

## SCIENCE SPIN-OFFS IN THE CONTEXT OF BRAZILIAN ACADEMIC ENTREPRENEURSHIP

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### ABSTRACT

This paper analyzes the emergence of academic spin-offs, with a specific focus on those derived from basic knowledge in the natural sciences (mainly Physics and Chemistry). These companies emerged in the context related to science, technology and innovation and the evolution of the University's mission. Hence, it is possible to state the importance of initiatives to stimulate university-industry relationship, the transfer/licensing of technologies and the creation of spin-off companies.

In addition, the literature review addresses the concepts related to academic entrepreneurship, as well as the definitions, development models and factors that affect the process of creation and development of academic spin-offs.

Therefore, an exploratory and qualitative approach was adopted. Three case studies were conducted in chemistry and physics incubated companies founded between 1990 and 2009, created by senior researchers of University of Sao Paulo, Brazil. The main interest was to understand the similarities and particularities of these companies within technology-based start-ups. By performing multiple case studies, it is possible to conclude that there are characteristics related to the entrepreneur and to his company that greatly influence their growth. These characteristics are mainly related to their process of creation and development, the importance of resources, corporate formation and team formation, the product development process and the articulation of the business model.

These cases are important to stimulate entrepreneurial initiatives among researchers and professionals in those areas, as examples that induce the creation of a culture for generation of new business in the midst of academic origin.

**Key words:** Science, Technology, Innovation, Entrepreneurship, University Spin-off.

### INTRODUCTION

For some researchers, economic progress and scientific development are closely linked, but for other scholars science's discovery and its application are so far away that the scientist and the entrepreneur's worlds could not be used in the same context or for the same person. However, more and more traditional environments of scientific knowledge generation - such as universities - are taking an important role in the development of entrepreneurs and companies.

The United States are considered the cradle of academic entrepreneurship. This reputation began last century, with the emergence of the "Silicon Valley" and "Route 128" connected respectively to

Stanford University and the Massachusetts Institute of Technology (MIT) (ROBERTS, 1991). These entrepreneurial environments created favorable social, institutional, organizational, economic and territorial conditions. They enable both the continued development of innovation in enterprises established there, as the proliferation of new technology-based companies or academic spin-offs (NDONZUAU et al., 2002).

Several governments have launched similar initiatives to stimulate the company-university relationship, inspired by the emergence of these early Technopolis (CASTELLS; HALL, 1994) and the consequent growth of their regions, – such as the creation of science and technology parks and business incubators, and the establishment of "seed capital" public funds. These actions arise as a means of achieving economic development through academic research (PINTO, 2012), using universities as tools for technological change and regional development, following the American model.

Within universities, this type of initiative is gaining ground and the old mentality of academic researchers, directed only by the advancement of knowledge and by publication, has been expanded to an entrepreneurial mindset, which also focuses on research with practical application that can generate economic value and social welfare (PLONSKI, 1999). Thus, science, technology and innovation are increasingly seen as important drivers of economic and social transformation of the countries (GIBBONS et al., 1994; ETZKOWITZ; LEYDESDORFF, 1995; 2000).

However, in the Brazilian context, the process of creating companies by academic researchers is a recent phenomenon that despite the existence of some previous cases, developed in the early 1990s.

This national and international movement is part of an historical and institutional context in evolution, in which universities play a significant role in the new paradigm of the knowledge society (ETZKOWITZ; LEYDESDORFF, 1995).

However, not all entrepreneurial researchers and the companies created by them have the same characteristics, the same logic of creation and development, or the same goals and visions (DOMINGUES, 2010; 2012). The understanding of these differentiating factors can be an important point to guide the generation of new business, favoring the success of this process.

For Reamer et al. (2003), in each path of science, technology and product, the process that unfolds is idiosyncratic, entirely dependent on the individual and organizational capabilities context and other unique circumstances.

This study had the objective to analyze the emergence of spin-offs or technology-based start-ups, in order to understand how the academic ventures differ according to the original research area of knowledge. Its specific focus are the spin-offs developed as original academic research in the natural sciences (with emphasis on physics and chemistry). Its intention is to understand the similarities and particularities of these companies (in the context of academic entrepreneurship), taking them as a particular group within the set of spin-offs.

## **ENTREPRENEURSHIP AND THE CREATION OF NEW BUSINESSES**

The advancement of knowledge and the understanding of how this evolves into a technological application is important to comprehend the innovation process. Besides that, this latter concept can

not, by definition, be comprised dissociated from a business, since this is a way to required application and acceptance by the market. Similarly, the formation of a new technology-based business, created to commercially exploit an innovation, should not be understood isolated of its founder (or entrepreneur).

Hence, the central concepts related to entrepreneurship and the generation of new academic business should be discussed, integrating the theoretical framework necessary for case studies understanding and the fulfillment of the paper's goals.

Some concepts must be addressed in order to create the theoretical framework linked to the development of entrepreneurial in academia and the generation of new businesses. They should comprise the whole process, from identifying the opportunity (arising from the scientific development discussed in the previous section) to the structuring and growing of the company (with potential success ) on the market.

This paper defines an entrepreneur as the person who knows how to identify business opportunities and market niches, and also knows how to organize in order to achieve progress, with analytical skills and creativity (FILLION, 1999). In addition, he is the one who carries out activities that lead to the transformation of ideas into opportunities (DORNELAS, 2005), taking risk on the creation of a new business with potential of success. In the context of the Entrepreneurial University (ETZKOWITZ, 1998), the main result of this process is the creation of spin-offs.

Academic spin-offs are identified as companies that emerged from the results of research carried out in universities (ARAUJO et al, 2005;. GUSMÃO, 2002; DJOKOVIC; SOUITARIS, 2008; NICOLAOU; Birley, 2003; O'SHEA et al, 2008;. PIRNAY et al. 2003; RADOSEVICH, 1995; SHANE, 2004). This definition is not restrict to the spin-offs which have as academic partners, but is not as comprehensive as to include companies that were created from the knowledge acquired at the university, without performing research and academic development (COSTA; TORKOMIAN, 2008).

In this context, Azevedo (2004), Borges and Fillion (2013), Clarysse and Moray (2004), Pérez and Sánchez (2003), Sbragia and Pereira (2004), Van Geenhuizer and Soetanto (2004) and Vohora et al. (2004) identified the key internal and external factors that contribute to the success of start-ups. These factors, considered in the development of the study, were summarized in Table 1.

*Table 1: Facilitating and inhibiting factors for the creation of academic spin-offs.*

<b>Facilitating Factors (internal)</b>	<b>Facilitating Factors (external)</b>	<b>Inhibiting Factors (internal)</b>	<b>Inhibiting Factors (external)</b>
Technical Knowledge	University interaction	Partners conflicts	Market penetration
Creativity	Use of university laboratories	Non-Business degree	Government regulation and bureaucracy
National level innovation	Incubator's support	Fast product development	Dealing with the interests of different stakeholders
Networking	Incubator's infrastructure	Difficulties with intellectual property (IP)	Logistics
Use of Market information or product	Networking with other incubated companies	Cash flow control, capital investment,	Lack of entrepreneurship

Facilitating Factors (internal)	Facilitating Factors (external)	Inhibiting Factors (internal)	Inhibiting Factors (external)
development		R&D investment (research and development)	encouragement in the academic environment
Partner's Entrepreneurial abilities	Partnership	Lack of marketing knowledge, sales abilities and customer relations	IP legislation
Business Plan			

Regarding these new business development process, based on the mixed approach proposed by Vohora et al. (2004), complemented with those presented by other authors (NDONZUAU et al, 2002;. CLARYSSE; MORAY, 2004; DEGROOF; ROBERTS, 2004;. VANAELST et al, 2006), the creation process model and structuring of academic spin-offs used in the article can be outlined as shown in Figure 1. This model and the concepts involved on it will be used as a basis for understanding the development stages of academic companies.



Figure 1: Creation and development process of academic spin-offs.

## METHODOLOGY

This topic describes the research strategies that authors used to achieve the goals of this paper. In general, a research can have the following macro objectives: to familiarize the researcher with a phenomenon or achieve a new understanding of it; provide information on a given situation, group or entity; check the frequency that something occurs or how it is linked to other phenomena; verify a hypothesis of a causal relationship between variables (SELLTZ et al., 1975).

Due to the characteristics intended for the study, and taking into account the previously stated conditions, necessary for the development of a scientific study, the multiple cases method with the integrated analysis of multiple units (YIN, 2010) was the most appropriate to the issues and aims of this research.

The study was guided by the sequence of steps proposed by Miguel (2007) in order to accomplish a case study, presented in Figure 2.

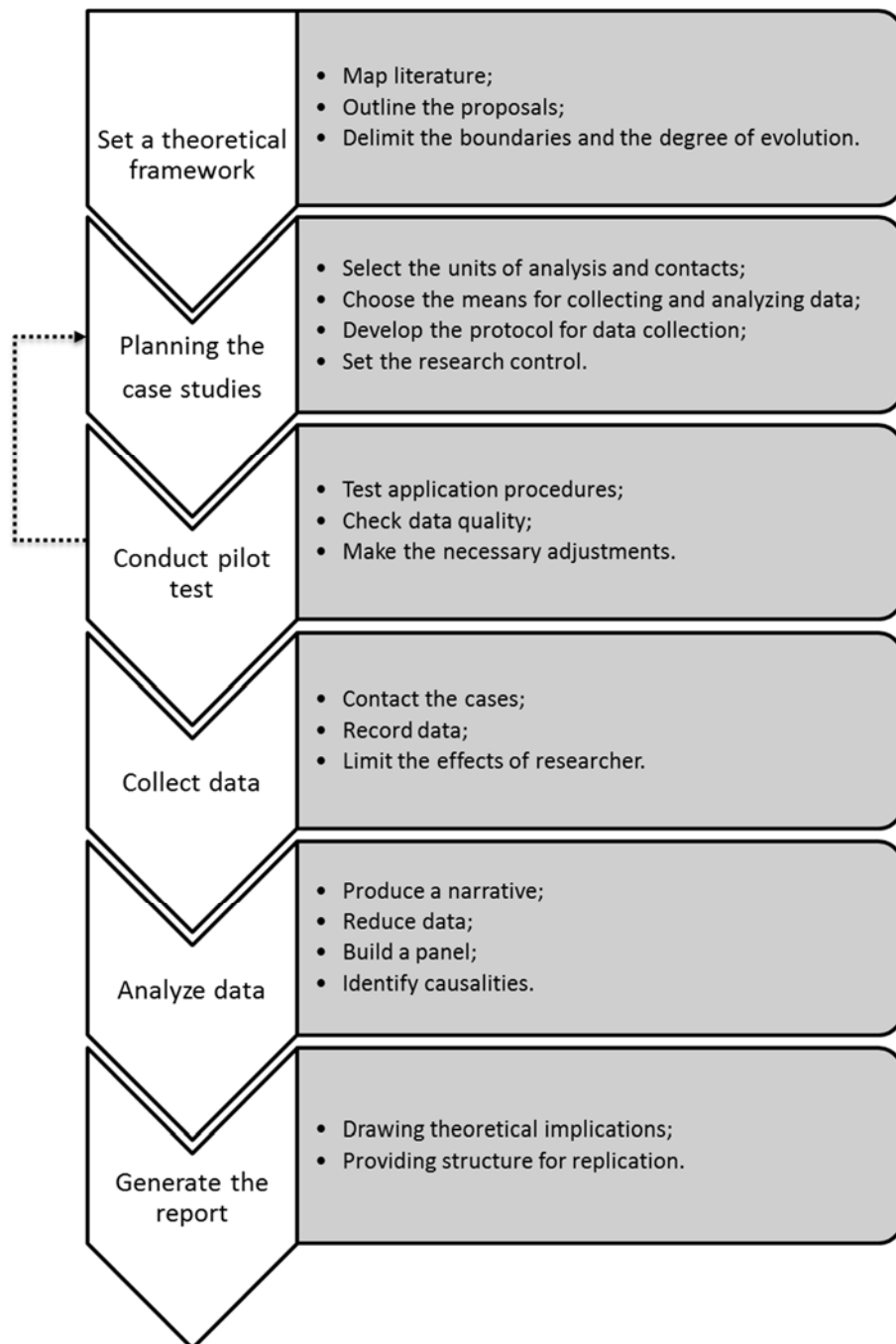


Figure 2: General stages of a case study, Source: Miguel (2007)

### Spin-offs studied

Yin (2010) recommends that the choice of cases is guided by the results intended by the survey. Thus, for the study of multiple cases intended, three cases were selected for analysis. This number complies with the needs of analytical generalization (not fitting the criteria of statistical inference).

The criteria for choosing a company was the theoretical contribution that the case may have to validate the theoretical concepts discussed, and the understanding of the context linked to the Brazilian academic entrepreneurship. In addition, the selection of the companies did not follow any

random sampling criterion, as it could have resulted in getting firms without characteristics that contribute to the proposed research.

The three cases are summarized in Table 2.

*Table 2: General properties of the three companies selected for the case study.*

	<b>Spin-off 1</b>	<b>Spin-off 2</b>	<b>Spin-off 3</b>
<b>Field</b>	Physics	Chemistry	Chemistry
<b>Foundation Year</b>	1998	2009	2007
<b>Relationship with the Incubator</b>	Graduated	Incubated	Incubated
<b>Number of Partners</b>	6	4	2
<b>First degree of the main partner</b>	Physics	Chemistry	Physics / Chemical Engineering

The main purpose for conducting the case study at Spin-off 1 was to understand the evolution of a technology spin-off founded by a professor of in the field of Physics. This spin-off was founded at the beginning of discussions about entrepreneurship in Brazil (1998) and before the enactment of the legal framework intended to encourage such practice, beginning with the Law of Technological Innovation in 2004.

The main aim of conducting the case study at Spin-off 2 was to understand the process of setting up and developing a spin-off founded by an academic researcher in the field of Chemistry. He has a remarkable academic expertise, and seeks to develop an innovative product to Brazil in a context considered more favorable to entrepreneurship (post 2004).

The main intention of conducting the case study at Spin-off 3 was to contrast the development and growth of a spin-off active in the chemical industry, founded by engineers (educated in a traditionally applied knowledge area) with great previous experience in multinational companies, to one founded by an academic chemist (Spin-off 2).

## **CASES ANALYSIS**

This topic aims to expose and analyze the information collected during the case study and with the various actors selected for illustrating the context mentioned. The study analyzed the environment of University of São Paulo (USP) and its Innovation Agency (which operates mainly as an Office of Technology Transfer), of USP's business incubator (CIETEC), of USP's Institutes of Physics and of Chemistry, and of the selected companies.

University of São Paulo (USP) is a public university, maintained by the State of São Paulo Government, organizationally linked to the Department of Economic Development, Science, Technology and Innovation (SDECTI). Founded in 1934, it is one of the leading higher education institutions in Brazil. Its excellence is recognized by numerous world academic rankings (such as the Institute of Higher Education Shanghai Jiao Tong University ranking, Webometrics Ranking of World Universities 2010 Performance Ranking of Scientific Papers for World Universities and the Times of Higher Education ranking), designed to measure the quality of universities according to various criteria, mainly those related to scientific productivity.

This institution was chosen due to its importance in the scientific and technological context, both in Brazil and Latin American. The quality of the scientific knowledge produced by researchers from the

academic environment was considered because it is as an important factor in generating technology-based companies.

### Process of creation and development of the spin-offs

Analyzing the process of creation and development of the companies studied, it is possible to note that the main entrepreneurs of the new businesses are committed to its development and have personal characteristics that contribute to its success, such as risk propensity, analytical skills, creativity, and opportunities identification potential.

However, for companies originated by researchers from the fields of natural sciences (Spin-off 1 and Spin-off 2), the original corporate constitution was based on the academic relations of the partners. In these cases, the commitment of the other partners was not the same as the main entrepreneur (interviewed), which led to the need for corporate restructuring (change of partners).

In the case of Company 3, created by chemical engineers (applied knowledge area), the corporate constitution was based on family ties between the partners, and it has not been restructured due to the same commitment of the partners to the business.

In this context, despite failures related to the selection of partners, the company's initial team had a key role in the business development. In the case of Spin-off 1 and Spin-off 3, the main entrepreneurs sought to add to the team people with complementary skills (technical, product development, and management, to help structuring the business), in order to fill their knowledge gaps. In the case of Spin-off 2, this was not an entrepreneur's point of attention, and the lack of managerial knowledge was identified as critical to the success of the company (this fact was only noticed after the work of an external consultant).

Analyses related to the corporate establishment and the formation of team are highlighted in Table 3.

Table 3: Corporate constitution and team formation in the spin-offs.

	Spin-off 1	Spin-off 2	Spin-off 3
<b>Initial partnership (Corporate constitution)</b>	Academic relationship	Academic relationship	Family
<b>Main difficulties</b>	Partner's lack of commitment	Partner's lack of commitment	-
<b>Corporate restructuring</b>	Incorporation of people committed to the business and withdrawal of some members	Withdrawal of some partners and family restructuring	-
<b>Team formation</b>	Partners + Technical Fellows (RHAE)	Partners + Technical Fellows (RHAE/FAPESP)	Partners + Technical Fellows (RHAE) + Managers (PRIME)
<b>Main difficulties</b>	-	Team homogeneity and lack of professional experience	Lack of professional experience
<b>Team restructuring</b>	Interaction with the community	Hiring a consultant	Interaction with the community

RHAE (Programa de Formação de Recursos Humanos em Áreas Estratégicas): Training Program of Human Resources in Strategic Areas

FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo): Research Support Foundation of the State of São Paulo

PRIME (Primeira Empresa Inovadora): First Innovative Company Program

The incubation process was considered essential, since the incubator was able to provide support for the company's physical structure, by making low cost infrastructure available, in addition to the establishment of a network contacts (internal and external). Still, a point considered of great importance was the possibility of obtaining information and support about funding programs (economic subsidies), a benefit that the entrepreneurs were not aware of before starting the incubation process.

The incubator has failed to fulfill the role of facilitating market tests and feasibility assessments of technology/product. In this sense, the only initiatives that could positively influence this aspect are the support for participation in fairs and events and the promotion of business roundtables (activities that were not highlighted by respondents).

In this context, the importance of the business plan (BP) was a controversial point. In the case of Spin-off 2 it was considered important as a previous study of market opportunities (checking its feasibility before carrying out significant investments), although the entrepreneur believe it was not well developed. As for the Spin-off 3 it was considered important for structuring information about the company, seeking to obtain venture capital investments. For Spin-off 1, the BP was appointed as a tool for participation in foment publishing, the result of which would be monitoring the implementation of the financed project (in terms of meeting schedule and budget).

In this sense, the initial products of the company (described in BP submitted to enter the incubation process) were developed from the direct application of the results of academic research of the entrepreneurs. With the exception of one company, which had its widely accepted product (in the absence of competitors), both Spin-off 2 and 3 restructured their product line after verifying the non-feasibility of the initial project.

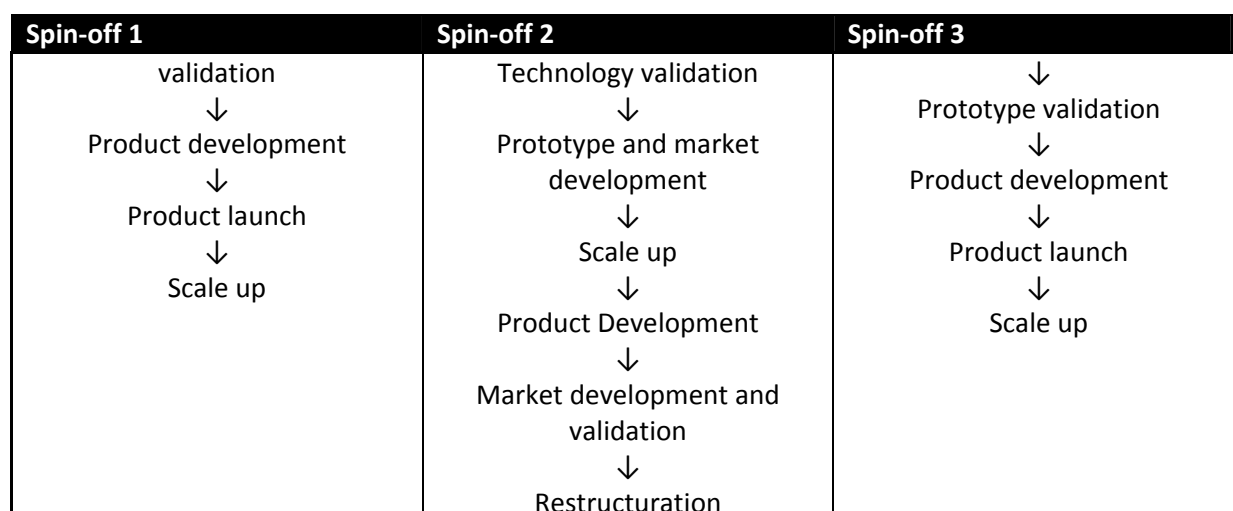
In the case of Spin-off 2, the product development was not based on a combination of technical expertise and market opportunity. The Spin-off 3, the products were developed in order to meet the needs and requirements of consumers (including the establishment of partnerships with potential clients for performing R&D). In Spin-off 1, when the product launched, the application was filed in trade shows and its development has been guided by the market acceptance.

Table 4 presents the process of development, testing and launch of the product in enterprises.

*Table 4: Product development process in the spin-offs.*

Spin-off 1	Spin-off 2	Spin-off 3
Business Opportunity of Academic Research	Business Opportunity of Academic Research	Business Opportunity of Academic Research
↓	↓	↓
Prototype and market development	Opportunity validation	Opportunity validation
↓	↓	↓
Prototype and market	Technology development	Prototype development with potential costumers
	↓	





The more successful companies in this process were those ones that made contact with potential customers in advance and tried to validate the opportunity to support technological development. In the case where this validation is only considering the technical requirements of the project and the market potential (without performing tests with direct customers) the development process was significantly longer and had a greater number of recasting steps (usually intuitive or based on suggestions received from other scholars in the field - as in the case of Spin-off 2).

In the cases studied, the development of the company occurred during the incubation period, and full production and marketing of products only gave the company after graduation. Of the three cases investigated, only the Spin-off 2 was still installed in the incubator and did not have a commercial product.

Table 5 link the theory presented to the main stages of this process (for each company).

Table 5: Development stages of the spin-offs.

Stage	Spin-off 1	Spin-off 2	Spin-off 3
1	Scientific development / Academic Research	Scientific development / Academic Research	Scientific development / Academic Research
2	Opportunity Identification	Opportunity Identification	Opportunity Identification
3	Incubation	Incubation	Incubation
4	Corporate constitution	Corporate constitution	Corporate constitution
5	Company Infrastructure Development	Financing (people + infrastructure)	Business opportunity change
6	Financing (people)	Technical team structuring	Financing (people)
7	Technical and managerial team structuring	Opportunity development	Technical and managerial team structuring
8	Financing (infrastructure)	Prototype development	Opportunity development (marketing interaction)
9	Enter the market	Product development	Financing (infrastructure)
10	Corporate Restructuring	Corporate Restructuring	Corporate Reorientation
11	Exit incubator	New prototype development	New opportunity development
12	Strengthening and financial returns	New product development	New products development

Stage	Spin-off 1	Spin-off 2	Spin-off 3
13	New spin-offs generation	Market and product validation	Market validation
14	-	Exit incubator	Exit the incubator
15	-	Enter the market	Enter the market

Regarding the conceptual model shown in Figure 1, the main point of attention in the cases studied is the formal structure of the company (or launch the spin-off) before the detailed investigation of the opportunity and the reorientation of the company. This may be due to the pre-requisite of getting the National Corporate Registry for obtaining financial support.

While creating the company, obtaining financial resources through participation in foment publishing is considered as a point of extreme importance for entrepreneurs. This is due to the large investment required to set up a R&D infrastructure for the development and testing of prototypes / products. This fact is in line with theory of Druilhe and Garnsey (2004) regarding the need for resources (since the Spin-off 2 and Spin-off 3 can be classified as product companies and the Spin-off 1 as infrastructure creator). However, unlike this theory, the relevance of the scientific knowledge of entrepreneurs is extensive.

Finally, Table 6 highlights the main factors in the process of creation and development of the spin-offs examined.

Table 6: Facilitating and inhibiting factors for the creation of the spin-offs.

Facilitating Factors (internal)	Facilitating Factors (external)	Inhibiting Factors (internal)	Inhibiting Factors (external)
Technical Expertise of the partners	Interaction with the University (for the joint development of technology)	Initial corporate structure based on academic relations	Difficulty to enter the market
Networking	Use of University laboratories (R&D infrastructure)	No managerial education of partners and professional inexperience of technical fellows	Government regulation and bureaucracy - certifying agencies
Entrepreneur partners profile	Incubator support in the search for funding	Product development without market validation	Difficulty in obtaining operating licenses
Use of market information for the development of new products	Access to financial resources	Long time for product development and revenue generation	Logistics difficulties
Potential of the technical team	Infrastructure offered by the incubator	Lack of marketing knowledge and selling skills	Lack of entrepreneurship encouragement in the academic environment
Product development in partnership with customers	Networking with other incubated companies	Difficulty in scaling up	Difficulty with University partnerships

## CONCLUSIONS

This paper aimed to carry out an exploratory study of academic spin-offs arising from scientific research in the natural sciences (with emphasis on Physics and Chemistry), by conducting a study of multiple cases.

Thus, the realization of case studies made it possible to arrive at the following conclusions:

- i. The scientific knowledge can be converted into innovation through the alignment between the considerations of use / application of scientific research and the opportunities / market needs;
- ii. Researchers who opt for the creation of a new business to apply their knowledge seem to have some characteristics that distinguish them from other academic (such as the need to return to society the investment for the production of knowledge, the broad understanding of the economic context and concern its development; the propensity to take risks during the transformation of knowledge into product, given the opportunity to envisioned application, and the commitment to the development of new business, even in situations of uncertainty or failure);
- iii. The corporate structure of the spin-offs based on science is one of the critical points in the process. While some researchers are committed to the new business, most are only involved due to the expectation of financial return. They do not dedicate to operations and do not support the daily decisions of the company. The same relationship "teacher-student" which was held during the development of academic research often prevails in these societies;
- iv. While creating and developing new business, the team plays a key role. At first, the technical expertise aligned with the understanding of the market helps in rapid product development. Over time, the quality of administrative, financial and production functions helps the company to meet the potential demand. Thereafter, skills related to commercial, marketing and logistics enable entry and consolidation of the company in the market;
- v. In the context of transformation of know-how in a product, an important feature is the market knowledge, developed through the application of management tools such as the Business Plan or Feasibility Study; equally useful is the joint development of projects with potential customers or the validation of the developed prototypes in the market;
- vi. A major difficulty faced by academic researchers in the development of products (besides the interaction with the market), is related to the production process and production scheduling (mainly in the chemical industry). Therefore, the previous experience of entrepreneurs in large companies allows greater experience or the understanding of the application context (as the areas of Engineering);
- vii. The foundations agencies have a key role in structuring the company, providing the necessary resources for their development (from creation to market entry), in terms of infrastructure, product validation and testing and payment of personnel, among others;
- viii. The governmental programs aimed at management development of new business (are very important to supply the company with no technical knowledge related to the management

of the enterprise, usually absent in academic entrepreneurs originated in the areas of the natural sciences;

- ix. The incubator has a significant role in the company's development process, because it offers infrastructure and access to information (funding programs and knowledge management). In addition, there is the possibility of obtaining support in critical areas such as intellectual property and private investment;
- x. In the company graduation process, it is important to obtain financial resources for structuring the company (usually achieved through private investors), to set a professional management team, and to articulate local actors;
- xi. For entrepreneurs in the natural sciences, the University proved an environment for cooperative development of technical knowledge. It was not an inspiring place for entrepreneurship.

Such conclusions are not exhaustive and may not be generalized to all academic spin-offs, given the limitations of the study. However, they can serve as future research issues, such as:

- i. Understanding the characteristics that contribute or not to academic profile, for the development of entrepreneurial career;
- ii. Analysis of the efficiency and effectiveness of entrepreneurship stimulus initiatives in academia, as well as its scope (in terms of knowledge areas);
- iii. Analysis of the link between scientific and entrepreneurial development as ways of reducing the time "new knowledge - new product";
- iv. Analysis of the real impact and relevance of basic research (unused considerations) in the development of technological innovations;
- v. Survey of the main facilitating and inhibitors factors to generation and development of spin-offs in the natural sciences.

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