


## UNIVERSITY INNOVATION ECOSYSTEMS AND INNOVATION CHANNELS: CONCEPTUAL FRAMEWORK AND VALIDATION

## ECOSSISTEMAS DE INOVAÇÃO UNIVERSITÁRIA E CANAIS DE INOVAÇÃO: ESTRUTURA CONCEITUAL E VALIDAÇÃO

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**Abstract:** Universities play a fundamental role in the economy and social development. In this role they use different channels for the inception of innovations in markets. It is still necessary a systematic view capable of identifying the existent innovation channels and their relationship with the university innovation ecosystem. Drawing upon the university-industry literature, this article outlines a conceptual framework about the university innovation channels, the main agents of university innovation ecosystems and their respective roles in the technology-transfer process. This framework is based on three layers: 1 – macro-context; 2 – micro-context; and 3 – internal-context. There are identified three types of innovation channels: 1 – university spin-offs; 2 – cooperation with external agents; and 3 – licensing of patents. This framework is validated by a qualitative approach through visits and interviews with nine agents (4 spin-offs; 1 technology center; 2 science parks; and 2 business incubators) of three different university innovation ecosystems in Brazil. This article contributes to the theory presenting an integrative perspective about the agents of university innovation ecosystems, explaining how they contribute to the university innovation channels insert innovations in markets. For the practice this article can guide the assessment and planning of the improvement of university innovation ecosystems.

**Key-words:** University-industry. University spin-offs. Technology transfer. Innovation ecosystems. Knowledge transfer. Innovation channels. Licensing of patents. Innovation.

**Resumo:** As universidades desempenham um papel fundamental na economia e no desenvolvimento social. Nesse papel, elas usam diferentes canais para a introdução de inovações nos mercados. Ainda é necessária uma visão sistemática capaz de identificar os canais de inovação existentes e sua relação com o ecossistema de inovação universitária. Com base na literatura universidade-indústria, este artigo delinea uma estrutura conceitual sobre os canais de inovação universitária, os principais agentes dos ecossistemas de inovação universitária e seus respectivos papéis no processo de transferência de tecnologia. Essa estrutura se baseia em três camadas: 1 - macrocontexto; 2 - microcontexto; e 3 - contexto interno. Foram identificados três tipos de canais de inovação: 1 - spin-offs universitários; 2 - cooperação com agentes externos; e 3 - licenciamento de patentes. Essa estrutura é validada por uma abordagem qualitativa por meio de visitas e entrevistas com nove agentes (4 spin-offs; 1 centro tecnológico; 2 parques científicos; e 2 incubadoras de empresas) de três diferentes ecossistemas de inovação universitária no Brasil. Este artigo contribui para a teoria apresentando uma perspectiva integrativa sobre os agentes dos ecossistemas de inovação universitária, explicando como eles contribuem para que os canais de inovação universitária insiram inovações nos mercados. Para a prática, este artigo pode orientar a avaliação e o planejamento da melhoria dos ecossistemas universitários de inovação.

**Palavras-chave:** Universidade-indústria. Spin-offs universitários. Transferência de tecnologia. Ecossistemas de inovação. Transferência de conhecimento. Canais de inovação. Licenciamento de patentes. Inovação.

## 1 INTRODUCTION

Across the last decades, the role played by universities in society had been expanded beyond the limits of education and research, where they seek to contribute to the development of technological innovations (Lee and Miozzo, 2019). Technological innovation is materialized in the form of new goods, processes, and services (henceforth products) (Baregheh *et al.*, 2009; Drejer, 2004; Williamson *et al.*, 2020), and it is one of the critical drivers for the economic, environmental, and social development (Leibowicz, 2018; Pecorari and Lima, 2020; Rasmussen and Wright 2015; Sehnem *et al.*, 2021). One of the most developed theoretical branches of the research about the role of the university in generating innovation is the field that addresses university-industry relations (e.g., Guan and Zhao, 2013; Mascarenhas *et al.*, 2018; Viana *et al.*, 2018).

Even though a great number of studies had been made about several aspects of university-industry relation, most articles use quantitative methods, being scarce qualitative approaches that attempt to draw an overall picture of the university-industry ecosystem elements responsible for the introduction of innovation in markets. In this direction, it is important to highlight two main types of conceptual approaches. Firstly, those that conceptualize a specific aspect of the university-industry. For example, Rasmussen and Wright (2015), Audretsch *et al.* (2016), and Wright *et al.* (2017), outline conceptual models about the development of university spin-offs. The second type of conceptual approach is more recent and seek to encompass several aspects of university-industry relation in a comprehensive perspective. For example, there are recent articles that approach the relation between universities and external agents for innovation from a holistic perspective denominating these social and institutional settings as innovation ecosystems (Good *et al.*, 2019; Librelato and Lacerda, 2021; Mascarenhas *et al.*, 2018; Rybnicek and Königsgruber, 2019; Sehnem *et al.*, 2021).

Despite these recent efforts, there are still several shortcomings in the university-industry literature that difficult the formation of a general understanding of this topic. First, the absence of a systematic view of the agents and mechanisms used by universities to technology transfer to market agents. Second, the absence of a

holistic view of this topic, ranging from elements of the general environment until internal elements of the university, capable of form an overall picture of the types of innovation channels in the university ecosystem. Third, the extant studies normally are focused on the university ecosystem agents do not analyze how the ecosystem elements contribute to universities introduce technological innovations in markets.

Accounting to the above-presented gaps in this article, we outline a conceptual framework about the university innovation channels, the main agents of university ecosystems and their respective roles in the technology transfer process. This framework is based on three layers: 1 – macro-context; 2 – micro-context; 3 – internal-context, and four types of innovation channels: 1 – university spin-offs; 2 – cooperation with external agents in research projects; and 3 – licensing of patents. This framework is applied to analyze the use of these three channels in three university ecosystems and seems to be highly adherent to the practice.

In the following, this paper is comprehended by the method (Section 2); the presentation of the conceptual framework (Section 3); the presentation of the innovation channels used by universities to technology transfer to market agents (Section 4); the validation of the conceptual model through empirical studies in three university ecosystems (Section 5); and conclusion (Section 6).

## **2 THE METHOD**

The conceptual part of this research is based on the proposition of a framework of the university ecosystem and the types of university innovation channels. This framework was based on multiple stages of the literature review explained as following (see Figure 1).

To this, we performed four stages: 1 – in the Scopus database there were selected papers through their abstracts; 2 – reading the papers selected in the first phase, discarding those not related to the research proposal; 3 – Codification of the remaining papers selected prior step; 4 – Formation of a general framework and identification of the existent innovation channels of universities. Through the analysis and codification of 100 articles, it was possible to identify the existing innovation channels and better understand the university-industry ecosystem.

**Figure 1** – Phases of this study

<p><b>1- Search for articles in leading innovation journals</b></p> <ul style="list-style-type: none"> <li>• Database: Scopus;</li> <li>• Search carried out from the Scopus database: University innovation; <ul style="list-style-type: none"> <li>○ Keyword: Innovation;</li> <li>○ English language;</li> <li>○ Year: 2000 to 2019;</li> <li>○ Type of document: article.</li> </ul> </li> </ul>
<p><b>2- Selection and reading of articles</b></p> <ul style="list-style-type: none"> <li>• Selection of articles by reading their abstracts; <ul style="list-style-type: none"> <li>○ Result of the search carried out in the Scopus database: 3051 articles;</li> <li>○ Total number of selected articles: 135;</li> </ul> </li> <li>• Reading the articles; <ul style="list-style-type: none"> <li>○ Total number of articles analyzed: 100 articles;</li> </ul> </li> </ul>
<p><b>3- Coding/annotations of the analyzes articles</b></p> <ul style="list-style-type: none"> <li>• Annotations of each article with seven itens, namely: References; comments on the article; methodology; study object; keywords, codes, brief report on the relationship of the articles to the topic;</li> <li>• Panel with all references and their respective codes;</li> </ul>
<p><b>4- Indication of innovation channels and selection of coded articles for each innovation channel</b></p> <ul style="list-style-type: none"> <li>• Formation of a general panel with the identified channels and their respective articles, in view of step 3</li> </ul>

The deductive method was fundamental to compose the conceptual framework, where the researchers departed from the several terms extracted from the articles that were ordered in a multilevel and nuanced perspective through the initial codification and successive meetings.

## 2.1. Empirical Validation Study

As a form of validating the conceptual framework, we present an empirical study that approaches several innovations that emerged in the university context, with some different types of innovation agents of the university ecosystem. There are presented data from three universities ecosystems. According to Figure 2, there were gathering data from managers of four spin-offs and a technology center<sup>1</sup> in three different university ecosystems in Brazil. Through a qualitative approach the data were collected through interviews performed *in loco* in the innovation agents.

With the complementary and triangulation strategy, we also obtained data from two science parks and two business accelerators, according to Figure 3. Data were obtained through interviews with professionals of the managerial level of these agents. Interviews were based on a protocol of open-ended questions trying to identify the

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<sup>1</sup> we used fictitious names

relations of these agents with the university ecosystem. Interviews were recorded and coded through their issues in longitudinal tables, presenting a sketch of the responses of the interviewees.

**Figure 2** – The spin-off and other agents research in the universities' ecosystems.

<b>Achronim</b>	<b>Product – Innovation</b>	<b>Field</b>	<b>University</b>
Autom-Tec	Deploys systems to monitor and extract dynamic data for automobiles	Computing, automation	A
Inno-Management	A managerial spin-off that supports other spin-offs and agents in consulting innovation management activities	Management, industrial engineering	A
Tec-Center	Centre that intermediate relationship between the university and big firms in nanotechnology projects	Physics and chemical, and engineering	A
Educ-Games	Develops educative games and information systems for public administration	Information systems	B
Photo-Tecn	Develops technologies for several applications with phototherapy and materials	Physics and food engineering	C

**Figure 3** – Business incubators and Science Parks researched.

<b>Agent</b>	<b>Ecosystem</b>	<b>Foundation</b>
Business incubator 1	University A	University A
Business incubator 2	University C	University C
Science park 1	University A	Cooperation of government in several levels and University A
Science park 2	University B	University B and government funding

### 3. A conceptual framework of the university-industry ecosystem

Multilevel approaches about the university-industry relationship are important because they provide a generally high-level view that facilitates the visualization of the several existent agents in this context. For example, Wright *et al.* (2017) present a framework about the support elements for student startups, wherein the main levels can be subsumed in the university environment, support actors of the university context (e.g., investors, incubators, technological parks, etc.), and the external context formed mainly by governmental agencies. In a review paper, Mathisen and Rasmussen (2019) present a multilevel framework for evaluating the literature about the growth of university spin-offs based on the following levels, institutional and ecosystems, firm, individual, and team. In a recent study, Good *et al.* (2019) introduce a holistic view of

the technology transfer ecosystem in the university context that detailed how TTOs, science parks, business incubators, and funds contribute to the technology transfer from university to industry.

Inspired by these views, it is possible to analyze the university-industry relations in three levels, the macro-context, which comprehends the general economic, cultural, and social environment where the university is inserted; the micro-context, which is formed by the agents specifically related to the context of innovation of a university; and the internal context that comprehends the agents and actions performed in the interior of the university (see Figure 4). This perspective is detailed in the following subsections.

**Figure 4** – A multilayered perspective of university-industry innovation ecosystems

<b>Context</b>	<b>Agent</b>	<b>Roles</b>
<b>Macro</b>	Governmental	Create laws incentives, funding foments agencies, financial incentives, public policies)
<b>Micro</b>	Agencies	Support to R&D, cooperation, patenting
	Science parks, incubators, accelerators	Host and support university spin-offs
	Financial agents (public and private capital)	Afford spin-offs with capital through investments
	External - Big, middle, small, Internal spin-offs founded by faculty, students; or mixed	Introduce innovations through innovative products, services or processes
<b>Internal</b>	University (entrepreneurial versus academic)	Propagate the innovation culture, seek to cooperation with the external agents, applied research
	TTOs	Technology transfer activities, patenting, licensing
	Faculty, students, departments, laboratories, research projects, courses	R&D, cooperation with firms, spin-offs funding

### 3.1 Macro context of the university-industry innovation ecosystem

The university macro-context is normally positively benefitted by the capacity of the university in creating innovation (Rasmussen and Wright 2015; Chang, 2017; Hong *et al.*, 2019), contributing to the regional development (Autant-Bernard *et al.*, 2013; Hong *et al.*, 2019). From an instrumental perspective, technological innovation takes place in the form of innovative goods or services (Vial *et al.*, 2015 and Olmos, 2015; Hou *et al.*, 2019), and processes (Barra *et al.*, 2019; Datta *et al.*, 2019). As a result,

the generation of innovations in the context of university can create new employment for students and other professionals (Boh *et al.*, 2016; Wright *et al.*, 2017).

Even though the university has an important role in economic growth, it also suffers the effects of the actions of agents of its macro-context. Cultural aspects and innovation policies are important to the development of innovation (Santos *et al.* 2020). Another aspect is that government agents have considerable influence on the actions of universities as vectors of promotion of innovation, thanks to the structuration of an institutional setting that promotes innovative initiatives (Abbas *et al.*, 2019; Fischer and Moraes, 2019; Lanahan and Feldman, 2015). For example, Cunningham *et al.* (2019), in a study about the effects of changes in incentives laws for intellectual property and innovation directed to researchers, observed that the promotion of incentives positively affected the creation of academic spin-offs and technology transfer.

Another aspect of the role of governments in the foment of innovation in the context of universities is the promotion of public policies (Silva *et al.*, 2020; Liu *et al.*, 2011), manifested in initiatives such as the creation of support agencies (Wright *et al.*, 2017; Faria *et al.*, 2019), granting of public funds for research projects with innovation purpose (Abbas *et al.*, 2019; Fischer and Moraes, 2019; Faria *et al.*, 2019; Hou *et al.*, 2019a), and investment in the establishment of incubators and science parks (Amankwah-Amoah, 2016; Chan and Lau, 2005; Hansson, *et al.*, 2005; Ratinho and Henriques, 2010).

Lastly, the patenting laws consist of one of the most important institutional instruments of guarantee of intellectual property, serving as an incentive to the development of innovations (Viana *et al.*, 2018; Cunningham *et al.*, 2019). Patents safeguard the revenue of the research and development projects by generating tradable innovations (Abbas *et al.*, 2019; Datta *et al.*, 2019; Hou *et al.*, 2019; Hou *et al.*, 2019a). In the context of the university, the patent licensing also guarantee the return of innovation development in the context of universities in the form of royalties for the financing of new researches (Chang, 2017). We will return to this issue in the next section, approaching the patent as an instrument to the university-industry relationship.

### 3.2 Micro-context of the university-industry innovation ecosystem

At this level, there are agents that have establish relationships with the university with the purpose of incept innovation in markets. Through a nuanced view of the formation of the university-industry innovation ecosystems, the support of fomenting agencies is the element that is most close to the macro-context. These agencies are normally established by governmental agents with the specific purpose of fomenting research projects that can generate innovation (Wright *et al.*, 2017). These actions take place in the form of funding of projects, support to patenting (Fischer and Moraes, 2019), incentives to projects of cooperation between university and industry (Faria *et al.*, 2019; Franco and Pinho, 2019), and even then, the funding of the building of infrastructure, such as incubators and science parks (Albahari *et al.* 2017; Hansson *et al.* 2005; Ratinho and Henriques, 2010; Vial and Montoro-Sanches, 2016).

There are three main types of settings developed to house and support the startup development, science parks, business incubators, and business accelerators. These settings generate for their tenants' spatial benefits, contributing to the formation of a social environment that enables the knowledge flow (Koçak and Can, 2014). Science parks are well-structured spatial settings designed to give support to technologically based firms, which are in a mature development stage (McAdam and McAdam, 2008; Silva *et al.*, 2020). Firms hosted in a science park find it easier to establish links with universities to enact knowledge flows, which can take place in various forms of pecuniary or non-pecuniary initiatives (Villasalero, 2014).

Business incubators are normally projected in the university context to support the formation of spin-offs, being important instruments for knowledge flow Wright (2015). In this vein, the collaboration of incubated startups with universities can augment the chance of overcoming the incubating stage (Stefanelli *et al.*, 2020). Business accelerators support firms in an intermediary development stage between the beginning and maturity (Mian *et al.*, 2016). However, these settings also can support initiatives of students in the formation of spin-offs (Boh *et al.*, 2016; Wright *et al.*, 2017). Other important actors in the micro-context of university-industry relation are the financial agents that can channel the financing flow between investors and spin-offs (Bertoni *et al.*, 2011; Colombo *et al.*, 2016; Nevalainen *et al.*, 2020; Taylor and Khan, 2021). Indeed, spin-offs are attractive to investors as a possibility of superior profit. In this scenario, there are several types of financial agents such as public



funding, public venture capital (Audretsch *et al.*, 2016), private funding in the form of angel capital, venture capital, and banks (Wright *et al.*, 2017; Padilla-Medéndez *et al.*, 2020; Taylor and Khan, 2021). In some cases, the advising of the university to spin-offs in financial issues and the design of contracts can contribute to facilitating the raising of financial resources of financial agents (Stefanelli *et al.*, 2020).

Finally, in the micro context of universities, firms are directly responsible vectors for incepting innovation in markets (Dahlborg *et al.*, 2017). Owing to the firms in the context of university-industry relations, one can identify the following types and relations: external firms, which there are those which are formed independently of the university context, and internal firms, which are those formed thanks to actions of persons in the context of the university (named as spin-offs). External firms can be classified as big, middle, and small companies (Radziwon *et al.*, 2017). As such, universities can establish cooperation agreements with external firms to obtaining financial sourcing and, transfer knowledge (Franco and Pinho, 2019; Fischer and Moraes, 2019; Hou *et al.*, 2021). Owing to the relationship between universities and big companies, cooperation between firms and universities helps multinational companies adapt their products to local markets (Fischer and Moraes, 2019). Recently these firms have known the importance of interaction with small firms based on intensive knowledge, as a source of new insights, renew its products and prospection of new markets (Gutmann *et al.*, 2020). Still, owing to small external firms, intermediary agents such as science parks can approximate these two types of agents to the enacting of partnerships to knowledge transfer (Vial *et al.*, 2015; Hou *et al.*, 2019; Silva *et al.*, 2020).

Universities can foment the formation of spin-offs. These firms can have a diverse origin, such as those founded by experienced researchers (Wright *et al.*, 2017; Cunningham *et al.*, 2019; Rasmussen *et al.*, 2017 and Stefanelli *et al.*, 2020), by students (Wright *et al.*, 2017; Padilla-Medéndez *et al.*, 2020), and mixed spin-offs, which are formed by teams composed by researchers, students and professional managers (Boh *et al.*, 2016; Olli-Matti *et al.* 2020; Padilla-Medéndez *et al.*, 2020).

### **3.3 Internal context of university-industry relations**

The configuration of the internal elements of a university is determinant in its capability to establish cooperation with external agents and contribute to the inception

of innovation in markets. One important characteristic of a university is its profile, that is, its main focus, that can range from universities dedicated eminently to research in the frontier of Science, until universities that can be focused on the regional development, applied research, and entrepreneurial support (Mascarenhas *et al.*, 2018; Padilla-Medéndez *et al.*, 2020). In this sense, Datta *et al.* (2019) identified in the United Kingdom four clusters of universities, classified according to the two dimensions, the form of knowledge, which can range between abstract and practical, and knowledge nature, that ranges from tacit to explicit. On the other hand, Barra *et al.* (2019) differentiate universities into tiers, whereas top tiers universities are more dedicated to general research, and low tiers are more dedicated to regional innovation.

One important aspect in university is the culture of innovation, which can be manifested through several support actions through championships, and the inception of entrepreneurial content in disciplines of its courses (Fischer and Moraes, 2019). An important internal agent to the university in the context of technology transfer is the TTO; it plays an important intermediary role between university and market agents, facilitating the establishment of cooperation agreements, the technology transfer, and the intellectual protection (Bergegal-Mirabent *et al.*, 2015; Horner *et al.*, 2019; Buratti *et al.*, 2021).

Among the tasks performed by TTOs there are patenting, licensing, and cooperation agreements. In this context, patenting is probably the most important protection instrument, whereas it can be assigned uniquely by a university, until multiple assignees, which occurs through cooperation agreements among universities and other agents (Chang, 2017; Fischer and Moraes, 2019). Another form of knowledge transfer is the issuing by the university of initial public offerings (IPOs), which are public concessions for spin-offs to explore innovation produced in the university (Audretsch *et al.*, 2016).

Finally, the academic staff is fundamental to innovation generation. This staff is formed by professors, researchers, and students in several graduating levels (Boh *et al.*, 2016). These agents are allocated in the academic infrastructure, such as departments (Rybnicek and Königsgruber, 2019), institutes, and laboratories (Barra *et al.*, 2019; Stefanelli *et al.*, 2020). The academic staff is that effectively establishes knowledge transfer activities through the foundation of spin-offs or cooperative agreements with external firms (Young-Choon and Mooweon, 2018).

## **4 A FRAMEWORK OF INNOVATION CHANNELS IN THE CONTEXT UNIVERSITY-INDUSTRY**

After outline a nuanced view of the main elements of the university-industry relation, this section outlines a typology of the innovation channels in the context of the university industry. Through the systematic review presented above, one can identify three innovation channels, namely, cooperation agreements, patent licensing, and spin-offs, that consist in the three main forms that technological innovations generated in universities reach the market.

Owing to the first type of innovation channel, cooperation between university and industry agents, it is necessary to consider first the institutional limits of universities, whereas their basic function is educating and create knowledge through its research. As such, it is not the primary purpose of the university to form firms or commercialize innovation directly. Accordingly, the association between universities and firms is a necessary mean to the introduction of innovation in markets, as a mean of obtaining financial resources to support research and contribute to economic development (Guan and Zhao, 2013; Franco and Haase, 2015; Galan-Muros and Plewa, 2016; Szücs, 2018).

The second type of channel, patent licensing, will normally be used when a new technology is developed inside the university, and it wants to explore it commercially, as a form of obtaining revenue, through the knowledge transfer to firms (Dahlborg *et al.*, 2017; Viana *et al.*, 2018; Young-Choon and Mooweon, 2018). In this case, it can issue an IPOs (Audretsch *et al.*, 2016) to transfer the technology to firms that can be interested in exploring the technology commercially.

The third innovation channel takes place through the university spin-offs that can be established by persons directly inserted in the academic context (Boh *et al.* 2016; Wright *et al.* 2017; Padilla-Medéndez *et al.*, 2020). Normally, these agents want to commercially explore the technology developed internally.

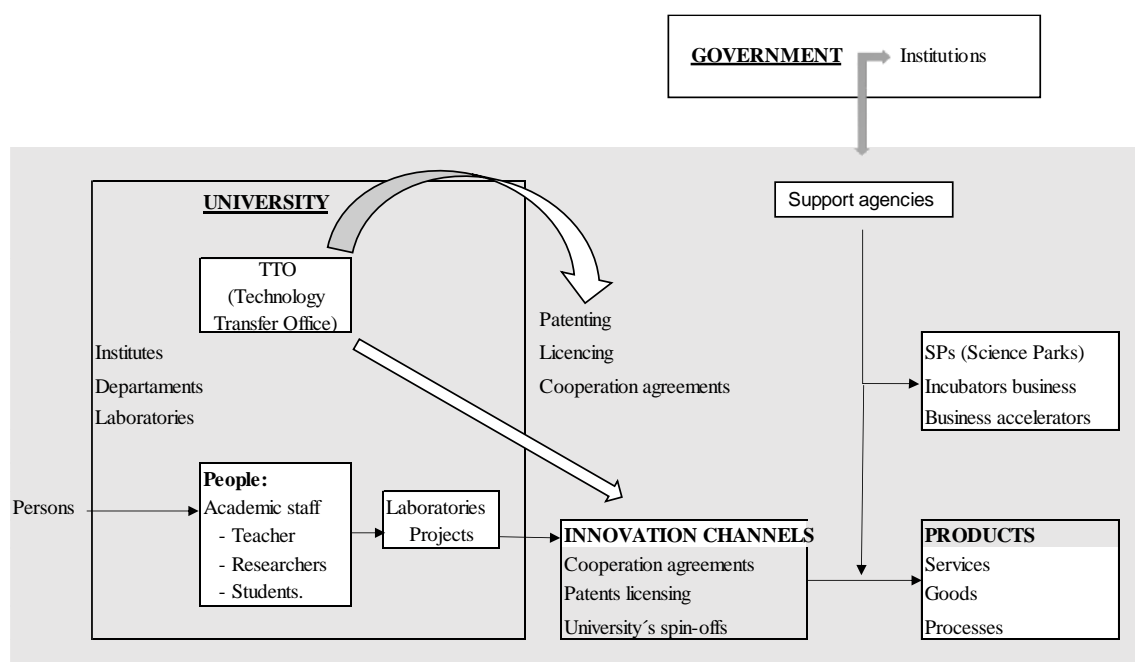
Figure 5 outlines how these three types of innovation channels interact with the elements of the three levels of the university-industry ecosystem. One can infer that the capability of universities to introduce innovations in markets through the three types of innovation channels will depend on the level of development of the elements of internal context, micro context, and macro context. In the internal context, it is

necessary the formation research teams dedicated to the development of innovations capable of carrying out research for this end. Another issue is that it is desirable for the university to have an entrepreneurial orientation to the regional development (Autant-Bernard *et al.* 2013; Hong *et al.*, 2019). This will certainly contribute to the structuration of a TTO dedicated to promoting cooperation with their external micro-context.

In the university micro context, the availability of fomenting agencies, innovation settings such as science parks, business incubators, business accelerators, and financing agents are key aspects to the development of university spin-offs (Nevalainen *et al.* 2020). Owing to the cooperation between university and external firms, in this channel, besides the availability of economic environment relatively developed, it is important to the university establish communication channels with external firms for build a cooperation culture to the inception of innovation.

Lastly, a well-structured institutional framework capable of incentive the innovative behavior (Abbas *et al.*, 2019; Fischer and Moraes, 2019; Lanahan and Feldman, 2015; North, 2002) and a policy mix to the structuration of a material and cultural environment to the development of innovation (Amankwah-Amoah, 2016; Liotard and Revest, 2018; Silva *et al.*, 2020). In summary, to the innovation be concretized, it is necessary the action of several types of different agents in the context of the university, in an intricated and complex network of relations and incentives.

**Figure 5** – Channels and the mediator's factors of innovation



## 5 VALIDATION AND ANALYSIS OF THE FRAMEWORK

In this section, we seek to validate the conceptual model introduced in the previous section. Through the data collecting in four university spin-offs, one technology center, two science parks, and two business incubators, we seek to study the innovation channels used and the role of agents of the university-industry ecosystem in support of the inception of innovation in markets. It is important to highlight that were approached agents directly responsible for the inception of innovations generated in the context of universities in the market, and after through a backward screening method seek to identify how they are supported by other ecosystem agents in this task (see Figure 6).

Beginning with the formation of the agents, three spin-offs are funded by students, the Tec-Centre is funded and operated by researchers, and only Photo-Tec is funded by researchers and students. However, in all cases, there were related a close relationship with researchers in their respective universities. This situation is present in the following statement:

I always have a relationship with the university for [development of] some products. [...]. The last project that I developed that is about education, [...], was in partnership with departments of education and informatics. [...]. The education department contacted us and asked if we would like to develop a product... (Educ-Games).

All the agents revealed the intermediation of the TTOs of the universities to the formalization of agreements between university departments, researchers and the respective agents, as presented by Educ-Games:

Inside the park and university has a commission {TTO} of support to intellectual property [...]. Then, they make all [...], brand register, software register, ... (EducGames).

Besides the formal contact, all agents revealed the importance of informal relations with university actors as a form of giving access to university knowledge. In this respect, the manager interviewed in Autom-Tec, reveal the importance of its geographic location in the neighborhood of University A:

**Figure 6** – The relationship between spin-offs and other agents with university' ecosystem agents

	A	A	A	B	C
	Autom-Tec	Inno-Management	Tec-Center	Educ-Games	Photo-Tecn
Student protagonist	x	x		x	
Mixed spin-off (researcher and student)					x
Researcher			x		
Technology transfer office	x		x	x	x
Informal cooperation	x	x	x	x	
Formal cooperation	x	x	x	x	x
Business incubator					x
Science Park	x	x	x	x	
Public funding through support agencies	x		x		
Cooperation with companies	x		x		x
Channel	Access to Phd students, development of researchers that began in university; PhD students developed technology thanks to cooperation context granted by fomenting agency	Development of managerial tools in cooperation with researchers in university; cooperation agreement	Cooperation with big companies; patent licensing; co-patenting	Development of some educative games with the cooperation of education department of university B; cooperation agreement	Creation of products based on research; developed in the Physics Department of University C; patent licensing

The geographic proximity with the university is very important because I can “bring” the student from that to here. [...] The guy (sic) is making master or Phd and can go to the [Univesrity A] and come to here rapidly (Autom-Tec).

Two of the five agents researched have access to some financial support from fomenting agencies. This support involves activities such as granting of Phd granting for technological development in the firm (Autom-Tec), financing of projects for technological development (Tec-Center).

Owing to the innovation channels used developed in the context of universities to the technology transfer. In several cases, there were observed that the agents

interact with researchers in university departments to the development of products and technologies, as is showed in the statement:

Thanks to our proximity to University [...] there is a nucleus of technology and innovation that is our big partner in the development of [managerial] methodologies (Inno-Management).

This study also revealed the technology transfer between university and industry through the technology center, that is a hybrid structure constituted by the University A to transfer technology to market. Another important finding is that some of the spin-offs and the technology center, also established cooperation with big companies, with the purpose of developing products based on their technologies. This is expressed in the following statement:

There is a textile company that contact us to with a contract for know-how transfer [...] about our photo sensor technology" (Photo-Tecn).

In the case of Tec-Center, which is a branch of the University A dedicated to technology transfer, there were related partnerships for product development. In this case is also used the patent licensing process as a technology-transfer method.

## **5.2 The role of ecosystems agents in support of the innovation channels**

It is important to highlight that most of the spin-offs responsible for the technology transfer from university to markets and the research center are installed in science parks dependencies, which can occur because technology transfer needs more developed environments to effectively engage in a technology transfer process.

While business incubators are small structures that gained support only of their respective universities for their structuration, science parks are more mature environments, as such, required in addition of the support of universities, public funding of fomenting agencies in different levels (state and federal) for their funding and operation, and in the case of Science Park A, with the support of entrepreneurial associations. This can be viewed in the two following quotations:

.. The federal government launched a contest to park foundation, via [its foment agency] [...] then we were one of the parks in Brazil that received support to the elaboration of a viability plan... (Science Park1).

Without these agencies [a national research funding agency, a national innovation projects financing agency, a state research financing agency] it would be impossible for a park-like ours to exist (Science Park 2).

All we depend on [University A], [...]. We have a coordinator that is [Professor Name] that has 15 years in innovation experience [...]. Incubator A

It is important to report that financial agencies are responsible for several types of funding, inclusive of other agents such as the case of Tec-Center, such as the quotation at the following:

This technological center was created through a triple helix, that is [...], that is the link between industry, university and government. [...]. This Centre makes the link between the technology developed in the university and the industry” (Tec-Center).

In the case of business incubators how they are smaller structures compared with science parks, they received support only from their respective universities. As such, business incubators and science parks are important settings to the operation of spin-offs, whereas the last support more developed spin-offs. In these settings, besides the hostage of the spin-offs and other innovation agents, there are also available support services as pointed out at the following:

We have two consultants, contracted to the incubator, [...], they give support to the tenants ... (Incubator A).  
The university gives credibility for the business [the incubated] [...], see the incubate can receive clients here [...] (Incubator C).

### **5.3 Analysis of the empirical data under the lights of the model**

This article corroborates the current view about the role of innovation ecosystems as a set of agents that are capable of supporting the development of innovations and their inception in markets. As such, this study presents a multilevel perspective of the university innovation ecosystem that can be viewed as an alternative and complementary perspective of current authors that address innovation ecosystems (Good *et al.*, 2019; Librelato and Lacerda, 2021; Padilla-Medéndez *et al.*, 2020; Wright *et al.* 2017).

Even though the current authors address several ecosystems elements, this article extends this process by showing how the university innovation channels are constituted and how the elements of the ecosystem contribute to the inception of innovations in markets. Additionally, it shows the systemic role of ecosystems agents that support innovation through actions such as funding, physical, social and managerial support (Hansson *et al.*, 2005; Ratinho and Henriques, 2010).

Also, this article corroborates the view of several authors about the important role of government as a supporting agent of innovation through foment agencies in financing the establishment structures such as science parks and business incubators (Amankwah-Amoah, 2016; Albahari *et al.*, 2017; Silva *et al.*, 2020; Chan and Lau, 2005; Vial and Montoro-Sanches, 2016). Another aspect that corroborates the literature is the role of agencies as financers of innovation of research projects, that is the base for the development of innovations (e.g., Abbas *et al.*, 2019; Fischer and Moraes, 2019; Faria *et al.*, 2019; Hou *et al.*, 2019a; Wright *et al.*, 2017).

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The main agents identified in this research as vectors of university innovations are spin-offs and a research center. The research center emerges as a new type that universities can use to insert innovations in markets. In relation to spin-offs, this study corroborates the literature (Boh *et al.*, 2016; Wright *et al.*, 2017; Padilla-Medéndez *et al.*, 2020) about the importance of them to introduction of innovation in markets.

An important finding is that the three innovation channels are intertwined in relations, whereas the innovation can be manifested through the concurrence of several channels. For example, in several of the cases presented here there is the collaboration of universities and spin-offs, and university with the technology center. This type of situation manifests concurrently the channels spin-offs and collaboration. And lastly, this also can occur through the patenting licensing process.

## **6 CONCLUSION**

This article introduced a framework of the university-industry ecosystem based on three levels, internal context, micro context and macro context. In the sequence, there were presented three innovation channels used by universities to incept technological innovations in markets, namely, licensing of patents, collaboration with firms in research projects, and academic spin-offs. Considering this article under the light of the current literature about university-industry relations, one can identify the following contributions for the theory and practice.

From the theoretical point of view, while recent integrative studies (e.g. Audretsch *et al.*, 2016; Librelato *et al.*, 2021; Wright *et al.*, 2017, Mascarenhas *et al.*, 2018; Mathisen and Rasmussen, 2019) are concentrated on specific aspects of university-industry relations, in this article, there was presented a general picture that permits to understand the existent innovation channels and the role of agents of different levels of the university ecosystems, in promote innovations, corroborating a tendence for encompassing studies in literature (Sehnem *et al.*, 2021). Further, the clear link enacted between the university-industry ecosystem and the three types of innovation channels introduces a holistic view of the innovation in the context of university-industry relations. It also suggests a system of cause and effect between the level of maturity of a university ecosystem and its capacity of introducing technological innovations in markets, through these three innovation channels.

This article opens several paths for future research. Firstly, it can serve as a reference for the development of systematic assessment tools for the evaluation of the maturity of university ecosystems. From the qualitative perspective, some suggestions for research are to investigate the mechanisms used by TTOs to mediate innovative activities between university agents and firms; map the current financial agents and their mechanisms to support university spin-offs; map the existent types of university initiatives to commercialize their patents. Another perspective is to investigate the entire path of innovation in terms of activities performed for the multiple actors in the process of innovation, in an innovation chain.

From the pragmatism perspective, in line with the importance of the participation of university as a active agent in the promotion of the environmental, economic and social progress (Pecorari and Lima, 2020), this article opens an opportunity for the development of strategic plans to be conducted by universities, beginning with the assessment of their current situation as agents of innovation in their regional context, and to the establishment of strategic actions for the development of their innovation ecosystems.

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Artigo recebido em: 10/02/2022 e aceito para publicação em: 07/05/2024

DOI: <https://doi.org/10.14488/1676-1901.v24i1.4572>