compose the first group. Bonaccorsi and Piccaluga (1994) proposed six cooperation types: informal personal relationships, formal personal relationships, participation of an intermediary institution, formal agreements without clearly defined goals, agreements without clearly defined goals, creation of structure for the relations. Meyer-Krahmer and Schmoch (1998) suggested eleven types of U-I collaborations: collaborative research, conferences, consultancy, contract research, committees, doctoral theses, education of personnel, informal contacts, publications, seminar for industry, scientist exchange. Cunha and Fracasso (1999) stated the U-I collaborations follow three models: classic model, market model, and partnership model. Using relation outcome as the main variable in the classification, Santoro (2000) proposed that U-I collaborations can be classified as research support, cooperative research, knowledge transfer, and technology transfer.

Schartinger et al. (2002) proposed nine types of relationships: mobility of researchers from universities to industries, collaborative research, contract research and consulting, financing of university research assistants by industries, scientific publications, joint supervision of Ph.D. and master's theses, lectures at universities held by industry members, training, and the creation of spinoff.

D'Este and Patel (2007) investigated the factors that underly the variety of U-I collaborations. First, they mapped interaction activities, which were: attendance at industry-sponsored meetings, attendance at conferences with industry and university participation, consultancy work, contract research agreements, creation of spin-off, construction of physical facilities with industry funding, training of postgraduates by companies, training of company employees, and collaborative research. Then, nine interaction types were grouped into five categories: meetings and conferences, consultancy and contract research, building of physical facilities, training, and joint research. Arza (2010) grouped different interactions in channels according to the reason of interaction: traditional, services, commercial and bi-directional.

Typologies of the second group were designed for the scientific, innovation and U-I collaborations surveys. Thus, Carnegie Mellon Survey, while evaluating the contribution of public research on industrial R&D, divided U-I collaborations according to interaction channels, which are: patents, publications and reports public meetings or conferences, informal interaction, personnel hiring, technology licensing, joint ventures, contract research, consulting, personnel exchange (Cohen et al., 2002).

Brazilian agency of CNPQ – Conselho Nacional de Desenvolvimento Científico e Tecnológico, uses the following typology of thirteen U-I collaborations in the research group census it conducts since 2002: training of research group personnel by the research partner including on-site courses and training; training of research partners by the research group, including on-site courses and training; technology transfer from the group to the research partner; technology transfer from the research partner to the group; development of non-routine software for the research group by the research partner; development of software by the group for the research partner; supply, by the group, of input materials for the research partner's activities without any linkage to a specific mutual interest project; supply, by the partner, of input materials for the research activities of the group without any linkage to a specific mutual interest project; technical consultancy services not covered by any of the previous categories; non-routine engineering activities, including development of prototype or pilot plant for the partner; non-routine engineering activities, including development/manufacture of equipment for the research group; scientific research with possible immediate use of results; scientific research without possible immediate use of results.

DGP-CNPq's typology used direction of knowledge and technology flows as one of the classification criteria. Also, DGP-CNPq's typology uses, among others, adaptation of some U-I collaboration types and classification criteria proposed by Bonaccorsi and Piccaluga's (1994), such as those related to the existence (or not) of clear goals.

The university-industry relations survey, also called *BR Survey*, subdivided the U-I collaborations according to information sources they provide to the companies: Publications and reports, conferences, joint R&D, informal interactions, post-graduated or graduated staff hired by the companies, outsourced R&D, participation in university networks composed the category of interaction based on technical information. Relations based on physical resources included companies' formation by the universities, business incubation, science and technology parks, temporary staff exchange, technology licensing (Povoa & Rapini, 2010). It is observed that national scientific and innovation surveys used elements of Meyer-Krahmer and Schmoch's (1998), Schartinger's et al. (2002), D'este and Patel's (2007) typologies, Bonaccorsi and Piccaluga's (1994) and Cunha and Fracasso's (1999) typologies.

The third group is composed by empirical studies that measured the U-I collaboration outcomes. Fernandes et al. (2010) used Arza's (2010) typology for U-I collaboration channels. Brehm and Lundin (2012) distinguished U-I collaborations by activity performed: collaborative, entrepreneurial, and educative. Puffal (2014) used factor analysis to group DGP-CNPq's typology into two types of relations: interaction based on technical information and interactions based on physical resources.

Dezi et al. (2018) proposed that U-I collaborations are based on services or partnerships. Apa et al. (2020) divided the U-I collaborations into formal and informal. Some authors did not distinguished types of U-I collaborations in their empirical models (Freel & Harrison, 2006; Guzzini & Iacobucci, 2017; Robin & Schubert, 2013; Scandura, 2016; Velez et al., 2019).

The analysis of the third group of studies in the previous paragraph shows that, in general, empirical studies explored only partially the scholars' typologies of U-I collaborations. For instance, Bonaccorsi and Piccaluga's (1994) original classification was not operationalized strictly through the variables by empirical studies, except for formal/informal relations (Fudickar & Hottenrott, 2018).

U-I collaborations may occur in different physical spaces and through different channels. Transfer channels influence the relation type; however, the transfer channel and the transfer content are not the same thing (Povoa & Rapini, 2010). The main issue of previous typologies are blurred boundaries between relation type, U-I collaboration channel, and the transferred content.

For instance, within BR Survey (2009), the business incubators and science parks were considered both information sources and collaboration types. However, McAdam and McAdam (2006) posit that university incubators and science parks can be seen as places of interaction or university elements rather than relations based only on physical resources (McAdam & McAdam, 2006).

Povoa and Rapini (2010) and Puffal (2014) argued that patents, recruitment of graduates, consulting, and scientific publications are transfer channels. In contrast, many scholars have viewed U-I collaboration types (Cohen et al., 2002; D'Este & Patel, 2007; Meyer-Krahmer & Schmoch, 1998; Schartinger et al., 2002).

2.2 Assessment of firm-level benefits of U-I collaboration

Since the emergence of Triple Helix and entrepreneurial university concepts, different studies on outcomes of U-I collaborations were published. The studies can be divided into four categories according to the variables included in evaluation models and study purpose (Table 2). The first category includes studies incorporating environmental factors in measurement models that used variables related to local intellectual property policies and international openness (Kafouros et al., 2015) and scientific productivity of a given region (Abbate et al., 2020).

The second category comprises articles that analyzed actors' characteristics focused on companies' size (Eom & Lee, 2010; Robin & Schubert, 2013; Velez et al., 2019), employees' formal education and R&D expenditures (Kobarg et al., 2017; Robin & Schubert, 2013), university' scientific productivity (Tang et al., 2019), and organizational and technological proximity between university and company (Ratchukool & Igel, 2018). Also, the innovation orientation of the firm, based on the geographical distance of the partner university it cooperated with, can be considered an actor's characteristic (Tang et al., 2020).

Articles that investigated the influence of internal aspects of U-I collaborations comprised the largest category in terms of a number of studies. U-I collaboration types (Puffal, 2014; Puffal et al. 2020; Mikhailov et al., 2020), relations' formality (Fudickar & Hottenrott, 2018), reasons for cooperation (Eom & Lee, 2010), cooperation channels (De Fuentes & Dutrenit, 2012; Grimpe & Hussinger, 2013), cooperation governance (Garcia-Perez-de-Lema et al. 2017), number of research cooperations (Suzuki, 2017), knowledge management practices (Chen & Wei, 2018), and project success (Guzzini & Iacobucci, 2017) on firm innovativeness.

Finally, some studies analyzed outcomes of collaboration with different actors, including universities. The relations included interactions based on R&D (Kang & Kang, 2010). Jordan and O'Leary (2011) analyzed the influence of the frequency of interactions with actors on innovation. Fitjar and Rodrígues-Pose (2013) analyzed the influence of the "science and technology and innovation" (STI) collaboration mode and the "doing, using and interacting" (DUI) on companies' innovation. Suppliers, clients, competitors, and universities compose the set of actors used by the studies.

Table 2.

Categories of studies that measured the outcomes of U-I collaborations for the companies[1]

Core aspects	Description of category	References

[1] The creation of categories was based on extensive systematic literature review conducted at Scopus and Web of Science in 2020. The method description is available in attachment 1.

Environmental factors	This category includes factors related to regional, institutional, and market characteristics of the environment	Abbate et al. (2020), Kafouros, Wang, Piperopoulos, Zhang (2015)
Actors' characteristics	These studies focus on investigating the influence of actors' characteristics such as university type and academic productivity, and companies' characteristics such as sector, size, R&D activities, cognitive proximity and firm innovation orientation on the outcomes of U-I collaborations.	Arant et al. (2019), Baba et al. (2009), Bishop et al. (2011), Chen et al. (2018), D'Este et al. (2011), Eom & Lee (2010), Fu & Li (2016), , Giannopoulou (2019), Guan et al. (2005), Kobarg et al. (2018), Ratchukool & Igel (2018), Robin & Schubert (2013), Tang et al., (2020), Velez et al. (2019).
Intrinsic aspects of the U-I collaboration	These studies analyzed internal aspects of relations, including its types and transfer channels, governance mechanisms, knowledge management activities as potential factors that influence outcomes of U-I collaborations.	Apa et al. (2020), Ahrweiler et al. (2011), Arvanitis et al. (2008), Brehm and Lundin (2012), De Fuentes and Dutrénit (2012), Dezi et al. (2016), Eom and Lee (2010), Fernandes et al. (2010), Garcia-Perez-de-Lema et al. (2017), Guzzini & Iacobucci (2017), Fudickar & Hottenrott (2018), Hu et al. (2020), Kobarg et al. (2018), Mikhailov et al. (2020), Puffal (2014), Puffal et al. (2020), Ratchukool & Igel (2018), Suzuki (2017), Vega-Jurado et al. (2017), Wang et al. (2013).
Studies that evaluated outcomes of companies' relations with different actors, including universities	These studies evaluated outcomes of companies' relations with different actors including universities. The actors included in studies' models are usually clients, suppliers, and other companies. To study the impact of U-I collaborations on companies' innovativeness was not the main objective of these studies	Belderbos et al. (2004), Inauen and Schenker-Wicki (2011), Fitjar and Rodríguez-Pose (2013), Jordan and O'Leary (2011), Kang and Kang (2010), Nieto and Santamaria (2007), O'Connor et al. (2020), Un and Asakawa (2015), Un et al. (2010).

Source: based on a systematic literature review conducted by the author

But what results were found by the studies? The following subsection describes it.

2.3 U-I collaboration and firm innovation

Table 3 shows main findings of empirical studies that investigated benefits of U-I collaboration obtained by the firms. As shown at Table 3, different types of collaborations have different effect on firm technological, innovation and financial performances.

Table 3.

Summary of the findings of the quantitative studies on UIC outcomes for the firms[2]

	Without sectoral perspective		With sectoral perspective	
	Positive	No positive effect	Positive	No positive effect
Overall innovation performance	Arvanitis et al. (2008); Lin (2019); Abdulai et al. (2020) in case of formal UIC	Abdulai et al. (2020) in case of informal UIC;	Ahrweiler et al. (2011); De Fuentes & Dutrenit (2012) - for particular UIC types; Garcia-Perez-de-Lema et al. (2017) - for formal UIC; Ratchukool & Igel (2018); Apa et al. (2020) for both formal and informal UIC	De Fuentes & Dutrenit (2012) - for particular UIC types; Garcia-Perez-de-Lema et al. (2017) - for informal UIC

[2] Part of the studies used samples composed exclusively by the firms that engaged in collaboration with universities. Thus, in these studies it is not possible to state whether U-I collaboration increase or decreases firm performance per se. However, once the effect of a given type X of U-I collaboration is positive and of the type X of U-I collaboration is negative, or non-significant, it is possible to state that U-I collaboration type X is comparatively more benefic for the collaborative firms than U-I collaboration type Y.

Product innovation	Eom & Lee (2010); Ahrweiler et al. (2011); Robin & Schubert (2013); Fu & Li (2016); Bianchini et al. (2019); Gretsch et al. (2019); Puffal et al. (2021) in case of knowledge-based UIC;	Puffal et al. (2021) in case of knowledge based UIC	Maeitta (2015), Fudickar & Hottenrott (2018); Vega-Jurado et al. (2018) for new-to-the-firm innovation in case of outsourced R&D-based UIC and new-to-the-market in case of R&D-based UIC; Melnychuk et al. (2021); Storz et al. (2021) for new-to-the-firm innovation	Ahrweiler et al. (2011); Vega-Jurado et al. (2017) for new-to-the-firm innovation in case of R&D-based UIC and new-to-the-market in case of outsourced R&D-based UIC
Process innovation	Puffal et al. (2021) in case of knowledge-based UIC	Eom & Lee (2010); Robin & Schubert (2013); Bianchini et al. (2019); Puffal et al. (2021) in case of infrastructure-based UIC;	Maeitta (2015)	-
Technological performance/Patents	Eom & Lee (2010); Wirsich et al. (2016); Bianchini et al. (2019)	Suzuki (2017) in case of collaboration with foreign universities	Baba et al. (2009) - positive except when collaboration is performed with "Star scientists"; Nishimura & Okamuro (2011); Petruzzelli & Rotolo (2015); Buenstorf & Heinisch (2020); Yang et al. (2021)	-

Financial performance	Bianchini et al. (2019); Min et al. (2019); Velez et al. (2019)	Eom & Lee (2010), Vasquez-Urriago et al. (2016),	Colombo & Delmastro (2002); Hanel & St-Pierre (2006), Meoli et al. (2013); Lee et al. (2015); Chen et al. (2016); Jones & De Zubielqui (2017) for particular UIC types	Temel et al. (2013); Jones & De Zubielqui (2017) for particular UIC types

As shown at the beginning of chapter 2, different U-I collaboration types require different levels of complexity, absorptive capacity, and resources. Therefore, it is crucial to investigate When discussing the influence of different types of relationships and their characteristics in the results of the U-I collaboration for the company, it is essential to talk about the influence of the formality of relationships. Few studies have proposed to investigate internal factors of the U-I collaboration on the innovativeness of companies, emphasizing mainly the influences of different U-I collaboration types on innovation in companies. Apa et al., (2021), when investigating collaboration between universities and small and medium-sized enterprises in Italy, found that while informal collaboration positively impacts innovation in product, process, service and organizational companies, formal collaborations individually have no significant impact.

Results of the study by Garcia-Perez-de-Lema et al. (2017), on the contrary, suggested that it is formal collaborations, that is, relationships based on contractual governance, that have a positive and significant influence on innovation. According to Grimpe and Hussinger (2013), formal and informal collaboration, when unique maintained by companies, does not impact the company's innovation.

Another interesting question within the literature concerns differences between influence and force of influence of different types of U-I collaboration on innovation. When studying the results of the U-I collaboration for a company in the Latin American context, it was found that specific types of U-I collaboration, such as relation based on the use of university resources (Puffal, 2014) and the consulting base (De Fuentes and Dutrénit, 2012), contribute negatively to the innovative performance of companies.

For instance, in Puffal's (2014) investigation, it was found that collaboration based on technical knowledge flow contributes to increasing the degree of innovation of the company.

It is also important to note that, in general, different studies work with samples of different compositions. For example, when analyzing relationships, many studies analyze only companies that engaged in U-I collaboration, making impossible to make comparison of isolated effect of collaboration with universities on firm' performance (i.e. Puffal, 2014). On the other hand, studies that use mixed samples composed both companies that had relation and those that did not engage in relations with universities (Fitjar & Rodríguez-Pose, 2013).

When interpreting the results of a study it is important to consider the sample, time and environmental characteristics of the investigated relations used to understand the reference points in terms of the company's innovativeness on which the impact of the U-I collaboration is produced. As an example, although the Puffal's study (2014) demonstrated that the engagement in U-I collaboration based on the use of universities resources decreases the innovativeness of companies that interacted with universities, it is not possible to affirm that companies that engaged in U-I collaboration the university's resource base innovate less than companies that did not interact with universities, since, in the case of the present study, the sample was composed exclusively of companies that had relation.

Although different studies use additional factors, such as environmental and locational factors, and actors characteristics, most studies still treat university-industry relations as a binary variable, that is, present or absent (Brehm & Lundin, 2012; Inauen & Schenker-Wicki, 2011; Kobarg et al., 2018; Li et al., 2020; Nieto & Santamaria, 2007).

It is not uncommon for companies to engage in different U-I collaborations simultaneously. Thus, some studies checked the impact of the number and intensity of relations on the company's innovativeness. Kafouros, Wang, Piperopoulos and Zhang (2015) found that the intensity of collaboration with universities, measured by the proportion of R&D spending on projects with universities in relation to total R&D spending, positively impacts the sales performance of new products. Similarly, higher frequency of U-I collaborations contributes positively to the company's innovativeness (Jourdan & O'Leary,2011). Li, Li and Wu (2020), when studying results of U-I collaboration for Chinese companies listed on the stock market, found that the number of universities with which the company had relationships increases its patent stock.

However, some studies identified non-significant or even negative effect of U-I collaborations on the companies' results. Suzuki (2017) showed that the number of co-operations with universities by companies does not affect their technological performance. On the other hand, Jordan and O'Leary (2011) suggested that, in the particular case of high-tech companies in Ireland, the more frequent the collaboration with universities, the more significant the negative impact of relation on business product innovation. Lin et al. (2019) suggested that the higher the number of U-I collaborations maintained by the company, the lower its innovation performance.

Regarding the diversity of relations, Apa et al. (2020) and Lin (2019) was among the first authors who demonstrated the importance of the diversity of U-I collaborations for companies' innovativeness. For instance, formal and formal U-I collaborations show complementary effect on the company's innovativeness, which is higher than the impact of a single type of U-I collaboration individually (Apa et al., 2020; Grimpe & Hussinger , 2013). Recently Mikhailov's et al. (2020) empirical investigation through qualitative-comparative analysis (QCA) suggested that companies need to engage in at least one research-oriented or development-oriented U-I collaboration to innovate

Based on the results of the studies presented above, it is important to emphasize that the way to evaluate the intensity of U-I collaboration varies according to the study conducted. So, Kafouros et al. (2015) used the proxy of the financial investment made by the company within the U-I collaboration. Apa et al. (2020) divided the relations into formal and formal, while Lin (2019) evaluated the diversity according to the number of different areas of knowledge used in the relation. Garcia-Perez-de-Lema et al. (2017) showed that U-I collaborations with contractual governance positively affected firm innovativeness, while U-I collaborations with less formal governance did not present a significant effect on innovation.

Some studies showed that particular types of U-I collaborations might contribute negatively to firms' innovativeness. For instance, Puffal's (2014) study showed that collaborations based on the use of university resources contribute negatively to the level of firms' innovation. A De Fuentes's and Dutrénit (2012) study showed that U-I collaboration based on basic informational exchange and training is negatively related to Mexican firms' technological capabilities.

Robin & Schubert (2013) stress that U-I collaborations should not be encouraged at all costs since they may not sustain all forms of innovation. Therefore, it is necessary to learn more about U-I collaboration types that are the most beneficial for firms to formulate better U-I collaboration policies.

Perhaps the highest responsibility of an entrepreneurial university in its impact on the companies' innovativeness concerns providing them with valuable resources and upgrading companies' innovation capabilities by transferring knowledge and technology through engaging in fruitful relations. Interaction with universities and research centers allows companies to obtain access to state-of-art knowledge and human resources, use laboratories and physical infrastructure, increase technical efficiency, outsource R&D projects, and enhance the company's reputation (Arza, 2010; Meyer-Krahmer & Schmoch, 1998; Puffal, Ruffoni & Schaeffer, 2012; Santoro, 2000). Grant (1991) argues that resources are crucial for companies to build capabilities. In this sense, universities may act as suppliers of essential resources for companies' innovativeness.

Overall, considering that previous studies had shown that different types of U-I collaboration impact differently on the firms, it is proposed that: **different U-I collaboration types present different impacts on firms' innovation capability and performance.**

Until now, the impact of U-I collaborations on a firm's innovation capabilities received much less attention than the impact of these relations on companies' technological, innovation and financial, which is quite surprising. To properly evaluate the impact of U-I collaboration on innovation capabilities, it is important to choose an adequate model of innovation capability. That is only possible by deep learning on current innovation capabilities models.

2.4 U-I collaboration in Brazil

In Latin America, the institutionalization of science, technology and innovation followed a different path from its European and North American counterparts (Rapini et al., 2015). Brazil had been the country of late industrialization and foundation of universities, which appeared even later than in many Latin-American countries (Schwartzman, 1979; Suzigan and Villela, 1997). Thus, the first Brazilian universities were founded in the 1930s and had been focused exclusively on human capital formation at the undergraduate level rather than graduate students, as the demand from the productive sector for skilled human resources was quite modest. (Rapini et al., 2015)

The institutionalization of science began in the mid-1950s and was started by local scientists who had graduated from universities in developed countries and who were acknowledged in international communities. In this period, S&T policies followed a 'supply logic' to generate knowledge based upon internal priorities defined by R&D institutions, without the participation of industry (Rapini et al., 2015). The knowledge was understood to be automatically transferred to the productive field (Dagnino, 1996).

Due to the above-mentioned context, which comprised the late establishment of universities and late industrialization, Brazil, like other developing countries, has seen the emergence of entrepreneurial universities only after the beginning of the 21st century (Dalmarco, Hulsink & Blois, 2019). According to Suzigan and Albuquerque (2008), although Brazil has traditional teaching and research institutions, the country had been unable to promote an interactive dynamic between these actors to the point of establishing a positive feedback process between the scientific and technological spheres until the end of the 2000-s.

However, some recent studies argued that U-I collaboration in Brazil has intensified (Fischer, Schaeffer and Vonortas, 2019). Since the 2000s, the openness of the university to interactions with industry has constantly been growing, as has the percentage of companies that engage in U-I collaborations (Fischer et al., 2019). For instance, while in 2003 only 1.96% of Brazilian companies with an innovative profile declared having participated in some kind of relations with universities, in 2008 this number increased to 4.27% and 7.20% in 2014. (Fischer al., 2019)[3]. Considering that in the last two decades, the country has promoted the emergence of research-intensive universities, which has spawned a wide range of new scientific and technological knowledge, there is still room for the translation of national regulatory policies into productive U-I collaboration (Fischer et al., 2019).

When arguing the importance of university-industry collaborations for firms' innovativeness, it is important to add that the comparison between PINTEC data and

[3] Statistics presented by Fischer et al. (2019) are based on the compilation of PINTEC data in the years 2003, 2005, 2008, 2011 and 2014. PINTEC is the Brazilian innovation survey carried out every three years by the IBGE – Brazilian Institute of Geography and Statistics. The recent editions of the surveys used questionnaires based on Oslo Manual (2005) and were similar to Community Innovation Survey (CIS) in different aspects. For more information, go to https://www.ibge.gov.br/estatisticas/multidominio/ciencia-tecnologia-e-inovacao/9141-pesquisa-de-inovacao.html?=&t=what-is.

BR Survey[4] data. The latest mentioned is the largest U-I collaboration survey in Brazil, that showed that the nominal innovativeness rates of low-tech firms that collaborated with universities are much higher than those of Brazilian low-tech manufacturing companies in general (Table 4).

Table 4

Comparison of the degree of novelty of new products launched by manufacturing firms surveyed by PINTEC (2008) and BR Survey (2009)

	PINTEC			BR Survey		
Technological intensity	New to the Firm	New to the country[5]	New to the world	New to the firm	New to the country	New to the world
Low	34,41%	11,03%	0,71%	90,20%	63,04%	21,74%
Medium-low	33,01%	14,49%	1,77%	90,20%	67,39%	17,39%
Medium-high	44,35%	37,40%	8,18%	96,30%	59,62%	30,77%
High	53,82%	58,72%	13,35%	95,83%	54,35%	23,91%
Overall	35,98%	19,34%	3,05%	93,14%	61,05%	23,68%

Source: statistics based on data from BR Survey (2009) and PINTEC (2008)

For instance, while 34,41% of low-tech companies from PINTEC (2008)[6] introduced at least new-to-the-firm innovations, the BR Survey counterparts showed a 90,20% innovation rate. The higher the innovation degree used in the comparison, the higher the nominal differences in innovation rates between companies from the PINTEC and BR surveys. Overall, while 23.68% of BR Survey manufacturing companies introduced new-to-the-world innovations, the PINTEC counterparts presented a rate of only 1,77%, suggesting that companies which collaborate with universities innovate more than those that do not. Nevertheless, caution is urged in interpreting the conclusions, as the numbers were not statistically compared[7].

[4] BR Survey was conducted in Brazil within the first large initiative of understanding the landscape of U-I collaboration through the project "University-industry cooperation in Brazil", that took place between 2007 and 2009. BR Survey was applied with the firms which collaborated with the universities in the year 2002, as well as with the research groups with Brazilian firms which collaborated with universities as well as research groups engaged in U-I collaboration. The survey structured questionnaire was based on the Carnegie Mellon Survey on Industrial R&D (Cohen et al., 2002) and the Yale Survey on Industrial R&D (Klevorick et al., 1995). In total, BR Survey comprise information on 328 firms that collaborated with universities, and it is still the largest U-I collaboration survey conducted in Brazil.

[5] The ratio for "new to the country" and "new to the world" is calculated out of the total firms that declared to innovate.

[6] The PINTEC 2008 survey comprised data on 100.500 manufacturing firms.

[7] The microdata from PINTEC survey are not publicly available, so it was not possible to perform tests of statistically significant differences between the data from PINTEC and BR Survey. Also, it is crucial to stress that PINTEC and BR Survey are different databases collected for different purposes.

The second large initiative which involved understanding the landscape of Brazilian U-I collaboration relates to the publication of the book named "As Hélices da Inovação[8]", which comprised a deep explanation of the nature, characteristics, and gaps in U-I collaboration in Brazil through the presentation of a different chapter involving studies on Triple Helix in Brazil (Amaral et al., 2022).

Concerning the outcomes of U-I collaboration for the Brazilian firms, Puffal's et al. (2021) showed that depending different collaboration types of impact differently on different innovation types. For instance, while interactions based on knowledge transfer are more benefic for the firms' process innovation than those based on the use of university infrastructure are the most benefic for product innovation. Likewise, the use of public funding for innovation negatively affected the degree of collaborative firms innovativeness in comparison to those that did not use it .

Mikhailov's et al. (2020) study suggested that the presence of research-oriented or development-oriented collaborations is necessary to allow the firm to achieve high innovativeness. Liboreiro's et al. (2022) showed that even though university laboratory spinoffs are important for U-I collaboration, they generally are not able to create innovative products. Likewise, previous quantitative investigations showed that intellectual property created by universities through collaborative research labs may not translate into new products' creation or success (Liboreiro et al., 2022; Zawislak & Dalmarco, 2011).

As argued by Dalmarco et al. (2011), the distance between scientific results and commercial application may jeopardize the patent itself, as it is unable to predict all possible applications for the actual technology. A patent that is incorrectly filed may reveal critical details of the invention, instead of protecting it. Likewise, due to the lack of IP expertise from inventors, it is difficult to translate the academic result to the commercial world of patents (Dalmarco et al., 2011).

Likewise, Brazilian firms, even those which interacted with universities, may have relatively low absorptive capacity (Da Rosa & Ruffoni, 2014; Teixeira et al., 2014) and therefore may have difficulties to assimilate and transform acquired knowledge into a new useful innovation, as per absorptive capacity theory (Cohen & Levinthal, 1990; Zahra & George, 2002).

[8] In English the name means "Innovation Helixes"

2. INNOVATION CAPABILITY

Innovation in companies can be analyzed from different perspectives (Reichert et al., 2016). For instance, in high-tech companies, such as those from pharmaceutical, aerospace, electronics and communications sectors, innovation has long been associated with technological transformations and is measured by R&D investment, new product development (NPD) and patent applications (Hagedoorn & Cloodt, 2003). The Organization for Economic Cooperation and Development - OECD (2011) uses the R&D expenditures indicator to classify industries in four levels: high, medium-high, medium-low, and low-technology intensity. However, the researchers need to be careful when associating the innovation to mere R&D activities or patent creation (Dodgson et al., 2014).

While the high-tech companies tend to develop innovation internally, the sectors of low technological intensity are rather adopters than creators of technological innovations (Reichert et al., 2016; Smith, 2005). For instance, the leather and footwear industries, food and beverage companies adopt rather than produce new technologies. Reichert et al. (2016) argue that innovation in low-tech industries is misunderstood. It comes from process improvements, management activities and even better abilities to engage in transactions with companies' partners (González-Moreno et al., 2019; Hirsch-Kreinsen, 2008; Reichert et al., 2016). Like for high-tech industries, launching new products is an important opportunity for low-tech companies to innovate. It is crucial to add that NPD in low-tech companies usually does not require high science-based capabilities as much as it does in high-tech sectors (Hirsch-Kreinsen, 2015; Lee et al., 2018; Von Tunzelman and Acha, 2005). As the type of innovation activities and innovation outcomes vary according to the sector, measuring companies' innovativeness through its innovation capabilities becomes an interesting opportunity (Saunila & Ukko, 2012; Reichert et al., 2016; Zawislak et al., 2012).

The concept of innovation capability gives back to a capability concept introduced by Richardson (1972). The author argued that capabilities are composed of companies' experience, knowledge, and skills. Capabilities comprise routines that make companies different (Nelson, 1991; Nelson & Winter, 1982). Prahalad and Hamer (1990) posit the companies' capabilities are related to core competencies that should be difficult to replicate. In turn, these competencies will provide the company with a competitive advantage (Prahalad & Hamel, 1990).

Since Richardson (1972), many models of innovation capabilities were proposed, and early models analyzed innovation from a technological perspective. Lall (1992) proposed one of the first frameworks of innovation capabilities, focused on technological aspects. In a national context, he proposed that innovation is created by the production, investment and linkage capabilities. Thus, production capability comprehends product and process development skills. Building facilities, machinery and equipment, compose the investment capability. Finally, the linkage capability concerns skills and routines in acquiring new technologies and building knowledge.

Leonard-Barton (1992) argues that firm's core capabilities are embedded in employee knowledge and skills, technical systems, organizational systems, values and norms. Helfat (1997) researched oil industry, arguing that innovation capabilities reside on R&D activities, particularly om R&D investment rates and R&D investment rate growth over the years.

It is crucial to state that innovation capabilities view exclusively under a technological perspective is somewhat limited. Oslo Manual (2005) defined four types of innovation: product, process, marketing and organizational. In large economic sectors, such as food and beverage, furniture, textile and footwear, wood, wood products and paper, the innovations may come from branding, marketing activities, and consumer services development (González-Moreno et al., 2019; Hirsch-Kreinsen, 2008; Janssen et al., 2016) rather than from technological capabilities. Technical and production improvements such as machinery and equipment acquisition, manufacturing system reorganization, production planning and control and managerial capacity can be enough for low-tech companies' innovativeness (Hoveskog, 2011; Lee et al., 2018; Kastelli et al., 2016; Smith, 2005).

To understand why firms may benefit from U-I collaboration to build its innovation capability requires a review of existing innovation capabilities models and measurement instruments. Lall (1992) proposed a model of innovation capability focused on technological approach. According to the authors firm technological capability is composed of production, investment and linkage capabilities. Thus, production capability comprehends product and process development skills. Building facilities, machinery and equipment, compose the investment capability and int turn these resources can be accessed through infrastructure-based U-I collaboration (Puffal et al., 2020). Linkage capability ability concerns skills and routines in acquiring new technologies and building knowledge (Lall, 1992), which in turn can be accessed by using technology transferred by university to the firm and joint R&D (Maietta, 2015; Wirsich et al., 2016; Vega-Jurado et al., 2017).

Leonard-Barton (1992) argues that firm's core capabilities are embedded in employee's knowledge and skills, technical systems, organizational systems, values and norms. Universities are well-known as qualified human-resource providers and specific types of U-I collaborations, such as those that include HR exchange or transfer. Helfat (1997) researched oil industry, arguing that innovation capabilities reside on R&D activities, particularly on R&D investment rates and R&D investment rate growth over the years.

Similarly, Guan & Ma' (2003) model categorized R&D as a component of a firm innovation capability. In turn, conducting R&D together with a university or, for instance, outsourcing R&D to the university is a possibility not only to develop new product or process, but lower costs of investment, as R&D conducted with universities require fewer financial expenditures than cooperation with other actors (References needed). The importance of employees as an element of firm innovation capabilities was also argued by Castela et al. (2018).

Different authors which investigated factors that affect firm innovation capability agree that knowledge, and knowledge exchange activities are important for the firm (Le & Lei, 2019; Ganguly et al., 2019). In this context, university is widely acknowledged as an actor which possess the state-of-the-art both technological and basic knowledge (D'este & Patel, 2007; Etzkowitz et al., 2019).

In the XXI century, innovation scholars addressed the issue of a one-sided view of innovation capabilities by formulating models and constructs that mixed technological and managerial approaches (Castela et al., 2018; Hertog et al., 2010; Hogan et al., 2011; Lee et al., 2001; Zawislak et al., 2012). Lee et al. (2001) were one of the first authors who mixed technological and managerial approaches into innovation capabilities metrics. However, the authors measured the entrepreneurial orientation in terms of R&D activities, such as R&D investments and a number of risky R&D projects. In fact, Lee' et al. (2001) approach has technological rather than technological and managerial approaches.

Guan & Ma (2003) advanced the incorporation of the managerial approach into innovation capabilities model by proposing seven dimensions: learning, R&D, manufacturing, marketing, organizing, resource, and strategy. Lin (2007) measured innovation capabilities through likert scale new ideas, a new way of doing things, creativity in the use of methods, agility in launching new products and services, risk perception, and new product introduction rate growth.

Hertog et al. (2010) argued that innovation capabilities is composed by six dimensions: signaling user needs and technological options, conceptualizing, (un-) building capability, co-producing and orchestrating, scaling and stretching, learning and adapting. Hogan et al. (2011) suggested seven dimensions of innovation capability: client-oriented solutions, technology, service/product, marketing, strategy, behavioral, and operational process.

Saunila & Ukko (2012) conducted an in-depth review of previous models and measurement instruments of innovation capabilities. They suggested two types of measurement instruments of innovation capabilities: the input measures, represented by the activities, and the output measures. Then, the proposed framework comprises three elements: innovation potential, innovation processes, and innovation outcomes, all of which could be subjective or objective.

Zawislak et al. (2012) used a theory of a firm and innovation management literature to compose an innovation capability model. The model divided innovation capabilities into two dimensions: management-driven and technology-driven. Castela et al. (2018) conducted a literature review of the previous innovation capabilities model. They used a non-parametric and integrative approach to propose an assessment model composed of five factors: infrastructure, organizational aspects, employees, managers/CEO, and external factors. Table 5 shows a summary of previous models.

Table 5.

Innovation capabilities' models

Authors	Perspective	Concept or construct definition
Lall (1992), Bell & Pavitt (1995)	Technological	The innovation capability is constructed by production, investment, and linkage capabilities
Leonard-Barton (1992)	Technological	The author posits the innovation capability resided on company's core capability, which is embodied in four dimensions: employee knowledge and skills, technical systems, managerial systems, and values and norms
Helfat (1997)	Technological	Innovation capability resides in R&D activities, particularly in R&D investment and its growth over the years.
Lee et al. (2001)	Technological	Internal capabilities were operationalized by measuring entrepreneurial orientation, technological capabilities and financial resources of companies

Guan & Ma (2003)	Technological and managerial	Seven dimensions composed the innovation capability: learning, R&D, manufacturing, marketing, organizing, resource, and strategy
Lin (2007)	Managerial	Innovation capability was measured through a seven-point likert scale of six items: new ideas, a new way of doing things, creativity in the use of methods, agility in launching new products and services, risk perception, growth of new product introduction rate
Yang, Marlow, Lu (2009)	Technological and managerial	Innovation capability is measured through five items: service quality management, new services, operational system improvement, employee reward system, and methods for corporate goals achievement
Hertog et al. (2010)	Technological and managerial	Authors proposed six dimensions of innovation capability in service companies: signaling user needs and technological options, conceptualizing, (un-) building capability, co-producing and orchestrating, scaling and stretching, learning and adapting
Hogan et al. (2011)	Technological and managerial	Innovation capabilities are measured by seven dimensions: client-oriented solutions, technology, service/product, marketing, strategy, behavioral, and operational process
Saunila & Ukko (2012)		The concept of innovation capability includes three elements: innovation potential, innovation processes, and innovation outcomes.
Zawislak et al. (2012)	Technological and managerial	Four capabilities form the companies' innovation capability: development, operations, management, and transaction (Zawislak et al., 2012). Later the measurement instrument based on Zawislak's et al. (2012) model was created and validated within a probabilistic sample of manufacturing firms (Alves et al., 2017; Reichert et al., 2016)
Castela et al. (2018)	Managerial	After reviewing the previous innovation capabilities models and measurement instruments, the authors proposed a framework that included five elements: infrastructure, organizational aspects, employees, managers/CEO, and external factors.
Rajapathirana and Hui (2018)	Managerial	Innovation capability was measured through a construct composed of three items: use of knowledge from different sources, involvement of workers and customers, and organizational culture

Source: elaborated by the author

Two issues were found by analyzing the main innovation capabilities' models, approaches, and measurement instruments. First, most models are unbalanced in terms of technological and managerial approach (i.e. Castela et al., 2018; Guan & Ma, 2003; Lall, 1992; Lee et al., 2001; Leonard-Barton, 2002; Lin, 2007). Second, some models (Guan & Ma, 2003; Hogan et al., 2011) have relatively a high number of dimensions (seven), making the analysis more difficult.

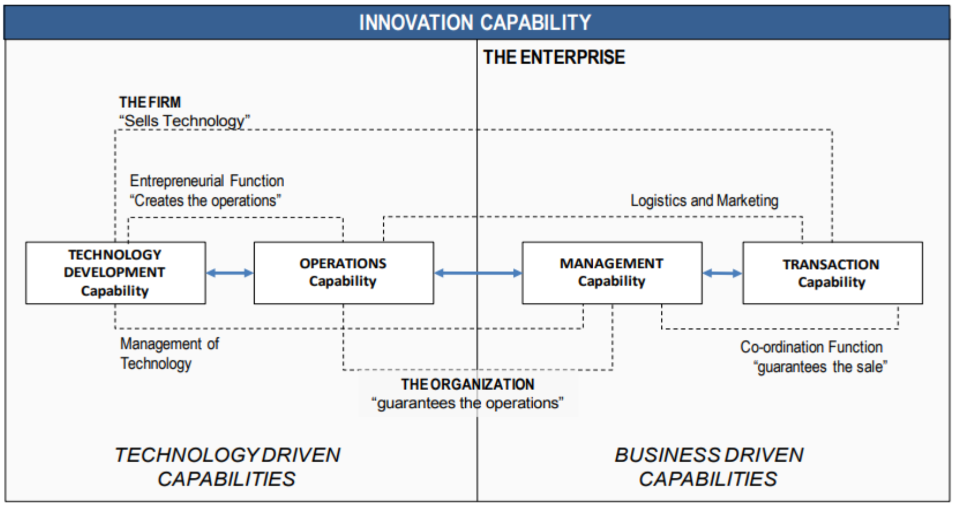
As shown in section 3.1 (below), Zawislak et al. (2012) addressed the previous two issues by applying a theory of a firm and innovation management literature theory to compose a theoretical model and data measurement instrument of innovation capabilities.

3.1 Zawislak's innovation capability model

Zawislak et al. (2012) divided the innovation capability into two dimensions: technological and managerial (Figure 1). The technological dimension was divided into operations and development capability and the managerial dimension in management and transaction capability.

Figure 1.

Zawislak's et al. (2012) innovation capabilities model



From the theoretical point of view, the company can be analyzed under Coase's (1937) coordination function and Schumpeter's (1942) entrepreneurial function (Zawislak et al., 2012). Here, the firm can be considered an entity that sells the technology (Zawislak et al., 2012). In turn, the organization "guarantees the operations". Thus, the firm aspect of a company is composed of two capabilities: development and transaction. The organization element of a company is composed of operations and management capabilities.

The development capability refers to a company's ability to transform a given technology into a change of production capacity, reaching a higher level of technical efficiency. Operations capability is a process of sustaining production capacity through a set of daily routines, skills and knowledge. Management capability is the ability to transform technology development into operations and transactions arrangement. Lastly, transaction capability is efficiency and efficacy in logistics, bargaining with suppliers and marketing activities (Alves et al., 2017; Zawislak et al., 2012).

All four capabilities allow the company to perform its primary functions. For instance, the company manages the technology function (development and management capabilities) and the logistics and marketing function (operations and transaction capabilities). Operations and development capability support the entrepreneurial function. Except for operations, all capabilities are dynamic (Alves et al., 2017). It happens because the high operations capability has a low influence on the company's innovativeness. (Alves et al., 2017).

It took a theoretical article to propose the Zawislak's et al. (2012) model. Later, it was operationalized and validated through a scaling proposal which was validated by a survey with a probabilistic sample of manufacturing firms (Alves et al., 2017; Oliveira et al., 2019; Reichert et al., 2016; Ruffoni et al., 2018) and applied to different case studies (Zawislak et al., 2013; Zawislak et al., 2018) from different technological intensity sectors according to OECD (2011).

From the analysis of Zawislak's et al. (2012) model, some conclusions are made. First, it has a clear structure and solid theoretical base. Second, it includes both technological and managerial drivers of innovation. Finally, the measurement instrument based on this model was validated by different empirical studies in Brazil, therefore, was tested for validity and reliability (Alves et al., 2017; Reichert et al., 2016). Finally, the measurement instrument, that is, structured questionnaire designed from the abovementioned model was developed particularly to measure innovation capability of manufacturing companies[9].

[9] The measurement instrument was developed by NITEC Innovation Research for a project "Paths of Innovation in the Brazilian Industry", covering a four-year observation period from 2010 to 2014. The survey was sent to a sample of 6143 Brazilian firms with ten or more employees in all manufacturing industries listed in the Industry Association of Rio Grande do Sul (FIERGS) business register. The survey questionnaires were based on the results of a literature review and interviews with 70 managers of manufacturing firms (see Barbieux, Zawislak, Padula, and Camboim (2015, pp. 2114–2115) for detailed information on the survey procedures and questionnaire development). The survey received 1331 valid responses from the senior manager or owner, giving a 21.7% response rate.

3. METHOD AND MEASURES

The researcher applied a survey method to a sample of Brazilian manufacturing companies that interacted with universities. This method is the most adequate when it is not possible to obtain data directly from available databanks. In addition, it allows the researcher to control the data collection procedures and obtain deep insights about the analyzed object, which is not possible when only secondary data collection takes place.

4.1 Population and Sample

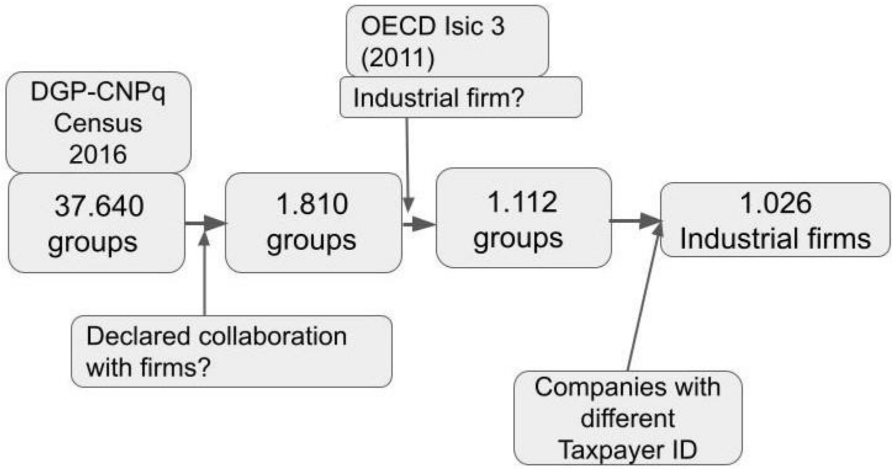
The list of manufacturing companies was obtained from DGP-CNPq Research Group Census 2016[10], which is a periodic census of Brazilian research groups' 2016 Census and by far the largest national database containing information on U-I collaboration[11]. Out of 37.640 groups, only those that cooperated with firms were considered for further analysis, resulting in 1.810 groups (Figure 2). The researcher applied the OECD (2011) criteria of industrial classification of economic activities (CNAE) of the partners indicated by the research groups, reducing the number of groups to 1.112.

Then, the list of companies that engaged in collaboration with universities was formed by compiling the data provided by 1.112 research groups that stated to engage in U-I collaboration, resulting in a group of 1.026 industrial firms which collaborated with universities during the period 2015-2016.

Figure 2.

[10] By the date of the beginning of sample selection procedures, the 2016 edition of DGP-CNPq research group census was the most recent edition. Currently, in March 2023, it continues to be so.
[11] CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) is a Brazilian National Council for Scientific and Technological Development that funds scientific research in Brazil. It conducts periodical research group census (DGP-CNPq Census) since 2002. The research groups are mostly from universities, but not only, as there are also research groups from research institutes and hospitals. The DGP-CNPq data are provided by the leaders of the research groups. For more information access the following webpages: https://lattes.cnpq.br/web/dgp/sobre, http://lattes.cnpq.br/web/dgp/como-os-dados-sao-obtidos/ .

Sample selection procedures



Source: elaborated by the author

4.2 Data collection procedures

All 1.026 companies were contacted by the specialized team between September and November of 2021, out of which 176 responded, resulting in a response rate of 17.2%, which is similar to the previous innovation and U-I collaboration non-mandatory surveys (i.e. Bishop et al. 2011; Puffal et al. 2020; Reichert et al., 2016; Robin & Schubert, 2013). To answer questions concerning firm innovation capabilities it is recommended to interview the company's decision-makers, as they tend to have a holistic view of different companies' areas (Reichert et al., 2016). Therefore, the researcher conducted phone and online interviews using structured questionnaires applied to firms' CEOs and managers.

4.3 Data collection instrument

The firm-level data was collected online and by phone. For that purpose, the researcher developed a structured questionnaire which comprised five sections: I – innovation capabilities, II – innovation sources and U-I collaboration, III – pandemics impact scale, IV – innovation outcomes and V – additional data. The data collection instrument validity and reliability are crucial parts of a survey method (Churchill, 1979; Ladeira, 2010). For that reason, all questions, except the COVID scale, were obtained from data measurement instruments from articles published in peer-reviewed journals and national innovation surveys (Table 6). Particularly the questions, scales and constructs used for measuring U-I collaboration, innovation capability and firm performance were retrieved from the literature in its unchanged form.

The innovation capabilities scale section uses precisely the same questions and scale of Alves et al. (2017) and Reichert et al. (2016) measurement instruments based on Zawislak et al. (2012) innovation capability model. The question on the use of innovation sources uses the structure of Machado & Zen (2015) validated construct and adds additional innovation sources listed at PINTEC (2017). The question on U-I collaboration channels used by the company to collaborate with universities was obtained from BR Survey (2009).

Section III evaluated the impacts of the COVID pandemic on two key indicators of firm performance – revenue and profit, and key innovation input indicator - R&D investment. The section was included to allow the researcher to control the COVID pandemic impacts on innovation and capabilities and innovation performance. Section IV comprises questions related to innovation performance. Particularly the measurement of innovation performance was divided into two different groups of variables. The first group of variables is composed of a latent variable (factor) used by Engelman's et al. (2017) study. The second group of variables evaluated the novelty level of product and process innovation implemented by the firm and used the scale previously applied by PINTEC and CIS innovation surveys. Only first groups of variables was used in the present study, as the structured equation modelling was used as a data analysis techniques.

Table 6.

Structured questionnaire dimensions

Section	Collected data	References
I – Innovation sources and U-I collaboration	Innovation sources Use of university resources accessed manufacturing companies. Use of U-I collaboration channels	Composed by PINTEC (2014) Br Survey (2009), all Likert-scale
II – Innovation capabilities scale	Operations capability Development capability Management capability Transaction capability.	Alves's et al. (2017) questionnaire based on Zawislak's et al. (2012) model Likert-scale
III – Pandemics impact	Revenue	Elaborated by the author

scale	Profit R&D investment. All Likert-scale.	
IV – Innovation outcomes dimension	Product innovation novelty (categoric Process innovation novelty (categori(Market share increase (Likert-scale) Comparative innovation output (Liker scale) Comparative NP revenue (Likert-scal	PINTEC (2014), Br Survey (2009) PINTEC (2014), Br Survey (2009), Engelman et al. (2017) Engelman et al. (2017) Engelman et al. (2017)
V – Additional data	Diverse (dummy, continuous)	Br Survey (2009) Reichert's et al. (2016)

Source: elaborated by the author

To assess the firm use of U-I collaboration to conduct innovation activities and develop new products and processes two different questions were used. In the first question, managers were asked to evaluate the importance of 11 U-I collaboration channels for the development of the firm's innovation activities through Likert-scale. In the second question, the managers evaluated the importance of the use of 8 university resources. Answering the first question in two ways: first, the firm' managers was asked to evaluate the importance of collaboration channels for the firm's innovation activities; second, managers indicated the use of university resources for new product and process development. The reason to separating the question concerning the importance use of university resources and U-I collaboration channels was the following:

- First, even if the type of transferred resource is influenced by the collaboration channels, the transferred content (university resources) and collaboration channels are not interchangeable concepts (Povoa & Rapini, 2010; Zawislak & Dalmarco, 2011).
- Second, new product and process development is a specific component of innovation activities and is more directly related to the innovation firm performance than a given innovation activity per se. Thus, evaluating the influence of two instead of one aspect of U-I collaboration allowed creating a wider and more holistic view of the influence of U-I collaboration on innovation

capability and performance. This holistic view is what makes the present study different previous empirical investigations, which focused on either U-I collaboration resources or collaboration channels (Colombo & Delmastro, 2002; Bishop et al., 2011; Robin & Schubert, 2013)

4.4 Variables

Independent variables

As stated previously, the researcher applied 4 different model types: the first model analyzed the influence of the use of university resources for new product and process development on the firm innovation capabilities and innovation performance. The second model analyzed the influence of the use of interaction channels for innovation activities on the firm innovation capabilities and innovation performance. Accordingly, the third and fourth models are similar to the first and second, except they were run through regression and structural equation modeling (SEM).

The running of SEM requires conducting factor analysis first. Thus, the factor analysis was performed through IBM SPSS software and used the principal component factor analysis with varimax rotation to build latent variables from different types (7) of university resources used by the firms (Table 7). The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy is 0.805 and the Bartlett's Test of Sphericity is statistically significant ($p < 0.001$), suggesting the suitability of the study data for dimension reduction through factor analysis. The total variance explained by two factors was 58.34%. The results suggested the presence of the two categories of the university resources: *knowledge infrastructure* (3 items with composite reliability = 0.84 and average variance extracted = 0.90) and *applied science* (4 items with composite reliability = 0.88 and average variance extracted = 0.87). The factor loadings are presented in Table 7.

Table 7[12].

Factor analysis of the university`s resources used by the firms for new product and process development.

[12] Names of the factors shown in Table 7 and 8 was formed through the use of fator analysis, literature review and validation of the names through consulting with three brazilian U-I collaboration researchers.

Factor	Variables	Component	
		1	2
Factor 1: knowledge infrastructure	Scientific research results	0.784	
	Laboratories and infrastructure	0.820	
	New instruments and equipme	0.539	
Factor 2: applied science	Prototypes		0.774
	New techniques and processe		0.505
	New materials		0.741
	New designs		0.831

Likewise, factor analysis was performed (Table 8) with the variables which represented different interaction channels (11). The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy is 0.825 and the Bartlett's Test of Sphericity is statistically significant ($p < 0.001$), suggesting the suitability of the study data for dimension reduction through factor analysis. The total variance explained by two factors was 51.34%. The results suggested the presence of the two categories of the U-I collaboration channels: *knowledge transfer* (4 items with composite reliability = 0.86 and average variance extracted = 0.92) and *innovation networks* (6 items with composite reliability = 0.84 and average variance extracted = 0.83). The factor loadings are presented in Table 8.

Table 8.

Factor analysis of U-I collaboration channels used by the firm to conduct innovation activities.

Factor	Variables	Component	
		1	2
Knowledge transfer	Licensed technology	0.80	
	Training	0.68	
	HR recruitment	0.52	
	Publications and reports	0.69	
Innovation networks	Consulting		0.39
	Outsourced R&D		0.74
	Joint R&D		0.828
	University networks		0.798
	HR exchange		0.604
	Spinoff		0.692

Source: elaborated by the author

Dependent variables

As explained previously, it was used measurement instrument of firm innovation capability based on Zawislak et al. (2012) model, and previously applied by Alves et al. (2017) and Ruffoni et al. (2019). As shown in Table 9, innovation capability is formed by 4 internal capabilities, which are: management, transactions, operations, and development, each being measured by a set of variables measured through a Likert-scale. Each capability was measured by calculating mean value of all questions comprised by it.

Table 9.

Description of the measurement instrument of firms' innovation capability

Capability	Question description
Management capability	Formally defines its strategic objectives annually.
	Includes social and environmental responsibilities on its strategic age
	Updates its management tools and techniques.
	Maintains personnel trained for the company functions.
	Uses modern financial management practices.
Transactions capability	Imposes its negotiating terms on its suppliers.
	Imposes its prices on the market.
	Imposes its negotiating terms on its customers.
	Uses formal criteria to select its suppliers.
Operations capability	Carries out the productive process as programmed.
	Establishes productive routines that does not generate rework.
	Delivers products promptly.
	Can expand the installed capacity whenever necessary.
	Can ensure the process does not lead to products being returned.
Development capability	Designs its own products.
	Monitors the latest technological trends in the sector.
	Adapts the technology in the use to its own needs.
	Prototypes its own products.
	Uses formal project management methods (i. e. Stage-Gate, PMBOK
	Launches its own products

Source: elaborated by the author

The innovation performance was measured through the factor composed of three Likert-scale observed variables (Table 10), that evaluated: (1) firm market share growth in comparison to the competitors in the last 3 years, (2) firms' revenue from new products in comparison with the competitors in the last 3 years, (3) the number of new products and processes introduced in the last 3 years in comparison with the competitors.

Table 10.

Factor analysis of firms' innovation performance

Factor	Variables	Loading
Innovation performance	Market share	0.867
	NPD's revenue in proportion of total revenue	0.798
	Number of new products and processes	0.888

Control variables

Table 11 shows the list of control variables applied by the present dissertation. The following control variables were used: firms' size, firms' age; firms' technological intensity coded into low, medium-low, medium-high and high; sectoral technological intensity, coded into low-tech, which included companies from low and medium-low tech, and high-tech, which included medium-high and high-tech sectors; presence of formal R&D department (dummy); continuity of R&D activities (dummy); presence of cooperation with university research groups after the start COVID-19 pandemics (dummy); impact of COVID-19 pandemics on firms' R&D investment (Likert-scale). The reason to add the impact of COVID-19 on R&D investment resides on the necessity to be more precise in the evaluation of the firm R&D intensity, as it could change since the start of the COVID-19 pandemics.

It is important to stress that particularly size, age and R&D intensity are among the most common control variables within U-I collaboration empirical literature, as they represent important factors that may affect firm performance (Bishop et al., 2011; Garcia-Perez-de-Lema et al., 2017; Yang et al., 2021).

Table 11.

List of control variables

Variable	Variable type	Coding
Size (Log10_Size)	Continuous	Log10 of the total number of employee
Age (Log10_Age)	Continuous	Log10 of age in years
R&D intensity - R&D investment in proportic revenue (Tec_Int_Firm)	Ordinal	Below 1% = 1, between 1 and 2.5% = 2 between 2.6% and 7% = 3, over 7% = 4

Sectoral Technological (OECD, 2011) inten (Tec_Int_Sector)	Ordinal	Below 1% = 1, between 1 and 2.5% = 2 between 2.6% and 7% = 3, over 7% = 4
Presence of formal R&D department (Dep_R&D)	Dummy	Present = 1, absent = 0
Collaboration with research groups after the start of COVID-19 (Coll_groups)	Dummy	Firm collaborated = 1, firm did not collaborated = 0
Impact of COVID-19 on the firm R&D investment (COVID_R&D)	Continuous	Very negative = 1, negative = 2, neithe negative nor positive = 3, positive = 4, very posit = 5

Source: elaborated by the author

Table 12 shows descriptive statistics of control variables.

Table 12.

Descriptive statistics of control variables[13]

	Mean	Minimum	Maximum	Std. Deviation
Number employees	435.72	3	5600	858.57
Age	39.78	2	152	22.87
Dep_R&D	0.80	0	1	0.40
Coll_groups	0.60	0	1	0.49
Tec_Int_Firm	2.27	1	4	0.86
Tec_Int_Sector	2.2	1	4	1.11
COVID_R&D	3.48	1	5	1.00

Source: elaborated by the author

As shown at Table 13, variable number of employees present statistically significant correlation with all six control variables. In turn, firm' technological intensity showed statistically significant correlations with all other control variable, except for sectoral technological intensity.

Table 13.

Correlation matrix of control variables[14]

	Log10 _Size	Log10 _age	Tec_Int _Firm	Tec_Int _Sector	COVID _R&D	Dep _R&D	Coll_Groups
Log10_Size	1	,421**	,415**	-,215**	,182*	,288**	,256**
Log10_Age	,421**	1	,188*	-0,032	0,084	,203**	0,14
Tec_Int_Firm	,415**	,188*	1	0,048	,404**	,247**	,334**
Tec_Int_Sector	-,215**	-0,032	0,048	1	0,106	-0,015	0,019
COVID_R&D	,182*	0,084	,404**	0,106	1	,170*	,241**

[13] The frequency statistics for firm' R&D investment, sectoral technological intensity, presence of R&D department, cooperation with research groups after COVID will be present in the chapter 5.
[14] "*" – significant at 5%, "**" – significant at 1%.

Dep_R&D	,288**	,203**	,247**	-0,015	,170*	1	0,098
Coll_groups	,256**	0,14	,334**	0,019	,241**	0,098	1

Source: elaborated by the author

4.4 Data analysis

The data analysis comprised three different types of procedures. To address the objective of describing the characteristics of U-I collaboration in manufacturing firms in Brazil, descriptive statistics and cluster analysis were applied. The objectives of identifying the most benefic university resources and U-I collaboration channels for the firm's innovation capability and performance were addressed addresses by applying partial least square (PLS) structural equation modeling (SEM). The third procedure, which also addressed the two latter objectives, included the use of multiple regression. While the SEM allows to identify influence of a given set of factors on outcome variable, the multiple regression model identifies the influence of observed variables, that is, university resources and U-I collaboration channels in the case of present dissertation. The decision to use these additional quantitative analysis techniques was made seeking to deepen the outcomes provided by SEM.

The descriptive analysis included statistics on sample, such as companies' sector, location age, as well as on firm' innovation capability and use of university resources and collaboration channels. To run SEM models and multiple regression first it was performed evaluation of outliers (z-values and Mahalanobis distance of variables that measured innovation capability) resulting in the exclusion of 8 observations (below 5% threshold), so the final sample included 168 firms. In total, four SEM models were used, comprising two models of the influence of the influence of the use of university resources on innovation capability and performance (1A, 1B) and two models of the influence of the use of U-I collaboration channels (2A, 2B).

Ten different multiple regression models were run. Five models (1c, 1d, 1e, 1f, 1g) measured the influence of the use of university resources on four capabilities and innovation performance and another five models (2c, 2d, 2e, 2f, 2g) to the influence of the use of collaboration channels. Table 14 summarizes the performed statistical analysis.

Table 14 – statistical analyzes performed within dissertation.

Aim	Type of data analysis	Data
Description of characteristics of U-I collaboration in Brazilian manufacturing firms	Descriptive statistics	Firm size and R&D intensity; location; economic sectors; sectoral technological intensity; four capabilities which compose innovation capability; university's resources for product and process innovation; collaboration channels for innovation activities
	Cluster analysis	Observed variables comprised by management, operations, transactions, and development capabilities
Influence of the use of university' resources on firm' innovation capability and performance	Structural equation modelling	Two models: first model include influence of resources on innovation capability only (1A) and the second on both innovation capability and performance (1B).
	Multiple regression	Five models (1c, 1d, 1e, 1f, 1g), including influence of all university' resources on each capability, and innovation performance
Influence of the use of U-I collaboration channels on firm' innovation capability and performance	Structural equation modelling	Two models: first model include influence of resources on innovation capability only (2A) and the second on both innovation capability and performance (2B).
	Multiple regression	Five models (2c, 2d, 2e, 2f, 2g), including influence of all U-I collaboration channels on each capability, and innovation performance

Source: elaborated by the author

4. RESULTS AND DISCUSSION

The present chapter is divided into three sections. Section 5.1 presents descriptive statistics of the sample and cluster analysis. Section 5.2 shows models that answer the research question of the present dissertation, which is: which are the most benefic U-I collaboration channels and university resources to the innovation capability and performance of manufacturing firms? In turn, section 5.2 is divided into two parts: subsection 5.2.1, which contains analysis of the influence of the use of universities' resources on firms' innovation capability and performance, and subsection 5.2.2 which shows the results on the influence of the use of U-I collaboration channels by the firms on their innovation capability and performance. Section 5.3 comprises summary of the results.

It is crucial to stress that the main data analysis technique used to answer the research question is SEM. Each subsection includes 2 different SEM Models, corresponding to Models 1A and 1B in 5.2.1 and 2A and 2B in 5.2.2. The multiple regression analysis was used to deepen the outcomes provided by SEM. That is, to check the isolated impact of each university's resource and U-I collaboration channel, compare with the results suggested by SEM and thus extend the knowledge about the most benefic resources and channels for firms' innovation capability and performance.

To put it simply, the purpose of including multiple regression to the set of statistical analyzes is to add an even greater holistic view of the impact of U-I collaboration on manufacturing firms, which in turn is what makes the present different from previous empirical investigations.

5.1 Descriptive statistics

As shown at Table 15, 44% of surveyed companies were small, 34% - medium and 22% - large companies. Likewise, most companies presented medium-low technology intensity (43%), followed by medium-high (28%), low (20%) and high technological intensity (9%). Most companies (79,2%) stated they have formal R&D department and conducted R&D activities in continuous manner (92,9%).

Table 15.

Surveyed firms' size and R&D intensity according to OECD Isic 3 Revision's (2011) thresholds.

Firms' R&D intensity	Total

		Low	Medium-low	Medium-high	High	
Size	Small	14%	20%	10%	1%	44%
	Medium	5%	16%	9%	3%	34%
	Large	1%	7%	9%	5%	22%
Total		20%	43%	28%	9%	100%

Source: elaborated by the author

The sample was composed of firms from 20 out of 26 Brazilian states, including 10 out of 10 most populous. Four states, which are Rio Grande do Sul (25,6%), São Paulo (25,6%), Santa Catarina (14,2%) and Minas Gerais (12.5%) accounted for over three-fourths (77,9%) of the total number of analyzed firms (Table 16).

Table 16.

Distribution of firms per state.

State	**Frequency**	**Percent**
RS	45	25,6
SP	45	25,6
SC	25	14,2
MG	22	12,5
PR	13	7,4
PA	5	2,8
BA	3	1,7
PE	3	1,7
RJ	3	1,7
CE	2	1,1
AL	1	0,6
AM	1	0,6
AP	1	0,6
ES	1	0,6
GO	1	0,6
MS	1	0,6
MT	1	0,6
PB	1	0,6
PI	1	0,6
RO	1	0,6
Total	176	100

Source: elaborated by the author

Distribution of companies by economic sectoral activity is shown in Table 17.

Table 17.

Number of companies and frequency per sector

Sector	**Number of companies**	**Frequency %**
Machinery and equipment	40	22.8
Food and beverage	37	21
Paper, wood, and wood products	19	10.8
Chemicals	14	8
Pharmaceuticals	13	7.4
Leather and footwear	12	6.8
Metal products	11	6.3
Medical and optical equipment	8	4.5
Electrical equipment	6	3.4
Rubber and plastics	8	4.5
Precision instruments	2	1.1
Non-metal products	2	1.1
Printing	1	0.6
Communication equipment	1	0.6
Electronics and hardware	1	0.6
Other manufacturing products	1	0.6
Total	176	100

Source: elaborated by the author

As shown at Table 17, the sample included firms from a variety of sectors, including Machinery and equipment (22.8%), food and beverage (10.8%), chemicals (8.0) and pharmaceuticals (7.4%). It is important to add that, according to DGP-CNPq Census 2016, the abovementioned sectors have a higher number of companies that collaborated with universities (Mikhailov et al., 2022). Small firms account for the largest share among surveyed firms (45%), followed by medium (33%) and large (22%).

As shown at Table 18, medium-low technological intensity sector contained highest number of firms (41.50% of total) followed by the firms with medium-high technological intensity (27.30% of total).

Table 18.

Firms' technological intensity according to R&D investment following OECD Isic 3 (2011) classification.

Tecnological intensity	Frequency	% of total
Low	33	18.80
Medium-low	73	41.50
Medium-high	48	27.30
High	15	8.50
Missing	7	4.00
Total	176	100.0

Source: elaborated by the author

Only 21.6% of a sample was composed of large companies, while 33% of it were represented by medium and 45.5 by small firms. Most firms stated to conduct R&D activities continuously (92.9%) and 79.8% have formal R&D department. The mean age of companies was 39.78 years. The youngest company was founded 2 years ago and the oldest 152.

The analyzed companies possess quite developed innovation capability (Table 19), as the sample presented high means for operations (4.38), transactions (4.0), development (4.34) and management capability (4.46).

Table 19.

Innovation capability of the surveyed firms

Capability	Mean	St. deviation
Management (MC)	4.46	0.42
Transactions (TC)	4.00	0.55
Operations (OC)	4.38	0.45
Development (DC)	4.34	0.42

Source: elaborated by the author

To deepen the exploration of the innovation capability of the analyzed firms, a cluster analysis was performed. This analysis was performed in two phases. First, a hierarchical cluster analysis through dendrogram analysis using Euclidian distances was used to visually identified the possible clusters. Then, as suggested, K-means cluster analysis was carried out (Hair, 2005).

The dendrogram allowed to identify two main clusters. Then, it was run K-means cluster. The validation analysis of the statistical significance of differences between two cluster were performed by using ANOVA (Aldenderfer & Blashfield, 1984). The ANOVA test showed significant differences for all innovation capability variables. The cluster analysis allowed to identify two clusters: firms with medium innovation capability and firms with high innovation capability (Table 20).

Table 20.

Mean values of capabilities of each cluster[15]

Capability	Medium capabilities	High capabilities	Nominal difference
Management	4.21	4.62	0.41
Transactions	3.65	4.17	0.53
Operations	4.19	4.51	0.32
Development	4.02	4.49	0.47

Source: elaborated by the author

Table 21 shows the means of the importance of the use of university's resources for product and process innovation.

Table 21.

Use of university's resources for product and process innovation

Type of resource	Mean	Std. Deviation
New instruments and equipment	4.62	.708
Techniques and processes	4.53	.685
Laboratories and physical infrastructure	4.40	.758
New materials	4.38	.73
New designs	4.22	.85
Research findings	4.15	.83
Prototypes	3.99	.98

Source: elaborated by the author

As shown at Table 21, the use of *new instruments and equipment* (4.62), *techniques and processes* (4.53), and *laboratories and physical infrastructure* (4.40)

[15] The mean value of each capability was calculated from mean value of each variable of which the given capability was composed of. All nominal differences between the variables' means were statistically significant.

are rated by the firm as the most important university resources for its new product and process development. In contrast, *prototypes* (3.99) are the least used university resources together with the *research findings* (4.15). Overall, the mean value of factor *knowledge infrastructure* was 4.41 and 4.29 for the factor *applied science*.

Table 22 shows mean for the importance of the use of U-I collaboration channels for innovation activities of the analyzed firms.

Table 22.

Importance of U-I collaboration channels for firm's innovation activities

Channel	**Mean**	**Std. Deviation**
Training	4.72	.675
Technology licensing	4.41	.788
Recruitment of universities professionals	4.40	.803
Consulting	4.02	.803
Exchange of professionals	3.47	1.022
Outsourced R&D	3.63	1.072
Publications and reports	3.98	.843
Joint R&D	3.96	1.038
Spinoff	3.74	1.010
Patents	3.65	1.145
University networks	3.69	.962

Source: elaborated by the author

The results show that *training* (4.72), *technology licensing* (4.41), *recruitment of qualified professionals* (4.40) and *consulting* (4.02) represent the most important interaction channels for firm's innovation activities. In contrast, *exchange of HR* (3.47), *outsourced R&D* (3.63) and *patents* (3.65) are the less common interaction channels. Hence it seems that many firms don't to find patents worthy for innovation. Here, Zawislak & Dalmarco (2011) explained that in Brazil most companies do not see patents as important source of innovation because they can be outdated, or to protect them takes too much time.

Still, all interaction channels have mean higher than 3 which suggests that analyzed firms do give importance to the U-I collaboration channels for conducting their innovation activities. Overall, the mean value of factor *knowledge transfer* was

4.23 and 3.65 for the factor *innovation networks*. Based on these number it is possible to state that in general the analyzed firms consider channels *of knowledge transfer* more important for conducting innovation activities than taking part of *innovation networks*.

Overall, from Tables 21 and 22 it is concluded that analyzed companies do consider universities as important sources for supporting both firm innovation activities and product and process development, as the lowest mean for the use of university resources is higher than 4 out of 5, and higher than 3.4 out of 5 for the U-I collaboration channels.

5.2 U-I collaboration, innovation capability and innovation performance

The present section contains the results of the inferential statistics which answer the dissertation's research question, and it is divided into two subsections. Subsection 5.2.1 presents the results of the influence of the use of the university's resources on firm innovation capability and performance. Subsection 5.2.2 shows the outcomes of SEM analysis of the influence of the use of U-I collaboration channels.

5.2.1 University resources, innovation capability and innovation performance

To deepen that understanding of the impacts of the use of university resources for product and process development on firms' innovation capability and performance, two SEM models were used (Table 22). The first SEM (1A) checked the impact of U-I collaboration on innovation capabilities and of those innovation performance. The second SEM (1B) analyzed the same relationships plus the influence of U-I collaboration on innovation performance. The purpose of running two instead of one SEM was to double-check the significance of identified statistical relationships. In addition, five multiple regression models (1c, 1d, 1e, 1f, 1g) were run to deepen the understanding of the impacts of the use of universities' resources on innovation capability and performance. Model fit indicators of Model 1A and 1B can be found below. All fitted the recommended thresholds.

Table 23.

Model fit indicators for models 1A and 1B

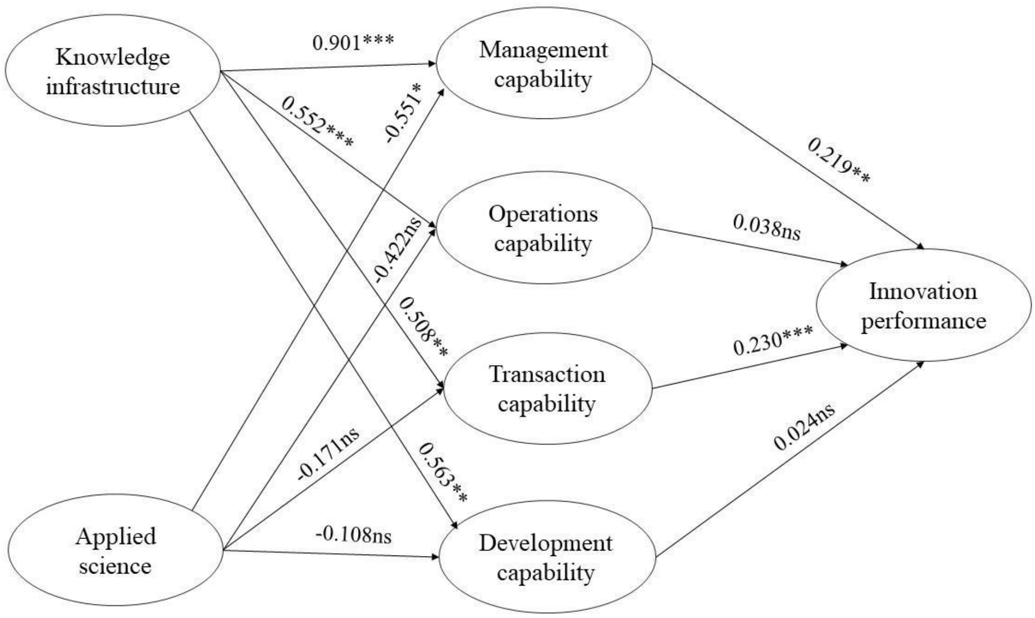
Indicators	Model 1A	Model 1B	Thresholds
p – significance	***	***	< 0.01
CMIN/DF	1.860	1.815	< 5.0
RMSEA - root mean squared error of approximation	0.072	0.070	< 0.08
CFI - comparative fit index	0.884	0.892	> 0.8
IFI (incremented fit index)	0.895	0.902	> 0.8
TLI - tucker-Lewis coefficient	0.800	0.811	> 0.8

Source: elaborated by the author

Results of Model 1A are shown in Table 24 and Figure 3, U-I collaboration based on *knowledge infrastructure* positively impacts all capabilities in model 1A. The positive impact of the factor *knowledge infrastructure* is quite expected, as it allows the company to access resources required for product and process development (Puffal et al., 2021). In contrast, U-I collaboration based on *applied science* showed a negative on firms` management capability and presented no significant influence on management, development and transaction capabilities.

Transactions and management capabilities showed a positive effect on innovation performance, but not operations and development capabilities.

Figure 3.
University resources and firm innovation capabilities (Model 1A)



Source: elaborated by the author

Table 24.

University resources and firm innovation capabilities[16] (Model 1A)

	MC	OC	TC	DC	INOV
U-I collaboration factors					
Knowledge infrastructure	0.901*** (0.232)	0.552** (0.186)	0.508** (0.254)	0.563** (0.191)	
Applied science	-0.551* (0.138)	-0.422 (0.117)	-0.171 (0.157)	-0.108 (0.116)	
Innovation capabilities					
MC	-	-	-	-	0.400 0.281)
TC	-	-	-	-	0.182(0.121)
OC	-	-	-	-	0.062(0.184)
DC	-	-	-	-	0.025(0.169)
Control variables					
Size	0.162 (0.053)	0.061 (0.049)	0.171 (0.067)	0.228* (0.050)	
R&D investment	0.136 (0.045)	0.191 (0.042)	0.063 (0.058)	0.099 (0.043)	
COVID_PeD	0.127 (0.038)	0.060 (0.035)	-0.049 (0.049)	0.056 (0.036)	
Sectoral technology intensity	-0.045 (0.034)	-0.037 (0.031)	0.040 (0.043)	0.104 (0.032)	
R&D department	-0.086 (0.116)	0.008 (0.102)	0.100 (0.141)	-0.05 (0.105)	
Research_group	-0.193* (0.066)	0.032 (0.063)	-0.020 (0.088)	-0.003 (0.065)	

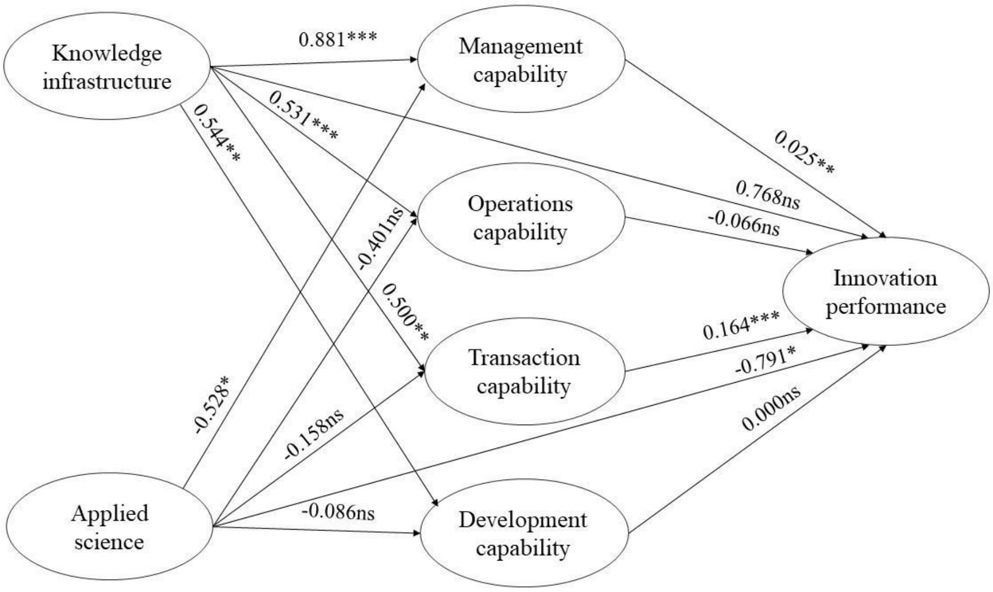
Source: elaborated by the author

What can be understood from the results of Models 1A and 1B? Considering that the sample was composed exclusively of the firms engaged in U-I collaboration, it is concluded that there is evidence that *applied science* resources are less beneficial for the firms than collaborations based on the use of the university's *knowledge infrastructure* in case of all capabilities, and, in turn, firms' innovation capability.

Figure 4.

[16] `*` refers to significance under 5%, `**` - under 1% and `***` - under 0,1%

University resources, innovation capabilities and firm innovation performance (Model 1B)



Source: elaborated by the author

Table 25.

University resources, innovation capabilities and firm innovation performance (Model 1B)

	MC	OC	TC	DC	INOV
U-I collaboration factors					
Knowledge infrastructure	0.881*** (0.221)	0.531** (0.117)	0.500** (0.244)	0.544** (0.182)	0.768 (0.799)
Applied science	-0.528* (0.13)	-0.401 (0.110)	-0.158 (0.149)	-0.086 (0.109)	-0.791* (0.392)
Innovation capabilities					
MC	-	-	-	-	0.025
TC	-	-	-	-	0.164
OC	-	-	-	-	-0.066
DC	-	-	-	-	0.000
Control variables					

Size	0.161 (0.052)	0.059 (0.048)	0.17 (0.067)	0.223* (0.049)	0.228 (0.134)
R&D investment	0.132 (0-.044)	0.188 (0.041)	0.062 (0.058)	0.096 (0.042)	0.306 (0.102)
COVID_R&D	0.123 (0.037)	0.056 (0.035)	-0.051 (0.049)	0.053 (0.036)	0.332* (0.085)
Sectoral technology intensity	-0.048 (0.033)	-0.04 (0.031)	0.038 (0.043)	0.100 (0.031)	0.060 (0.070)
R&D department	-0.078 (0.112)	0.017 (0.099)	0.103 (0.138)	0.002 (0.102)	-0.280 (0.257)
Research_group	-0.195* (0.065)	0.032 (0.062)	-0.021 (0.087)	-0.004 (0.064)	0.021 (0.139)

Source: elaborated by the author

What can be concluded from the results of Models 1A and 1B? Considering that the sample was composed exclusively of the firms engaged in U-I collaboration, it is concluded that there is evidence that *applied science* resources are less beneficial for the firms than collaborations based on the use of university's *knowledge infrastructure* in case of all capabilities, and, in turn, firm' innovation capability.

What is the possible explanation for these results? For instance, some previous studies conducted in Brazil showed that most technological output of the universities are outdated, and, for instance in the recent past it could take more than 10 years to register a patent in Brazil (Dalmarco et al., 2018). Also, some authors have been pointing out that academia in Brazil, despite its huge importance for the training of human resources, had its research focus in the field of science, having little correspondence with the needs of the productive sector (Costa et al. 2007). It can be also hypothesized that while the firms may need to develop it innovation capability to transform the use of knowledge infrastructure into viable products and processes, sourcing "ready" applied science outcomes do not require engaging in active R&D activities, as these activities were performed by the university alone. In fact, the patenting activities analysis provided by INPI[17] (2022) suggested that most patents developed in Brazil were created by the universities without participation of commercial firms.

Overall, from Models 1A and 1B it is suggested that once collaborative wants to improve its innovation capability, it should focus on the use of resources based on

[17] INPI (Instituto Nacional de Propriedade Intelectual), in English – National Institute of Intelectual Property is a Brazilian bureau encharged of registering intelectual property activities.

knowledge infrastructure rather than *applied science*. Still, further investigation with a qualitative approach is required to learn more about abovementioned results.

The analysis of the impact of capabilities which compose the firm's innovation capability suggests that in both Model 1A and Model 1B management and transaction capabilities impacts positively and significantly on the firm's innovation performance. In general, this finding is in line with previous studies on innovation capability (Alves et al., 2016; Reichert et al., 2016; Ruffoni et al., 2022).

To deepen the understanding of impacts of university resources on innovation performance, analysis of indirect effect was performed. As shown at Table 26, neither factor knowledge infrastructure nor applied science has significant indirect impact on innovation performance. However, the results shown at previous table (Table 25) suggest that to achieve superior innovation performance it is preferable to use *of knowledge infrastructure* rather than *applied science*.

Table 26.

Influence of university resources on innovation performance - indirect effects (Model 1B)

Factor	Path coeficient	Two-tailed significance
Knowledge infrastructure	0.096	0.546
Applied science	-0.007	0.524

Source: elaborated by the author

To deepen the understanding of the impact of universities' resources on innovation capability and performance, it was run a multiple linear regression model to check whether individual university resources impact on innovation capabilities. Table 27 shows that two out of three university knowledge infrastructure resources present positive and significant effects on firm' management capability while use of *new instruments and equipment* is non-significant. These results suggest that within resources based on *knowledge infrastructure,* the use of *research results* and *laboratories and physical infrastructure* are preferable over the use of *new instruments and equipment*.

Table 27.

Impact of use of university resources on firm management capability

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig	Collinearity Statistics

Model	B	Std. Error	Beta	t	Sig	Tolerance	VIF
(Constant)	3,378	,258		13,089	,000		
NPD_Pes	,117	,035	,276	3,314	,001	,723	1,383
NPD_Instr_Equip	-,038	,045	-,069	-,846	,399	,747	1,339
NPD_Tecn_Proces	,067	,042	,132	1,613	,109	,746	1,341
NPD_Materiais	,064	,041	,135	1,549	,123	,661	1,512
NPD_Designs	-,034	,037	-,083	-,902	,368	,598	1,671
NPD_Prototip	-,038	,036	-,104	-1,056	,293	,519	1,925
NPD_Laborat	,108	,041	,201	2,623	,010	,857	1,167

Source: elaborated by the author

In the case of firm' transactions capability (Table 28), the situation is similar to the results shown at Table 27. Two out of three university *knowledge infrastructure* resources present positive and significant effects on firm' management capability. These results suggest that in the case of transaction capability within resources based on *knowledge infrastructure,* the use of *research results* and *laboratories and physical infrastructure* are preferable over the use of *new instruments and equipment*.

Table 28.

Impact of use of university resources on firm transaction capability

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig**	**Collinearity Statistics**	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*
(Constant)	2,366	,398		5,939	,000		
NPD_Pes	,150	,054	,234	2,752	,007	,723	1,383
NPD_Instr_Equip	,102	,070	,122	1,462	,146	,747	1,339
NPD_Tecn_Proces	-,041	,065	-,052	-,628	,531	,746	1,341
				-	,307	,661	1,512
NPD_Materiais	-,065	,064	-,091	1,024			

NPD_Designs	,113	,058	,183	1,960	,052	,598	1,671
NPD_Prototip	-,022	,056	-,038	-,384	,702	,519	1,925
NPD_Laborat	,145	,064	,178	2,278	,024	,857	1,167

Source: elaborated by the author

Table 29 shows that none out of eight resources present significant impact on operations capability. Hence, it is not possible to suggest which university resources are most benefic in terms of a firm's operations capability.

Table 29.

Impact of use of university resources on firm operations capability

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig**	***Collinearity Statistics***	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*
(Constant)	3,718	,286		12,984	,000		
NPD_Pes	,018	,039	,042	,467	,641	,723	1,383
NPD_Instr_Equip	,021	,050	,038	,427	,670	,747	1,339
NPD_Tecn_Proces	,072	,046	,138	1,549	,123	,746	1,341
NPD_Materiais	,015	,046	,030	,318	,751	,661	1,512
NPD_Designs	-,033	,041	-,080	-,800	,425	,598	1,671
NPD_Prototip	-,002	,040	-,006	-,057	,955	,519	1,925
NPD_Laborat	,079	,046	,145	1,738	,084	,857	1,167

Source: elaborated by the author

Table 30 shows that only use of *new instruments and equipment* present positive and significant impact on firm' development capability. These results make sense as having access to proper instruments and equipment is considered important to be able to, for instance, perform R&D activities.

Table 30.

Impact of use of university resources on firm development capability

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig**	**Collinearity Statistics**	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*

(Constant)	2,877	,299		9,618	,000		
NPD_Pes	-,001	,041	-,003	-,032	,975	,723	1,383
NPD_Instr_Equip	,145	,053	,228	2,762	,006	,747	1,339
NPD_Tecn_Proces	-,015	,048	-,025	-,307	,759	,746	1,341
NPD_Materiais	,023	,048	,043	,487	,627	,661	1,512
NPD_Designs	,042	,043	,089	,969	,334	,598	1,671
NPD_Prototip	,068	,042	,160	1,622	,107	,519	1,925
NPD_Laborat	,056	,048	,091	1,176	,241	,857	1,167

Source: elaborated by the author

Overall, the results showed in Models 1A, 1B, and all four multiple regressions suggest that while factor use of *knowledge infrastructure* resources showed a positive impact on all firms' capabilities, the individual channels impacted on no more than 2 different capabilities (*research results*, *instruments and equipment*, *laboratories and physical infrastructure*). Therefore, it is possible to hypothesize that the intense use of a given set of multiple university resources (measured by factors) is more benefic for the firm than the intense use of an isolated university type of resource (measured by observed variables).

As shown in Table 31, the resource of *research results* is the only university resource to show the positive impact on the innovation performance of manufacturing firms that collaborated with universities. Hence, there is evidence that this resource is the best one for improving collaborative firms' innovation performance.

Table 31.

Impact of intensity of use of university resources on firm innovation performance

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig**	**Collinearity Statistics**	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*
(Constant)	2,693	,555		4,850	,000		
NPD_Pes	,173	,084	,185	2,064	,041	,705	1,419
NPD_Instr_Equip	,005	,108	,004	,048	,961	,725	1,379

NPD_Tecn_Proces	,047	,099	,042	,473	,637	,736	1,359
NPD_Materiais	,103	,097	,098	1,063	,289	,666	1,502
NPD_Designs	-,090	,088	-,100	-1,023	,308	,599	1,670
NPD_Prototip	-,153	,085	-,187	-1,787	,076	,520	1,923
NPD_Laborat	,073	,096	,067	,759	,449	,738	1,356

Source: elaborated by the author

Here it is important to add that even reading of even accessing the *research results* does not require the most intense interpersonal communications between firm employees and university researchers, it still allows the firm to absorb the valuable knowledge in the field it needs from reliable knowledge source.

5.2.2 U-I collaboration channels, innovation capability and innovation performance

To deepen that understanding of the impacts of the use of U-I collaboration for conducting innovation activities on firms' innovation capability and performance, two SEM models were used (Table 31). The first SEM (2A) checked the impact of U-I collaboration on innovation capabilities and of those innovation performance. The second SEM (2B) analyzed the same relationships plus the influence of U-I collaboration on innovation performance. The purpose of running two instead of one SEM was to double-check the significance of identified statistical relationships. In addition, five multiple regression models (2c, 2d, 2e, 2f, 2g) were run to deepen the understanding of the impacts of the use of universities' resources on innovation capability and performance. Model fit indicators of Model 2A and 2B can be found below. All fitted the recommended thresholds.

Table 32.

Model Fit indicators for Models 2A and 2B

Indicators	Model 2A	Model 2B	Thresholds
p – significance	***	***	< 0.01
CMIN/DF	1.740	1.761	< 5.0

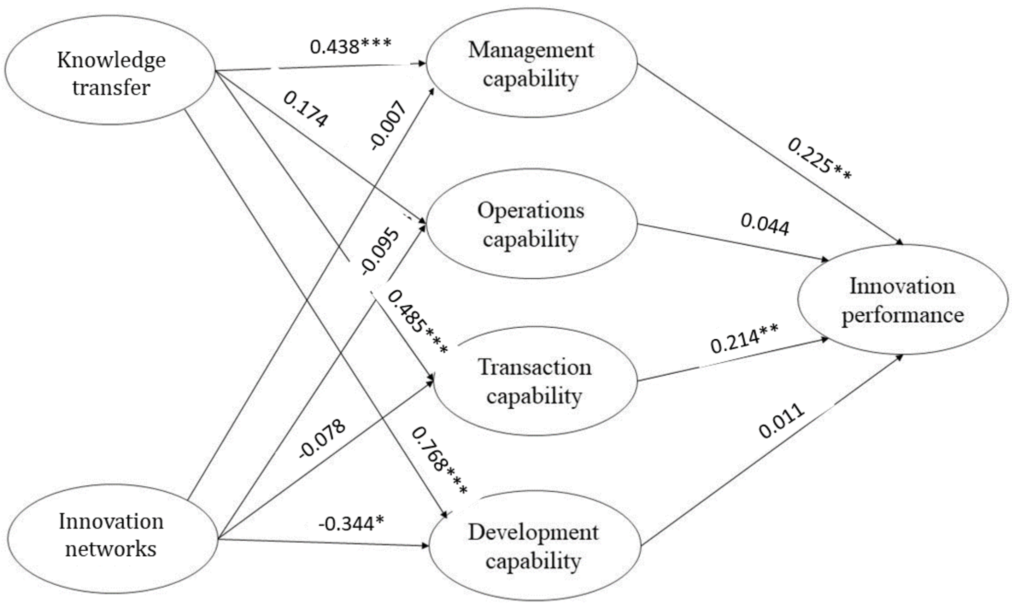
RMSEA - root mean squared error of approximation	0.067	0.068	< 0.08
CFI - comparative fit index	0.895	0.893	> 0.8
IFI (incremented fit index)	0.901	0.900	> 0.8
TLI - tucker-Lewis coefficient	0.848	0.844	> 0.8

Source: elaborated by the author

Results of Model 2A are shown in Table 33 and Figure 5. U-I collaboration channel based on *knowledge transfer* showed a positive impact on all capabilities except for operations capability. The positive impact of the factor *knowledge transfer* is quite expected, as it allows the company to access resources required for innovation activities (Puffal et al., 2021). In contrast, U-I collaboration channels based on *innovation networks* did not show a positive effect at any capability.

Transactions and management capabilities showed a positive effect on innovation performance, but not operations and development capabilities.

Figure 5.
U-I collaboration channels and firm innovation capabilities (Model 2A)
Source: elaborated by the author



Source: elaborated by the author

Table 33.

U-I collaboration channels and firm innovation capabilities[18] (Model 2A)

	MC	OC	TC	DC	INOV

[18] `*` refers to significance under 5%, `**` - under 1% and `***` - under 0,1%

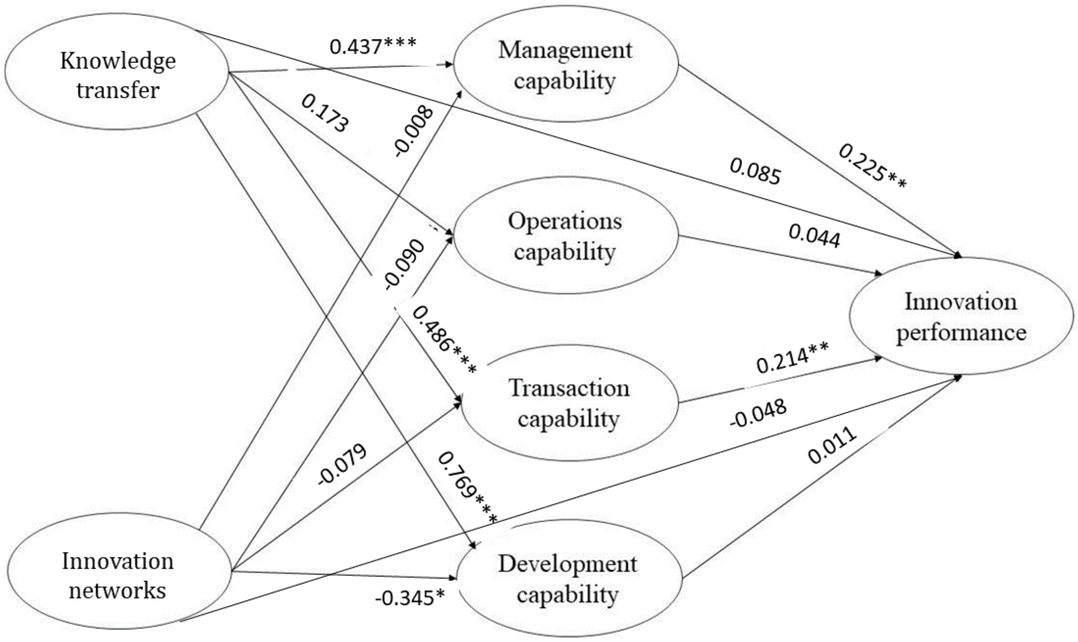
U-I collaboration factors					
Knowledge transfer	0.438***(0.123)	0.174(0.118)	0.485*** (0.193)	0.768*** (0.172)	
Innovation networks	-0.007 (0.085)	-0.095 (0.090)	-0.078 (0.131)	-0.344* (0.105)	
Innovation capabilities					
MC	-	-	-	-	0.225** (0.150)
TC	-	-	-	-	0.214** (0.099)
OC	-	-	-	-	0.044(0.139)
DC	-	-	-	-	0.011(0.133)
Control variables					
Log10_Size	0.083(0.046)	-.0.025(0.044)	0.069(0.067)	0.085(0.049)	-0.018(0.085)
Log10_Age	-0.017(0.107)	-0.07(0.113)	0.054(0.164)	0.027(0.119)	0.074(0.204)
R&D intensity	0.043(0.035)	0.164(0.037)	0.059(0.053)	0.086(0.039)	0.166(0.069)
Covid_R&D	-0.046(0.029)	-0.070(0.030)	-0.115(0.044)	0.022(0.032)	0.161(0.054)
Research_group	-0.073(0.078)	0.052(0.082)	0.150(0.120)	0.350(0.091)	0.058(0.107)

Source: elaborated by the author

The results of Model 2B are shown in Figure 6 and Table 34. They are the same as Model 2A in terms of the significance and directions of the influence of both factors on firms' capabilities and firms' capabilities on innovation performance. It means that while *knowledge transfer* showed a positive effect on firms' innovation capabilities except for operations capability, the effect of *innovation networks* was not positive at any of the four capabilities. Neither *knowledge transfer* nor *innovation networks* showed a significant effect on innovation performance.

Figure 6.

U-I collaboration channels, innovation capabilities and innovation performance (Model 2B)



Source: elaborated by the author

Table 34.

U-I collaboration channels, innovation capabilities and innovation performance (Model 2B)

	MC	OC	TC	DC	INOV
U-I collaboration factors					
Knowledge transfer	0.437*** (0.123)	0.173 (0.118)	0.486*** (0.193)	0.769*** (0.172)	0.085(0.36)
Innovation networks	-0.008 (0.085)	-0.090 (0.090)	-0.079 (0.131)	-0.345* (0.105)	-0.048(0.191)
Innovation capabilities					
MC	-	-	-	-	0.225*(0.166)
TC	-	-	-	-	0.214*(0.109)
OC	-	-	-	-	0.044(0.143)
DC	-	-	-	-	0.011(0.188)
Control variables					
Log10_Size	0.083(0.046)	-.0.025(0.044)	0.069(0.067)	0.085(0.049)	-0.018(0.085)
Log10_Age	-0.017(0.107)	-0.07(0.113)	0.054(0.164)	0.027(0.119)	0.075(0.208)
R&D intensity	0.043(0.035)	0.164(0.037)	0.059(0.053)	0.087(0.039)	

	-				0.170(0.069)
Covid_R&D	0.046(0.029)	-0.070(0.030)	-0.115(0.044)	0.022(0.032)	0.158(0.057)
Research_group	-0.073(0.078)	0.052(0.082)	0.150(0.120)	0.350(0.091)	0.095(0.179)

Source: elaborated by the author

What can be understood from the results of Models 2A and 2B? Considering that the sample was composed exclusively of the firms engaged in U-I collaboration, it is concluded that in terms of innovation capability improvement, there is evidence that the use of U-I collaboration channels based on *knowledge transfer* resources are more beneficial for the firms than those based on *innovation networks*. Specifically, the use of channels based on *knowledge transfer* are more beneficial for the firms than those based on *innovation networks* in terms of management, transactions and development capabilities. In the case of operations capability, it is not possible to conclude, as neither factor showed significant influence.

What is the possible explanation for these results? For instance, the possible reason of the superior benefits of the factor *knowledge transfer* in comparison with *innovation networks* is that the absorbed of new valuable knowledge allows the firm to improve its internal processes and in turn innovation capabilities. In contrast, the participation in *innovation networks* may not necessarily lead to formal transfer of knowledge. For instance, that can be the case of the use of channels such as *outsourced R&D* and *taking part of networks which involves universities*. Previously, Garcia et al. (2012) and Wu et al. (2015) found that the outsourced R&D may not be so benefic for the firms' innovation than other type of interactions.

As shown at Table 35 the factor *knowledge transfer* do have indirect effect on innovation performance. It means that even the *knowledge transfer* impact directly only at innovation capability and not innovation performance, it is still able to impact innovation performance having innovation capability as mediator. Also, the results of Model 2B suggests that in terms of improvement of its innovation performance through innovation capability increase, it should use collaboration channels based on *knowledge transfer* rather than on *innovation networks*.

Table 35.

Influence of U-I collaboration channels on innovation performance – indirect effect (model 2B)

	Path coeficient	Two-tailed significance
Knowledge transfer	0.115	0.021
Innovation networks	0.450	0.908

Source: elaborated by the author

The superior effect of knowledge transfer channels over innovation network channels for innovation performance may reside in the acquisition and assimilation of acquired knowledge, which are crucial for innovation (Zahra & George, 2002). The fact that the firm takes part in innovation networks and engages in informal communication with the university's researchers does not necessarily imply into the formal acquisition of advanced knowledge (Apa et al., 2021; Garcia-de-Perez-Lema et al., 2013). In contrast, once the firm hires university graduates or acquires licensed technology, it may incorporate the knowledge which it considers important for innovation activities directly into the firm's routines and processes. Still, further investigation with a qualitative approach is required to learn more about the above-mentioned results.

To deepen the knowledge of the impacts of the use of U-I collaboration channels on firm innovation capability and performance provided by SEM 2A and 2B, additionally, it was run multiple linear regressions, comprising models 2c, 2d, 2e, 2f and 2g to check for impacts of the use of individual collaboration channels. Table 36 shows that only one out of four *knowledge transfer* channels (*technology licensing*) presented positive and significant impact on firm' management capability. Similarly, one out of six different *innovation networks*' collaboration channels (*spinoff*) present negative and significant effect on the previously cited capability.

From this result, it is possible to suggest that once the firm uses a collaboration channel based on the of *knowledge transfer* to improve its management capability, it should pay particular attention on the channel *technology licensing*. Here, it is important to remember that the results of Models 2A and 2B showed that use of channels based on the use of channels based on *knowledge transfer* are more benefic for collaborative firms that those based on *innovation networks*. Thus, results shown by model 2c supports those of models 2A and 2B.

Table 36.

Impact of U-I collaboration channels on firm management capability (model 2c)

Model	**Unstandardized Coefficients**	**Standardized Coefficients**	**t**	**Sig**	**Collinearity Statistics**

	B	Std. Error	Beta	t	Sig	Tolerance	VIF
(Constant)	3,504	,219		16,001	,000		
Uni_Canal_TecLic	,112	,046	,226	2,440	,016	,608	1,645
Uni_Canal_Pat	,017	,025	,055	,683	,496	,791	1,264
Uni_Canal_Consul	,025	,036	,059	,711	,478	,747	1,338
Uni_Canal_Trein	,081	,050	,152	1,638	,104	,603	1,658
Uni_Canal_Recrut	,003	,040	,006	,069	,945	,682	1,467
Uni_Canal_Pub	-,021	,036	-,051	-,584	,560	,678	1,474
Uni_Canal_Pes_encom	-,026	,033	-,077	-,788	,432	,543	1,842
Uni_Canal_Pes_conj	,038	,042	,111	,905	,367	,346	2,889
Uni_Canal_Rede	,031	,042	,083	,730	,466	,406	2,465
Uni_Canal_Intercam	,036	,031	,106	1,181	,239	,652	1,533
Uni_Canal_Spinoff	-,072	,032	-,206	-2,266	,025	,630	1,588

Source: elaborated by the author

Table 37 shows that one out of ten different collaboration channels (*publications and reports*) present a significant impact on firm' transactions capability. From this result, it is possible to suggest that once the firm uses a collaboration channel based on the *knowledge transfer* to improve its transactions capability, it should pay particular attention on the channel *publication and reports*.

Here, it is important to remember that the results of Models 2A and 2B showed that use of channels based on *knowledge transfer* are more benefic for collaborative firms that those based on *innovation networks*. Thus, results shown by model 2d supports those one of models 2A and 2B.

Table 37.

Impact of U-I collaboration channels on transaction capability (model 2d)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	Collinearity Statistics	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*
(Constant)	2,653	,332		7,991	,000		
Uni_Canal_TecLic	,053	,070	,070	,759	,449	,608	1,645
Uni_Canal_Pat	-,021	,038	-,045	-,548	,585	,791	1,264

Uni_Canal_Consul	,005	,054	,007	,089	,929	,747	1,338
Uni_Canal_Trein	,036	,075	,045	,484	,629	,603	1,658
Uni_Canal_Recrut	-,010	,061	-,014	-,162	,872	,682	1,467
Uni_Canal_Pub	,195	,054	,317	3,607	,000	,678	1,474
Uni_Canal_Pes_encom	,028	,050	,055	,557	,579	,543	1,842
Uni_Canal_Pes_conj	,064	,064	,124	1,010	,314	,346	2,889
Uni_Canal_Rede	-,096	,064	-,170	-1,497	,136	,406	2,465
Uni_Canal_Intercam	,012	,046	,024	,264	,792	,652	1,533
Uni_Canal_Spinoff	,067	,048	,127	1,391	,166	,630	1,588

Source: elaborated by the author

Table 38 shows that two out of ten different collaboration channels (*training, taking part of university's networks*) present a significant and positive impact on firm' transactions capability. In contrast, channels *spinoff* and *technology licensing* present negative and significant effect on firms' operations capability. Hence, it is possible to suggest once again that to improve operations capability it is preferable to use U-I collaboration channels of *training*, *technology licensing*, and *taking part of university's network* rather than *spinoffs and technology licensing*.

Table 38.

Impact of U-I collaboration channels on firm operations capability (model 2e)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	Collinearity Statistics	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*
(Constant)	3,961	,223		17,749	,000		
Uni_Canal_TecLic	-,089	,047	-,176	-1,895	,060	,608	1,645
Uni_Canal_Pat	,001	,025	,002	,030	,976	,791	1,264
Uni_Canal_Consul	,049	,036	,112	1,337	,183	,747	1,338
Uni_Canal_Trein	,177	,051	,327	3,507	,001	,603	1,658
Uni_Canal_Recrut	-,073	,041	-,156	-1,776	,078	,682	1,467
Uni_Canal_Pub	-,029	,036	-,070	-,800	,425	,678	1,474
Uni_Canal_Pes_encom	,012	,034	,034	,343	,732	,543	1,842
Uni_Canal_Pes_conj	-,020	,043	-,058	-,472	,638	,346	2,889
Uni_Canal_Rede	,137	,043	,361	3,182	,002	,406	2,465

Uni_Canal_Intercam	,014	,031	,039	,437	,662	,652	1,533
Uni_Canal_Spinoff	-,069	0,32	-,196	-2,147	,033	,630	1,588

Source: elaborated by the author

Table 39 shows the impacts of the use of collaboration channels on firm development capability. If using Cronbach Alpha of 10% as a threshold, *technology licensing* and *publication and reports* are the only channels that showed positive and significant effect on firm' development capability. Hence, it is possible to suggest that to improve development capability it is preferable to use *technology licensing* and *publication and reports* over other collaboration channels.

Here, it is important to remember that the results of Models 2A and 2B showed that use of channels based on the use of *knowledge transfer* are more benefic for collaborative firms that those based on *innovation networks*. Thus, results shown by model 2f supports those one of models 2A and 2B.

Table 39.

Impact of U-I collaboration channels on firm development capability (model 2f)

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig**	**Collinearity Statistics**	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*
(Constant)	2,762	,240		11,508	,000		
Uni_Canal_TecLic	,100	,050	,175	1,981	,049	,608	1,645
Uni_Canal_Pat	,019	,027	,055	,705	,482	,791	1,264
Uni_Canal_Consul	,037	,039	,075	,943	,347	,747	1,338
Uni_Canal_Trein	,090	,054	,147	1,659	,099	,603	1,658
Uni_Canal_Recrut	,009	,044	,018	,213	,831	,682	1,467
Uni_Canal_Pub	,076	,039	,163	1,948	,053	,678	1,474
Uni_Canal_Pes_encom	-,038	,036	-,097	-1,043	,298	,543	1,842
Uni_Canal_Pes_conj	-,063	,046	-,160	-1,366	,174	,346	2,889
Uni_Canal_Rede	,068	,046	,158	1,464	,145	,406	2,465
Uni_Canal_Intercam	,040	,034	,100	1,178	,241	,652	1,533

Uni_Canal_Spinoff	,043	,035	,106	1,226	,222	,630	1,588

Source: elaborated by the author

Overall, according to regression results at least one of the firm's capabilities were positively impacted by the following U-I channels related to knowledge transfer: technology licensing (2 out of 4 capabilities), publication and reports (2 out of 4 capabilities), training (1 out of 4 capabilities). Here, it is important to add that while factor *knowledge transfer* showed positive impact on 3 out of 4 firm' capabilities, none of collaboration channels present the positive impact on same number of firm capabilities. Also, channels *patents* and *HR recruitment* did not show positive impact at any of firm' capabilities. Therefore, it is possible to hypothesize that the intense use of a given set of collaboration channels is more benefic for the firm than the intense use of an isolated channels.

Concerning the influence of the use of U-I collaboration channels based on innovation networks on the firm capabilities, only *technology licensing*, *spinoff* and *taking part of networks which involve university* showed significant influence on firm capabilities. Particularly channels of technology licensing, and *spinoffs* was the only channel which showed negative influence on firm' operations capabilities.

The channels *taking part of network which involve university* presented positive impact on firm operations capability. Hence, considering that the all analyzed firms used U-I collaboration channels, it is possible to conclude that once the firm need to choose only one collaboration channels for innovation capability improvement it is preferable to use channel *taking part of networks which involve university*.

As shown in Table 40, the channel *publications and reports* are the only ones to show the positive impact on the innovation performance of manufacturing firms that collaborated with universities. Hence, there is evidence that this channel is the most benefic for improving firm innovation performance. Here it is important to add that *publication and reports* are not necessarily the channel that involves the most intense interpersonal communications between firm employees and university researchers, it still allows the firm to access the valuable knowledge in the field it needs to and from reliable sources.

Table 40.

Impact of U-I collaboration channels on firm innovation performance (model 2g)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig	Collinearity Statistics	
	B	*Std. Error*	*Beta*			*Tolerance*	*VIF*
(Constant)	2,399	,506		4,741	,000		
Uni_Canal_TecLic	-,001	,106	-,001	-,009	,992	,608	1,645
Uni_Canal_Pat	-,017	,058	-,026	-,301	,764	,791	1,264
Uni_Canal_Consul	,125	,082	,133	1,524	,129	,747	1,338
Uni_Canal_Trein	-,119	,115	-,101	- 1,043	,299	,603	1,658
Uni_Canal_Recrut	,099	,093	,097	1,061	,291	,682	1,467
Uni_Canal_Pub	,214	,082	,239	2,599	,010	,678	1,474
Uni_Canal_Pes_encom	-,030	,077	-,040	-,391	,696	,543	1,842
Uni_Canal_Pes_conj	,005	,097	,006	,049	,961	,346	2,889
Uni_Canal_Rede	,068	,098	,082	,694	,489	,406	2,465
Uni_Canal_Intercam	-,032	,071	-,042	-,445	,657	,652	1,533
Uni_Canal_Spinoff	,043	,073	,057	,593	,554	,630	1,588

Source: elaborated by the author

5.3 Results summary

Table 41 shows the summary of the results based on SEM and multiple regression models.

Table 41.

Summary of the dissertation's finding

Benefit	Most benefic sets of resources and channels (factors)	Most benefic resources and channels
Management Capability	Knowledge infrastructure resources	Resources: research results, laboratories and physical infrastructure.
	Knowledge transfer channels	Channel: technology licensing
Transactions capability	Knowledge infrastructure resources	Resources: research results, laboratories and physical infrastructure, new designs.

	Knowledge transfer channels	Channel: publication and reports
Operations capability	Knowledge infrastructure resources	Resources: not identified
	Channels were not identified	Channels: technology licensing, training, taking part of university's networks
Development capability	Knowledge infrastructure resources	Resource: instruments and equipment
	Knowledge transfer channels	Channels: technology licensing, publications and reports,
Innovation performance	Knowledge infrastructure resources	Resource: research results
	Knowledge transfer channels	Channel: publications and reports

Source: elaborated by the author

Overall, the obtained results from SEM Models 1A, 1B and multiple regression models suggest that the university resource based on the *knowledge infrastructure* is the one the firm should pursue to improve innovation capability and performance. Specifically, the use of knowledge infrastructure is more benefic for all four firms' capabilities (management, transactions, operations, and development) than the use of *applied science* resources.

Concerning the isolated influence of each university resource, *research results* and *laboratories and physical infrastructure* showed to be the most benefic university resources for management and transactions capabilities. In turn, *new instruments and equipment* is the most benefic resource type for development capability.

The obtained results make sense as the *knowledge infrastructure* offers crucial resources for the firm to have tools for experiencing innovation development. In contrast, using *applied science* resources which may not require the firms' active commitment and so does not encourage the firm to create a capability that will be required for developing innovation on its own. Here, it is important to stress that many of the technologies developed by Brazilian universities, and not only Brazilian, were developed without market focus (Zawislak & Dalmarco, 2011). In this context, it may not be interesting for the firm to work on transforming the *applied science* resources into viable products. In turn, this may reflect on firms' innovation performance, as the results showed that the use of *knowledge infrastructure* resources showed to be more benefic for the firm than the *applied science* resources.

When analyzing the difference between U-I collaboration channels, it was found that the results of SEM Models 2A, 2B and multiple regression models suggest that the use of the *knowledge transfer* collaboration channels is more benefic for the firm innovation capability and performance than that of taking part in *innovation networks*. Specifically, the use of *knowledge transfer* collaboration channels is more benefic for firms' management, transactions, and development capabilities than the use of *innovation networks*.

Concerning the isolated influence of each channel, the results suggest that *technology licensing* is among the most benefic U-I collaboration channels for firms' management, operations and development capabilities. In turn, *publication and reports* is also among the most benefic channels for firms' transaction capability. *Taking part in university networks* and *training* are among the most benefic channels for operations capability. *Publication and reports* is one of the two most benefic channels for a firm's development capability. This finding also makes sense, as not necessary the use of *innovation networks* leads to the acquisition of assimilation and the use of the acquired knowledge.

Also, it is possible to suppose that when the firm uses *knowledge transfer* U-I collaborations channels, it aims more to apply the acquired knowledge to its innovation activities than in the case of taking part in *innovation networks*. Or also, then the knowledge flows in a more structured way in the case of *knowledge transfer* channels rather than *innovation networks*. Still, in-depth qualitative studies are required to unveil the reasons for these differences in benefits.

The results of the present dissertation showed that while *knowledge transfer* is the most benefic U-I collaboration channel, the *knowledge infrastructure* is the most benefic set of university resources for firms' innovation capability and performance. Hence, the term "knowledge" seems to be the most important aspect of U-I collaboration, particularly the knowledge flows.

5. FINAL REMARKS

The present dissertation explored the outcomes of different U-I collaborations for the firms using as evaluation tools the measurement of the use of university resources and collaboration channels. The study has exploratory nature, so the results presented below should be further explored by future studies. Still, the conclusions described below are supported by the obtained quantitative evidence.

The results of structural equation modelling suggested that use of resources base on *knowledge infrastructure* is more benefic for the firms' innovation capability and performance than of resources based on *applied science*. Also, it was found evidence that use of U-I collaboration channels based on *knowledge transfer* is more benefic for the firms' innovation capability and performance than of channels based on *innovation networks*. Hence, it is suggested that to improve its innovation capability and performance, firms should use U-I collaboration channels based on *knowledge transfer* and university' resources based on *knowledge infrastructure*.

The results of multiple regression models allowed to obtain detailed information about the impacts of specific interaction channels used for conduction innovation activities and university resources used for new product and process creation on innovation capability and performance. Thus, it was found that not all *knowledge infrastructure'* resources and *knowledge transfer* U-I collaboration channels are equally benefic for capabilities development and performance.

For instance, *research results* and *laboratories and physical infrastructure* represent the most benefic *knowledge infrastructure*' resources for firms' management and transactions capabilities. *Research results* also represent the most benefic university' resource for firm's innovation capability. In turn, *instruments and equipment* is the most benefic resource for the firm's development capability.

Channels of *technology licensing*, *publication and reports* are the most benefic for firm' management and transactions capabilities respectively. In turn, training is the most benefic U-I collaboration channels for operations capability. Technology licensing and publication and reports are also the most benefic interaction channels for development capability. Likewise, in terms of innovation performance the best knowledge transfer collaboration channel is *publication and reports*.

The theoretical contribution of the present dissertation is two-fold. First, the study extends the understanding of the benefits obtained by the firms through engaging U-I collaboration by adding innovation capabilities into the model and also by differentiating between university resources used for product and process development and U-I collaboration channels applied for firm' innovation activities. The second contribution refers to deepening the knowledge about the options a firm has to build its innovation capabilities.

The present study presents some limitations. First, the original database (DGP-CNPq 2016) does not cover all U-I collaborations in Brazil, as it is filled only by the leaders of the research groups but not by the firm managers (Mikhailov et al., 2022). For instance, any university researcher that interacted with the firms may have decided not to declare this in the database. Likewise, cooperation with the university does not necessarily involve research groups. It may involve contacting through a technological and business incubator, and science parks (Puffal et al., 2021). Still, this limitation is common to most empirical investigations of the effects of U-I collaboration (Arant et al., 2019; Baba et al., 2009; Bishop et al., 2012).

The second limitation refers to the fact that it is not possible to guarantee that the applied U-I collaboration typologies and innovation capability measurement instrument do not affect the study's results. It is important to add that previous studies created many different typologies of U-I collaboration (Schaeffer et al., 2017. In this case, it can be hard for research scholars to choose between such a vast range of typologies. Also, this limitation occurs due to the differences in data available through U-I collaboration and innovation survey databases collected in different countries through different questionnaires (Baba et al., 2009; Schaeffer et al., 2017). The same can be said about the innovation capability model applied in the present dissertation. The field of studies of innovation capability is still young, so different studies use different measurement scales and also the current empirical literature does not allow the researcher to compare the nomothetical or quantitative validity of different measurement instruments.

Finally, we stress that U-I collaboration in external environmental contexts, such as market competition, technological turbulence and institutional context varies from one country to the other, so the results of the present study cannot be generalized to other economies, as each country has it idiosyncratic contextual characteristics.

There are many opportunities to deepen the investigations of the impacts of U-I collaboration. First, it is suggested to deepen the investigation on the impact of U-I collaboration channels on firm innovation capabilities and performance. As the results showed that not all types of channels are equally beneficial for the firms, investigating why it happens would be an opportunity. Here, the use of an in-depth case study would represent an interesting opportunity.

In the present study, the researcher did not analyze how the acquired university resources are being applied to innovation activities. So, it is suggested for future studies investigate which firm's internal routines are the most impacted by the use of university resources and collaboration channels. Both case study and survey would be suitable methods to answer the above-mentioned questions.

Also, how does collaboration motivation influence the firm's capabilities and performance? And what about the impacts of the university's mission and academic productivity? Does the profile of a university scientist relate to the U-I collaboration impacts the firm? Which firm's routines are the most impacted?

The benefits obtained by the firms from U-I collaboration are subjected by moderation of actor's and environmental characteristics. The environmental characteristics include factors such as market competition, technological turbulence, and institutional features (Kafouros et al., 2015; Min et al., 2019; Shi et al., 2020; Yang et al., 2021). Hence, it is suggested to investigate how and how much abovementioned factors affect the benefits obtained by the firms from collaboration with universities.

Results of previous empirical studies (Hou et al., 2019) provided support to the hypothesis that universities and research institutes differ in their ability to provide resources and benefits to the collaborative firms. Thus, it is suggested to conduct studies comparing the possible differences in effects of abovementioned institutions on firm performance and capabilities.

To analyze impacts of U-I collaboration in, for instance, service-based firms and agricultural companies also would be interesting, as this companies may differ from the manufacturing firms in terms of the nature of their capabilities (Leo et al., 2022). Finally, we suggest conducting cross-country study to check the potential influence of institutional and market-related factors on the benefits obtained by the firms from U-I collaboration. We hope that the current study will enhance even more the interest of researchers in investigating the U-I collaboration effect on manufacturing firm innovation in emerging countries. This is particularly important considering that over half of the world's manufacturing production comes from these countries.

REFERENCES

Abbate, T., Cesaroni, F., & Presenza, A. Knowledge transfer from universities to low- and medium-technology industries: evidence from Italian winemakers. *The Journal of Technology Transfer*, 1-28.

Abdulai, A. F., Murphy, L., & Thomas, B. (2019). University knowledge transfer and innovation performance in firms: the Ghanaian experience. *International Journal of Innovation Management*, *24*(03), 2050023.

Ahrweiler, P., Pyka, A., & Gilbert, N. (2011). A new model for university-industry links in knowledge-based economies. *Journal of Product Innovation Management*, *28*(2), 218-235.

Alves, A. C., Fischer, B. B., & Vonortas, N. S. (2021). Ecosystems of entrepreneurship: configurations and critical dimensions. *The Annals of Regional Science*, 1-34.

Apa, R., De Marchi, V., Grandinetti, R., & Sedita, S. R. University-SME collaboration and innovation performance: the role of informal relationships and absorptive capacity. *The Journal of Technology Transfer*, 1-28.

Arant, W., Fornahl, D., Grashof, N., Hesse, K., & Söllner, C. (2019). University-industry collaborations—The key to radical innovations?. *Review of Regional Research*, *39*(2), 119-141.

Arvanitis, S., Sydow, N., & Woerter, M. (2008). Do specific forms of university-industry knowledge transfer have different impacts on the performance of private enterprises? An empirical analysis based on Swiss firm data. *The Journal of Technology Transfer*, *33*(5), 504-533.

Arza, V. (2010). Channels, benefits and risks of public—private interactions for knowledge transfer: conceptual framework inspired by Latin America. *Science and Public Policy*, *37*(7), 473-484.

Audretsch, D. B., & Lehmann, E. E. (2006). Do locational spillovers pay? Empirical evidence from German IPO data. *Economics of Innovation and New Technology*, *15*(1), 71-81.

Baba, Y., Shichijo, N., & Sedita, S. R. (2009). How do collaborations with universities affect firms' innovative performance? The role of "Pasteur scientists" in the advanced materials field. *Research Policy*, *38*(5), 756-764.

Belderbos, R., Carree, M., & Lokshin, B. (2004). Cooperative R&D and firm performance. *Research policy*, *33*(10), 1477-1492.

Bell, M., & Pavitt, K. (1995). The development of technological capabilities. *Trade, technology and international competitiveness*, *22*(4831), 69-101.

Bishop, K., D'Este, P., & Neely, A. (2011). Gaining from relations with universities: Multiple methods for nurturing absorptive capacity. *Research Policy*, *40*(1), 30-40.

Boyle, K. A. (1986). Technology transfer between universities and the UK offshore industry. *IEEE Transactions on Engineering Management*, (1), 33-42.

Bramwell, A., & Wolfe, D. A. (2008). Universities and regional economic development: The entrepreneurial University of Waterloo. *Research policy*, *37*(8), 1175-1187.

Balconies, M.; Brusoni, S. e Orsengo, L. Indefence of the linear model: an essay. Working Paper n. 216, *Research Center on Innovation and Internationalization Processes – Business University Luigi Bocconi*. Milan, 2008.

Barbieux, D. E. N. I. S. E., Zawislak, P. A., Padula, A. D., & Camboim, G. F. (2015). Disclosing the development capabilities of the firm. In 24th International Association for Management of Technology IAMOT Conference Proceedings: Technology, Innovation and Management for Sustainable Growth (pp. 2109-2130). Elsevier-Journal of Business Research The Westin Cape Town, South Africa.

Bonaccorsi, Andrea; Piccaluga, Andrea. A theoretical framework for the evaluation of university-industry relationships. *R&D Management*, v. 24, n. 3, p. 229-247, 1994.

Bruneel, Johan; D'este, Pablo; Salter, Ammon. Investigating the factors that diminish the barriers to university–industry collaboration. *Research policy*, v. 39, n. 7, p. 858-868, 2010.

Bush, V. (1945). Science the endless frontier: a report to the President by Vannevar Bush. *Director of the Office of Scientific Research and Development, United States Government Printing Office, Washington*.

Caliari, T., & Chiarini, T. (2018). Analysis of scientific research groups with greater productive applicability in Brazil: capacities and interactions with firms. *Apuntes. Revista de ciencias sociales*, *45*(82), 71-98.

Castela, B. M., Ferreira, F. A., Ferreira, J. J., & Marques, C. S. (2018). Assessing the innovation capability of small-and medium-sized enterprises using a non-parametric and integrative approach. *Management Decision*.

Chen, Jin; Wei, Shiyang. University–industry collaboration, knowledge management and enterprise innovation performance: An empirical study. *Industry and Higher Education*, v. 22, n. 5, p. 275-287, 2008.

Churchill Jr, G. A. (1979). A paradigm for developing better measures of marketing constructs. *Journal of marketing research*, *16*(1), 64-73.

Coase, R. H. (1991). The nature of the firm (1937). *The Nature of the Firm. Origins, Evolution, and Development. New York, Oxford*, *18*, 33.

Cunha, N. C. V., & Fracasso, E. M. (1999). University-enterprise interaction in biotechnology in the south of Brazil. *Journal of Knowledge Management*. Vol. 3 No. 1, pp. 66-74.

Dalmarco, Gustavo; Hulsink, Willem; Blois, Guilherme V. Creating entrepreneurial universities in an emerging economy: Evidence from Brazil. *Technological Forecasting and Social Change*, v. 135, p. 99-111, 2018.

D'este, Pablo; Patel, Pari. University–industry linkages in the UK: What are the factors underlying the variety of relations with industry?. *Research policy*, v. 36, n. 9, p. 1295-1313, 2007.

De Fuentes, C., & Dutrénit, G. (2012). Best channels of academia–industry relation for long-term benefit. *Research Policy*, *41*(9), 1666-1682.

Dezi, L., Santoro, G., Monge, F., & Zhao, Y. (2018). Assessing the impact and antecedents of university scientific research on firms' innovation commercialisation. *International Journal of Technology Management*, *78*(1-2), 88-106.

Dodgson, M., Gann, D. M., & Phillips, N. (2014). *Perspectives on innovation management* (pp. 3-25). Oxford, UK: Oxford University Press.

Ebersberger, B., Bloch, C., Herstad, S. J., & Van De Velde, E. L. S. (2012). Open innovation practices and their effect on innovation performance. *International Journal of Innovation and Technology Management*, *9*(06), 1250040.

Eom, B. Y., & Lee, K. (2010). Determinants of industry–academy linkages and, their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. *Research Policy*, *39*(5), 625-639.

Etzkowitz, H., & Zhou, C. (2018). *The triple helix: University–industry–government innovation and entrepreneurship*. Routledge.

Etzkowitz, H. (2017). Innovation Lodestar: The entrepreneurial university in a stellar knowledge firmament. *Technological Forecasting and Social Change*, *123*, 122-129.

Etzkowitz, H., Ranga, M., Benner, M., Guaranys, L., Maculan, A. M., & Kneller, R. (2008). Pathways to the entrepreneurial university: towards a global convergence. *Science and Public Policy*, *35*(9), 681-695.

Etzkowitz, Henry. The evolution of the entrepreneurial university. International Journal of Technology and Globalisation, v.1, n. 1, p. 64-77, 2004

Etzkowitz, H. (2003). Research groups as 'quasi-firms': the invention of the entrepreneurial university. *Research policy*, *32*(1), 109-121.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research policy*, *29*(2), 109-123.

Etzkowitz, H., & Leydesdorff, L. (1998). The endless transition: a" triple helix" of university-industry-government relations: Introduction. *Minerva*, 203-208.

Etzkowitz, H. (1983). Entrepreneurial scientists and entrepreneurial universities in American academic science. *Minerva*, *21*(2-3), 198-233.

Fiss, P. C. (2011). Building better causal theories: A fuzzy set approach to typologies in organization research. *Academy of management journal*, *54*(2), 393-420.

Fiss, P. C. (2007). A set-theoretic approach to organizational configurations. *Academy of management review*, *32*(4), 1180-1198.

Fitjar, R. D., & Rodríguez-Pose, A. (2013). Firm collaboration and modes of innovation in Norway. *Research policy*, *42*(1), 128-138.

Francis, D., & Bessant, J. (2005). Targeting innovation and implications for capability development. *Technovation*, *25*(3), 171-183.

Freel, M. S., & Harrison, R. T. (2006). Innovation and cooperation in the small firm sector: Evidence from 'Northern Britain'. *Regional Studies*, *40*(4), 289-305.

Fu, X., & Li, J. (2016). Collaboration with foreign universities for innovation: evidence from Chinese manufacturing firms. *International Journal of Technology Management*, *70*(2-3), 193-217.

Fudickar, R., & Hottenrott, H. (2019). Public research and the innovation performance of new technology based firms. *The Journal of Technology Transfer*, *44*(2), 326-358.

Fukugawa, N. (2013). University spillovers into small technology-based firms: Channel, mechanism, and geography. *The Journal of Technology Transfer*, *38*(4), 415-431.

Garcia-Perez-de-Lema, D., Madrid-Guijarro, A., & Martin, D. P. (2017). Influence of university–firm governance on SMEs innovation and performance levels. *Technological forecasting and social change*, *123*, 250-261.

Geisler, E., Furino, A., & Kiresuk, T. J. (1991). Toward a conceptual model of cooperative research: Patterns of development and success in university-industry alliances. *IEEE Transactions on Engineering Management*, *38*(2), 136-145.

Giannopoulou, E., Barlatier, P. J., & Pénin, J. (2019). Same but different? Research and technology organizations, universities and the innovation activities of firms. *Research Policy*, *48*(1), 223-233.

Gluck, M. E., Blumenthal, D., & Stoto, M. A. (1987). University-industry relationships in the life sciences: Implications for students and post-doctoral fellows. *Research policy*, *16*(6), 327-336.

Goldhor, R. S., & Lund, R. T. (1983). University-to-industry advanced technology transfer: a case study. *Research Policy*, *12*(3), 121-152.

González-Moreno, A.; Triguero, A. and Sáez-Martinez, F.J. (2019). Many or trusted partners for eco-innovation? The influence of breadth and depth of firms knowledge network in the food sector. Technological Forecasting and Social Change, 147, 51-62

Grimpe, C., & Hussinger, K. (2013). Formal and informal knowledge and technology transfer from academia to industry: Complementarity effects and innovation performance. *Industry and innovation*, *20*(8), 683-700.

Guan, J., & Ma, N. (2003). Innovative capability and export performance of Chinese firms. *Technovation*, *23*(9), 737-747.

Guan, J. C., Yam, R. C., & Mok, C. K. (2005). Collaboration between industry and research institutes/universities on industrial innovation in Beijing, China. *Technology Analysis & Strategic Management*, *17*(3), 339-353.

Guzzini, E., & Iacobucci, D. (2017). Project failures and innovation performance in university–firm collaborations. *The Journal of Technology Transfer*, *42*(4), 865-883.

Gulbrandsen, Magnus; Smeby, Jens-Christian. Industry funding and university professors' research performance. *Research policy*, v. 34, n. 6, p. 932-950, 2005.

Hagedoorn, J., & Cloodt, M. (2003). Measuring innovative performance: is there an advantage in using multiple indicators?. *Research policy*, *32*(8), 1365-1379.

Hair, J. F., Black, W.C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2009). *Multivariate data*analysis. Bookman editor.

Helfat, C. E. (1997). Know-how and asset complementarity and dynamic capability accumulation: the case of R&D. *Strategic management journal*, *18*(5), 339-360.

Ho, J., Plewa, C., & Lu, V. N. (2016). Examining strategic orientation complementarity using multiple regression analysis and fuzzy set QCA. Journal of Business Research, 69(6), 2199-2205.

Hoveskog, M. (2011). Innovation-related Activities in a Low-tech Industry: A Study of the Electroplating and Surface Treatment Industry in Sweden.

Hu, X., Tang, Y., & Motohashi, K. (2020). Varied university-industry knowledge transfer channels and product innovation performance in Guangdong manufacturing firms. *Knowledge Management Research & Practice*, 1-11.

Hulsink, W., Dons, H., Lans, T., & Blok, V. (2014). Boosting entrepreneurship education within the knowledge network of the Dutch agri-food sciences: the new 'Wageningen" approach. In *Handbook on the Entrepreneurial University*. Edward Elgar Publishing.

Inauen, M., & Schenker-Wicki, A. (2011). The impact of outside-in open innovation on innovation performance. *European Journal of Innovation Management*.

Janssen, M. J., Castaldi, C., & Alexiev, A. (2016). Dynamic capabilities for service innovation: conceptualization and measurement. *R&D Management*, *46*(4), 797-811.

Jordan, D., & O'Leary, E. (2011). The role of external relation for innovation in Irish high-technology businesses. *The International Journal of Entrepreneurship and Innovation*, *12*(4), 248-256.

Kafouros, M., Wang, C., Piperopoulos, P., & Zhang, M. (2015). Academic collaborations and firm innovation performance in China: The role of region-specific institutions. *Research Policy*, *44*(3), 803-817.

Kang, K. H., & Kang, J. (2010). Does partner type matter in R&D collaboration for product innovation?. *Technology Analysis & Strategic Management*, *22*(8), 945-959.

Kastelli, I., Tsakanikas, A., & Caloghirou, Y. (2018). Technology transfer as a mechanism for dynamic transformation in the food sector. The Journal of Technology Transfer, 43(4), 882-900.

Kimatu, J. N. (2016). Evolution of strategic interactions from the triple to quad helix innovation models for sustainable development in the era of globalization. *Journal of Innovation and Entrepreneurship*, *5*(1), 1-7.

Kobarg, S., Stumpf-Wollersheim, J., & Welpe, I. M. (2018). University-industry collaborations and product innovation performance: The moderating effects of absorptive capacity and innovation competencies. *The Journal of Technology Transfer*, *43*(6), 1696-1724.

Ladeira, W. J. (2010). Três décadas do modelo de Churchill: utilização da análise fatorial e do alfa de Cronbach na validação de instrumentos de coleta de dados no marketing. *pmkt Ciência*, *5*, 40-48.

Lall, S. (1992). Technological capabilities and industrialization. *World development*, *20*(2), 165-186.

Larsen, J. K., & Wigand, R. T. (1987). Industry-university technology transfer in microelectronics. *Review of Policy Research*, *6*(3), 584-595.

Lee, Ryeowon, Jong-Ho Lee, and Tony C. Garrett. "Synergy effects of innovation on firm performance." *Journal of Business Research* 99 (2019): 507-515.

Lee, C., Lee, K., & Pennings, J. M. (2001). Internal capabilities, external networks, and performance: a study on technology-based ventures. *Strategic management journal*, *22*(6-7), 615-640.

Lee, Yong S.' Technology transfer'and the research university: a search for the boundaries of university-industry collaboration. *Research policy,* v. 25, n. 6, p. 843-863, 1996.

Leo, R. M., Camboim, G. F., Avila, A. M. S., Reichert, F. M., & Zawislak, P. A. (2022). Innovation capabilities in agribusiness: evidence from Brazil. RAUSP Management Journal, 57, 65-83.

Leonard-Barton, D. (1992). Core capabilities and core rigidities: A paradox in managing new product development. *Strategic management journal*, *13*(S1), 111-125.

Li, X., Li, J., & Wu, X. (2020). University spillovers, spatial distance, and firm innovation: Evidence at Chinese listed firms. *Emerging Markets Finance and Trade*, *56*(7), 1504-1519.

Lin, J. Y. (2019). How does collaboration between universities and R&D firms influence performance?. *Management Decision*.

Leydesdorff, Loet. The triple helix: an evolutionary model of innovations. *Research policy*, v. 29, n. 2, p. 243-255, 2000.

Mansfield, E. (1991). Academic research and industrial innovation. *Research policy*, *20*(1), 1-12.

Mansfield, E. (1998). Academic research and industrial innovation: An update of empirical findings. *Research policy*, *26*(7-8), 773-776.

McAdam, M., & McAdam, R. (2006). The networked incubator: The role and operation of entrepreneurial networking with the university science park incubator (USI). *The International Journal of Entrepreneurship and Innovation*, *7*(2), 87-97.

Metcalfe, J. S. Equilbrium and evolutionary foundations of competition and technology policy: new perspectives on the division of labour and the innovation process. *Revista Brasileira de Inovação*, 2(1), 111-146, 2003.

Meyer-Krahmer, Frieder; Schmoch, Ulrich. Science-based technologies: university–industry relations in four fields. *Research policy*, v. 27, n. 8, p. 835-851, 1998.

Mikhailov A., & Puffal, D. P (2020). Análise dos tipos de interações universidade-empresa no setor industrial brasileiro. XLIV Encontro Nacional da Associação de Pós-Graduação e Pesquisa em Administração, 14th Oct – 16th.

Mikhailov, A., Puffal, D., & Santini, M. (2020). University-Industry Relations and Industrial Innovation: Evidence from Brazil. *Journal of Technology Management & Innovation*, *15*(3), 6-16.

Mikhailov, A., Puffal, D. (2020). Analysis of the types of University-Company relations in the industrial sector. In: XXIII Semead - Seminars in Administration. Porto Alegre

Mowery, David C.; Sampat, Bhaven N. The Bayh-Dole Act of 1980 and university–industry technology transfer: a model for other OECD governments*?. The Journal of Technology Transfer*, v. 30, n. 1-2, p. 115-127, 2004.

MacKenzie, N. G., & Zhang, Q. (2014). A regional perspective on the entrepreneurial university: Practices and policies. In *Handbook on the entrepreneurial university*. Edward Elgar Publishing.

Meyer-Krahmer, Frieder, and Ulrich Schmoch. "Science-based technologies: university–industry interactions in four fields." *Research policy* 27, no. 8 (1998): 835-851.

Nelson, R. (1991). Why do firms differ, and how does it matter? *Strategic Management Journal*, 12, 61-74, 1991.

Nelson, R. R., & Winter, S. G. (1982). The Schumpeterian tradeoff revisited. *The American Economic Review*, *72*(1), 114-132.

Nieto, M. J., & Santamaría, L. (2007). The importance of diverse collaborative networks for the novelty of product innovation. *Technovation*, *27*(6-7), 367-377.

Nishimura, J., & Okamuro, H. (2011). R&D productivity and the organization of cluster policy: An empirical evaluation of the Industrial Cluster Project in Japan. *The Journal of Technology Transfer*, *36*(2), 117-144.

O'Connor, M., Doran, J., & McCarthy, N. (2020). Cognitive proximity and innovation performance: are collaborators equal?. *European Journal of Innovation Management*.

OECD ISIC, R. (2011). Technology intensity definition. *Classification of manufacturing industries into categories based on R&D intensities. Eurostat*.

OECD/Statistical Office for the European Communities, Luxembourg (2005), Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition. The measurement of Scientific and Technological Activities, OECD Publishing.

Oliveira, C. A. O., Ruffoni, E. P., Maçada, A. C. G., & Padula, Â. D. (2019). Innovation capabilities in the food processing industry in Brazil. *British Food Journal*.

O'Shea, R. P., Allen, T. J., Morse, K. P., O'Gorman, C., & Roche, F. (2007). Delineating the anatomy of an entrepreneurial university: the Massachusetts Institute of Technology experience. *R&d Management*, *37*(1), 1-16.

Ostermann, C. M., da Silva Nascimento, L., Lopes, C. M. C. F., Camboim, G. F., & Zawislak, P. A. (2021). Innovation capabilities for sustainability: a comparison between Green and Gray companies. *European Journal of Innovation Management*.

Ragin, C. C. (2014). *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies*. University of California Press.

Ragin, C. C. (2009). *Redesigning social inquiry: Fuzzy sets and beyond*. University of Chicago Press.

Ratchukool, N., & Igel, B. (2018). The effect of proximity between universities and research institutes and firms on firm innovativeness. *Asian journal of technology innovation*, *26*(1), 69-89.

Ratten, V. (2017). Entrepreneurial universities: the role of communities, people and places. *Journal of Enterprising Communities: People and Places in the Global Economy*.

Reihlen, M., & Wenzlaff, F. (2014). Institutional change in the German higher education system: From professional dominance to managed education. In *Handbook on the entrepreneurial university*. Edward Elgar Publishing.

Reynolds, E. B., & Uygun, Y. (2018). Strengthening advanced manufacturing innovation ecosystems: The case of Massachusetts. *Technological Forecasting and Social Change*, *136*, 178-191.

Robin, S., & Schubert, T. (2013). Cooperation with public research institutions and success in innovation: Evidence from France and Germany. *Research policy*, *42*(1), 149-166.

Ruffoni, E. P., D'Andrea, F. A. M. C., Chaves, J. K., Zawislak, P. A., & Tello-Gamarra, J. (2018). R&D investment and the arrangement of innovation capabilities in Brazilian manufacturing firms. *Journal of technology management & innovation*, *13*(4), 74-83.

Santini, M. A. F., Faccin, K., Balestrin, A., & Martins, B. V. (2021). How the relational structure of universities influences research and development results. *Journal of Business Research*, *125*, 155-163.

Santoro, M. D. (2000). Success breeds success: The linkage between relationship intensity and tangible outcomes in industry–university collaborative ventures. *The journal of high technology management research*, *11*(2), 255-273.

Santos, J. N., Mota, J., & Baptista, C. S. (2018). Understanding configurations of value creation functions in business relationships using a fuzzy-set QCA. *Journal of Business Research*, *89*, 429-434.

Scandura, A. (2016). University–industry collaboration and firms' R&D effort. *Research Policy*, *45*(9), 1907-1922.

Schaeffer, P. R., Dullius, A. C., Rodrigues, R. M., & Zawislak, P. A. (2017). Searching to bridge the gaps: a new typology of university-industry relation. *Academia Revista Latinoamericana de Administración*.

Schaeffer, P. R., Ruffoni, J., & Puffal, D. (2015). Razões, benefícios e dificuldades da interação universidade-empresa. *Revista brasileira de inovação*, *14*(1), 105-134.

Schumpeter, J. (1942). Creative destruction. *Capitalism, socialism and democracy*, *825*, 82-85.

Soh, P. H., & Subramanian, A. M. (2014). When do firms benefit from university–industry R&D collaborations? The implications of firm R&D focus on scientific research and technological recombination. *Journal of Business Venturing*, *29*(6), 807-821.

Suzuki, S. (2017). International University–Industry Linkage: Impact on Firm Technological Performance. *Millennial Asia*, *8*(1), 48-63.

Tang, Y., Motohashi, K., Hu, X., & Montoro-Sanchez, A. (2020). University-industry relation and product innovation performance of Guangdong manufacturing firms: The roles of regional proximity and research quality of universities. *The Journal of Technology Transfer*, *45*(2), 578-618.

Perkmann, Markus; Walsh, Kathryn. University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews*, v. 9, n. 4, p. 259-280, 2007.

Puffal, D. (2014). Effects of university-industry relation on firm's innovation: Empirical evidence from Brazilian firms. *Revista Ibero-Americana de Estratégia-RIAE*, *13*(1).

Reichert, F. M., Zawislak, P. A., & Arundel, A. (2016). Exploring innovation success recipes in low-technology firms using fuzzy-set QCA. *Journal of Business Research*, *69*(11), 5437-5441.

Rey-Martí, A., Porcar, A. T., & Mas-Tur, A. (2015). Linking female entrepreneurs' motivation to business survival. *Journal of business research*, *68*(4), 810-814.

Richardson, G. B. (1972). The organisation of industry. *The economic journal*, *82*(327), 883-896.

Smith, K. Measuring Innovation. In: Fagerberg, J; Mowery, D.; Nelson, R. The Oxford Handbook of Innovation. Estados Unidos: Oxford, 2004, p.149-177

Tang, Y., Motohashi, K., Hu, X., & Montoro-Sanchez, A. (2020). University-industry relation and product innovation performance of Guangdong manufacturing firms: The roles of regional proximity and research quality of universities. The Journal of Technology Transfer, 45(2), 578-618.

Un, C. A., & Asakawa, K. (2015). Types of R&D collaborations and process innovation: The benefit of collaborating upstream in the knowledge chain. *Journal of Product Innovation Management*, *32*(1), 138-153.

Un, C. A., Cuervo-Cazurra, A., & Asakawa, K. (2010). R&D collaborations and product innovation. *Journal of Product Innovation Management*, *27*(5), 673-689.

Vega-Jurado, J., Kask, S., & Manjarrés-Henriquez, L. (2017). University industry links and product innovation: cooperate or contract?. *Journal of technology management & innovation*, *12*(3), 1-8.

Velez, C.I., Afcha, S.M., & Bustamante, M.A. (2019). University-company cooperation and its effect on innovative business performance. *Technological*information, *30*(1), 159-168.

Wang, Y., Huang, J., Chen, Y., Pan, X., & Chen, J. (2013). Have Chinese universities embraced their third mission? New insight from a business perspective. *Scientometrics*, *97*(2), 207-222.

Yang, C. C., Marlow, P. B., & Lu, C. S. (2009). Assessing resources, logistics service capabilities, innovation capabilities and the performance of container shipping services in Taiwan. *International Journal of Production Economics*, *122*(1), 4-20.

Yin, R. K. (2015). *Case Study-: Planning and* Methods. Bookman editor.

Van Weele, M., van Rijnsoever, F. J., & Nauta, F. (2017). You can't always get what you want: How entrepreneur's perceived resource needs affect the incubator's assertiveness. *Technovation*, *59*, 18-33.

Zawislak, P. A., Cherubini Alves, A., Tello-Gamarra, J., Barbieux, D., & Reichert, F. M. (2012). Innovation capability: From technology development to transaction capability. *Journal of technology management & innovation*, *7*(2), 14-27.

Zawislak, P. A., & Dalmarco, G. (2011). The silent run: new issues and outcomes for university-industry relations in Brazil. *Journal of technology management & innovation*, *6*(2), 66-82.

Further Reading

DGP-CNPq (2004, 2006, 2008, 2010, 2014, 2016), "Base de dados do Censo do Diretório de Grupos de Pesquisa no Brasil 2016", available at: http://lattes.cnpq.br/web/dgp/censos2 (accessed 9-13 June 2019).

DGP-CNPq (2021) "Base de dados do Censo do Diretório de Grupos de Pesquisa no Brasil – Como os dados são obtidos", available at: http://lattes.cnpq.br/web/dgp/como-os-dados-sao-obtidos (accessed 9-13 May 2021).

Garcia, R., Rapini, M., & Cário, S. (2018). Estudos de caso da interação universidade-empresa no Brasil. *Belo Horizonte: Face/UFMG*. The book is based on BR Survey data (2009).

Attachment 1 – structured questionnaire applied in Portuguese.

Breve descrição do projeto/Project description

Esta pesquisa deve ser respondida pelo gestor de cargo mais elevado na empresa, e que possua uma visão holística de toda a empresa. Também, pode ser respondida pelo gestor das atividades de P&D da empresa ou gestor encarregado pelo desenvolvimento de produtos e tecnologia. Pedimos que responda da melhor forma possível a partir do entendimento de sua unidade de trabalho e suas respectivas atividades.

I – Fontes da Inovação e Interação Universidade-Empresa / Innovation sources and U-I collaboration

1. Fontes externas da inovação na sua empresa são: (source: PINTEC (2014))

Fornecedores 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Clientes 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Concorrentes 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Universidades e institutos de pesquisa 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Governo 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Empresas de consultoria 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Participação em feiras e exposições 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Participação em conferências científicas 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Outras empresas do grupo 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Outros 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

2. Qual a importância dos seguintes canais de interação com as universidades e/ou institutos de pesquisa para as atividades inovativos na sua empresa, sendo 1 – nada importante e 5 – muito importante (source: BR Survey (2009) and PINTEC (2014)):
Tecnologia licenciada 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Patentes 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Consultoria com pesquisadores individuais 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Treinamentos 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Recrutamento de profissionais 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Publicações e relatórios 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Pesquisa encomendada à universidade 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Pesquisa realizada em conjunto com a universidade 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Participação em redes que envolvam universidades 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Intercâmbio temporário de pessoal 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

3. Abaixo há alguns recursos provenientes das Universidades e Institutos de pesquisa. Por favor, atribua a cada uma dessas fontes um valor de acordo com a sua importância para as atividades inovativas, sendo 1 – nada importante e 5 – muito importante (source: BR Survey (2009))

Resultados de pesquisas 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Instrumentos e equipamentos 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Técnicas ou processos 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Novos materiais 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Novos designs 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Protótipos 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Laboratórios e infraestrutura física 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Patentes 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

II - Capacidades da Inovação (source: Alves et al. (2017) and Reichert et al. 2016, both based on Zawislak's et al. (2012) model) / Innovation capability

1. GESTÃO – A sua empresa... / MANAGEMENT CAPABILITY
Indique o grau de concordância com as afirmativas abaixo, onde 1 significa - Discordo totalmente e 5 - Concordo totalmente.

Define formalmente seus objetivos estratégicos anualmente.
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Inclui a responsabilidade socioambiental na pauta estratégica.
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Integra todos seus setores com o uso de informática.
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Padroniza e documenta os diferentes procedimentos de trabalho.
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Atualiza suas técnicas e ferramentas de gestão.
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Mantém a capacitação de pessoal adequada para as diferentes funções da empresa (treinamento...)
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Utiliza práticas modernas de gestão financeira
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

2. COMERCIAL – A sua empresa... / TRANSACTIONS CAPABILITY
Indique o grau de concordância com as afirmativas abaixo, onde 1 significa - Discordo totalmente e 5 - Concordo totalmente.
Realiza pesquisas para medir a satisfação de seus clientes
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Realiza pesquisas formais para monitorar o mercado
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Impõe as condições de negociação com seus fornecedores
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Impõe seus preços no mercado
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Impõe as condições de negociação com seus clientes
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Utiliza critérios formais para a seleção de seus fornecedores
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

3. PRODUÇÃO – A sua empresa... / OPERATIONS CAPABILITY
Indique o grau de concordância com as afirmativas abaixo, onde 1 significa - Discordo totalmente e 5 - Concordo totalmente.
Formaliza os procedimentos de PCP
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Mantém controle estatístico do processo
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Utiliza equipamentos atualizados na fronteira da tecnologia no setor
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Mantém o nível de estoques de materiais adequado ao processo
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Realiza o processo produtivo conforme o programado
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Estabelece uma rotina produtiva que não gera retrabalho
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Entrega os produtos pontualmente
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Consegue expandir a capacidade instalada sempre que necessário
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Consegue garantir o processo para não ter devolução
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

4. DESENVOLVIMENTO – A sua empresa... / DEVELOPMENT CAPABILITY
Indique o grau de concordância com as afirmativas abaixo, onde 1 significa - Discordo totalmente e 5 - Concordo totalmente.
Realiza a concepção original dos seus próprios produtos
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Monitora as últimas tendências tecnológicas do setor
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Adapta as tecnologias em uso para as suas necessidades
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Desenvolve produtos em parcerias com ICTs
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Realiza a prototipagem de seus produtos
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Utiliza metodologias formais de gestão de projetos (Stage-Gate, PMBOK, Funil da Inovação, etc)
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Lança seus próprios produtos
1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

III – Impacto da Pandemia (elaborated by the author / COVID-19 pandemics impact
Atribua a pontuação de acordo com o impacto que a pandemia trouxe para a sua empresa, sendo -2 – muito negativo e +2 – muito positivo
Faturamento em 2020 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Lucro líquido em 2020 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Investimento em P&D em 2020 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

IV – Desempenho / Performance
As perguntas abaixo referem-se ao desempenho da empresa.

Entre 2018 e 2020, a empresa introduziu produto novo ou produto existente significativamente aperfeiçoado? (PINTEC 2014)
( ) sim ( ) não

Caso sim, assinale o grau de novidade do produto mais inovador lançado pela empresa (PINTEC 2014; Br Survey empresas)
- *( ) Aperfeiçoamento significativo do produto já existente*
- *( ) Produto novo para a empresa*
- *( ) Produto novo para o mercado nacional*
- *( ) Produto novo para o mercado mundial*

Entre 2018 e 2020, a empresa implementou processo novo ou aperfeiçoou significativamente processo já existente? (PINTEC 2014)
( ) sim ( ) não

Caso sim, assinale o grau de novidade do processo mais inovador implementado pela empresa (PINTEC 2014; BR Survey empresas)
- *( ) Aperfeiçoamento significativo do processo já existente*
- *( ) Processo novo para a empresa*
- *( ) Processo novo para o país*
- *( ) Processo novo para o mundo*

Nas questões a seguir, avalie como está a sua empresa em relação ao mercado em que atua. Indique o grau de concordância com as afirmativas abaixo, onde 1 significa - Discordo totalmente e 5 - Concordo totalmente. (Engelman et al., 2017)
Nos últimos 3 anos a empresa aumentou sua participação de mercado em relação aos concorrentes 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
O número de inovações, seja de produto ou processo, introduzidas pela empresa nos últimos 3 anos foi maior do que dos concorrentes 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )
Porcentagem de vendas da empresa obtidas a partir de novos produtos é maior do que dos concorrentes 1. ( ) 2. ( ) 3. ( ) 4. ( ) 5. ( )

V – Informações adicionais (PINTEC 2014; Reichert et al., 2016) / Additional information

Empresa possui departamento formal de Pesquisa e Desenvolvimento?
( ) sim ( ) não

Selecione a faixa da média de investimento em Pesquisa e Desenvolvimento no período entre 2018 e 2020:
( ) menos de 1%
( ) entre 1 e 2,5%
( ) entre 2,6% e 7%

( ) acima de 7%

Qual o faturamento médio da empresa em nos últimos 3 anos (2018-2020)? _______
Qual é a margem de lucro média da empresa nos últimos 3 anos (2018-2020)? _________
Qual foi o percentual médio do faturamento decorrente dos novos produtos lançados nos últimos 3 anos (2018-2020) _________

Você deseja receber os resultados da pesquisa por e-mail?
1. ( ) Não
2. ( ) Sim (todas as informações individuais serão estritamente confidenciais e usadas somente para o envio dos resultados)

Identificação/ Identification of the firm
Nome da empresa
CNPJ
Ano de Fundação
Número de funcionários
Cargo do entrevistado
Setor