UNIVERSIDADE FEDERAL DE MINAS GERAIS – UFMG

PROGRAMA DE PÓS-GRADUAÇÃO EM INOVAÇÃO TECNÓGICA E PROPRIEDADE INTELECTUAL

Victor Nikolaus Bistritzki

EMPREENDEDORISMO ACADÉMICO:

Um desafio para transferência de biotecnologia na Universidade Federal de Minas Gerais

---

ACADEMIC ENTREPRENEURSHIP:

A challenge for biotechnology transfer at the Universidade Federal de Minas Gerais

Belo Horizonte – MG

2017

Victor Nikolaus Bistritzki

EMPREENDEDORISMO ACADÉMICO:

Um desafio para transferência de biotecnologia na Universidade Federal de Minas Gerais

---

ACADEMIC ENTREPRENEURSHIP:
A challenge for biotechnology transfer at the Universidade Federal de Minas Gerais

Dissertação apresentada ao curso de Mestrado Profissional em Inovação Tecnológica e Propriedade Intelectual da Universidade Federal de Minas Gerais; UFMG, como requisito à obtenção do título de Mestre em Inovação Tecnológica e Propriedade Intelectual.

Área de concentração: Gestão de Inovação e Empreendedorismo

Orientador: Professor Francisco Vidal Barbosa

Co-Orientador: Professor Allan Claudius Queiroz Barbosa

Belo Horizonte – MG

2017

Acknowledgment

In erster Linie danke ich meinen Eltern Britta & Walter, meiner Schwester Anna, meinen Cousins Katya & David, meiner Tante Ingrid, meinen Großeltern Franziska, Otto, Karl-Heinz, Ingeborg und Frieder, die mich alle so geprägt haben wie ich heute bin.

Ich bin über alles dankbar für die bedingungslose Unterstützung meiner Eltern. Ohne euch wäre dieser große Schritt nicht möglich gewesen.

Meiner Schwester Anna danke ich für das Vertrauen das sie in mich hat und alle Gespräche vor und während meines Brasilien-Abenteurer. Danke das es dich gibt!

Meinem Cousin David und meiner Cousine Katya danke ich auch für zahllose Gespräche die unsere kleine Familie zusammengetrieben hat und uns alle verbindet.

Thanks to my partner Marina, who is strengthening me in every aspect of life – personal and professionally. Thank you for your patience and contributions.

Agradeço à minha família brasileira Rosana, Nicolas e Dona Lia por receber-me em sua casa e ajudar-me com o difícil começo neste país tropical.

Agradeço aos meus orientadores Prof. Vidal e Prof. Allan pela orientação e apoio.

Agradeço ao Prof. Ruben e ao Prof. Frezard pela ajuda a vinda ao Brasil e pelas boas-vindas ao curso.

Agradecimentos especiais à Kelly, que auxiliou em muitos problemas burocráticos

Agradeço à CAPES, CNPq, ao governo brasileiro e a todos os brasileiros por tornar este mestrado possível.

ABSTRACT

Biotechnology is considered to be a key factor in fighting diseases and world hunger. Because of strict regulations, high investments and extensive research, most of the research and development that leads to biotechnology products and services are executed in universities and is then transferred to established companies or spun off by academics themselves. However, the technology transfer process from university research to industry commercialization comes with challenges. This present work is concerned with understanding why biotechnologies, developed at the Universidade Federal de Minas Gerais (UFMG), are not finding the way to the market. To investigate this question, the main objective of this work was to understand the university-industry interaction and its challenges out of the perspective of professors, researching in biotechnology. A quantitative research model is used to explore the biotechnology landscape of UFMG and collect information on the university-industry interaction, R&D obstacles, financial support, R&D collaboration, management experience and entrepreneurial activity. One contribution of this present work is to present the biotechnology landscape of UFMG, its issues and interactions as well as challenges of technology transfer in the immature National System of Innovation of Brazil. The main contribution is the identification of a low technology transfer interest of professors and a lacking academic entrepreneurial activity in area of biotechnology at UFMG.

SUMÁRIO

A biotecnologia é considerada um fator chave na luta contra doenças e fome no mundo. Devido a regulamentos rigorosos, investimentos elevados e pesquisas extensas, a maior parte da pesquisa e desenvolvimento que leva a produtos e serviços de biotecnologia é realizada nas universidades e, em seguida, transferida para empresas já consolidadas ou para uma nova empresa criada pelos próprios acadêmicos. No entanto, o processo de transferência de tecnologia da pesquisa universitária para a comercialização da indústria apresenta desafios. O presente trabalho busca compreender por que biotecnologias desenvolvidas na Universidade Federal de Minas Gerais (UFMG) frequentemente não alcançam a fase de mercado. Para investigar esta questão, o principal objetivo do presente trabalho foi compreender a interação universidade-indústria e seus desafios na perspectiva de professores pesquisadores na área de biotecnologia. Um modelo de pesquisa quantitativa é usado para explorar o cenário da biotecnologia na UFMG e coletar informações sobre a interação universidade-indústria, obstáculos à P&D, apoio financeiro, colaboração em P&D, experiência de gestão e atividade empresarial. Uma contribuição do presente trabalho é apresentar de forma descritiva o cenário da pesquisa da biotecnologia na UFMG de acordo com a perspectiva dos professores que pesquisam nesta área, seus principais obstáculos, forma e intensidade de interações e desafios relativos à transferência de tecnologia no Sistema Nacional de Inovação brasileiro. A principal contribuição é a identificação de pouco interesse em transferência tecnológica e da baixa atividade empresarial acadêmica na área de biotecnologia na UFMG. Os resultados deste trabalho sugerem que o baixo interesse pela atividade empresarial acadêmica (relacionados a transferência tecnológica moderada) não estão, necessariamente, relacionados a uma questão setorial da biotecnologia, mas uma consequência do sistema de inovação imaturo do Brasil.

List of Figures

List of Tables

List of Abbreviations

CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico
COLTEC	Colégio Técnico da UFMG
CT	Centro Technológico
CTIT	Coordenadoria de Transferência e Inovação Tecnológica
FINEP	Financiadora de Estudos e Projetos
Fundep	Fundação de Desenvolvimento da Pesquisa
Fundepar	Fundep Participações S.A.
In avg	in average
NSI	National System of Innovation
QT	Question Type
U.S.	United States of America
UFMG	Universidade Federal de Minas Gerais

SUMMARY

1 INTRODUCTION

This work is concerned with the academic entrepreneurial activity and challenges of technology transfer at the *Universidade Federal de Minas Gerais* (UFMG) related to the university's biotechnology cluster in order to investigate why biotechnologies are not finding their way to the market. With this work, I seek to enhance the understanding of university-industry interaction and its challenges out of the perspective of the scientist that is involved in biotechnology research and development.

On the one hand, hunger in this world is a socioeconomic challenge that is not overcome yet, what is related to the lack of resources to produce enough food to feed the world. On the other hand, one can argue, that there is enough food supply and production to sufficiently distribute it to every human on earth. But as long as food, land and capital is distributed unequally in the world, science has to deliver solutions to overcome the challenge of the rapid growth of our population. By 2050, we will be approximately 9.7 billion humans on earth with an expected growth rate of 1.18% per year (UNITED NATIONS, 2015). The denser population challenges our immune systems and gives space for bacteria and diseases to grow and develop. Over the last centuries many epidemics and plagues got controlled by identifying genes and DNA sequencing and developing technologies to fight diseases.

Biotechnology is often confronted with bioethics that associates it with stem-cell research that threatens to change human nature, chemical warfare or harmful consequences from experimenting with the genetic pool. However, it is due to biotechnology that rice and corn crops can be resistant to plagues and minimize food loss, it is due to biotechnology that the development of biofuels and alternative energy generation can reduce Co_2 emission and generate electricity for isolated areas, and it is due to biotechnology that a large number of vaccines and medical applications can be developed to cure diseases.

As biotechnology products must pass several tests to be approved by national health departments and relies often on expensive equipment and laboratories, its development consumes many years of research and financial investments. The slow market approval through strictly monitored regulations can extent the available resources and lead to the abortion of the technology. Most biotechnology innovations are developed in research institutes and universities due to the high specificity and complexity of such technologies. After first successful tests, the technology can follow two main paths to reach the market: i) companies acquire these promising biotechnologies, in certain circumstances realize clinical trials and eventually market the technology themselves or, ii) the inventor decides to commercialize his research himself in form of university spin-offs. In both cases, the inventor's action is essential to either protect his intellectual property and approach potential buyers or create his own venture as an entrepreneur.

Various examples reflect the essential role of the academia in the development of successful biotechnology products. Scottish biologist Alexander Fleming discovered Penicillin in 1928, but it was the Australian professor Howard Florey and his team at the University of Oxford who devised the drug and made mass-production possible (AMERICAN CHEMICAL SOCIETY, [s.d.]). The drug Adenocard that consists out of the purine nucleoside Adenosine was developed in 1985 and is widely used for regulating heart rates until today. The research that lead to Adenocard can be traced back to the scientists Robert Berne from the University of Virginia (SAXON, 2001). Raymond Schinazi, Dennia Liotta, and Woo-Baeg Choi from the Emory University discovered Emtricitabine (or Emtriva) which is used in the treatment and prevention of HI-Virus infections and can prolong the life expectancy of patients (LEAF, 2005).

The locus of this present work, the *Universidade Federal de Minas Gerais* (UFMG) in Minas Gerais, was selected as it is one of the most extensive focus areas of biotechnology research in Brazil (NIOSI; BAS, 2013). As the results of this study will show, the institution's research on biotechnology spreads over several departments from chemistry over engineering to biology and finds application in medicine, human and veterinary health, nutrition, environmental protection, bioinformatics, aquaculture and others. The complexity of biotechnology leads to a wide array of definitions that aggravates the understanding of what comprises biotechnology. In this present study, biotechnology R&D is considered to be R&D that is performed with the help of biotechnology techniques (DNA/RNA, Proteins, tissue engineering etc.). The definition of biotechnology itself and its techniques and application areas will be outlined in more detail in this work.

Although the university has a focus on biotechnology and the biotechnology cluster in Minas Gerais is one of the biggest in Brazil (BIOMINAS FOUNDATION, 2007; DIMOVA et al., 2009; NIOSI; BAS, 2013; ZYLBERBERG; ZYLBERBERG, 2012), only few technologies, developed at UFMG, were transferred to spin-offs or to established companies over the years, what lead to the research question of this work.

The research question of this present work is to analyze why biotechnologies[1], developed at UFMG, are not finding the way to the market. To investigate this question, the main objective of this work was to understand university-industry interaction and its challenges out of the perspective of professors, researching in biotechnology. Other objectives included sketching a biotechnology landscape of UFMG to gain an overview of the locus of the study; identifying possible biotechnology R&D obstacles that might hinder professors in advancing their technologies; investigating the academic entrepreneurial intensions of biotechnology scientists at the locus of the study; and analyzing the university-industry interaction of professors at UFMG.

To support the research question of this present work, the theoretical background discusses four main topics. The first topic discussed is innovation. It contributes in general to the theme as this work is concerned with biotechnology development and technology transfer. The second topic relates to the university-industry interaction. This part will discuss university-industry technology transfer, the role of the university in the context of the theoretical models of university-industry-government interaction with a focus on the immature innovation system of Brazil. The third topic presents a review on entrepreneurship with a focus on academic entrepreneurship. This topic highlights the role of the academic as inventor and his relation to the commercialization stages. The theoretical background will finish with a discussion on biotechnology, focusing on the definition of biotechnology techniques (e.g. DNA/RNA, Proteins, tissue engineering etc.), and applications (e.g. human health, agriculture, nutrition etc.) and biotechnology in the context of university-industry interaction.

This work uses a quantitative research model to capture the biotechnology activity of UFMG professors that are involved in biotechnology activities. The survey aims at collecting data on the professor's research, financing, R&D obstacles, R&D

[1] Technologies developed though biotechnology techniques (Annex 1)

collaboration, stage of development and management experience. The questionnaire also comprises items that were used to collect data on professor's entrepreneurial activity related to company ownership.

Several results of this present work suggest why biotechnologies are not finding their way to the market. The study's results corroborate with the literature in identifying biotechnology R&D obstacles; low university-industry interaction; and modest industry investments. The results of this study show a considerably low transfer interest of professors and the low management experience correlates with the low transfer interest. Professors of the examined sample classify the access to capital as major obstacle in pursuing biotechnology R&D, followed by access to inputs and qualified human resources.

2 THEORETICAL BACKGROUND

The theoretical background will discuss innovation, university-industry technology transfer and interaction, entrepreneurship with a focus on academic entrepreneurship and biotechnology.

2.1 Innovation

In the beginning of the 20th century, the German psychologist Wolfgang Köhler published an ethological and cognitive psychological study on anthropoid apes (KÖHLER, 1917). On the Canary Islands in Spain, he conducted several experiments on chimpanzees with the objective to define the line between humans and apes beyond their anatomy and evolutionary knots. In one of his experiment, he challenged hungry apes to reach hanging bananas with the help of objects. The ape had access to several boxes that it could move and stack to its advantage. Not immediately, but after some time, the chimpanzee had a stroke of insight that made it observe the big picture of the situation and connect two independent objects - the boxes and the fruits - to come to a solution. At this moment, the animal acts in a non-instinctive way, driven by a sort of intelligence, which allows it to find unique solutions for the same problem.

However, apes would never be able to execute some activities that distinguished them from humans. Even if the animal repeats the learned action several times, its acts always finish as soon as the movements are done, in other words, the ape would not invent an instrument, improve it or save it for later use. The ability to invent and improve objects like sharpening a stone, tying it to a stick and keeping the constructed hammer for more than one use differs the human intelligence from animal ones. From this intelligence, that enables us to develop and evolve, derives one of the most notable human capacities: the ability to innovate.

Although innovation was always around, it was only established in the 1960s as its own field of study after the contribution of Schumpeter on the Theory of Economic Growth in 1934 was translated from German into English what made it accessible for a broader range of readers. Different arguments could explain why innovation had been neglected for so long as a research field. One reason is that, as innovating is a genuine human behavior, the importance of this outstanding capacity had never called the attention of the academy. As Fagerberg (2009, p. 1) wrote, innovation “is as old as mankind itself". Another reason relates to the unpredictability of the innovation phenomenon itself, making it hard to systemize and, consequently, making it a challenge to produce scientific knowledge. Another reason is that most of the traditional economic growth models "used to focus on factors such as capital accumulation or the working markets, rather than on innovation" (FAGERBERG, 2009, p. 1).

Many disciplines payed a considerable amount of attention to innovation studies. Through an exploratory literature review, Martin (2012) mapped such disciplines in one of his publications, which had the goal to detect the most influential academic advances in the field of innovation studies and analyze their evolvement over time. He identified hundreds of papers from areas like economics, economic history, management science, organizational studies, policy studies and sociology. Also through a literature review, Baregheh et al. (2009) recognize this interdisciplinarity. They identified definitions of innovation in articles with significant contribution in the innovation field. Those publications come from a variety of disciplines such as Economics, Business and Management, Marketing, Engineering and Organizational studies. Adams et. al. (2006) also highlight the diversity of disciplines that perceive innovation from diverse perspectives. They argue that the fragmented literature of innovation contributes to its complexity and multidimensionality as each discipline proposes different approaches to describe and analyze this phenomenon.

A multidisciplinary topic as innovation does not have a single definition but the economist Joseph Schumpeter, who is considered to be the father of innovation across all disciplines, can be used as a starting point. In his magnum opus *Theorie der wirtschaftlichen Entwicklung*[2] (1911), Schumpeter states that innovation is to enforce new combinations into reality that generate profit. Those new combinations can result in products, processes, markets or sources of resources. Although Schumpeter's vision of innovation is generalized and applicable to most disciplines, he puts a lot of emphasis on profit generation.

In his contribution, Pavitt (1984, p. 2), describes and explains the sectorial patterns of technical change on innovations in the case of Great Britain. Also from an economic

[2] English translation from 1934: Theory of Economic Growth

perspective, he defines innovation as “a new or better product or production process successfully commercialized or used”[3]. Tidd and Bessant (2013, p. 19), who researched on the area of innovation management tried to provide a definition that agrees with several scholars from different disciplines like Freeman (economics), Porter (Marketing) and Drucker (Innovation and Entrepreneurship), and suggested that “innovation is a process of turning opportunity into new ideas and of putting these into widely used practice” (TIDD; BESSANT, 2013, p. 19).

Although most scholars of various disciplines share Schumpeter’s emphasize on profit generation in some way as part of the innovation definition, a few academics explicitly exclude commercial success from the equation. For an instance, Rampino (2011), who looks at innovation from a design perspective, states that the value of design-driven innovation often cannot be measurable only related to commercial success. She stresses the importance of implementation after idea generation and product creation as essential part of innovation. Therefore, he adopts von Stamm’s (2003 p 1 *apud* RAMPINO, 2011, p. 4) definition: “innovation equals creativity plus a successful implementation process”.

The discussions around the term innovation received a lot of attention in the last decades. Not only can innovation generate wealth for individuals, but it is the foundation of economic growth (SALTER; ALEXY, 2014; BAUMOL, 2002 *apud* TIDD; BESSANT, 2013). However, it is important to recognize that not all innovative accomplishments have the same effect on growth. The extent of an innovation’s impact on companies, the market or the society differs in each case and often is related to the degree of novelty or change. It is important to distinguish between different types of innovation. Damanpour (1991) identifies three pairs of typologies: radical and incremental; product and process; and technical and administrative. Like Damanpour, Schumpeter labels continues improvements on organizational level as incremental or marginal and the innovations with great impact on organizational structures as radical (SCHUMPETER, 1942 *apud* FAGERBERG, 2009).

Many other authors are concerned with the difference and impact of radical and incremental innovations: Lundvall argues that depending on the extent on

[3] Citation adapted to American English

accumulation of incremental innovations, their impact can be just as great or even greater than radical innovations (LUNDVALL, 1992 *apud* FAGERBERG, 2009). It is important to note that the degree of novelty can relate to the market (products and services) and to the organization (changes in the organizational structure). Not necessarily, this novelty has the same degree in both spaces. A useful concept, especially use in New Product Development literature, is the Ansoff Matrix, which crosses the novelty level of market and product (ANSOFF, 1957). Davis and Moe (1997) adopt Ansoff's concept and add the risk factor that depends on the degree of novelty in product innovation. Their concept suggests that the newer the product to the market and the company, the higher the risk to invest in resources that are essential to peruse the product development (DAVIS; MOE, 1997; *apud* PRAJOGO; SOHAL, 2001). With his innovation pyramid and the product-design field, Rampino (2011), categorizes radical and incremental innovation in four sectors – aesthetic, use, meaning and typology . An incremental product innovation can be an improvement of its aesthetic perception by changing its form, or an improvement in its use by changing its function. Radical products can be innovative related to their meaning or typology and both in form or function.

Damanpour (1991) differentiates between product and process innovation. Product innovation involves the introduction of new products or services on the marketplace and are therefore easier to identify in contrast to process innovations that usually occur inside organizations and involve modifications on operations or tasks (SALTER; ALEXY, 2014).

Damanpour (1991) puts emphasis on the technical-administrative typology. Depending on the type, the decision-making process often varies. On the one hand, the emergence of new products or services is related to technical innovation. Administrative innovation, on the other hand, affect organizational structure and processes.

2.2 University-industry interaction

The following section sheds light on the university-industry interaction to discuss the dynamics and interaction of those two spheres. For this, a brief discussion on university-industry technology transfer will follow. Subsequently I will present an overview on innovation systems, introducing the concept of National Systems of Innovation (NSI) and the Triple Helix model. This section on university-industry interaction will finish with the specificities of the immature System of Innovation and Brazil.

2.2.1 Technology transfer

The literature on the technology transfer processes discusses the transfer from university to the industry, transfer from governmental labs to the industry and transfer within the industry (HARMON et al., 1997). However, this study will focus on the technology transfer process from the university to the industrial sector (further referred to as U-I transfer) since this is most relevant for this present work.

The university is a fundamental source of knowledge in science and technology areas and therefore, it is important to discuss how science finds its way to commercialization (AGRAWAL, 2001). The economist Thorstein Veblen was one of the first scholars in the early 1920s who recognized the commercial potential of universities through the research they produce. However, it is to note that universities primary mission is not to engage in commercial enrichment but in educating and preparing qualified workforce and producing scientific and tacit knowledge (VEBLEN, 1918 *apud* ETZKOWITZ, 1983;). Among others, O'Shea et al. (2004) state that universities become more central in economic development, mainly through research and development produced and patented technologies that potentially lead to spin-off companies or income through licensing or royalties. Transferring technologies to the private sector can, on the one hand, provide revenues for the university and, on the other hand, contribute to regional and national economic growth (PHAN; SIEGEL, 2006).

The U-I transfer process is seen as a linear process from idea generation and technology development, over intellectual property protection to a search process that links the technology provider (university) to the recipient (industry) (HARMON et al., 1997). In the last decades, university are increasingly involved in technology licensing and patenting - not only to established industries but also to university spin-offs that are created by university staff or their students to commercialize university-generated technologies (MOWERY; SHANE, 2002). This academic entrepreneurial activity is often highlighted in the literature as an essential part of U-I transfer process

(ETZKOWITZ, 1983; O'SHEA et al., 2004; TIDD; BESSANT, 2013; WRIGHT; BIRLEY; MOSEY, 2004), and will be discussed in more detail in section 2.3 of this work.

To understand the challenges of technology transfer processes, it is relevant to shed the light on the interaction of the key spheres – government, university and industry – as part of an innovation system. For this work, it is relevant to discuss also the specificities of innovation systems in peripheral countries such as Brazil.

2.2.2 Innovation systems

For most of the 19th century, tuberculosis was one of the deadliest diseases, known to humankind. Known as the white plague, tuberculosis was responsible for 25% of all deaths in Europe at that time (BLOOM, 1994). After Robert Koch identified the bacteria responsible for the infection, the public health community engaged in sanitary initiatives that helped controlling proliferation of the disease. However, it was only in the 1940s that doctors of the Rutgers University discovered the antibiotic streptomycin, capable of treading the death-bringing plague. Like streptomycin, many other technologies would have not been possible without the contribution of academic scientific research.

The traditional universities that were established during the middle ages, orientated themselves on two missions: higher education and research. After the World War I and II, an especially during the cold war, the research in the academy played an increasing role in the economic development, with a third mission to directly contribution to the industrial growth (ETZKOWITZ; LEYDESDORFF, 2000). These three primary missions of the academy were the first insights of how the university contributes to the complex university-industry interaction that in the modern sense was shaped in the mid-1980s (MURRAY, 2004) in form of innovation systems. An innovation system can be defined in many perspectives. Two of them seem to be relevant for this present work. The first one is related to the concept of the National System of Innovation with roots in the economic science, defined by many academics during the 1980s. OECD

(1997, p. 10) aggregated the most relevant contributions to the definition of the term, as presented in Figure 1.

Figure 1 OECD-aggregated definitions of National System of Innovation

Freeman, 1987:

" .. the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies."

Lundvall, 1992:

" .. the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state."

Nelson, 1993:

"... a set of institutions whose interactions determine the innovative performance ... of national firms."

Patel and Pavitt, 1994:

" .. the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country."

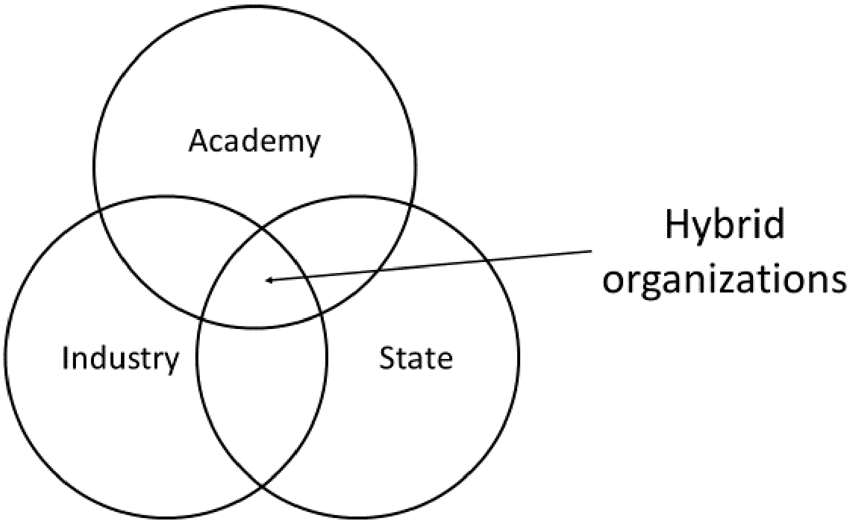
Metcalfe, 1995:

".. that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies."

The definitions, although differently articulated, come to a central point: different performance regarding the innovation capabilities reveals how some key players interact to invent, launch and manage new products in the market. It is worth mentioning that a system of innovation is not necessarily national (e.g. local or regional).

The second concept is the Triple Helix Model of Innovation by the sociologists Etzkowitz & Leydesdorff (2000) that, just like the NSI, highlights the role of the university-government-industry interaction in the innovation process and popularized this concept in the 1990s (MOWERY; SAMPAT, 2005). As already mentioned, the Triple Helix is a model which is commonly represented as three spheres (State-Academia-industry) that overlap. This model is visualized in Figure 2 This representation is the result of various changes, that previous models went through over time. According to Etzkowitz & Leydesdorff (2000; LEYDESDORFF; ETZKOWITZ, 1998), the first Triple Helix was defined to approach the interaction of academia and industry, directed and guided by the state. In contrast, the second version of the model places the three spheres equally distributed, suggesting that the academia and industry can have links without the governance of the state. However, hybrid innovation institutions were only represented in the third version of the concept, with the overlapping of the spheres. This overlap symbolizes the emergence of organizations such as university business incubators, governmental laboratories and academic spin-offs.

Figure 2 Triple Helix Model



Although these two concepts use the same key players in their interactions, there are important differences that should be considered. First, the NSI is no model. This means, that the authors and adapters of this theory are not concerned with making a representation of the innovation structure in a simplified scale, as the Triple Helix. An opposite effort is made when it comes to the NSI. The contributors of this theory engage in writing with detail about the historical perspective that lead the analyzed location (national, regional, local) to its current innovation system. Secondly, different than in the concept of the National System of Innovation that attributes the industry as primary force in innovative activities, the Triple Helix places the emphasis on the academy in innovation generation, (ETZKOWITZ; LEYDESDORFF, 2000).

This work investigates the university-firm interface; therefore, the focus of this section is primarily on those two spheres and less on the government. A central question should be how this interaction is usually made. Many authors have described how the academy and industry interact, in a sense of supporting innovation. Such literature, especially the one regarding the NSI, does not provide enough elements to understand the innovation dynamics of countries such as Brazil. The reason is, as highlighted by

Albuquerque (1999), that in immature NSI the mainstream patterns and mechanisms for innovations are often not present. In this case, a better discussion for the present work should be based on the specificities of such immature systems.

2.2.3 Immature innovation systems and Brazil

National System of Innovation theorists found different classification for countries innovation performance due to their System of Innovation. Albuquerque (1999) “tempted” to sketch a unique typology of such classifications, focusing on non-OECD countries (the periphery). Based on statistical tests, the author created three typologies to categories 46 countries: i) “mature” – grouping the countries responsible for pushing the scientific boarder and its diffusion; ii) “catching up” – countries with first indications of establishing NSI and; iii) “non-mature” – the category of countries that are permanently risking to “fall behind” (ALBUQUERQUE et al., 2008).

According to Alberquerque’s classification, Brazil falls into the “non-mature” NSI typology, which is subdivided into three. It is worth mentioning that countries such as Brazil, Mexico and Spain belong to the “old and ineffective science and technology structure” (OISTS) subgroup, different than the past-“socialist” countries (e.g. Russian and Poland) and the Asian cubs (e.g. Malaysia and Philippines).

Freeman (1995 *apud* ALBUQUERQUE, 1999) points out the main characteristics of the Latin American economies, that are included in Albuquerque’s OISTS-category. Those economies are characterized by having:

> “the existence of a scientific infrastructure (universities, research institutes, and governmental agencies); weak commitment of business firms to innovative investments; presence of educational skills, but with problems and serious flaws. In the last decades, they have also shared low levels of economic growth”. (ALBUQUERQUE, 1999, p. 3).

Albuquerque (1999) points out that countries like Brazil have different roles in the interaction of science and technology as developed countries. The role of science in the periphery is not to contribute directly to the technological progress, also because of budget restrictions for scientific development, but to identify the opportunities of “mature” nations and receive their knowledge. Albuquerque uses the metaphor of an antenna. Even though such countries have a limited scientific infrastructure, science is essential as an advisory body that directs and guides the technological development to avoid wasting resources in a blind treasure hunt (ALBUQUERQUE, 1999).

In the specific case of Brazil, according to Albuquerque *et al.* (2008) the university-industry interaction is present but characterized by only punctuated interference of the two spheres. However, in their research, the authors highlight sectors with competitive advantages that Brazil has on the international market. This advantage is a result of a scientific adapting capabilities that involved a strong network among the three parts of the NSI – Government, Industry and University. Brazil has a leadership role in i) the health sciences with the production of vaccines; ii) agrarian sciences, especially cotton, paper pulp and meats; iii) mining, materials engineering and metallurgy, with strong participation of UFMG; iv) aeronautical engineering, with an emphasis on the aircraft manufacture Embraer and; v) geosciences through the production of oil and gas, mainly by the oil giant Petrobras (ALBUQUERQUE et al., 2008, p. 4).

The immaturity of the Brazilian System of Innovation structure has a profound relationship with its historical path. Regarding the industrialization of the former Portuguese colony, it was only in the 1950s that Brazil went through a strong industrialization process, characterized by the substitution of importation strategy. Founded in 1951, the governmental institution CAPES[4] had the objective to ensure that specialized and qualified labor force was available in sufficient quantity to meet the demand of public and private companies to advance the country’s development (CAPES, 2017). The mission of the organization focuses on higher education (master and doctorial courses) by providing access to scientific productions, finance, international scientific cooperation and further education of academic staff (CAPES, 2017). Simultaneously with CAPES, CNPq was founded in 1951 by the agency of the Ministry of Science, Technology, Innovation and Communication (MCTIC) with the goal to promote scientific and technological research, encourage the training of Brazilian researchers and having a leading role in formulating and conducting science, technology and innovation policies (CNPQ, 2017).

Around the 1960s, “foreign subsidiaries accounted for more than 50% of the capital goods producers, 70% of chemicals (except petrochemicals), 90% of pharmaceuticals, and 100% of the nascent automobile industry” (DAHLMAN; FRISCHTAK, 1993, p. 430). The late establishment of universities in the beginning of the 20th century left

[4] Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Coordination of the Improvement of Higher Education Personnel)

major gaps in the educational systems, compromising the education of labor force and its technological capabilities (DAHLMAN; FRISCHTAK, 1993). It was only in the 1970s that the military government of Brazil was concerned with the technological development as a strategy of economic growth.

However, the necessary innovation structure took longer to be built and was introduced to a few innovation supporting legislations over the years. Although the first patent laws in Brazil date back to 1809 and the country was also founding member of the Paris Convention in 1883, the legal strength of Brazil's intellectual property laws was not comparable to more developed countries (BOLTWOOD, 2008). With the Industrial Property Law N° 9279/96 of 1996, the Brazilian patent system was improved and since then is the general patent law of the country (BRASIL, 1996). Other legal marks also contributed in promoting a more efficient innovation system, e.g. Law N° 9991 of 2000, which obligates public energy companies to invest a fixed percentage of their revenue in R&D (BRASIL, 2000), and the innovation law N° 10.973 (BRASIL, 2004), which was introduced in 2004 and renovated in 2016 (Law N° 13.243) as bundle of initiatives that encourages innovation and scientific and technological research (BRASIL, 2016). The renovation of 2016 includes articles that are concerned with the promotion of the cooperation and interaction between the public, public and private sectors and companies (Art. 2° V).

Since 1962, starting with the creation of the Research Support Foundation of the state of Sao Paulo (FAPESP), the regional scientific investment funds spread all over Brazil including Minas Gerais in 1985 (FAPEMIG). Nowadays, all the Brazilian states feature their own regional research foundations. Those state research foundations (FAPs) were created to offer resources for the pursuit of R&D and play a significant role defining national scientific and technological policies (MENEZES, 2001).

2.3 Entrepreneurship

The creation of wealth and new ventures is directly linked to the concept of entrepreneurship. The central figure in such an innovation process is the entrepreneur. He is responsible for translating an idea into a concept and implementing that concept in the market. Like innovation, the concept of entrepreneurship is multidimensional. Entrepreneurship not only finds its place as a field of study in several disciplines, but also ranges from the individual level to the company level and must be considered in a regional, national or even international context. As the interdisciplinarity and multidimensionality make it impossible to define the entrepreneur universally, I will present and discuss the different views on entrepreneurship literature in an historical approach in this section. Several authors acknowledged the complexity of the entrepreneurship literature (AUDRETSCH, 2003; RUSU et al., 2012; STEVENSON; JARILLO, 1990; VAN PRAAG, 1999).

Stevenson and Jarillo (1990) try to cluster the discussion on entrepreneurship according to three perspectives related to how the entrepreneur is analyzes by the literature. The first category relates to the results of entrepreneurial actions and not the entrepreneur itself or his actions. This viewpoint is the origin of entrepreneurial studies, mainly represented by economists. Secondly, the authors create the category that relates to the reason of entrepreneurial actions. Entrepreneurship from this perspective sheds light on the individual and his characteristics. Stevenson and Jarillo term this category as “psychological/sociological approach”. The third perspective is one how the entrepreneur acts. The focus of this approach is on entrepreneurial management.

The first record known to us that mentions the term entrepreneur was the Irish-French economist Richard Cantillon (1680 – 1734). He was the first to pay considerable attention to the entrepreneur and recognized his impact on the economy. Cantillon’s entrepreneur has a central role in the economic system and brings an equilibrium to the market’s supply and demand. This equilibrium function is a result of engaging in arbitrage and risk taking (VAN PRAAG, 1999). Cantillon sees the entrepreneur out of an economic perspective. He recognizes his importance as equilibrium function but pays little attention to the entrepreneur as individual (STEVENSON; JARILLO, 1990).

Around 1800, the economist Jean Baptist Say extents Cantillon’s perception of the entrepreneur and adds a central role in production, distribution and managerial tasks (VAN PRAAG, 1999). Say, who is mainly recognized for his law of markets, describes the entrepreneur as an individual who increases his profit by transferring recourses while increasing productivity (RUSU et al., 2012).

Schumpeter contributes significantly not only in the field of innovation but also to the development of entrepreneurship theory. In contrast to the managerial perspective of

Say's entrepreneur, Schumpeter's entrepreneur is not only the leader of a venture, he is also the innovator and pushes the economic system (SCHUMPETER, 1911; VAN PRAAG, 1999). Schumpeter gives the entrepreneur a distinctive role in the economic system. He sees the entrepreneur as a disruptive force in the economy that, unlike Cantillon's view, brings disequilibrium through innovative ventures, leading to a higher degree of economic growth (AUDRETSCH, 2003).

Under the consideration of multiple dimensions, Stevenson, Roberts and Grousbeck (STEVENSON; ROBERTS; GROUSBECK, 1989 *apud* STEVENSON; JARILLO, 1990 p 8) define entrepreneurship as "a process by which individuals-either on their own or inside organizations-pursue opportunities without regard to the resources they currently control".

2.3.1 Academic Entrepreneurship

Etzkowitz (ETZKOWITZ, 1983) was one of the first that shed the light on academics as entrepreneurs as he noticed their favorably respondents to the idea of creating own ventures to profit from their own research and development. In their research, O'Shea et al. (2004) stress the importance of the academic entrepreneur that plays the central part in academic spin-offs and several other contributions study the role of scientists as entrepreneurs and with the increasing attention on innovation and entrepreneurship, the area of academic entrepreneurship receives more consideration by the literature.

Scientists always played an immense role in not only developing new technologies, but also in finding applications in our society in form of entrepreneurial activity and creating new ventures. Samsom and Gurdon (1993 *apud* FRANKLIN; WRIGHT; LOCKETT, 2001 p. 128) define the academic entrepreneur as: "an academic whose primary occupation, prior to playing a role in a venture start-up, and possibly concurrent with that process, was that of a lecturer or researcher affiliated with a Higher Education Institute".

Radosevich (1955) presents a model of two kinds of entrepreneurs that come from public technology sources: (1) the inventor-entrepreneurs, the classical academic entrepreneur, that commercializes his own technology; (2) and the surrogate-entrepreneur, an "outsider" that acquires the intellectual property from the inventor and institution to spin-off the technology. Although the inventor is not engaging himself in pursuing the commercial activities of his technology, he is actively supporting the advancement of the technology from the lab to the market and has therefore certain entrepreneurial characteristics.

For promoting university spin-offs, Franklin, Wright and Lockett (2001) agree with those two models and discusses the advantage and disadvantage of both approaches. The study identified as biggest advantages of academic entrepreneurs the tacit knowledge the scientist brings to the spin-off and his commitment to the technology he created out of the view of the university. The biggest disadvantage of scientist-entrepreneurs, according to the study, is the lack of managerial expertise. Contrary to the academic entrepreneur, the study shows that commercial experience is the biggest advantage of surrogate-entrepreneurs. As the “outsider” is immersed in the business environment, he brings objectivity towards the technology and the ability to conduct business activity, complementary to the inventor’s expertise. The biggest disadvantage of surrogate-entrepreneurs is their insufficient knowledge related to the technology functions and lacking connection to the university that provides the technology. The university fears a conflict of interest and is less likely to trust someone outside the universities borders with their technology as the inventor himself is not involved in the commercial stages of the technology. It can be observed that the disadvantages of surrogate entrepreneurs are the advantages of academic entrepreneurs and vice versa. This suggests that those two models should be implemented complementary without excluding each other.

Based on Radosevich’s (1955) groundwork, Festel (2011) recognized this gap and introduces a third model that functions as an intermediate solution for inventors without managerial expertise – Founding angel. The founding angel, an outsider, acts together with the inventor on the creation and early stages of the venture and provides managerial consultation, business network and finance. In this model, the inventor is actively involved in the new venture, contrary to the surrogate model. Founding angles can be very valuable in high-tech sectors such as biotechnology, as the gap between research, development and commercialization can disrupt the innovation process and force it to come to a standstill. Which of the three models are being executed depend on each scientists need (WÜRMSEHER, 2017).

Baglieri and Lorenzoni (2012) observe the apprehension of the academy that scientists show lower dedication towards their university liabilities when affiliated with the commercialization of their technology. They propose that a scientist that also acts as a lead user[5] leverages synergies from being active and familiar with the academy and the industry. The authors observe that those Principle Investigators (PIs) have no negative effect on the academy. The authors define the PI as a leading scientist that conducts research but also a manager that controls and executes projects without neglecting administrative obligations. Baglieri and Lorenzoni (2012) stress the importance of PI as key performers of technology transfer in universities, being aware that those individuals require a wide set of skills and capabilities to execute all tasks.

Scientists that also engage in the commercialization process of their technologies play an essential role in academic entrepreneurship and technology transfer. As lead users with market perception, they anticipate problems that might occur during implementation of their technologies on industrial scale. The academic entrepreneur has the potential to close the gap between academia and industry.

To close this gap, Murray (MURRAY, 2004) highlights the importance of academic inventors in entrepreneurial firms especially related to their social not human capital. According to Murray's contribution, the biggest advantage of integrating academic inventors in firms is not having them as human resource but having access to their social and scientific network. According to Murray's empirical study, one element of this social capital is the academics local research network and laboratory interactions and another relates to their broader network with fellow scientists outside the laboratory borders. Murray suggests that giving academic scientists a career in entrepreneurial firms, is one of the key factors in shaping science-based ventures as the previously mentioned elements of their social capital immerse the firm in the scientific community and therefore gives the firm the opportunity to interact with and profit from the frontier of scientific knowledge. Although not specifically characterizing the inventor as entrepreneur, but as part of nascent, entrepreneurial firms, Murray agrees with the results of those previously mentioned, Franklin, Wright and Lockett

[5]"The lead user concept describes a particular type of customer who is technically trained, has considerable interest and experience with manufacturing aspects and perceives key economic benefits from an innovation or a solution to a problem."(BAGLIERI; LORENZONI, 2012, p. 3)

that identified the tacit knowledge of the scientists as biggest advantage of the academic entrepreneur.

Although the entrepreneurial scientist brings new ideas, new developments and new technologies, they usually do not continue to approach costumers, search for business alliances or create business concepts (O'CONNOR; PAULSON; PETERS, 2008). With scientists being public servants, their job is usually characterized by secure pensions, fixed working hours, regulated working conditions and stable workplace with low risk of being let go. In contrary, entrepreneurship is characterized by taking high risks and handling uncertainty. Collins and Moore (1964) reflected the essence of entrepreneurship as the "desire for independence" (COLLINS; MOORE, 1964 *apud* STEVENSON; JARILLO, 1990 p. 20). Therefore, it is to note that academics, scientists and professors are adding immense value to entrepreneurial firms; they usually do not have the profile and mindset of a risk taker and engage in business activities, especially not in a high-regulated field such as biotechnology. Nevertheless, the academics market perception and orientation are essential to go beyond the R&D phase.

2.4 Biotechnology

Traditional biotechnology has been around since people started to drink beer and eat bread but modern biotechnology revolution started in 1973 with the discovery of the basic technique for recombinant DNA by Stanley Cohen and Herbert Boyer, that later became the foundation of genetic engineering (COHEN; CHANG; BOYER, 1973 *apud* MCMILLAN; NARIN; DEEDS, 2000). The use and application of biotechnology changed over time and therefore also its definition. Biotechnology relates to a technology and its application, other than life science that is more generally concerned with the study of living organisms. Today, the United Nations define biotechnology as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" (UNITED NATIONS, 1992). However, the literature does not provide a unique definition for biotechnology and is thereby perceived differently by practitioners. Because most definitions of biotechnology are very broad and the research on this area gained lots of attention in the last decades, in 2005, OECD presented "a statistical framework to guide the measurement of biotechnology activity" (OECD, 2005, p. 5). This framework does not only provide a broad definition on biotechnology, it opens the biotechnology black box and draws up a list-based definition. The single, broad definition reads: "The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of know ledge, goods and services." (OECD, 2005, p. 9). The list-based definition comprises following biotechnology techniques: DNA/RNA; Proteins and other molecules; Cell and tissue culture and engineering; Process biotechnology techniques; Gene and RNA vectors; Bioinformatics; and Nanobiotechnology (OECD, 2005, p. 9). The complete list-based definition with all subordinate keywords can be found in Annex 1.

The definitions provided by OECD and the United Nations determine biotechnology as an application or technique not facilitating the understanding of the dynamics of this sector, as the same technique can be applied in different application areas. For an instance, the same DNA technique can be applied to modifying crops and to identifying genetic causes for human cancer. In this case, the unique DNA technique finds application in the sector of agriculture and human health. The other way around, many different biotechnology techniques can be used in one application area.

To complement the definition of OECD, their published list of classifications of biotechnology applications can be consulted: Human Health, Veterinary health, Agriculture, Natural resources, Environment, Industrial processing, Non-specific applications and other applications (OECD, 2005). Although OECD recognizes the rapid development of the biotechnology sector[6] and updated the report in 2009 (VAN BEUZEKOM; ARUNDEL, 2009), the definition of 2005, including the list-based one, stays unchanged.

Other efforts have been made to define biotechnology according to their application. The Indian microbiologist and former director of the Life Science division of UNESCO, Edgard J. DaSilva, introduced a classification of the biotechnology application, intertwining with the color code of the rainbow (DASILVA, 2004). His arrangement of color types in relation to the area of biotechnology diversifies the application areas of biotechnology related to OECD. The biotechnology colors of DaSilva are visualized in Table 1.

[6] "The list is indicative rather than exhaustive and is expected to change over time as data collection and biotechnology activities evolve" (OECD, 2005, p. 9)

Table 1 Biotechnology colors according to DaSilva

Color Type	Area of Biotech Activities
Red	Health, Medical, Diagnostics
Yellow	Food Biotechnology, Nutrition Science
Blue	Aquaculture, Coastal and Marine Biotech
Green	Agricultural, Environmental Biotechnology – Biofuels, Biofertilizers, Bioremediation, Geomicrobiology
Brown	Arid Zone and Desert Biotechnology
Dark	Bioterrorism, Biowarfare, Biocrimes, Anticrop warfare
Purple	Patents, Publications, Inventions, IPRs
White	Genebased Bioindustries
Gold	Bioinformatics, Nanobiotechnology
Grey	Classical Fermentation and Bioprocess Technology

The polish chemist Paweł Kafarski picks up and adapts the concept to create the rainbow code of biotechnology (KAFARSKI, 2012). He points out that although classifying biotechnology by colors is commonly used, the rainbow-concept is not established yet and the classification is in current change as biotechnology research is evolving and spreading quickly in recent years.

In the development of biotechnology products and processes, several authors highlight the role of universities and research institutions as indispensable: Gelijns & Rosenberg (1995 *apud* ALBUQUERQUE; CASSIOLATO, 2002) stress the great amount of scientific and technological information flows, related to the health sector, that originate from such institutions. They point out that universities are a central knot in the health-care sector with extensive scientific knowledge. Medical innovation is increasingly depending on interdisciplinary research of universities and their interaction with industrial companies. Nelson (1995 *apud* ALBUQUERQUE; CASSIOLATO, 2002) states that emergence of modern biotechnology intensifies the relationship between university and industry. He supports the strong information flow between industry and universities and research institutions. Through an extensive US patent analysis, Rosenberg & Nelson (1994) observed, that the innovation activity in the sector of biotechnology at universities is greater than in the industry, contrary to other sectors.

Narin *et al.* (1997) examine the contribution of public science to industrial technology in the United States and state that patents related to drugs and medication are those with the strongest dependence on public science. His research shows that only 17%

of all drugs and medicine patents in his sample are related to the industry while half of all patents come from U.S. public science and one third from foreign science, mostly public as well.

In addition to Narin *et al*.'s discussion, McMillan *et al.* (2000) narrow down the focus of research on the importance of public science to the sector of biotechnology in the U.S. Their results confirm the findings of Narin *et al*. and highlight the critical role of public science in biotechnology. The authors conclude that the public funding in this sector is strategically important as biotechnology has the capacity to revolutionize the pharmaceutical, chemical and agricultural industry at that time (MCMILLAN; NARIN; DEEDS, 2000, p. 8).

Liebeskind *et al.* (1996 *apud* MCMILLAN; NARIN; DEEDS, 2000) observed biotechnology companies regarding their social networks. In their research, they discovered that companies that are engaging in research, together with the academy, show a more effective way in sourcing novel scientific knowledge than companies without links to public science.

Despite the immature NSI, Brazil has an international competitive advantage in health science and biotechnology. With the creation of the National Biotechnology Committee under the Presidential decree number 6041, it became a priority of the Brazilian government (BRASIL, 2007): Article one of the decree reads:

> Fica instituída a Política de Desenvolvimento da Biotecnologia (...) que tem por objetivo o estabelecimento de ambiente adequado para o desenvolvimento de produtos e processos biotecnológicos inovadores, o estímulo à maior eficiência da estrutura produtiva nacional, o aumento da capacidade de inovação das empresas brasileiras, a absorção de tecnologias, a geração de negócios e a expansão das exportações.[7] (BRASIL, 2007, p. 1)

With this decree, the Brazilian government prioritized the sectional areas of Human Health, Agriculture, Industrial production and environment. Article 1, paragraph 3 II of the decree encourages the formation and training of human resources for the

[7] English translation: The Biotechnology Development Policy is created with the objective of establishing an adequate environment for the development of innovative biotechnological products and processes, stimulating greater efficiency of the national productive structure, increasing the capacity of Brazilian companies to innovate, absorbing technologies, business creation and expand the export.

development of Science and Technology and innovation in biotechnology focusing on the bio-industry.

The governmental support, in form of policies, investments and projects, and expansion of the biotechnology sector led to creation of many new companies with focus on biotechnology. More than 70% of all biotechnology related companies are located in the states Sao Paulo (42,3%) and Minas Gerais (29,6%), representing the major cluster of biotechnology in Brazil (BIOMINAS FOUNDATION, 2007). The biotechnology cluster of Minas Gerais is mainly focused on human health, agribusiness, animal health and the environmental sector (DIMOVA et al., 2009).

According to a study of Biominas regarding Brazilian biotechnology companies, surveyed ventures claim following issues (BIOMINAS FOUNDATION, 2007, p. 5):

- "Lack of expertise in managing the regulatory affairs process"
- "Inexperience protecting intellectual property"
- "Problems identifying and recruiting qualified personnel"
- "Insufficient know-how related to commercialization strategies"
- "A lack of knowledge related to financing techniques."

The high regulated and research-intensive biotechnology industry requires intensive investments in R&D to prepare the product for market entry. According to the beforehand mentioned Biominas study (2007, p. 39), financing (e.g. cash generation, access to financiers, obtaining working capital) and regulations (Product registration, Patent application procedure, international certifications) are high barriers for the companies questioned in their study.

Conclusively, the four themes and dimensions that reflect the theoretical background of this present work are systemized in Table 2.

Table 2 Systemized summary of the theoretical background

Themes and dimensions	Discussed topics	Authors
Innovation	History of innovation	Schumpeter (1911)
	Definition of innovation	Pavitt (1984)
		Tidd and Bessant (2013)
		Freeman
		Rampino (2011)
		Drucker
		Porter
		von Stamm (2003)
	Innovation: Complex, multidisciplinary, multidimensional	Fagerberg (2009)
		Adams et. al. (2006)
	Literature review on Innovation	Martin (2012)
		Baregheh *et al*. (2009)
	Innovation as economic growth	Salter & Alexy (2014)
		Tidd & Bessant (2013)
		Baumol (2002)
	Radical vs incremental innovation	Damanpour (1991)
		Schumpeter (1942)
		Fagerberg (2009)
		Lundvall (1992)
		Ansoff (1957)
		Davis & Moe (1997)
		Prajogo & Sohal (2001)
		Rampino (2011)
	Product vs process innovation	Damanpour (1991)
		Salter & Alexy (2014)
	Technical vs administrative typology	Damanpour (1991)
University - Industry interaction	University-industry Technology Transfer	Harmon *et al*. (1997)
		Agrawal (2001)
		O'Shea et al. (2004)
		Phan & Siegel (2006)
		Mowery & Shane (2002)
		Veblen (1918
		Etzkowitz (1938
	National System of Innovation (NSI) definition	OECD (1997)
		Freeman (1987)
		Lundvall (1992)
		Nelson (1993)
		Patel and Pavitt (1994)
		Metcalfe (1995)
	Triple Helix Model of Innovation	Etzkowitz & Leydesdorff (2000)
		Etzkowitz & Leydesdorff (1998)
		Mowery & Sampat (2005)

	Immature NSI	Albuquerque (1999)
		Albuquerque (2008)
		Freeman (1995)
	Brazilian NSI	Albuquerque (2008)
		Dahlman & Frischtak (1993)
		Mendezes (2001)
Entrepreneurship	Literature review on entrepreneurship	Audretsch (2003)
		Rusu *et al.* (2012)
		Stevenson & Jarillo (1990)
		Van Praag (1999)
	History of entrepreneurship	Cantillon
		Say
		Schumpter
	Definition of entrepreneurship	Stevenson & Jarillo (1990)
		Stevenson, Roberts & Grousbeck (1989)
Academic Entrepreneurship	Importance of academic entrepreneurs	Etzkowitz (1983)
		O`Shea (2004)
		Samsom & Gurdon (1993)
		Franklin, Wright & Lockett (2001)
		Murray (2004)
	Models of academic entrepreneurship	Radosevich (1955)
		Franklin, Wright & Lockett (2001)
		Festel (2011)
		Würmseher (2017)
	Principle Investigators	Baglieri & Lorenzoni (2012)
	Scientist vs. Entrepreneur	O'Connor, Paulson & Peters (2008)
		Collins & Moore (1964)
		Stevenson & Jarillo (1990)
Biotechnology	Definition of biotechnology	OECD (2005)
		United Nations (1992)
		Beuzekom & Arundel (2009)
	Colors of biotechnology	DaSilve (2004)
		Kafarski (2012)
	Importance of university - industry interaction in the health and biotechnology sector	Geljins & Rosenberg (1995)
		Albuquerque & Cassiolato (2002)
		Nelson (1995)
		Rosenberg & Nelson (1994)
		Narin *et al.* (1997)
		McMillan, Narin & Deeds (2000)
		Liebeskind *et al.* (1996)
	Brazil, Minas Gerais and biotechnology	Brazilian Government (2007)
		Biominas Foundation (2007)
		Dimova (2009)

3 METHODOLOGY

The present work uses a quantitative questionnaire as a tool to investigate the biotechnology environment of UFMG. The target group are professors at UFMG that are involved in biotechnology R&D. The goal of the questionnaire was to identify professors and their research involvement in the area of biotechnology, more specifically regarding their R&D collaboration, research funding, perception of their research obstacles and entrepreneurial practices. It is to note that the following instruments that will be presented in this section and that were used in this study are not validated in the literature. Those instruments were constructed to serve the specificity of the research and to investigate the research objectives with a focus.

3.1 Quantitative survey strategy

Survey research finds its application in many different areas from business administration over social sciences and health services to politics and can provide a representative overview of the examined sample. Every data collection through surveys follows general guidelines to generate scientifically applicable and representative data. The basic structure starts with the planning and designing of the survey, leads to the development of the survey instruments (creating questions, scales and questionnaires), continues with the data collection after the field research and finishes with the interpretation of the results (ALRECK; SETTLE, 1985)

Correctly carried out surveys can reflect attitudes, behavior, lifestyle, demographics or needs of a sample and can be applied to a society, given the sample is large enough and representative. For the construction of questionnaires, it is important to keep the survey clear, neutral and understandable for the target audience to leave no room for wrong interpretation. Surveys that aim at gathering objective information should avoid or limit containing questions that might result in anchoring effects, priming or tendency to social acceptance (GERRIG; ZIMBARDO, 2008; KAHNEMAN; SLOVIC; TVERSKY, 1982).

The objectives of this work were investigated through a quantitative survey that was distributed online to the target population. This method was chosen as it provides quantifiable, structured data that can be analyzed through descriptive statistics to help understand the features of the collected data. Because of time limitations a qualitative method was not applied in addition to the quantitative survey. Although the case of UFMG is examined, the method used in this work is not considered to be a case study, as a case study focuses on a single case over time rather than an analysis of a time cut of a population or sample like in this present work.

3.2 UFMG innovation model

UFMG attempts to create an innovation environment that nurtures technologies that were developed at UFMG and provide the inventors with the necessary resources and networks to approach the market place. For academics that seek no direct involvement with commercializing technologies, the university offers a well branched network to promote scientific contributions in form of academic publishing. UFMG facilitates research and academic publishing by giving the academics support in approaching research foundations like CNPq, Fapemig and Capes.

Inventors at UFMG that seek for intellectual property regarding their scientific and technological knowledge, the Coordination of Transfer and Technological Innovation[8] (CTIT) provides management and expertise concerning the dissemination of the intellectual property culture. CTIT provides an infrastructure for innovation, starting with the protection of knowledge, over the technology transfer and incubation, up to the commercialization of the innovations generated at UFMG and supports the inventor along the way (CTIT, 2017).

The patent office is concerned with protecting the intellectual property of the inventor. This subunit of CTIT provides consultancy on intellectual property and, in collaboration with the inventor, creates the suitable protection of the inventors scientific or technological knowledge in form of patents. The sector of technology transfer of CTIT is responsible for the technology transfer process and licensing patents to third parties in return for licensing fees or royalty payments[9]. The sector also offers to create research projects for contracted inventors. From 1995 to 2017, CTIT filed 853 patents[10] to protect the intellectual property of UFMG. Out of those, 259 patents (30%) are

---

[8] Coordenadoria de Transferência e Inovação Tecnológica
[9] "Royalties is the term often used to describe either the regular payments made by the lessees of subsoil assets to the owners of the assets" (OECD, 2002, p. 1)
[10] Data retrieved on the 25.05.2017

related to biotechnology. Since its establishment, CTIT processed 16 technology transfer contracts of which six related to biotechnology spin-offs of UFMG scientists.

For inventors that aim at spinning off their technology from the university, CTIT offers the incubation system of INOVA. With a mission to stimulate entrepreneurship and support innovative companies and projects, INOVA is a multidisciplinary business incubator, linked to CTIT. The incubator was created in 2003, as a result of the combination of two incubation and entrepreneurship programs born from an initiative of university professors. This fusion led to the development of a support structure for nascent venture - INOVA. Until today, ten spin-offs graduated from the incubator and six are currently incubated (INOVADATAMG, 2016). According to INOVA's management, the incubator does not inhabit biotechnology ventures anymore as their space does not meet with ANVISA regulations that are essential for companies in such areas. The objectives of the incubator are to (INOVA, 2017):

- Consolidate the entrepreneurial formation, promoting an environment for productive innovation;
- Support the trajectory of technological projects;
- Facilitate the start-up of innovative businesses;
- Stimulate spin-offs within UFMG;
- Assist the incubated companies, reducing the costs in the initial phase;
- Expand the interface between university and the market;
- Strengthen the competitiveness of industries in the region;
- Renew the local business fabric.

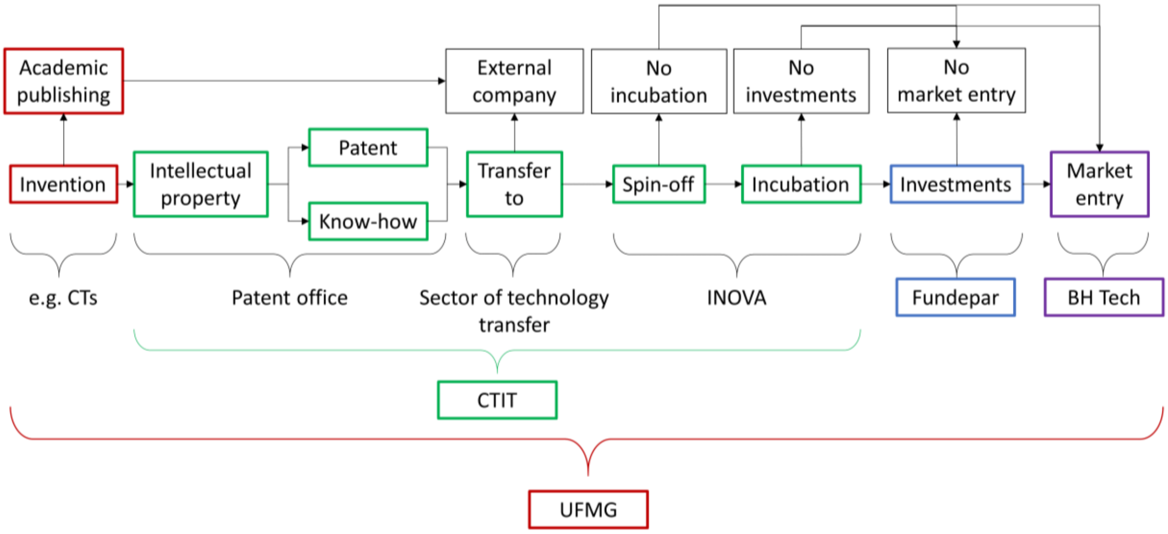
With or without being incubated, inventors can approach the foundation Fundepar[11] if they seek to spin-off UFMG technology. The organization is investing in projects of professors, researchers and students of Universities and Research Centers with a strong focus on UFMG. The organization also invests in structuring emerging and

[11] Fundep Participações S.A. (Fundepar) develops innovative businesses generated from projects of students, professors and researchers linked to Universities and Research Centers, such as the Federal University of Minas Gerais (UFMG), with financial investment and support to business structuring. Fundepar inaugurates in Brazil a successful model of financing for innovation in public and private universities in developed countries. Founded by Fundep with the endorsement of the Curadoria das Fundações, the Ministério Público de Minas Gerais, the UFMG University Council and the Conselho Curador da Fundação, Fundepar follows the international policies of Science, Technology and Innovation. (FUNDEPAR, 2017, p. 1)

innovative companies, with the purpose of transferring innovations from the University to the market. The organization considers itself as a venture capital foundation but with a lighter governance structure to recognize the characteristics of science, technology and innovation (FUNDEPAR, 2017). The foundation assists with business know-how and financial resources in the early stages of the risk capital chain. Fundepar develops together with the inventor business plans and projects for internal valuation of the projects and pass external scientific committees and final acceptance of the financing by the mother firm Fundep. The organization usually contracts the spin-off for two years and then either reinvests or exits. Fundepar adopts Fundep's mission to support UFMG in the research and subsequent activities (FUNDEPAR, 2017).

For spin-offs that successfully bridge the start-up phase to the implementation phase by entering the market with their technologies, UFMG is connected to the technology park BH-TEC. The business center was founded in 2005 by UFMG in partnership with the government of the state of Minas Gerais, Belo Horizonte City Hall, Sebrae Minas[12] and FIEMG[13]. With the mission to promote the innovative organization of the local society through the dissemination of knowledge, BH-TEC closes the innovation model of UFMG, visualized in Figure 3.

Figure 3 UFMG innovation model



[12] Brazilian support service for micro and small enterprises of Minas Gerais
[13] Federation of industries of Minas Gerais

It is notable that UFMG initiated and co-funded three technology centers (CT) that work as a platform for research and technology transfer for a wide spectrum of clients. All CT's are located in BH-Tec and directed by UFMG academics. The *CTNanotubos* was founded in 2013 with the goal of developing products, processes and services related to nanometric structure materials (CTNANO, 2017). The *CTNanotubos* researches, develops and scales-up technologies to promote interaction between the university and industry together with its 20 partners from nine Brazilian states that support the project (UFMG, 2013). The *CT Vacinas* was created in 2016 under similar conditions as the *CTNanotubos*, also placed into the operational space of BH-Tec. Like at *CTNanotubos*, the goal of *CT Vacinas* is to develop and produce. Through understanding basic mechanisms of immune response to infections, acquiring modern technologies for the formulation of vaccines and finally developing vaccines, the *CT Vacinas* contributes to the decreasing of the university-industry gap (MACIEIRA, 2016). The third technology center, *CTWeb*, focuses on internet innovations with the goal to generate and transfer technologies and develop business and products from research (CTWEB, [s.d.]).

3.3 Data collection – The "Somos method"

Professors employed at UFMG and conducting R&D in the area of biotechnology are the focus group of this study. To identify this target group, the database "Somos UFMG" was used as a tool. This open access database was generated by CTIT and developed to map the competencies at UFMG with the goal to increase the interaction between the scientific and technological research of the university and private and public institutions (CTIT, 2017). The name already states that the database contains only UFMG-related information and functions as the university's own search engine. The database offers a keyword search for research specialization, research keywords, laboratories, used equipment, professors, institutes and departments of UFMG. As Somos UFMG is crossed with the data of the Lattes platform[14] the database also offers information on professors' bibliographic production, graduated students, intellectual property, research areas, coauthors and more. It is to be noted that the Somos

[14] Lattes Platform: Platform database that collects and offers curricula vitae of researchers in Brazil, together with publication lists and other scientific accomplishments and is maintained by the Brazilian National Council for Scientific and Technological Development (CNPq).

database only contains professors that are employed at UFMG. Retired personnel or visiting professors that research at UFMG are not included in this study.

To cross biotechnology with the Somos database, the OECD list-based definition of biotechnology techniques (Annex 1) was used in form of keywords to create a table of professors at UFMG who are involved with biotechnology research. At this point it is to highlight that, for this work, biotechnology was defined over its techniques. Therefore, biotechnology comprises everything that is researched or developed through the techniques, defined in Annex 1. The keyword search was conducted in the original English definition and the equivalent Portuguese translation. Professors who are associated with the Colégio Técnico of UFMG (COLTEC) or who do theoretical research on biotechnology e.g. business management, history, law, economics or behavioral neuroscience were excluded. This selection was done because this group of researchers does not apply biotechnology familiar techniques.

Through this method, 330 professors with links to at least one biotechnology related keyword could be identified. It was assumed that the more biotechnology keywords per professor, the more intensified their research is on biotechnology. Therefore, professors with only one biotechnology reference were excluded. 128 professors correspond to two or more keywords. Together with the professors and their biotechnology references (keywords), the department, institute, published articles, patents and graduated students were captured. Out of those 128 professors, ten were excluded from this research as they stated that they have no or no direct relationship to biotechnology, despite the accordance with the Somos database. Some of the excluded professors are only collaborating with other researchers that relate to the field of biotechnology without being involved in the biotechnology activity itself. Others were involved with biotechnology research at other institutions but not at UFMG and are therefore not considered in this present work. The 118 professors with biotechnology references compile the target population.

The survey consists only of closed ended questions like rating scale, matrix, multiple choice and rank order questions. This survey was designed to obtain information on the participant’s biotechnology technique he is involved in, the stage of development, managerial experience, financing, research collaboration, research obstacles, technology transfer and pilot plants. For participants with company ownership questions were laid out to collect information on financial support, partners with managerial experience, products or processes, market entry issues, incubation, intellectual property and product portfolio.

The survey was constructed with and conducted through the academic online software Unipark (http://www.unipark.com/en/). This tool was used as it offers a wide spectrum of question types which was needed for some questions of this survey. The program also allowed the use of filters that was essential for directing the respondents according to their attributes. After the construction of the questionnaire (Appendix 3), a pilot test was conducted with ten participants. The survey was subsequently sent via email to each professor of the target group and conducted online over the period of one month from the 02. April to the 02. May 2017. Table 3 summarizes the affiliated academic units and departments of the 118 professors that the survey was sent to. Distributing the survey via internet has the advantage of capturing researchers that were not physically present at UFMG during the time of the research. It also is time saving for the researcher (WRIGHT, 2006) and convenient for the respondent as he can choose the time and place freely when taking the survey without disrupting his daily routine (LEFEVER; DAL; MATTHIASDOTTIR, 2007).

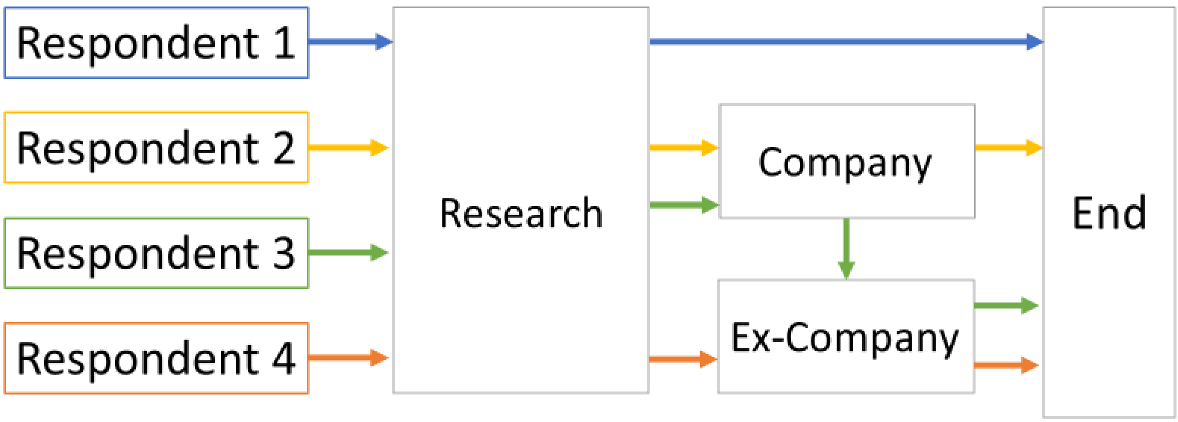
Table 3 Academic units and departments of the target population

Academic Unit	Amount	%	Department	Amount	%
Faculty of Pharmacy	6	5,1%	Dep. of Foods	3	2,5%
			Dep. of Clinical and Toxicological Analysis	1	0,8%
			Dep. of Pharmaceutical Products	2	1,7%
School of Engineering	7	5,9%	Dep. of Metallurgical Engineering and Materials	4	3,4%
			Dep. of Chemical Engineering	1	0,8%
			Dep. of Sanitary and Environmental Engineering	2	1,7%
School of Veterinary	18	15,3%	Dep. of Clinic and Veterinary Surgery	4	3,4%
			Dep. of Veterinary Preventive Medicine	5	4,2%
			Dep. of Technology and Inspection in Products of Animal Origin	3	2,5%
			Dep. of Animal Husbandry	6	5,1%
Faculty of Medicine	12	10,2%	Dep. of Anatomy and Image	1	0,8%
			Dep. of Surgery	2	1,7%
			Dep. of Clinical Medicine	4	3,4%
			Dep. of Gynecology and Obstetrics	1	0,8%
			Dep. of Ophthalmology and Otorhinolaryngology	1	0,8%
			Dep. of Pediatrics	1	0,8%
			Dep. of Complementary Propedeutics	1	0,8%
			Dep. of Mental Health	1	0,8%
Faculty of Dentistry	4	3,4%	Dep. of Clinical, Pathology and Dental Surgery	3	2,5%
			Dep. of Restorative Dentistry	1	0,8%
Institute of Agrarian Sciences	4	3,4%	Board of Directors	4	3,4%
Institute of Biological Sciences	57	48,3%	Dep. of General Biology	10	8,5%
			Dep. of Biochemistry and Immunology	12	10,2%
			Dep. of Botany	2	1,7%
			Dep. of Physiology and Biophysics	4	3,4%
			Dep. of Microbiology	13	11,0%
			Dep. of Morphology	6	5,1%
			Dep. of Parasitology	8	6,8%
			Dep. of Pathology	1	0,8%
			Dep. of Zoology	1	0,8%
Institute of Exact Sciences	10	8,5%	Dep. of Computer Science	1	0,8%
			Dep. of Physics	1	0,8%
			Dep. of Chemistry	8	6,8%
TOTAL	118	100%	TOTAL	118	100%

3.4 Questionnaire Structure

The survey was constructed to capture information on professors that research in biotechnology and, if so, own or owned biotechnology related companies. The complete survey can be found in Appendix 3. A survey model was designed so that professors only answer questions that occur to their situation. For professors that research in biotechnology without company ownership appear only questions about their research. If professors own a biotech company or have owned (ex-company), those question pages are added to the survey through a filter. It is to be noted that “ex” does not necessarily mean that the company is not active but that the professor is not involved in any activity with this company anymore. Figure 4 shows the simplified flow chart of the questionnaire construct that will be explained in more detail in this section.

Figure 4 Simplified questionnaire flow chart

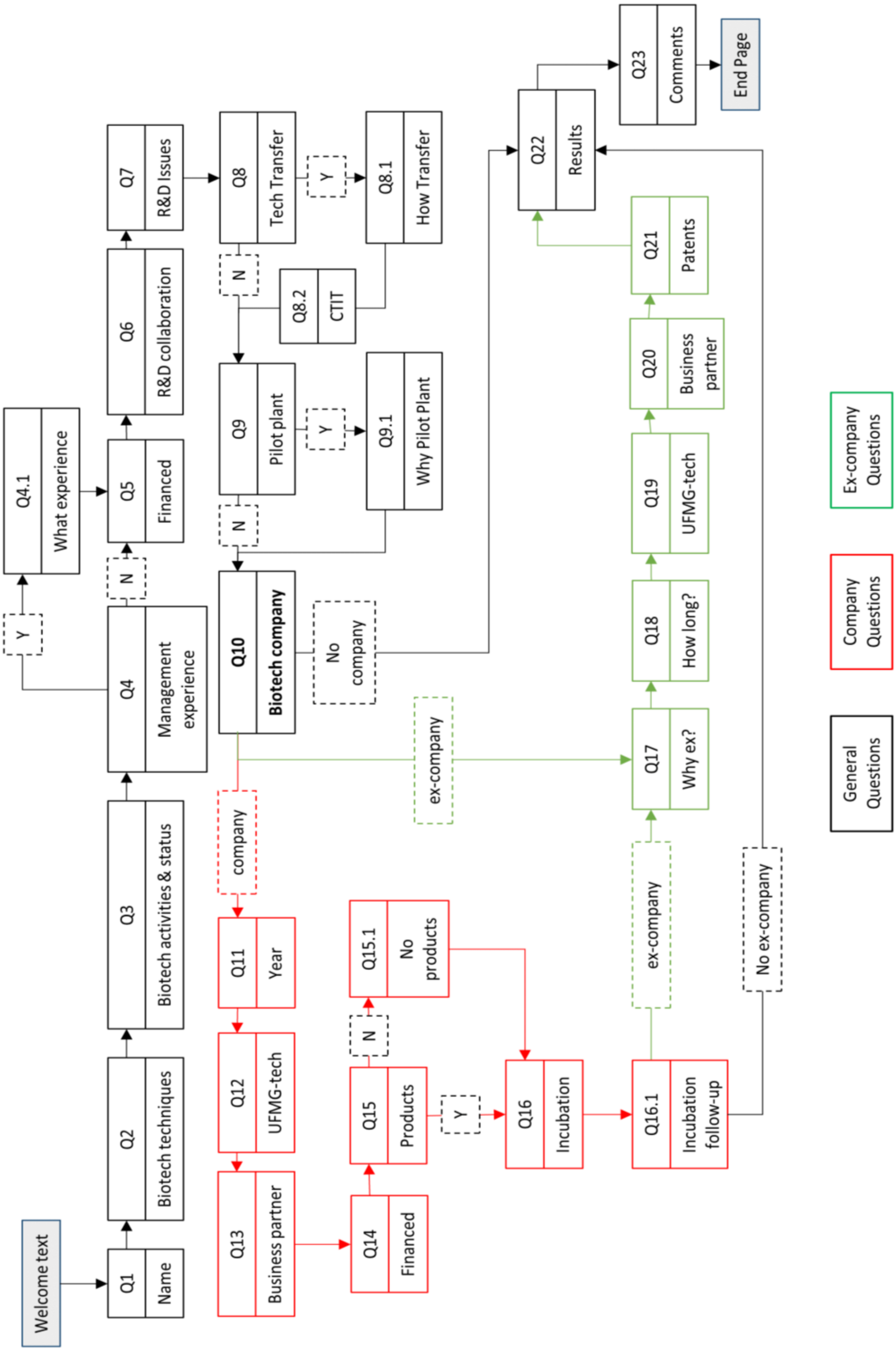


As visualized in Figure 4, the questionnaire shapes itself according to the characteristics of the respondent. The survey has four different paths and depending on the respondent, items are added to capture more data on specific participants. Respondent 1 does only research in the area of biotechnology but never owned a company with biotechnology activities. This person is only confronted with questions related to their biotechnology research and no company-related questions. Respondent 2 researches in biotechnology and in addition has ownership in a venture that has biotechnology activities. After going through the same questions as R1, questions appear that ask him about his company involvement. Respondent 3 has, like R2, company ownership but in addition, he also had a biotechnology company but has currently no involvement with this venture anymore (ex-company). This participant is confronted with all possible questions of this questionnaire. Respondent 4, like all other respondents, is involved in research in biotechnology but also had biotechnology company ownership. He is asked to answer questions about his research and his ex-company. The complete flow chart is visualized in Figure 5.

All questions, the questionnaire comprised, are listed in Appendix 1 together with a short explanation of each question. Following, I will present the questions of the section “Research”. As Figure 5 shows, all respondents went through this section as all participants were involved in biotechnology research. Here he was confronted with questions about his biotechnology techniques and activities (application area of his research); development status; management experience; investments; R&D collaboration and issues; technology transfer and pilot plant interest and if the participant was or is involved in biotechnology ventures in form of ownership. With this question, the “Research” section closes. Here the participant is asked to indicate if he owns or owned a biotechnology company. If he has the profile of Respondent 1 (Figure 4 on page 35 assists in visualizing the structure) and states that he never owned a biotechnology venture, he is directed to the end page.

Only participants with the profile R2 or R3 were asked to go through the following “Company” section as they currently have ownership in biotechnology ventures. Respondents with the profile of R1 are not confronted with this part and researchers with the profile R4 skip the section “Company” and are directed to Q17 the section “Ex-company”. In this part, the participant was asked to answer question on the year of establishment of his company; if the technologies of the company were developed at UFMG; if the professor has a partner with business experience; if he company can financially sustain itself or is dependent on external investments, if the company offers products or services on the market and finally if the company has or had any relations to business incubation.

Figure 5 Full questionnaire flow chart



Only participants with the profile R3 or R4 were asked to go through the section "Ex-company" as they had ownership in biotechnology ventures in the past. Professors that fit in this profile were asked about the reason that he is not involved with the company anymore (e.g. sold, left or company stopped its activities); how long the company was established; if the technologies, used in the company, were developed at UFMG; if the professor had a partner with business experience and if the company owned any patents.

To summarize this section, the main body of the questionnaire "Research" that all respondents went through consists of eleven items with three situational follow-up items, depending on the participant's characteristic, situation or biotechnology involvement. The main body closes with questioning the participant about possible ownership or past ownership of a biotechnology venture. If the respondent currently owns a company with biotechnology activity, six items followed, including two situational follow-up items (section "Company"). If he previously owned a company with biotechnology activity, he was asked to peruse six more items, presented in the "Ex-company" section. A comment page closed the survey. The minimal number of items to pass through was therefore eleven, if the participant is only involved with biotechnology research. The maximum number, if the respondent owned and currently owns a company with biotechnology activity, adds up to 23 items and five situational follow-ups.

Because of some limitations[15], it is assumed that the biotechnology landscape of UFMG is larger than recorded in this study. However, a superficial look at the total patents related to biotechnology, recorded by CTIT (259 patents[16]) and the sum of all patents that were registered by the 118 professors of this studies target group (233 patents) show that a great amount of biotechnology research was captured in this study.

---

[15] The list-based definition of OECD from 2005 does not include several biotechnology techniques that were developed in the last ten years. Therefore, professors that use techniques, developed after 2005, are not included in this study. Another limitation is related to the keyword search in the Somos database. Several words can form one keyword and cannot be found by the search engine separately e.g. if Somos creates the keyword-term "*Biomaterial para regeneração de tecidos*" the professor with this term who researches on biomaterial for the regeneration of tissues will not be displayed if keywords like "*biomaterial*" or "*tecidos*" are entered in the search engine separately.

[16] Data retrieved on the 25.05.2017

4 RESULTS

To facilitate the understanding of the content, this section is clustered in five subsections. The first subsection relates to general information on the sample. The second subsection discriminates the respondents profile. The third subsection outlines to results concerning the professor's research, and the fourth subsection presents biotechnology-related results. The last subsection is concerned with company and ex-company results. The results will be presented and briefly discussed, as the complexity of the data cannot stay without a more detailed explanation.

118 professors with biotechnology references compile the target population. The questionnaire has a response rate of 46% with 54 completed surveys which forms the sample of this study. The average processing time of the survey according to the arithmetic means was 10 minutes. It is to highlight that the results of this study are descriptive. The results of this study describe only the data that were collected through the questionnaire and the results are not used to compare them to other universities or clusters.

4.1 Sample Information

The distribution of the target population on all academic units was similar to the obtained data from the sample. Table 4 shows the percentages of each academic unit in the target population (column 2) in contrast with the collected sample (column 3). E.g. 10% of the entire target population that consists of 118 professors; and 11% of the collected sample that consists of 54 professors are affiliated with the *School of Medicine.*

Table 4 Percentage of academic units related to the target population and sample

Academic unit	%Target population	%Sample
School of Engineering	6%	4%
School of Veterinary	15%	15%
Faculty of Pharmacy	5%	4%
Faculty of Medicine	10%	11%
Faculty of Dentistry	3%	2%
Institute of Agrarian Sciences	3%	2%
Institute of Biological Sciences	48%	54%
Institute of Exact Sciences	8%	9%
Total	100%	100%

As seen in Table 4,the target population, affiliated to the academic units, show similar percentages as the sample. According to this table, the collected data in the sample represents very accurate the distribution on the academic units as in the target population. Almost the same percentage of professors that were identified as the total target group, responded to the percentage of professors in the sample.

Table 4 also gives an insight into the distribution of the professors on the academic units of the university campus. More than half of the surveyed staff (54%) is affiliated to the *Institute of Biological Sciences*, forming the biggest cluster of biotechnology inside the university. The *School of Veterinary* (15%), *Faculty of Medicine* (11%) and *Institute of Exact Sciences* (9%) follow. A detailed division of the eight academic units that are associated with biotechnology into 25 departments can be found in Appendix 2. The most represented department is the Department of Microbiology in the *Institute of Biological Sciences*.

In section 3.2.1, I explain the Somos-Method and how the target group was defined through a biotechnology keyword search. Table 5 shows the distribution of those keywords, related to the target population (column 2) and the obtained sample (column 3). All professors that were identified in the target population and correspond to exactly two keywords make up for 53%. In the collected sample, professors that correspond to two keywords make up for 50%. Professors with three, four, five, six and seven corresponding keywords are in the target population similar distributed as in the sample

The results that are presented in Table 4 on page 39 and Table 5 emphasize the accurate representation of the collected data and substantiate the significance of the results of this study.

Table 5 Number of keywords related to the target population and the sample

Amount of keywords per professor	%Target population	%Sample
2	53%	50%
3	25%	24%
4	13%	15%
5	3%	6%
6	3%	2%
7	3%	4%
Total	100%	100%

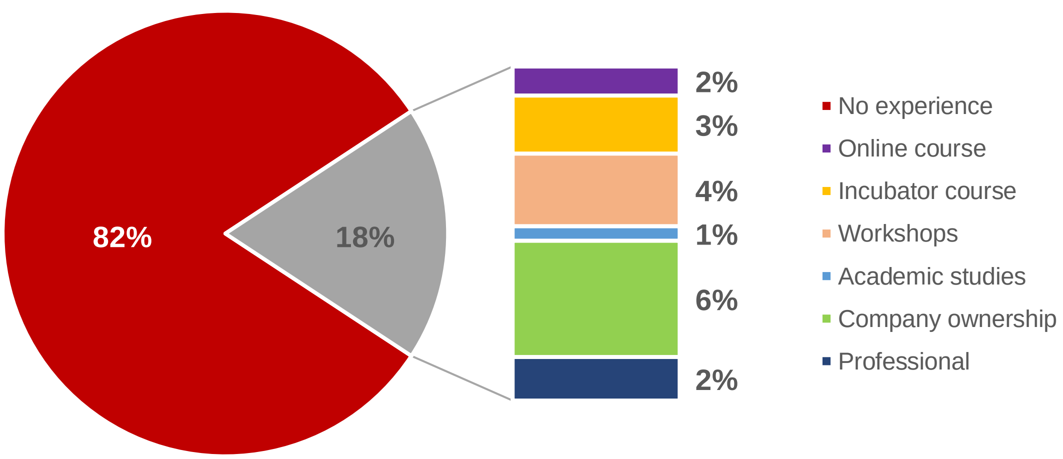
4.2 Professor characteristics

Through crossing the information from the database Lattes with the data of the collected sample, more results were obtained. In total, the sample contributed to 4168 articles (77,2 in avg), registered 233 patents (4,3 in avg) and successfully orientated 858 master (15,9 in avg), 590 doctoral (10,9 in avg) and 182 post-doctoral students (3,4 in avg). The distribution of the gender of the participants is almost equal with 28 female and 26 male participants.

One aim of the research was to observe the market orientation of the professors at UFMG. For that, two questions and two follow-ups (Q4, Q4.1, Q8, Q8.1 in Appendix 1) were formulated to identify whether the responded has any management experience, if yes, what kind and what their attitude towards technology transfer is. If the participant shows transfer interest, he was asked if a technology transfer would be carried out through patents or know-how.

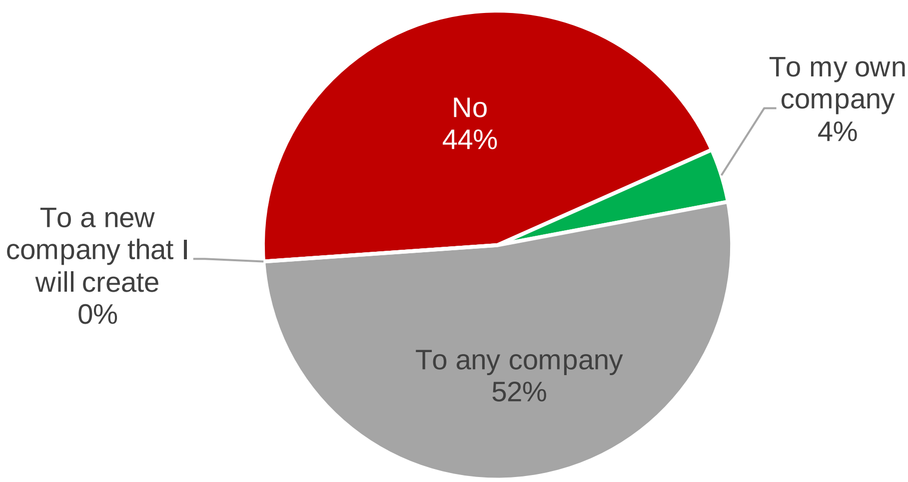
Figure 6 shows that 82% of the professors in the sample have no previous experience in management. The other 18%, experienced management through company ownership (6%), workshops (4%), incubator courses (3%), professional work (2%), online courses (2%) and academic studies (1%). This result demonstrates the strong academic orientation of biotechnology scientists at UFMG. Most of the management experienced respondents obtained tacit knowledge through company ownership and did not appropriate managerial knowledge beforehand.

Figure 6 Management experience



Related to transferring technologies that were developed in the professors' research, Figure 7 presents that 52% of the respondents show interest in selling or transferring their technologies to companies. 44% have no interest in transferring their technologies and 4% want to transfer them to their own company. At this point it is to mention that although 44% of sample does not want to transfer their developments, their technologies might find application in the context of consultancy work, offered by the inventor. No one in the sample has the willingness to transfer their technology to a new company that they will create. Those results show, that no professor in the sample has the intention in spinning off any of his technologies. Of all the professors that show interest in technology transfer, 53% would transfer patents and 10% know-how. 37% of the participants that want to transfer their technologies do not know yet, how to pursue this interest. 87% of the respondents that aim at transferring their technologies, already approach CTIT. A great percentage of professors interested in transferring their research to companies search for assistance and consultancy from the patent and transfer office CTIT.

Figure 7 Interest in technology transfer



Syndicating the sample with their patent activity reveals that the 44% of the sample that has no transfer interest hold 9% of the sample's patents. This indicates that there might be a relation between lack of transfer interest and low patent activity.

Crossing the management experience of professors (Q4) with their interest in technology transfer (Q8) reveals that 90% of management experienced professors want to transfer their technologies. This demonstrates a high significance between management experience and willingness to commercialize.

Professors that have no interest in technology transfer (Q8), crossed with their affiliated academic unit, is presented in Table 6. The last column represents the percentage of professors that have no interest in transferring their technologies related to their academic unit. Five out of eight professors (63%), affiliated with the *School of Veterinary,* do not want to transfer their technologies. At the *Institute of Biological Sciences*, 41% of the sample have no interest in technology transfer. Every professor in the sample that is affiliated with the *Institute of Exact Sciences* shows interest in transferring their technology to companies. Four out of six professors (67%) from the *Faculty of Medicine* do not want to transfer their developed technologies. The responses of other academic units were excluded here due to the low representation of professors. Those results highlight that the interest of technology transfer is in some units stronger than in others.

Table 6 Technology transfer interest classified by academic unit

Academic Unit	**Total sample**	**No transfer**	
	Amount	Amount	%
School of Veterinary	8	5	63%
Institute of Biological Sciences	29	12	41%
Institute of Exact Sciences	5	0	0%
Faculty of Medicine	6	4	67%

4.3 Research

The research of professors on biotechnology at UFMG is in different stages of development. The collected data through Q6 show that every participant is collaborating with either Professors at UFMG, Professors in other Brazilian Universities, Professors outside Brazil, Companies, Institutes, Government or other organizations. Table 7 differentiates between basic research, applied research and development of product or service and shows the interactions and collaborations the survey participant has with beforehand mentioned categories. To exemplify, 55,6% of the questioned professors at UFMG have collaborations with other professors at

UFMG in basic research. 16,7% of the sample of this study have collaborations with companies in applied research and 11,1% of the respondents have collaborations with institutes or governmental organizations in development of products or services.

UFMG professors in the sample have more collaboration with other professors at UFMG in applied than in basic research. If professors have connections to professors at other Brazilian universities or internationally, it is more likely that this link is to pursue basic and not applied research. This demonstrates that the more the technology advances, the more likely it is that professors search for partnerships inside UFMG. Most collaboration that the participants have with organizations outside the academy (company, institute and government) is in applied research. For developing products or services, the respondents interact mainly with other professors at UFMG. The sample rarely collaborates with companies, institutes and the government for basic research.

Table 7 Stage of development vs collaboration of UFMG professors

Collaboration with	Basic research	Applied research	Development of product or service
Prof at UFMG	55.6%	66.7%	20.4%
Prof national	44.4%	33.3%	11.1%
Prof international	35.2%	29.6%	5.6%
Company	7.4%	16.7%	14.8%
Inst/Gov	11.1%	20.4%	11.1%

Table 8 Activity status vs technology transfer interest

	Research & Development	Pre-clinical trials/ confined field trials	Regulatory phase/ unconfined release assessment	Approved/ marketed /in production	Total
Transfer	20	7	1	2	30
not transfer	23	1	0	0	24
Total	43	8	1	2	54

Table 8 presents the activity status of the technology, the scientists of the sample are involved in (Q3), crossed with their willingness to transfer their technologies (Q8). The technologies of 43 participants (79.6%) are at the time of the study with the status of R&D. The other eleven professors (20.4%) state, that their biotechnology activities extent the R&D stage. Of those eleven, eight (15%) stated that they are involved in pre-clinical trials. One respondent (2%) deals with the regulatory phase or unconfined release assessment and two professors (4%) are involved in biotechnology activities related to the market phase. When observing the transfer enthusiasm of the participants in relation to the activity status, it stands out that professors that are in more advanced stages of activity than R&D, are more likely to have interest in transferring technologies.

Figure 8 Source of research funding

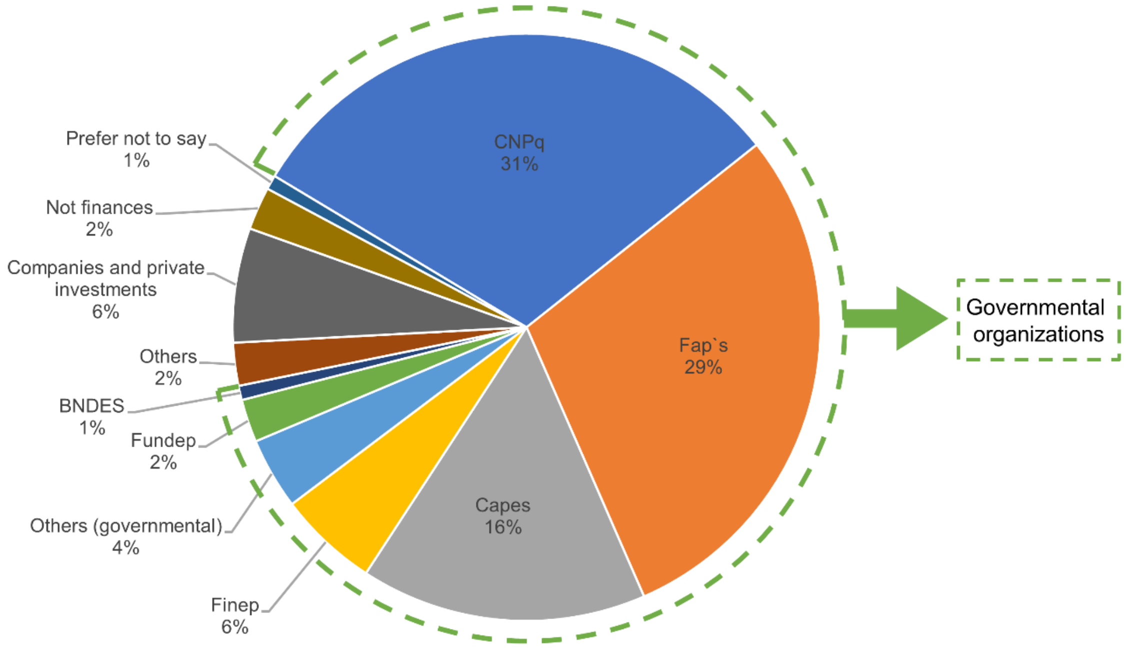


Figure 8 shows the results of the finance types (Q5), the professors in the sample receive for pursuing their R&D. The main investments are coming from CNPq (31%), Fap's (29%) and Capes (16%). The sum of governmental investments makes up for 89% of all the finances. 6% of the scientists in the sample are financed by companies or private investments and only 2% state that their R&D is currently not financed. Those results highlight that almost the entire sample is financially backed in their R&D.

In Q9, the participant was set in a scenario in which UFMG would own a Pilot Plant, he would have access to. The respondent was asked if he would use such a plant and if yes, what for (Q9.1). Table 9 shows, that more than half of the participants (55.6%) would use a Pilot Plant for applied research. 22 of the professors (40.7%) would use the plant to check the viability of their research on industrial scale. 19 scientists (35.1%) would want to use the plant for training purposes. 24.1% (13 responses) would not use the plant at all. The interest in doing applied research by using a Pilot Plant is therefore highly represented in the sample. One third of the questioned professors are willing to use the plant for educational purposes and teach students the problems in scaling up technologies and using industrial machinery to test the research on a larger scale. However, the fact that 24% are not interested in scaling up their research to take a glance at the next steps of the development process, cannot be neglected.

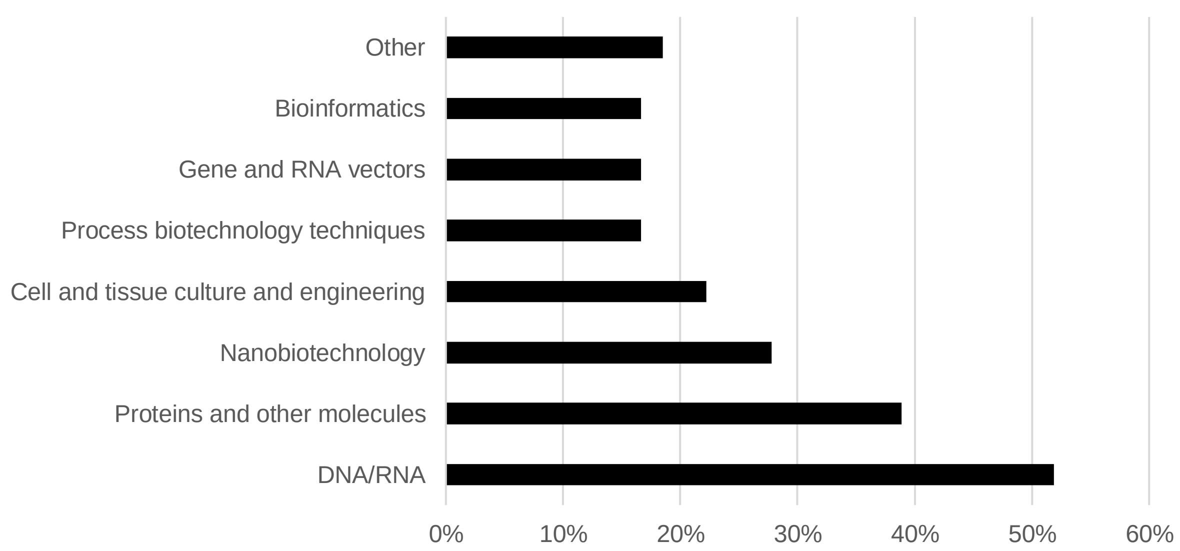
Table 9 Pilot Plant uses

Professors would use Pilot Plant for	
Training of students	35.1%
Check the viability of the research on industrial scale	40.7%
For applied research	55.6%
No use	24.1%

4.4 Biotechnology characteristics

The following part of the result section outlines the survey responses related to the biotechnology activities of the obtained sample. At UFMG, most of the biotechnology research (Q2), according to the obtained sample, is conducted with the techniques in DNA and RNA, with 52% of all participants involved in this field. The second biggest research area is Proteins and other molecular (39%), followed by Nanobiotechnology (28%) and Cell and tissue Culture and engineering (22%). Less represented but equally distributed are the techniques Bioinformatics, Process biotechnology

Figure 9 Biotechnology techniques at UFMG



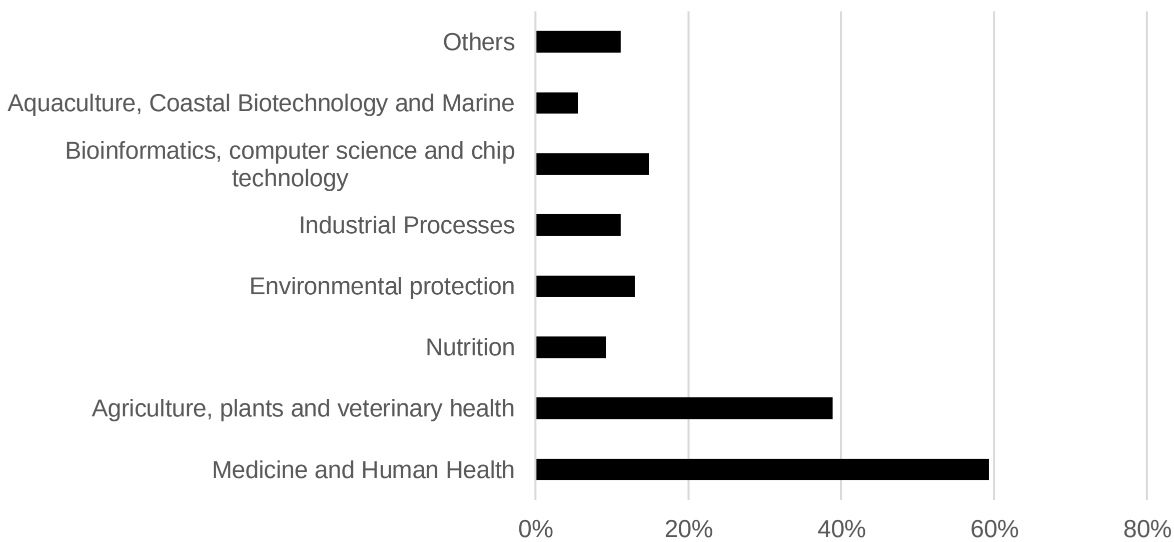
techniques and Gene and RNA vectors with 17% each. This distribution of the biotechnology techniques of the sample (Q3) is illustrated in Figure 9.

Another result regarding the biotechnology techniques is related to the willingness to transfer technologies. From all the listed techniques, only professors that research on DNA/RNA have less interest in technology transfer contrasting the ones that want to transfer. Professors that are involved with any of the other areas are more likely to show interest in technology transfer than not.

Related to the area that the biotechnology technique is applied in, 32 participants (59%) state that their research finds application in the sector of Medicine and Human Health and 21 (38%) indicate that their research is applicable to Agriculture, plants and veterinary health. Those two are the major fields of research at UFMG and are followed by Bioinformatics, computer science and chip technology with eight (14%), Environmental protection with seven (13%), Industrial processes and the category Others with each six (11%), Nutrition with five (9%) and Aquaculture, Coastal Biotechnology and Marine with three (6%) representatives. The distribution of the different application areas of the biotechnology techniques are displayed in Figure 10.

Biotechnology activities at UFMG extend R&D and some professors are involved with stages after R&D (pre-clinical, regulatory phase or commercialization). Table 10 sums up the activities of the sample in two rows: R&D stage and stages after R&D. Those result show that all application areas (except aquaculture and others) show a similar

Figure 10 Application area of biotechnology techniques<



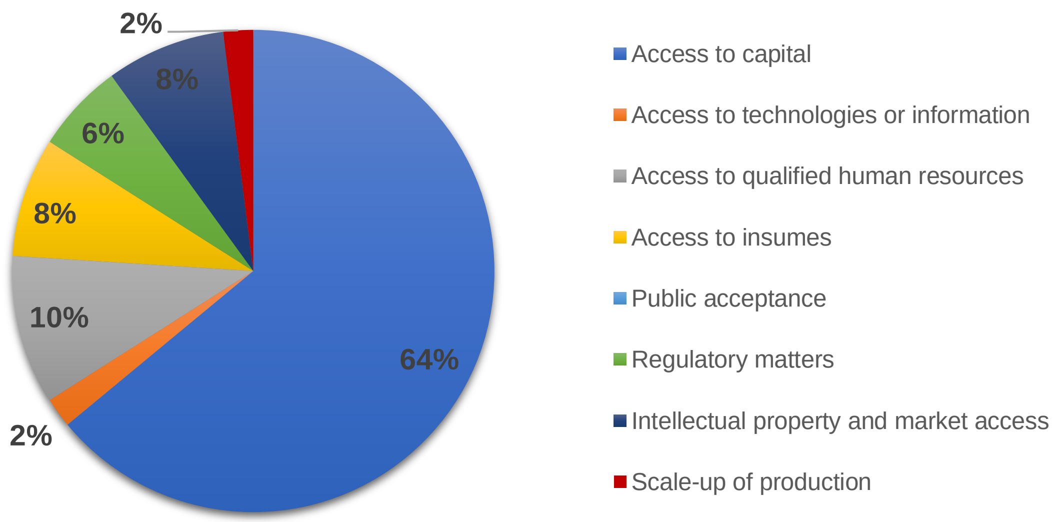
percentage of professors that are involved with R&D. Between 12.5% and 22.2% of the professors are involved in biotechnology stages after R&D, depending on the application area. This distribution suggests, that going beyond R&D phases in biotechnology is not related to the application area.

Table 10 Biotechnology application areas and activity stages of participants

Biotechnology application area	R&D	Stages after R&D	Total
Medicine and Human Health	32	6	38
	84.2%	15.8%	100%
Agriculture, plants and veterinary health	21	6	27
	77.8%	22.2%	100%
Nutrition	5	1	6
	83.3%	16.7%	100%
Environmental protection	7	1	8
	87.5%	12.5%	100%
Industrial Processes	6	1	7
	85.7%	14.3%	100%
Bioinformatics, computer science and chip technology	8	2	10
	80.0%	20.0%	100%
Aquaculture, Coastal Biotechnology and Marine	3	0	3
	100%	0%	100%
Others	6	0	6
	100%	0%	100%

Biotechnology comes with specific hurdles that hinder the advancement in the research and development. Figure 11 presents the biggest issue for biotechnology

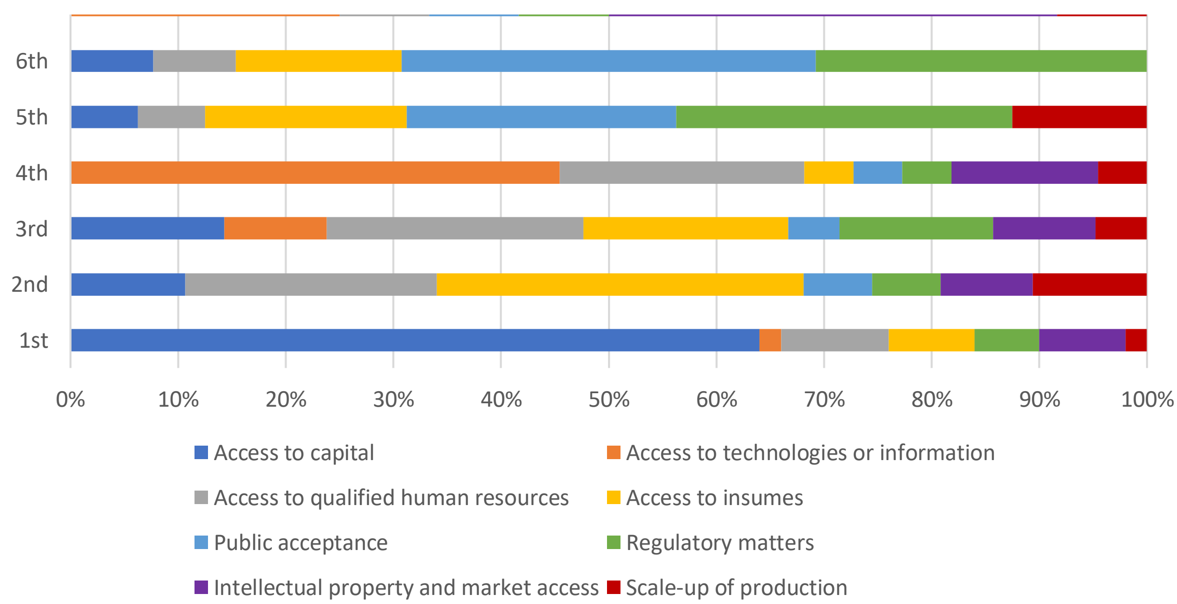
Figure 11 Biggest obstacle in biotechnology R&D



R&D out of the respondent's view (Q7). According to the sample, the access to capital was rated the biggest obstacle from 64% of all participants. 10% stated that the access to qualified human resources is the biggest issue for their R&D in biotechnology. 8% rate access to inputs as biggest obstacle and another 8% intellectual property and market access. No one in the sample indicated that the public acceptance is the biggest issue of their R&D.

Figure 12 presents the complete results of the biotechnology issue rating. The 1st issue of biotechnology R&D was already presented in Figure 11 (page 48). The line above shows what professors classified as their 2nd biggest obstacle in biotechnology R&D. More than 50% of the respondent's state that for them the access to qualified human resources and access to inputs are the second biggest issue. The graphic shows that the access to qualified human resources, even if not often rated as the biggest issue, is strongly represented in the Top 4 biggest obstacles, just like the access to inputs. The scaling-up and intellectual property and market access is not seen as a huge obstacle for the respondents as it is often named as only the 7th or 8th biggest obstacle. Also, the issue of public acceptance of their technologies is not in the focus of the participants and mainly represented as the 5th or 6th biggest issue. In summary, access to capital is overall seen as the biggest obstacle in biotechnology R&D. The access to inputs is seen as second biggest issue in pursuing biotechnology activities at UFMG and the access to qualified human resources is the third biggest obstacle.

Figure 12 Biotechnology R&D obstacle full ranking



4.5 (Ex-)company

In the following section, I will present the results that were obtained from professors that are or were involved in biotechnology ventures. Of the collected sample, six professors stated they are currently owning a company with biotechnology activity (further referred to as "company sample") and four indicated, they already owned a biotechnology company but are not involved in the business anymore either because the professor left the venture or the company is not active anymore (further referred to as "ex-company sample").

In total, the sample contained ten participants (18.5%) that already had or still have ownership of a biotechnology venture (further referred to as inventor-entrepreneur). Table 11 summarizes the results of those ten inventor-entrepreneurs. Half of the participants that have or had a biotechnology venture, did not offer products or services on the market. Six of those inventor-entrepreneurs had business partner with managerial expertise and eight companies work or worked with UFMG-developed technologies.

Table 11 Company and ex-company sample summary

	Company sample	**ex-company sample**	**Total**
Product(s) or service(s) on the market	2	3	5
No product(s) or service(s) on the market	4	1	5
			10
Business partner	4	2	6
No business partner	2	2	4
			10
Technology developed at UFMG	5	3	8
Technology not developed at UFMG	1	1	2
			10

In the company sample, five out of six ventures use technologies that were developed at UFMG. Those results reflect a successful technology transfer from the university to the spin-off and suggest entrepreneurial intention of academics. However, of all six companies only one can be sustained independently, the other five depend on external investments, as they do not generate enough revenue to sustain themselves. Four of those six in the company sample are currently not offering any service of product on the market and state that this is due to the lack of necessary resources, insufficient investments and regulatory problems (Anvisa, MAPA, ISO, etc.). Four of the six companies indicate that they have business partners with company management experience. All those results reflect the financial and regulatory difficulties that biotechnology spin-offs are facing.

Related to incubation, out of the company sample, two ventures are currently incubated, two were incubated and two never were incubated. Both spin-offs, which are currently incubated at the time of data collection, state that they are incubated because of the physical infrastructure and the services, offered by the incubator. The two other companies that are not incubated anymore left because of i) high costs and ii) completion of the incubator process. The two companies without any relation to business incubators indicate that they were never incubated because i) they do not have interest in incubation and ii) they do not have to necessary financial resources to be incubated.

The results related to the ex-company sample are visualized in Table 12. Two of the ex-companies are not active anymore and the other two are active but the respondents left the company. The two non-active firms had one to three years working activity, no business partner and no patents that protected their product or service. The two professors that left the company state that they are active for more than six years at the time of research, had business partner and patents. Three companies of the ex-company sample worked with technology that was developed at UFMG and three had one to two technologies in their portfolio.

Table 12 Ex-company results

Why ex	years of establishment	Origin	Number of techs	Business partner	Patents
closed	1-3	External	1-2	No	No
closed	1-3	UFMG	0	No	No
left	More than 6	UFMG	1-2	Yes	2
left	More than 6	UFMG	1-2	Yes	11

Although the size of the ex-company sample is not large enough to draw quantitative conclusions, the results highlight some common issues of biotechnology ventures. The two companies that are not active anymore, were only established for 1-3 years, had no business partner and no patents. Contrary to the two active ex-companies, that are established for more than six years, have products in the market, have partners with business expertise and their technologies are patent protected. However, the few results are not enough to conclude, it appears that management expertise and existing intellectual property is related to company success.

Table 13 provides a summarized overview of the most important results obtained.

Table 13 Summarized results

General	54 out of 118 completed surveys (46% response rate)
	The sample of this study represents very accurate the target population
	Biotechnology is mainly researched at the Instituto de Ciências Biológicas (48%)
Professors characteristics	82% have no management experience
	44% have no technology transfer interest
	No one wants to spin-off the technology himself
	Interest in technology transfer interest varies according to departments
Research	High R&D collaboration among UFMG professors
	Low R&D collaboration with government and industry
	Dominant source of investment comes from the government (89%)
	75.9% of the sample would use a Pilot Plant
	However, only 40.7% would use it for scaling up.
Biotechnology	DNA/RNA is the most frequently use biotechnology technique at UFMG
	Most R&D finds application in Medicine & Human Health and Agriculture, plants and veterinary health
	The difficulty of going beyond R&D phases in biotechnology is not related to the application area
	64% see access to capital as biggest R&D obstacle (2nd - access to inputs; 3rd - access to qualified human resources)
Company	18.5% of the sample are or were involved in company ownership (10 professors)
	Six are still involved; Four are no longer involved
	Half of the professors related to companies, offer/offered no products or services on the market
	Most of the technologies were developed at UFMG (80%)

5 ANALYSIS

The descriptive results discussed in this present work corroborate with the theoretical background. The main objective of this original work is to understand the university-industry interaction and its challenges out of the perspective of professors, researching in biotechnology. This objective served in analyzing why biotechnologies developed at UFMG are not finding their way to the market. This section will analyze such issue and shed the light on the interaction between university and industry, sectorial obstacles of biotechnology, and academic entrepreneurial initiatives.

Some of the results agree with the immature Brazilian System of Innovation, introduced by Albuquerque and provide answers to the main objective of this study. One key aspect relates to finance for science in such systems. The low science investment has an influence on the innovation process in peripherical countries like Brazil. In this present work, two significant findings can appropriate this discussion. The first one is the professor's perception of their main R&D obstacle. 64% of the sample state that access to capital is the main reason that is hindering them in pursuing their research and development in biotechnology. However, a second finding reveals that 98% of the sample are being financed. This could mean that either the R&D investments are not sufficient for the research or that professors have a wrong perception of their obstacles. The insufficient investments could be confirmed by the characteristics of the immature System of Innovation that does not see science as a priority. It could also be confirmed by the heavy research investments that are necessary to advance in biotechnology. The results obtained and theoretical background presented lacks in evidence to justify the professor's perception of their R&D issues and therefore, cannot be discussed.

Two results of this present work, that relate to the collaboration of UFMG professors, show a weak commitment of the industry to invest in innovative technologies. First, although professors of the sample have high research interaction with professors locally, nationally and internationally, the respondents have only a few R&D partnerships with companies, institutes or the government. The industry is rarely included in university R&D and is even less included in product/process development than in applied research as shown in Table 7 on page 44. This opposes to the literature, which states that modern biotechnology intensifies the relationship between university and industry with intense information flow between the two instances. Second, the low interaction of the university with the industry is also reflected in the R&D investment, that professors receive. Only 8% of the sample is backed by companies, private investments or other non-governmental funds as shown in Figure 8 on page 45. Those results corroborate with the discussions of Albuquerque. The low industrial investment share in R&D and the industrial partnerships that occur in only a few cases, match with the literature on immature NSI. According to the literature the industry depends strongly on available science knowledge as this sector's R&D is mainly conducted in universities and institutes, however, the low collaboration between the industry and professors indicates that the industry does not frequently demand biotechnologies to be developed by professors.

Related to the professor's interest in Pilot Plant uses. Although 75,9% of the sample would use a Pilot Plant, a considerate part of the professors would use it in the traditional sense of the university's missions – education and research. Less than 50% of the sample would use the facilities to test the viability of their research on an industrial scale and 24,1% would not have any interest in using the Pilot Plant.

The present work presents the structure of UFMG that intents to assist in every step of the innovation process from the generation of knowledge, through basic research investment, over the technology transfer mechanisms to the integration into the marketplace. The research of scientists is directly link with the investment channels of governmental funds like CNPq, FAPs and CAPES. The results indicate that the research in the investigated sample is heavily funded by governmental initiatives and 98% of the respondents are using those mechanisms to finance their research. However, foundations like CNPq, FAPs and CAPES, which fund 75% of the sample (Figure 8 p. 45), provide investments primarily for research purpose, academic publishing and higher education. Those organizations focus less on the commercialization steps after R&D. By establishing the university patent office CTIT, the university offers inventors to protect their intellectual property. The results show that 86,7% of the professors that are interested in technology transfer, already contacted the patent office of UFMG, suggesting that when it comes to technology transfer, CTIT's function is being recognized. In essence, UFMG tries to establish a local innovation system to encourage the interface between university and industry, however, the technology transfer activity related to biotechnology R&D remains low.

Another objective of this work was to identify obstacle of biotechnology R&D out of the perspective of professors. The sector of biotechnology presents challenges that lead to major obstacles in innovating and transferring technologies. The literature shows that the biggest issues of biotechnology ventures are similar to the major obstacles of biotechnology R&D in universities. According to the results of the present work, the major obstacles of biotechnology R&D were i) access to capital; ii) access to inputs and; iii) access to qualified human resources, visualized in Figure 12 on page 49. Those obstacles correspond with the literature and confirm the large amount of resources that are needed to advance biotechnology R&D. It is worth mentioning that even though some biotechnology applications require overcoming more regulatory and clinical procedures than others, this could not be observed in the data. Table 10 on page 48 shows that the percentage of professors being involved in stages after R&D do not vary according to their involvement in different application areas.

The strongest argumentation for the low transfer activity of UFMG technologies is the low entrepreneurial intentions of UFMG professors that research in biotechnology. It should be noted that the nature of academics and public servants is not to engage in risk-taking activities and face an uncertain environment. However, without any market perception and willingness to advance research to the next development stages, it is unlikely that innovative products will emerge. Without the promotion of inventors, their technologies will either continue to stay in the research stage or in rare cases, discovered by coincidence.

The results of the study and the analysis of the local and national innovation systems give hints that the low transfer interest is not only related to the professor's willingness of transferring their technologies. The environment, policies and support play their part in the low technology transfer of biotechnologies. The mechanisms of the university and main funders like CNPq and CAPES are focusing on the primary objectives of the university: basic research and education of labor force. The investments that are meant to advance technologies in development stages and support entrepreneurial initiatives might not be enough to spin-off technologies or motivate to invest time in technology transfer.

This present study shows results that confirm that management experience is related to interest in technology transfer. 58% of the sample want to transfer their technologies either to their own company or to any interested venture (Figure 7 on page 42). Focusing on only the 18% of the sample with management experience, the results show that 90% of them want to engage in technology transfer. Those numbers demonstrate that a certain degree of management experience relates to the interest in advancing technologies in the commercialization chain and therefore reflect entrepreneurial initiatives. The results also show that the more professors are involved in market orientated activities such as pre-clinical trials, regulatory phases and the production phase, the more they show interest in technology transfer.

Furthermore, the interest of technology transfer is not equally distributed, but concentrated in some departments. The data show that in the *Institute of Exact Sciences* all participants want to transfer their technologies to the industry. On the other hand, some academic units show an above average percentage of professors that have no interest in technology transfer like the *School of Veterinary* and the *Faculty of Medicine* with 63% and 67%, respectively (Table 6 on page 43).

The inventor-entrepreneur was defined as the classical entrepreneur who commercializes his own technology and is actively involved in the company management. The results show that 18,5% of the sample actively founded their own venture and is or was involved in company ownership and can therefore be classified as inventor-entrepreneurs. However, the results show that biotechnology venture ownership does not correlate with having products or services on the market as half of the ventures do or did not offer any technology to customers. This can be explained by the high market entry barriers that biotechnology products or services are facing. Overcoming the strict regulations in the biotechnology sector demands in general much more time and money than in other sectors.

Another aspect related to the inventor-entrepreneur model is concerning his interaction with business partners. The data show that five of the companies already introduced a product or service to the market (Table 11 on page 50). Out of those five, three ventures are or were led by only the inventors without a business partner. The literature contributes to those results as the entrepreneurial inventor is characterized by a strong technology commitment and technical knowledge. As the inventor without business partner must face all administrative and technical occurrences alone, he is more involved in the venture than inventors with business partners. His commitment to and integration in the venture is therefore higher and he is less likely to give up his company.

The entrepreneurial activity of the inventor highly correlates to the universities technology transfer activity. 80% of the professors in this sample that are or were involved in company ownership, developed their technologies at UFMG (Table 11 on page 50). This shows that most of the academic entrepreneurs are contributing to the technology transfer activity of the university.

Although the characteristics of the inventor-entrepreneur are observed in the sample, the data reveal that no one of the questioned professors has interest in spinning-off their own technologies and creating a new venture. This could be related to the investment types that finance the professors research. As more than 75% of the R&D investments come from the organization CNPq, CAPES and FAPs (Figure 8 on page 45) that promote research, the commercialization stages might not be sufficiently funded. As most of the investments are distributed according to the academic contributions, professors would have a financial disadvantage if pursuing company related activities instead of academic ones.

The results suggest that 52% of the investigated sample show interest in technology transfer. However, those participants do not want to spin-off the technology to their own company or create a new venture. Therefore, the technology can only be licensed to an established company or spun-off up by an "outsider" that creates a new venture. In both cases, the inventor fits in the surrogate entrepreneurial model as he accepts the technology transfer but without being directly involved in the business.

Some professors try to advance the product development to decrease the distance between their research and the industry. 40% demonstrate interest in testing the viability of their technology on industrial scale (Table 9 on page 46). This initiative would build a bridge between applied research and industrial application and is especially interesting for companies if the results of the Pilot Plant tests show the possibility of industrial implementation.

6 CONCLUSIONS

Biotechnology receives increasing attention by the academic science and the industry and is necessary to advance the research on human diseases, to overcome world hunger and to spare the environment. As several biotechnologies influence directly with human health, regulatory mechanisms monitor new product development. Although, such regulatory matters are often high barriers for ventures and entrepreneurs to introduce new products and services to the market, the process cannot start with technologies staying in laboratories and research institutes. Without promoting groundbreaking inventions, biotechnologies cannot benefit society.

This present work discussed the university-industry interaction and challenges out of the perspective of professors, researching on biotechnology at the Universidade Federal de Minas Gerais (UFMG) and concludes that the lack of academic entrepreneurial initiatives is one of the crucial points to consider. However, the way to the market is also aggravated by the sectorial issues of biotechnologies and the immature System of Innovation of Brazil that lacks in initiatives to promote the commercialization of such technologies.

Biotechnologies face several issues that are specifically related to this sector. However, some of the aspects in this work that justify the research question suggest that lack of transfer interest is not necessarily a sectorial issue. The immature System of Innovation of Brazil has several flaws that generate innovation challenges in the system itself. Additionally, the considerable number of respondents that have no interest in transferring technologies, is not directly related to the obstacles of the sector. Therefore, it is to consider if the low transfer interest is related to the sector of biotechnology or reflects in the system limitations and cultural setting.

This work was confronted with some limitations. Although the collected sample is big enough to analyze the biotechnology sector of UFMG, the collected data cannot be used for an inferential statistical analysis. Therefore, the collected data does not allow deducing the properties of the sample to the total population. Furthermore, as outlined in the methodology, this work detected some limitations of the database used to define the total population. Furthermore, several professors state that their research does not relate to biotechnology although their activities correspond with the definition provided by OECD. This might be related to the broad definition that biotechnology is ascribed to which interweaves with other areas and disciplines.

The main contribution of this work lies in identifying that the lack of entrepreneurial activity is directly related to the low technology transfer. As no professor has the interest in spinning-off their technologies to create new ventures, those technologies need to find other ways to reach the industrial stages. As a considerable number of scientists reflect no interest in transferring technologies, the research cannot advance to the commercialization stages. The results of this present work show that the collaboration between professors and the industry is considerably low. Direct links between the inventor and the industry are very rare, leading to a low interaction activity. This could explain why biotechnology are not finding their way to the market.

However, it is to note that low academic entrepreneurial intentions are not the only reason for biotechnologies to advance in the innovation process. R&D in biotechnology is confronted with several hurdles that aggravate the advancement of such technologies. Strict regulations, high investments and long-term commitment characterize this sector. The sample of this study reflected that the main issue for biotechnology R&D is access to capital, although their research is widely funded. This leads to the conclusion that the investments in biotechnology R&D are not sufficient to advance technologies. However, with stronger ties to the industry, such investments could be obtained. This indicates another conclusion of this work

This present work also identifies the university-industry interaction in the immature NSI as a challenge. The low commitment of industry towards innovative technologies is reflected in the results of this study. Low investment activity and low direct collaboration with the scientist's research, force the professors to rely mainly on governmental funds that are, according to the sample of this study, not sufficient. Therefore, I conclude that the technology transfer and university-industry interaction would likely enhance, if the collaboration between professors and the industry would increase and more investments would be directed from the industry directly to the professor's biotechnology R&D.

For future research, I suggest implementing a qualitative research model in addition to the quantitative approach that I presented here. Such a qualitative approach could be used to deepen the understanding of the situation of UFMG biotechnology spin-offs related to obstacles and academic entrepreneurship. Furthermore, the research method presented in this work can be adjusted to different areas of research and be used to investigate the hypothesis that the lack of transfer interest is not a sectorial issue. The research model can be expanded to other universities that are situated in immature National Systems of Innovation and compared with the presented results.

As this work identifies the lack of academic entrepreneurial activity but also the low interaction of university and industry as the main problem for biotechnology transfer, future work could investigate what professors would motivate to become more active in advancing their technology towards commercialization. Although the commercialization is not in the scope of the scientist’s duties, his entrepreneurial intentions can be a great asset in promoting technologies. Furthermore, future work could investigate why the industry is almost not present in biotechnology R&D and what are options to strengthen the link to the university.

To fully explore the entrepreneurship activity at UFMG, future research should be extended from the academic scientist to his students. The source of spin-offs and technology transfer is not exclusively attributable to professors but often to his students. Therefore, it would be relevant to investigate the role of students in technology transfer, spin-off activity and entrepreneurial intensions.

Finding solutions to motivate academics to engage more in entrepreneurial activity, to increase the technology transfer activity and to give external, surrogate entrepreneurs easier accessibility in order to spin-off technologies would be a challenge to overcome and very interesting to pursue in future research.

REFERENCES

ADAMS, R.; BESSANT, J.; PHELPS, R. Innovation management measurement: A review. **International Journal of Management Reviews**, v. 8, n. 1, p. 21–47, 2006.

AGRAWAL, A. University-to-industry knowledge transfer: literature review and unanswered questions. **International Journal of Management Reviews**, v. 3, n. 4, p. 285–302, 2001.

ALBUQUERQUE, E. et al. **An investigation on the contribution of universities and research**. Mexico City: 2008

ALBUQUERQUE, E.; CASSIOLATO, J. E. As especificidades do Sistema de Inovação do Setor Saúde. **Revista de Economia Política**, v. 22, n. 88, p. 134–151, 2002.

ALBUQUERQUE, E. D. M. E. **National Systems of Innovation and Non-OECD Countries: Notes About a Rudimentary and Tentative "Typology"Brazilian Journal of Political Economy**, 1999.

AMERICAN CHEMICAL SOCIETY. **Discovery and Development of Penicillin**. Disponível em: <https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/flemingpenicillin.html#wwii-penicillin-commercial-production>. Acesso em: 2 abr. 2017.

ANSOFF, H. Strategies for diversification. **Harvard business review**, 1957.

AUDRETSCH, D. B. Entrepreneurship: A Survey of the Literature. **Acta Radiologica [Old Series]**, v. 14, 2003.

BAGLIERI, D.; LORENZONI, G. Closing the distance between academia and market: Experimentation and user entrepreneurial processes. **Journal of Technology Transfer**, v. 39, n. 1, p. 52–74, 2012.

BAREGHEH, A.; ROWLEY, J.; SAMBROOK, S. Towards a multidisciplinary definition of innovation. **Management Decision**, v. 47, n. 8, p. 1323–1339, 2009.

BAUMOL, W. **The free-market innovation machine: Analyzing the growth miracle of capitalism**. New York: Princeton University Press, 2002.

BIOMINAS FOUNDATION. **A Biominas Study of the Brazilian Biotechnology Companies**. Belo Horizonte: [s.n.].

BLOOM, B. R. Tuberculosis: pathogenesis, protection, and control. **ASM Press**, 1994.

BOLTWOOD, R. Basic Patent Law in Brazil, and Recent Developments. **International In-house Counsel Journal**, v. 1, n. 2, 2008.

BRASIL. **Lei N°9279, of 14 may 1996**. Disponível em: <http://www.planalto.gov.br/ccivil_03/leis/L9279.htm>.

BRASIL. **Lei N°9991, of 24 July 2000**. Disponível em: <http://www.planalto.gov.br/ccivil_03/leis/L9991.htm>.

BRASIL. **Lei N° 10.973, of 2 Dezember 2004**. Disponível em: <http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/lei/l10.973.htm>.

BRASIL. **Decree Number 6041, of 8 February 2007**. Disponível em: <http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/decreto/d6041.htm>.

BRASIL. **Lei N°13.243, of 11 January 2016**. Disponível em: <http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2016/lei/l13243.htm>.

CAPES. **História e missão**. Disponível em: <http://www.capes.gov.br/historia-e-missao>. Acesso em: 28 maio. 2017.

CNPQ. **Apresentação - Portal CNPq**. Disponível em: <http://cnpq.br/apresentacao_institucional>. Acesso em: 28 maio. 2017.

COHEN, S.; CHANG, A.; BOYER, H. Construction of biologically functional bacterial plasmids in vitro. **Proceedings of the**, 1973.

COLLINS, O.; MOORE, D. **The enterprising man**. 1st. ed. Michigan: Michigan State Univ Pr, 1964.

CTIT. **Sobre - Somos UFMG**. Disponível em: <http://somos.ufmg.br/sobre>. Acesso em: 1 maio. 2017.

CTNANO. **CTNanotubos**. Disponível em: <http://ctnanotubos.com.br/>. Acesso em: 1 maio. 2017.

CTWEB. **CTWeb - Sobre**. Disponível em: <http://www.ctweb.org.br/sobre/>. Acesso em: 3 abr. 2017.

DAHLMAN, C. K.; FRISCHTAK, C. R. National Systems supporting technical advance in industry: The Brazilian experience. In: NELSON, R. R. (Ed.). . **National innovation systems: A comparative analysis**. New York: Oxford University Press, 1993. p. 427–463.

DAMANPOUR, F. Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators. **Academy of Management Journal**, v. 34, n. 3, p. 555–590, 1991.

DASILVA, E. J. The Colours of Biotechnology: Science, Development and Humankind Biotechnology. **Electronic Journal of Biotechnology**, v. 7, n. No 3, p. 2–5, 2004.

DAVIS, S. .; MOE, K. Bringing innovation to life. **Journal of Consumer Marketing**, v. 14, n. 5, p. 338–361, 1997.

DIMOVA, M. et al. Brazil Biotech Cluster: Minas Gerais. **Microeconomics of Competitiveness Spring 2009**, p. 31, 2009.

ETZKOWITZ, H. Entrepreneurial scientists and entrepreneurial universities in American academic science. **Minerva**, v. 21, n. 2–3, p. 198–233, 1983.

ETZKOWITZ, H.; LEYDESDORFF, L. The dynamics of innovation : from National

Systems and "' Mode 2 '" to a Triple Helix of university – industry – government relations. **Research Policy**, v. 29, p. 109–123, 2000.

FAGERBERG, J. Innovation: A Guide to the Literature. In: FAGERBERG, J.; MOWERY, D. C.; NELSON, R. R. (Eds.). . **The Oxford Handbook of Innovation**. Oxford: Oxford University Press, 2009. p. 1–18.

FESTEL, G. Founding Angels as early stage investment model to foster biotechnology start-ups. **Journal of Commercial Biotechnology**, v. 17, n. 2, p. 165–171, 2011.

FRANKLIN, S. J.; WRIGHT, M.; LOCKETT, A. Academic and Surrogate Entrepreneurs in University Spin-out Companies. **The Journal of Technology Transfer**, v. 26, n. 1, p. 127–141, 2001.

FREEMAN, C. The "National System of Innovation"in historical perspective. **Cambridge Journal of economics**, 1995.

FUNDEPAR. **Quem Somos - Fundepar.** Disponível em: <http://fundepar.ufmg.br/quem-somos/>. Acesso em: 20 maio. 2017.

GELIJNS, A.; ROSENBERG, N.; ROSENBERG, N. The changing nature of medical technology development. **Sources of medical**, 1995.

HARMON, B. et al. **Mapping the university technology transfer processJournal of Business Venturing**, 1997.

INBIA. **Operational Definitions**. [s.l: s.n.]. Disponível em: <https://inbia.org/wp-content/uploads/2016/09/InBIA-Industry-Terms.pdf?x84587>. Acesso em: 12 fev. 2017.

INOVA. **INOVA UFMG - Incubadora de Empresas**. Disponível em: <http://www.inova.ufmg.br/>. Acesso em: 19 maio. 2017.

INOVADATAMG. **Incubadoras de Minas**. Disponível em: <https://inovadatamg.com.br/empresas>. Acesso em: 3 jun. 2017.

KAFARSKI, P. Rainbow code of biotechnology. **Chemik**, v. 66, n. 8, p. 814–816, 2012.

KÖHLER, W. Intelligenzprüfungen an anthropoiden. **Königliche Akademie der Wissenschaften**, v. 1, n. 1, 1917.

LEAF, C. The Law of Unintended Consequences. **CNN**, 19 set. 2005.

LEYDESDORFF, L.; ETZKOWITZ, H. The triple helix as a model for innovation studies. **Science and public policy**, v. 25, n. 3, p. 195–203, 1998.

LIEBESKIND, J. P. et al. Social networks, Learning, and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms. **Organization Science**, v. 7, n. 4, p. 428–443, ago. 1996.

LUNDVALL, B.-A. **National systems of innovation : toward a theory of innovation and interactive learning**. London: Anthem Press, 1992.

MACIEIRA, L. Centro de desenvolvimento e produção de vacinas será inaugurado amanhã, no BH-TEC. 18 abr. 2016.

MARTIN, B. R. The evolution of science policy and innovation studies. **Research Policy**, v. 41, n. 7, p. 1219–1239, 2012.

MCMILLAN, G. S.; NARIN, F.; DEEDS, D. L. An analysis of the critical role of public science in innovation: the case of biotechnology. **Research Policy**, v. 29, n. 1, p. 1–8, 2000.

MENEZES, E. T. DE. **FAPs (Fundações de Amparo à Pesquisa)**. Disponível em: <http://www.educabrasil.com.br/faps-fundacoes-de-amparo-a-pesquisa/>. Acesso em: 28 maio. 2017.

MOWERY, D. C.; SHANE, S. Introduction to the Special Issue on University Entrepreneurship and Technology Transfer. **Management Science**, v. 48, n. 1, p. v–ix, 2002.

MOWERY, D.; SAMPAT, B. Universities in national innovation systems. **The Oxford handbook of innovation**, p. 1–38, 2005.

MURRAY, F. The role of academic inventors in entrepreneurial firms: Sharing the laboratory life. **Research Policy**, v. 33, n. 4, p. 643–659, 2004.

NARIN, F.; HAMILTON, K. S.; OLIVASTRO, D. The increasing linkage between U.S. technology and public science. **Research Policy**, v. 26, n. 3, p. 317–330, 1997.

NELSON, R. The intertwining of public and proprietary in medical technology. In: ROSENBERG, N.; DAWKINS, H. V. (Eds.). . **Sources of Medical Technology: Universities and Industry**. 5. ed. Washington: National Academy: [s.n.]. p. 219–220.

NIOSI, J.; BAS, T. Biotechnology services in Latin America by small and medium enterprises A study of Argentina, Brazil, Chile and Uruguay. **International Development Research Centre**, 2013.

O’CONNOR, G. C.; PAULSON, A. S.; PETERS, L. S. **Grabbing Lightning - Building a capability for breakthrough innovation**. San Francisco: John Wiley & Sons, Inc, 2008.

O’SHEA, R. et al. Universities and Technology Transfer : A Review of Academic Entrepreneurship Literature. **Irish Journal of Management**, v. 25, p. 11–29, 2004.

OECD. **National Innovation System**. Paris: [s.n.].

OECD. **OECD Glossary of Statistical Terms - Royalties Definition**. Disponível em: <https://stats.oecd.org/glossary/detail.asp?ID=2365>. Acesso em: 19 maio. 2017.

OECD. **Framework for Biotechnology Statistics**. Disponível em: <https://www.oecd.org/sti/sci-tech/34935605.pdf>.

PAVITT, K. Sectoral patterns of technical change: Towards a taxonomy and a theory. **Research Policy**, v. 13, n. 6, p. 343–373, 1984.

PHAN, P. H.; SIEGEL, D. S. **The Effectiveness of University Technology Transfer**. [s.l: s.n.]. v. 2

PRAJOGO, D. I.; SOHAL, A. S. TQM and innovation: A literature review and research framework. **Technovation**, v. 21, n. 9, p. 539–558, 2001.

RADOSEVICH, R. A model for entrepreneurial spin-offs from public technology source. **International Journal of Technology Management**, v. 10, n. 7–8, p. 897–893, 1955.

RAMPINO, L. The innovation pyramid: A categorization of the innovation phenomenon in the product-design field. **International Journal of Design**, v. 5, n. 1, p. 3–16, 2011.

ROSENBERG, N.; NELSON, R. American universities and technical advance in industry. **Research policy**, 1994.

RUSU, S. et al. Entrepreneurship and entrepreneur : A review of literature concepts. **African Journal of Business Management**, v. 6, n. 10, p. 3570–3575, 2012.

SALTER, A.; ALEXY, O. The Nature of Innovation. In: **The Oxford Handbook of Innovation Management**. 1. ed. New York: Oxford University Press, 2014. p. 26–53.

SAMSOM, K. J.; GURDON, M. A. University scientists as entrepreneurs: a special case of technology transfer and high-tech venturing. **Technovation**, v. 13, n. 2, p. 63–71, 1993.

SAXON, W. Robert M. Berne, 83, Cardiologist, Medical Educator and Author. **The New York Times**, 17 out. 2001.

SCHUMPETER, J. **Theorie der wirtschaftlichen Entwicklung: Eine Untersuchung über Unternehmergewinn, Kapital, Kredit, Zins und den Konjunkturzyklus**. Berlin: Duncker & Humblot, 1911.

SCHUMPETER, J. **Capitalism, Socialism and Democracy**. 1. ed. New York: Harper & Brothers, 1942.

STEVENSON, H. H.; JARILLO, J. C. A paradigm of entrepreneurship: Entrepreneurial management. **Strategic Management Journal**, v. 11, n. Special Issue: Corporate Entrepreneurship, p. 17–27, 1990.

STEVENSON, H. H.; ROBERTS, M. J.; GROUSBECK, H. I. **New business ventures and the entrepreneur**. Toronto: Irwin, 1989.

TIDD, J.; BESSANT, J. **Managing Innovation**. Fifth ed. United Kingdom: Wiley, 2013.

UFMG. **UFMG vai sediar centro de P&D em nanotubos de carbono financiado por parceria público-privada**. Disponível em: <https://www.ufmg.br/online/ndc/noticias/ufmg-vai-sediar-centro-de-pd-em-nanotubos-de-carbono-financiado-por-parceria-publico-privada/>. Acesso em: 1 jun. 2017.

UNITED NATIONS. **Convention on Biological Diversity**. New York CIty: [s.n.]. Disponível em: <https://www.cbd.int/doc/legal/cbd-en.pdf>. Acesso em: 13 abr. 2017.

UNITED NATIONS. **World Population Prospects: The 2015 Revision – Key Findings and Advance Tables**. New York: [s.n.].

VAN BEUZEKOM, B.; ARUNDEL, A. **Biotechnology Statistics**. [s.l: s.n.]. Disponível em: <http://www.oecd-ilibrary.org/science-and-technology/oecd-biotechnology-statistics-2009_9789264073937-en>.

VAN PRAAG, C. M. Some classic views on entrepreneurship. **Economist**, v. 147, n. 3, p. 311–335, 1999.

VEBLEN, T. **The Higher Learning in America.** New York: BW Huebsch, 1918.

WRIGHT, M.; BIRLEY, S.; MOSEY, S. Entrepreneurship and University Technology Transfer. **Journal of Technology Transfer**, v. 29, p. 235–246, 2004.

WÜRMSEHER, M. To each his own: Matching different entrepreneurial models to the academic scientist’s individual needs. **Technovation**, v. 59, n. October 2016, p. 1–17, 2017.

ZYLBERBERG, E.; ZYLBERBERG, C. Biotechnology in Brazil_ An industry overview. **Journal of Commercial Biotechnology**, v. 18, n. 4, p. 9–18, 2012.

APPENDIX

Appendix 1 Full list of questions with short explanation.

Section “Research”

Question 1: Name (Question type (QT): Single-line textbox)

The name of respondents was collected only for internal use. The names of the participants are handled anonymously and will not be presented in this study.

Question 2: Biotech techniques (QT: Multiple choice, multiple selection)

This question collected data on the biotechnology technique the participant was involved in. Possible answers comprised the list-definition of biotechnology techniques of OECD (Annex 1).

Question 3: Biotech activities & status (QT: Matrix, single selection)

The participants were asked to enter the application area of their research (e.g. medicine, agriculture etc.) and in addition the activity status for the application area(s) they are involved in (e.g. research, pre-clinical, regulatory phase, approved/marketed/in production.). The activity status was adapted from a model survey of OECD (OECD, 2005, p. 47) and the biotechnology activities were adapted from the two color code models and the OECD definition.

Question 4: Management experience (QT: Multiply choice, simple selection)

The researcher was asked if he has any experience in company management

Question 4.1 (follow-up): What experience? (QT: Multiple choice, multiple selection)

Only participants with management experience were asked to answer this question. The respondent was asked to specify his management experience and was given several options to select.

Question 5: Financed (QT: Multiply choice, multiple selection)

This question collects data on how the academic’s research is being financed. The answer options comprise a list of institutions.

Question 6: R&D collaboration (QT: Matrix, multiple selection)

Participants had to specify their collaboration with professors or institutions according to stage of development. The stage of development differentiates itself from the activity status in Q3 as it focuses on the research and divides it in three sections: basic research, applied research and service/product development. They also were asked about the amount of collaborations.

Question 7: R&D issues (QT: Click-ranking)

In this section, the researcher has to rate given research obstacles according to their importance while considering his research.

Question 8: Tech Transfer (QT: Multiple choice, simple selection)

In this question, the participant states his intentions about transferring his technology to his own company (if existing), to a company he intends to create, to any company or to no one.

Question 8.1 (follow-up): How transfer (QT: Multiple choice, simple selection)

Only participants with technology transfer intentions were asked to answer this question. They could choose between transferring through patents, knowhow or that they do not know yet.

Question 8.2 (follow-up): CTIT (QT: Multiple choice, simple selection)

The participants that show interest in technology transfer were asked if they already approached CTIT for consultation.

Question 9: Pilot plant[17] (QT: Multiple choice, multiple selection)

The question implemented a scenario in which UFMG had access to a pilot plant. The participant is asked what he would use this pilot plant for if this scenario would be hold true. He was presented with possible uses.

[17] Pilot Plant: A small industrial plant in which problems can be identified and resolved before the large-scale plant is built

Question 9.1 (follow-up): Why Pilot Plant (Multiple choice, multiple selection)

If the participant has no use or interest in a pilot plant, this question was not displayed. Depending on their answers in Q9, the participant is asked to specify why he selected the possible use(s).

Question 10: Biotech company (Multiple choice, multiple selection)

With this question, the “Research” section closes. Here the participant is asked to indicate if he owns or owned a biotechnology company. If he has the profile of R1 and states that he never owned a biotechnology venture, he is directed to the end page.

Section “Company”

Question 11: Year (QT: Single-line textbox)

The participant was asked about the year of establishment of his venture.

Question 12: UFMG-tech (QT: Multiple choice, simple selection)

This question asks about the origin of the technology used in the company: If it was developed at UFMG or not.

Question 13: Business partner (QT: Multiple choice, simple selection)

It is asked if the researcher has a partner with business expertise at his company.

Question 14: Finances (QT: Multiple choice, simple selection)

Here, the aim is to determine if the venture depends on investments to sustain or if it can finance itself independently.

Question 15: Products (QT: Multiple choice, simple selection)

It is questioned if the respondents company is offering products or services on the market or if this is not achieved yet.

Question 15.1 (follow-up): No products (QT: Multiple choice, multiple selection)

If the venture is not offering any products or services on the market yet, the participant is asked to choose out of a list of possible reasons why the company is not offering anything on the market yet.

Question 16: Incubation[18] (QT: Multiple choice, simple selection)

The participant is asked to state here if the company was, is or never was incubated.

Question 16.1 (follow-up): Incubation follow-up (QT: Multiple choice, multiple selection)

Depending on the venture relationship to incubation, the participant is asked why the company was, is or never was incubated. Q16.1 closes the section "Company"

Section "Ex-company"

Question 17: Why ex? (QT: Multiple choice, simple selection)

The participant is asked why his has not ownership in his biotechnology ex-business. Following options were give: (1) The company was sold; (2) The participant left the company; (3) The company is not operating anymore.

Question 18: How long? (QT: Drop-down list, simple selection)

It was questioned how long the company was running or is still operating.

Question 19: UFMG-tech (QT: Multiple choice, simple selection)

Identical to Q12 but now in relation to the ex-company. This question asks about the origin of the technology used in the ex-company: If it was developed at UFMG or not.

Question 20: Business partner (QT: Multiple choice, simple selection)

---

[18] The International Business Incubation Association INBIA defines incubators as follows: "Incubators typically charge monthly program fees or membership dues in exchange for office/desk space and access to program offerings. Incubators offer programs to member companies that typically include mentoring, education/training, and informal learning opportunities."(INBIA, 2017).

Identical to Q13 but now in relation to the ex-company. It is asked if the researcher had a partner with business expertise at his ex-company.

Question 21: Patents (QT: Multiple choice, simple selection)

The respondent is asked if the technology of his ex-company was protected by patents and if yes, how many. Q21 closes the section “Ex-company”.

As shown previously in Figure 4, all respondents are finishing in the “End” section. Here the researcher could add his contact information if he wants to receive the results of the survey or leave comments about the study.

Appendix 2: Categorization of surveyed faculty according to their academic unit and department

Academic unit	Amount	%	Department	Amount	%
Institute of Exact Science	5	9,30%	Dep. of Chemistry	4	7,40%
			Dep. of Computer Science	1	1,90%
Institute of Biological Sciences	29	53,70%	Dep. of Microbiology	9	16,70%
			Dep. of General Biology	7	13,00%
			Dep. of Biochemistry and Immunology	4	7,40%
			Dep. of Parasitology	4	7,40%
			Dep. of Physiology and Biophysics	3	5,60%
			Dep. of Morphology	1	1,90%
			Dep. of Botany	1	1,90%
Institute of Agrarian Sciences	1	1,90%	Board of Directors	1	1,90%
Faculty of Dentistry	1	1,90%	Dep. of Restorative Dentistry	1	1,90%
Faculty of Medicine	6	11,10%	Dep. of Surgery	1	1,90%
			Dep. of Mental Health	1	1,90%
			Dep. of Clinical Medicine	1	1,90%
			Dep. of Complementary Propedeutics	1	1,90%
			Dep. of Gynecology and Obstetrics	1	1,90%
			Dep. of Ophthalmology and Otorhinolaryngology	1	1,90%
Faculty of Pharmacy	2	3,70%	Dep. of Pharmaceutical Products	1	1,90%
			Dep. of Foods	1	1,90%
School of Veterinary	8	14,80%	Dep. of Animal Husbandry	3	5,60%
			Dep. of Veterinary Preventive Medicine	2	3,70%
			Dep. of Clinic and Veterinary Surgery	2	3,70%
			Dep. of Technology and Inspection in Products of Animal Origin	1	1,90%
School of Engineering	2	3,70%	Dep. of Sanitary and Environmental Engineering	1	1,90%
			Dep. of Metallurgical Engineering and Materials	1	1,90%
TOTAL	54	100%	TOTAL	54	100%

Appendix 3: Online questionnaire

Section 1: Research

BEM VINDO
Pesquisa para mapeamento do ambiente de biotecnologia da UFMG

Prezado/a Professor(a)

Meu nome é Victor Bistritzki e estou fazendo o Mestrado Profissional em Inovação Tecnológica e Propriedade Intelectual na UFMG.

O objetivo da minha pesquisa é prospectar o ambiente de biotecnologia da UFMG e identificar possíveis problemas e dificuldades de pesquisa e do mercado deste setor com a ajuda de um questionário.
Sua ajuda é muito valiosa para a avaliação e futuras melhoras no ambiente de biotecnologia no campus.

Atenciosamente,
Victor Bistritzki

Agradeço antecipadamente sua participação!

Q1 **Nome**

Q2 **Em quais técnicas de biotecnologia você está envolvido? (marque 1 ou mais)**

- ☐ DNA/RNA
- ☐ Proteínas e outras moléculas
- ☐ Cultura e engenharia de células e tecidos
- ☐ Técnicas e processos de biotecnologia
- ☐ Vetores de genes e RNA
- ☐ Bioinformática
- ☐ Nanobiotecnologia
- ☐ Outros

Q3 **Indique o estágio das atividades de biotecnologia em que você está envolvido.**

	Sem envolvi-mento	Pesquisa	Ensaios-pré-clínicos / ensaios-em campo confinado	Fase regulam-entar / Avaliaç-ão de liberaçã-o não confinada	Aprova-do / comerci-alizado / em pro-dução
Medicina e saúde humana	○	○	○	○	○
Agricultura, plantas e saúde veterinária	○	○	○	○	○
Nutrição (alimentação humana e animal)	○	○	○	○	○
Proteção ambiental	○	○	○	○	○

Processamento industrial	○	○	○	○	○
Bioinformática, informática e tecnologia de chip (Ferramentas de investigação, Software, etc.)	○	○	○	○	○
Aquacultura, biotecnologia costeira e marinha	○	○	○	○	○
Outros	○	○	○	○	○

Q4 Você tem alguma experiência em gestão de empresas?

- ○ Sim
- ○ Não

Q4.1 Quais experiências relacionadas a gestão de empresas você tem?

- ☐ Cursos Online
- ☐ Cursos em incubadoras (Inova, Habitat, etc.)
- ☐ Workshops
- ☐ Tenho curso de graduação ou pós-graduação em alguma área de gestão de empresas (administração, economia, engenharia de produção, etc.)
- ☐ Conhecimento prático como gestor da minha próopria empresa
- ☐ Conhecimento prático como contratado para cargo de gestão empresarial

Q5 Como sua pesquisa está sendo financiada?

- ☐ Empresas ou financiamentos privados
- ☐ Finep
- ☐ Fap`s
- ☐ CNPq
- ☐ BNDES
- ☐ Fundep
- ☐ Capes
- ☐ Outros
- ☐ Não é financiado
- ☐ Prefiro não informar

Q6 Quantos colaboradores você tem na sua(s) pesquisa(s)?

	Nenhum	1-5	6-10	Mais que 10
Professores da UFMG	○	○	○	○
Professores de outras universidades do Brasil	○	○	○	○

Professores de outras universidades do exterior	○	○	○	○
Empresas	○	○	○	○
Instituições, governo ou outras organizações.	○	○	○	○

Q7 Quais são seus obstáculos de pesquisa e desenvolvimento?

- Acesso a capital
- Acesso a tecnologia / informação
- Acesso a recursos humanos qualificados
- O acesso a insumos
- Percepção e aceitação do seu produto pelo público
- Assuntos regulatórios
- Propriedade intelectual e acesso ao mercado
- Escalonamento da produção

Q8 Você gostaria de transferir/vender alguma tecnologia sua?

- ○ Sim, para minha própria empresa
- ○ Sim, para uma empresa que pretendo criar
- ○ Sim, para qualquer empresa (vender)
- ○ Não

Q8.1 Como você pretende transferir sua tecnologia?

- ○ Patentes
- ○ Know-how
- ○ Ainda não sei

Q8.2 Você já procurou a CTIT da UFMG para avaliar a possibilidade de proteção intelectual?

- ○ Sim
- ○ Não

Q9 Caso a UFMG tivesse uma Planta-piloto, como VOCÊ poderia usufruir deste espaço?

- ☐ Para treinamento de alunos
- ☐ Para checar a viabilidade da minha pesquisa em escala industrial
- ☐ Para pesquisa aplicada
- ☐ Não usufruira

Q9.1 Por que você usaria uma planta-piloto para treinamento de alunos?

- ☐ Para explicá-los os desafios do escalonamento
- ☐ Para explicá-los como escalonar
- ☐ Para explicá-los como operar equipamentos em escala industrial

Q9.1 Por que você usaria uma planta-piloto para averiguar a viabilidade da sua pesquisa em escala industrial?

- ☐ Para facilitar o processo de transferência tecnológica
- ☐ Para identificar possíveis problemas na escala industrial
- ☐ Para alcançar o estágio de desenvolvimento de prototipagem
- ☐ Para reduzir o risco da tecnologia para investidores

Q9.1 Por que você usaria uma planta-piloto para pesquisa aplicada?

- ☐ Para avançar no estado da arte da área da pesquisa
- ☐ Para desenvolver protótipos
- ☐ Para geração de conhecimento tecnológico
- ☐ Para aplicar engenharia reversa

Q10 Você tem ou já teve uma empresa na área de biotecnologia?

- ☐ Eu TENHO uma empresa na área de biotecnologia
- ☐ Eu já TIVE uma empresa na área de biotecnologia.
- ☐ Não

Section 2: Company

Por favor, responda todas as perguntas nesta página SOMENTE relacionadas com a sua empresa de biotecnologia

Q11 **Em que ano foi criada a sua empresa?**

Q12 **A tecnologia da sua empresa é/foi desenvolvida na UFMG ?**

- ○ Sim
- ○ Não

Q13 **Você tem um parceiro de negócios com experiência em gestão de empresas?**

- ○ Sim
- ○ Não

Q14 **A sua empresa depende de suporte financeiro?**

- ○ Sim, a empresa ainda precisa de investidores para se sustentar
- ○ Não, a empresa opera de forma independente

Q15 **A sua empresa possui produtos ou serviços de biotecnologia disponíveis no mercado?**

- ○ Sim, produtos e serviços
- ○ Não, ainda não

Q15.1 **Por que sua empresa não oferece produtos / serviços de biotecnologia no mercado?**

- ☐ Problemas de gestão
- ☐ Não há quantidade de recursos necessária
- ☐ Problemas de desenvolvimento de produto
- ☐ Não houve investimento suficiente
- ☐ Tecnologia não se consolidou no mercado
- ☐ Problemas regulatórios (Anvisa, MAPA, ISO, etc.)
- ☐ Problemas nos canais de distribuição
- ☐ Outros

Q16 Sua empresa está ou esteve localizada em uma incubadora (por exemplo, Habitat, BH Tech, Inova)?

- ○ Sim, minha empresa é incubada
- ○ Sim, minha empresa foi incubada
- ○ Não, minha empresa nunca foi incubada.

Q16.1 Quais são os principais motivos para sua empresa estar incubada?

- ☐ Facilidades em relação ao registro Anvisa
- ☐ Amparo na gestão
- ☐ Networking
- ☐ Infraestrutura física e de serviços
- ☐ Outros

Q16.1 Por que sua empresa não está mais incubada?

- ☐ Custos altos
- ☐ Processo de incubação completado
- ☐ Insatisfeito com a incubadora
- ☐ Expansão da empresa
- ☐ Outros

Q16.1 Por que sua empresa não está incubada

- ☐ Nenhuma incubadora atende às necessidades da minha empresa
- ☐ Não há recursos financeiros
- ☐ Não há interesse
- ☐ Não há necessidade
- ☐ Outros

Section 3: Ex-company

Por favor responda todas as perguntas nesta página SOMENTE relacionadas com a sua ex-empresa de biotecnologia

Q17 O que aconteceu com sua empresa?

- ○ A empresa foi vendida
- ○ Eu saí da empresa
- ○ A empresa encerrou suas atividades

Q18 Por quantos anos a sua empresa funcionou ou funciona?

-- Por favor selecione --
- -- Por favor selecione --
- Menos de 1 ano
- 1 - 3 anos
- 4 - 6 anos
- Mais de 6 anos

Q19 A tecnologia da sua empresa foi desenvolvida na UFMG ?

- ○ Sim
- ○ Não

Q20 Você teve um parceiro de negócios com experiência em gestão de empresas?

- ○ Sim
- ○ Não

Q21 As tecnologias da sua empresa foram protegidas por patentes?

- ○ Não
- ○ Sim (quantas?) ____

Final Page

Deseja receber os resultados deste estudo?

- ○ Não
- ○ Sim, meu e-mail é: ____

Comentários

ANNEX

Annex 1: Listed base definition of biotechnology techniques

Source: (OECD, 2005)

DNA/RNA	Genomics, pharmacogenomics, gene probes, genetic engineering, DNA/RNA sequencing/synthesis/amplification, gene expression profiling, and use of antisense technology.
Proteins and other molecules	Sequencing/synthesis/engineering of proteins and peptides (including large molecule hormones); improved delivery methods for large molecule drugs; proteomics, protein isolation and purification, signaling, identification of cell receptors.
Cell and tissue culture and engineering	Cell/tissue culture, tissue engineering (including tissue scaffolds and biomedical engineering), cellular fusion, vaccine/immune stimulants, embryo manipulation.
Process biotechnology techniques	Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation, biofiltration and phytoremediation.
Gene and RNA vectors	Gene therapy, viral vectors.
Bioinformatics	Construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology.
Nanobiotechnology	Applies the tools and processes of nano/microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics, etc.