CAPÍTULO

17

Academic Entrepreneurship: the challegens of Biotechnology transfer at the Universidade Federal de Minas Gerais

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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.

As biotechnology products must pass several tests to be approved by national health departments and rely 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. Various examples reflect the essential role of the inventors and the academia in the development of successful biotechnology products e.g. 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 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). 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.).

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: Why are biotechnologies [footmark], developed at UFMG, 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 concerns innovation and contributes in general to this work. The second topic will discuss university-industry technology transfer. The third topic presents a review on entrepreneurship with a focus on academic entrepreneurship. The theoretical background will end in 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 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. A considerably low transfer interest of professors and the low management experience can be observed and correlates with the low transfer interest.

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

Although innovation was always around, it was only established in the 1960s as its own field of study after the contribution of after the contribution of Schumpeter, Theory of Economic Growth (1923), was translated from German into English and 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. Furthermore, 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 infuential academic advances in the feld 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.* (ADAMS; BESSANT; PHELPS, 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*[1] (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 perspective, he defines innovation as "a new or better product or production process successfully commercialized or used"[2] . 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).

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.

1 English translation from 1934: Theory of Economic Growth.

2 Citation adapted to American English.

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.

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). This study focuses on the technology transfer process from universities to the industrial sector (further referred to as U-I transfer).

The university is a fundamental source of knowledge in science and technology areas and therefore, it is important to discuss how science connects 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, universities 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 later discussed in more detail.

To understand the challenges of technology transfer processes, it is relevant to shed 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.

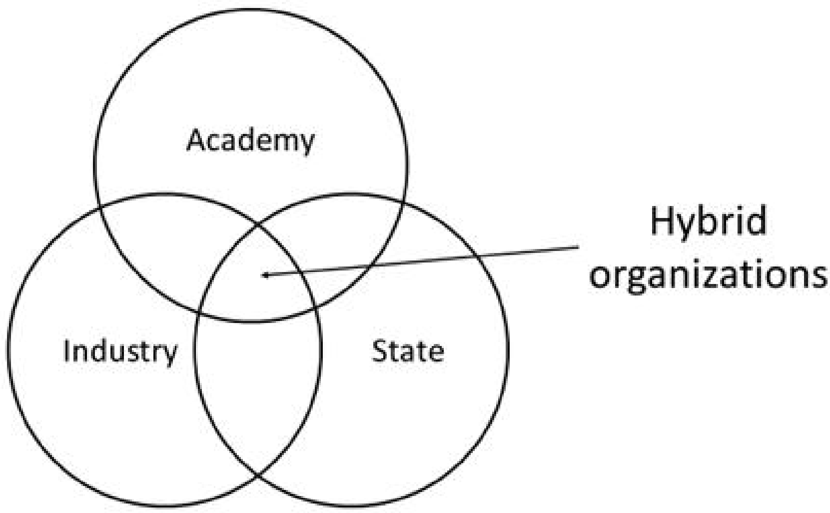
2.2.1 Innovation systems

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. 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.

The second concept is the Triple Helix Model of Innovation introduced 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 1. The overlapping of the three spheres symbolizes the emergence of hybrid organizations such as university business incubators, governmental laboratories and academic spin-offs.

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).

Figure 1. Triple Helix Model



This work investigates the university-firm interface; therefore, the focus of this section is primarily on those two spheres and less on the role of 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.

2.2.2 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) sketched 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" (ALBU-

QUERQUE *et al*., 2008). According to Alberquerque's classification, Brazil falls into the "non-mature" NSI typology.

Freeman (1995 *apud* ALBUQUERQUE, 1999) points out the main characteristics of the Latin American economies, which are included in Albuquerque's non-mature typology. 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, 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 (ALBUQUERQUE *et al*., 2008).

The immaturity of the Brazilian NSI 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[3] 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 doctoral 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

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3 Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Coordination of the Improvement of Higher Education Personnel).

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 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.

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, 1957; 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 analyzed 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, 1957).

Under the consideration of multiple dimensions, Stevenson, Roberts and 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 (1983) was one of the first who shed 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.

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[4] 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 (2004) highlights the importance of academic inventors in entrepreneurial firms especially related to their social not human ca-

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4 “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 benets from an innovation or a solution to a problem.”(BAGLIERI; LORENZONI, 2012).

pital. 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 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 changed over time and with it its definition. Because most definitions of biotechnology are very broad and the research on this area gained a lot 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 (Annex 1). 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 knowledge, goods and services." (OECD, 2005, p. 9).

To complement the definition of OECD, their published list of classifications of biotechnology applications can be consulted (OECD, 2005). Although OECD recognizes the rapid development of the biotechnology[5] sector and updated the report in 2009 (VAN BEUZEKOM; ARUNDEL, 2009), the definition of 2005, including the list-based one, stays unchanged.

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. 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 U.S. 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.* (NARIN; HAMILTON; OLIVASTRO, 1997) examine the contribution of public science to industrial technology in the U.S. and state that patents related to drugs and medication are those with the strongest dependence on public science. McMillan et al. (MCMILLAN; NARIN; DEEDS, 2000) narrow down the focus of research on the importance of public science to the sector of biotechnology in the U.S. They 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

5 "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)

the capacity to revolutionize the pharmaceutical, chemical and agricultural industry at that time (MCMILLAN; NARIN; DEEDS, 2000).

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). 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 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 São Paulo (42,3%) and Minas Gerais (29,6%), representing the major clusters 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.

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 biotechnology. 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.

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.

3.1 The UFMG innovation model

UFMG aims at creating an innovative environment that nurtures technologies that were developed at UFMG and tries to provide the inventors with the necessary resources and networks to approach commercialization. For academics that seek no direct involvement with commercializing technologies, university environment 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[6] (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

6 Coordenadoria de Transferência e Inovação Tecnológica.

inventor along the way (CTIT, 2017). From 1995 to 2017, CTIT filed 853[7] patents to protect the intellectual property of UFMG. Out of those, 259 patents (30%) are 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. With or without being incubated, inventors can approach the foundation Fundepar 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 innovative companies, with the purpose of transferring innovations from the university to the market (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[8] and FIEMG[9]. 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 2.

3.2 Data collection – The "Somos method"

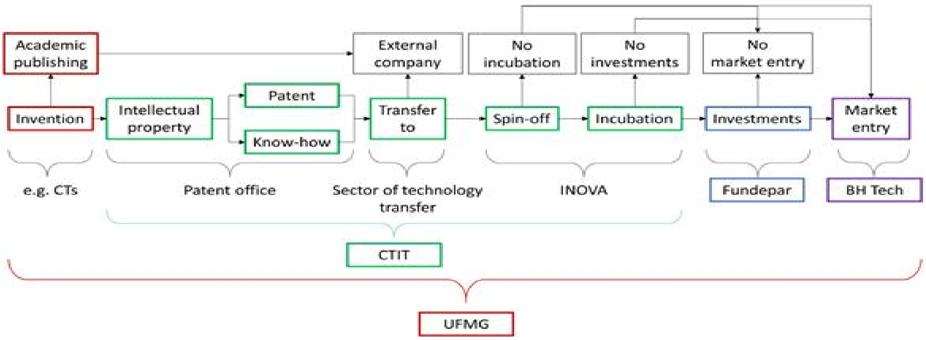
Professors employed at UFMG and conducting R&D in biotechnology are the focus group of this study. To identify this target group, the database "Somos UFMG" was used as a tool. This open access database was generated by CTIT and developed to map the competencies at UFMG with the goal to increase the interaction between the scientific and technological research of the university and private and public institutions (CTIT, 2017).

7 Data retrieved on the 25.05.2017.

8 Brazilian support service for micro and small enterprises of Minas Gerais.

9 Federation of industries of Minas Gerais.

Figure 2. UFMG innovation model



To cross biotechnology with the Somos database, the OECD list-based definition of biotechnology techniques 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.

Through this method, 118 professors with links to at least two biotechnology related keyword could be identified. Together with the professors and their biotechnology references (keywords), the department, institute, published articles, patents and graduated students were captured. The 118 professors with biotechnology references compile the target population and are spread over eight academic units and 33 departments of UFMG. The survey was distributed 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.

3.3 Questionnaire Structure

The survey was constructed to capture information on professors that research in biotechnology and, if so, own or owned biotechnology related companies. A survey model with filter questions was designed so that professors only answer questions that occur to their situation. Because of some limitations[10], it is assu-

10 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, introduced 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.

med that the biotechnology landscape of UFMG is larger than recorded in this study. However, a scan of the total patents related to biotechnology, recorded by CTIT (259 patents[11]) 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.

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 respondent's profile. The third subsection outlines to results concerning the professor's research, and the fourth subsection presents biotechnology-related results. As the size of the company sample (ten) is not large enough to draw quantitative conclusions, this part was excluded from this study. 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 and 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 1 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.

11 Data retrieved on the 25.05.2017.

Table 1. 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 1, 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 1 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

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. Figure 3 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 3. Management experience

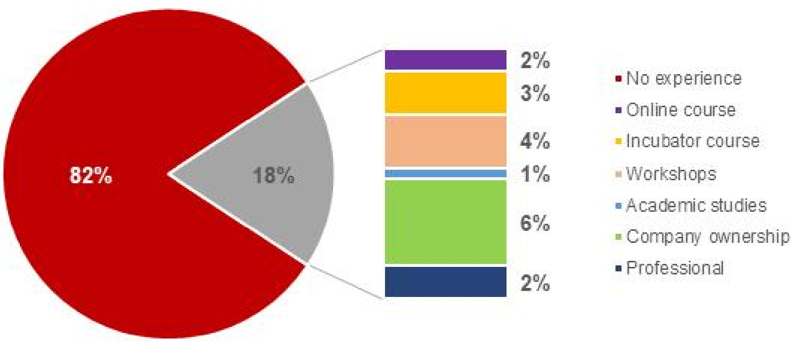
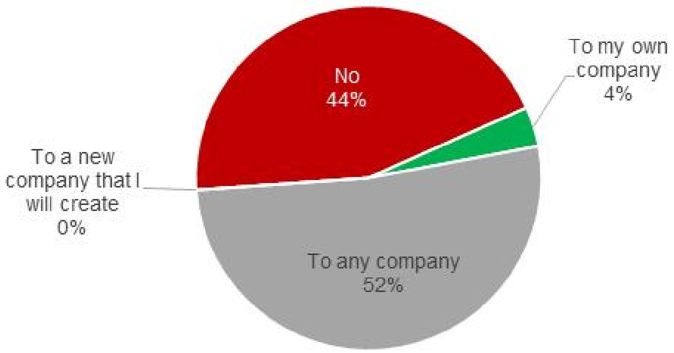


Figure 4. Interest in technology transfer



Related to transferring technologies that were developed in the professors' research, Figure 4 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.

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 with their interest in technology transfer 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, crossed with their affiliated academic unit, is presented in Table 2. 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 2. 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%

Source: authors elaboration

4.3 Research

The research of professors on biotechnology at UFMG is in different stages of development. The collected data 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 3 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 3. 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%

Source: authors elaboration

Table 4. Activity status versus 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

Source: authors elaboration

Table 4 presents the activity status of the technology, the scientists of the sample are involved in, crossed with their willingness to transfer their technologies. 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 5. Source of research funding

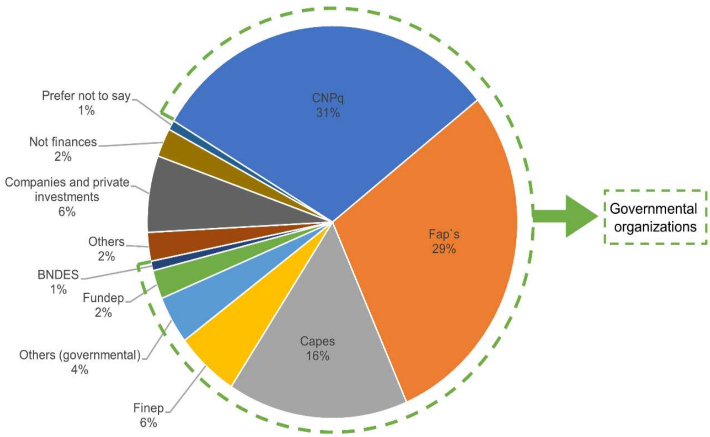
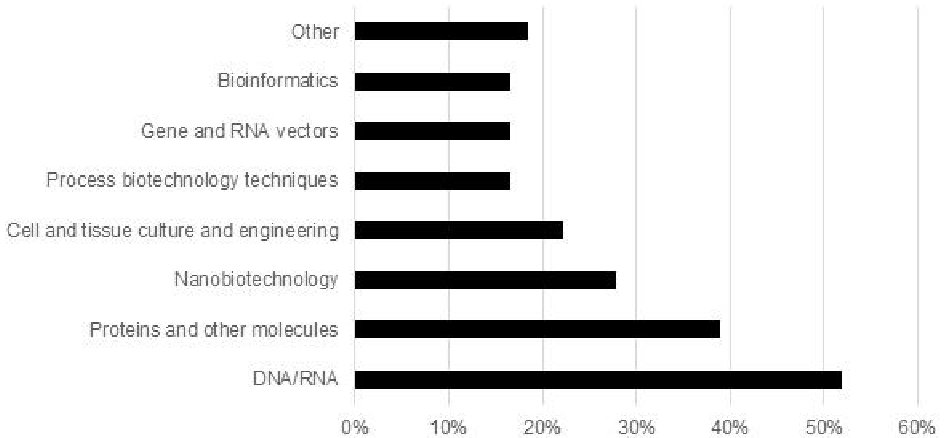


Figure 5 shows the results of the finance types, the professors in the sample receive for pursuing their R&D. The main investments are coming from CNPq (31%), Fap's (29%) and Capes (16%). The sum of governmental investments makes up for 89% of all the finances. 6% of the scientists in the sample are 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.

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, 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 techniques and Gene and RNA vectors with 17% each. This distribution of the biotechnology techniques of the sample is illustrated in Figure 6.

Figure 6. Biotechnology techniques at UFMG



Related to the area that the biotechnology technique is applied in, most participants state that their research finds application in the sector of Medicine and Human Health (59%), and to Agriculture, plants and veterinary health (38%). Those two major fields of research at UFMG and other relevant ones are displayed in Figure 7.

Biotechnology comes with specific hurdles that hinder that hinder R&D advancements. Figure 8 presents the biggest issue for biotechnology R&D out of the respondent's view. According to the sample, "access to capital" was rated the biggest obstacle by 64% of all participants. 10% stated that "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 "public acceptance" is the biggest issue of their R&D.

Figure 7. Application area of biotechnology techniques

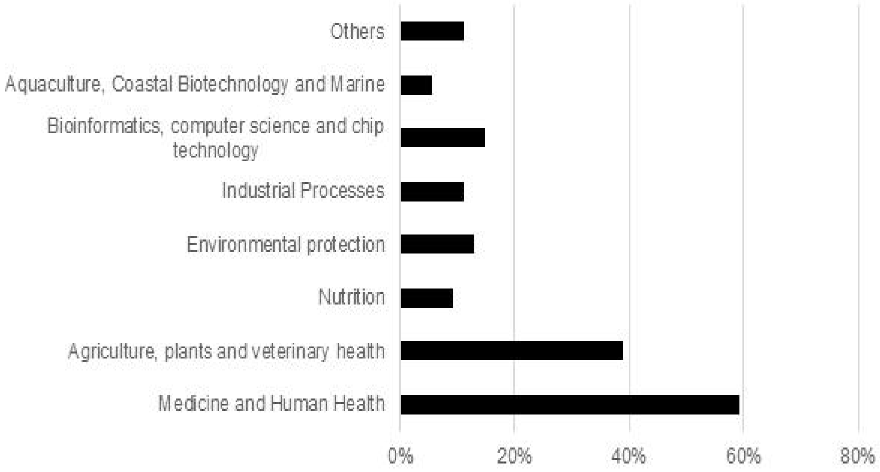
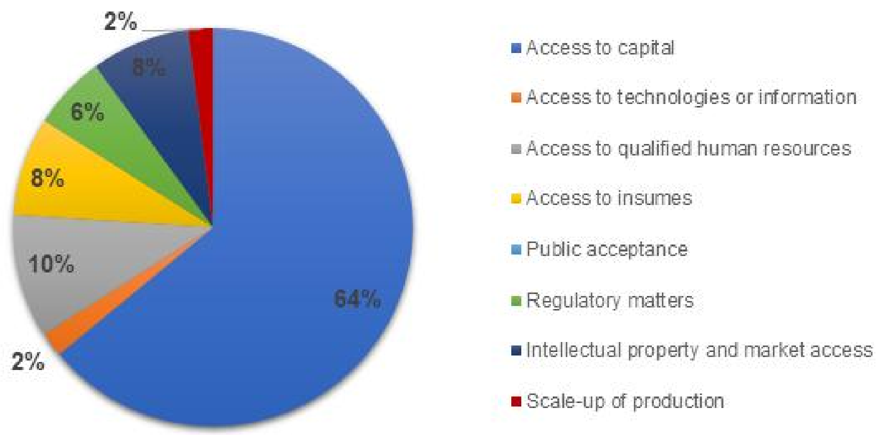


Figure 7. Application area of biotechnology techniques



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 among university and industry, sectorial obstacles of biotechnology, and academic entrepreneurial initiatives.

Two results of this present work, that relate to the collaboration of UFMG, 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 the results show. 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. Those results corroborate with the discussions of Albuquerque (1999). 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 scientific 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.

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, technology transfer mechanisms and 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, provide investments primarily for research purpose, academic publishing and higher education. Those organizations focus less on the commercialization steps after R&D.

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. 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.

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 financiers 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. 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 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 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.

FINAL CONSIDERATIONS

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.

This present work discussed the university-industry interaction and challenges out of the perspective of professors, researching on biotechnology at the Federal University of 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 biotechnology, basic research focused funding, 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.

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.

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 enough 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 enough. 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.

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