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Nathália Costa Santana

The Technology Transfer Process and the Role of the Universities - A comparison between Portugal, United States, and United Kingdom

Dissertação no âmbito do Mestrado em Biotecnologia Farmacêutica orientada pela Senhora Doutora Catarina Cunha Santos e pelo Senhor Professor Doutor João Nuno Moreira e apresentada à Faculdade de Farmácia da Universidade de Coimbra.

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Abstract

Portugal's recognition as a "Moderate Innovator" in the European Innovation Report 2022 shows that our innovation indicators still fall behind the European average. Universities, through their technology transfer offices, have excelled in developing innovation in our country by channeling the scientific and technological knowledge developed there into society. However, despite being crucial players in our innovation ecosystem, the number of academic-industry technology transfer processes in Portugal is still small and their impact limited.

This dissertation addresses key aspects of academia-industry technology transfer processes in Portugal, with the aim of identifying and understanding the main barriers and necessary improvements to this process. To carry out a more in-depth assessment, the Portuguese academic technology transfer process will be compared to the technology transfer model in the United States and the United Kingdom, two of the most recognized models in the world. This comparison was made through interviews with various technology transfer offices in these countries and research on institutional websites.

Despite the three countries present very similar technology transfer models, we can see that in Portugal, there is a strong focus on the initial support activities for researchers related to patent submission, but this focus is not seen in the subsequent phases of looking for partners to finance the technology. This focus is even lower when compared to support for the creation and maintenance of technology-based spin-offs, which is also one of the ways to materialize what has been developed in the laboratory.

The activities of the technology transfer offices have been increasingly recognized over the years. However, there is still a great responsibility on the part of the universities to make the work carried out in these offices more visible, to increase the number of technologies that are put on the market and their impact on our daily lives, so that we can move towards a better society.

Keywords: *Innovation, academia-industry, academic technology transfer offices, scientific and technological knowledge, spin-offs, researchers.*

Resumo

O reconhecimento de Portugal como ‘’ Inovador Moderado’’ no *European Innovation Report* 2022 demonstra que os nossos indicadores de inovação ainda se encontram aquém em comparação com a média europeia. As universidades, através dos seus gabinetes de transferência de tecnologia, têm-se destacado no desenvolvimento da inovação do nosso país através da canalização do conhecimento científico e tecnológico aí desenvolvido para a sociedade. Porém, e apesar de constituírem agentes cruciais no nosso ecossistema de inovação, os processos de transferência de tecnologia academia-indústria em Portugal são ainda em número reduzido e de impacto limitado.

Esta dissertação aborda aspetos-chave dos processos de transferência de tecnologia academia-indústria em Portugal, com o objetivo de identificar e compreender as principais barreiras e melhorias necessárias a este processo. De modo a realizar uma avaliação mais aprofundada, o processo de transferência de tecnologia académico português será comparado ao modelo de transferência de tecnologia dos Estados Unidos e Reino Unido, dois dos modelos mais reconhecidos no mundo. Esta comparação foi realizada através de entrevistas a vários gabinetes de transferência de tecnologia nestes países e pesquisa nos websites institucionais.

Apesar dos três países apresentarem um modelo de transferência de tecnologia semelhante, pudemos perceber que em Portugal, há um grande foco nas atividades iniciais de suporte aos investigadores relacionadas à submissão de patentes, mas esse foco não é visto nas fases seguintes de busca por parceiros para financiar a tecnologia. Esse foco é ainda menor quando comparamos com o suporte às atividades de criação e manutenção de spin-offs de base tecnológica, que também é uma das formas de materializar o que foi desenvolvido em laboratório.

O trabalho dos gabinetes de transferência de tecnologia ao longo dos anos vem sendo cada vez mais reconhecido. No entanto, ainda existe uma grande responsabilidade por parte das universidades no sentido de visibilizar o trabalho que é exercido nesses gabinetes, por forma a aumentar o número de tecnologias que são colocadas no mercado e o impacto destas no nosso dia a dia, para caminharmos em direção a uma sociedade melhor.

Palavras-Chave: *Inovação, academia-indústria, gabinetes de transferência de tecnologia académicos, conhecimento científico e tecnológico, spin-offs, investigadores*

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Abbreviations

GOTT - Government Office for Technology Transfer
TTO - Technology Transfer Office
EU - European Union
GDP - Gross Domestic Product
R&D - Research and Development
ICT - Information and Communication Technology
mRNA - Ribonucleic Acid messenger
SMEs - Small and Medium Enterprises
EU27 - 27 countries of the European Union
BES - Business enterprise
GOV - Government
HES - Higher Education
PNP - Private Non-Profit
SNA - System of National Account
EIS - European Innovation Scoreboard
CIS 2018 - Community Innovation Survey of 2018
P-BIO - Portugal's Biotechnology Industry Organization
IAPMEI - Institute of Support for Small and Medium Enterprises and Innovation
ESIF - European Structural and Investment Funds
MIT - Massachusetts Institute of Technology
INPI - National Institute of Intellectual Property (Instituto Nacional da Propriedade Industrial)
WIPO - World Intellectual Property Organisation
IP - Intellectual Property
IDF - Invention Disclosure Form
TRL - Technology Readiness Level
IPR - Intellectual Property Rights
PPP - Provisional Patent Application
EP - European Patent
EPO - European Patent Office
PCT - Patent Cooperation Treaty
ANI – National Innovation Agency (Agência Nacional de Inovação)
UPIN - University of Porto Innovation
UBINNOVATIVE - the Technology Transfer Office of the University of Beira Interior
UA Coopera - the Technology Transfer Office of the University of Aveiro
NOVA FCT – the Technology Transfer Office of NOVA School of Sciences and Technology
KVTT - Knowledge Valorisation and Technology Transfer
CNC - Center for Neuroscience and Cell Biology
UC - University of Coimbra
FEUP - Faculty of Engineering of the University of Porto
iup25K - the idea contest of the University of Porto
PCI - Pen Center for Innovation
OTL - Office of Technology Licensing
Oxford University Innovation (OUI)

Osage University Partners (OUP)
Entrepreneurs in Residence (EIR)

1. Introduction

The concern of transferring knowledge produced in the laboratories to the market is present in most economies of the world. The United States was the pioneer to introduce advances regarding the applicability of solutions raised by federal government-funded research through the implementation of the Bay Dole Act. This law allowed contractors (namely universities) to own, patent, and license knowledge and technologies raised from federal research funds. The Bay Dole Act was important not only to American institutions but also to around the world's universities.

The European countries were influenced by these improvements in the American innovation ecosystem and started to follow the United States' steps: the search for protecting from thirds what was developed in the academic institutions.

In Europe, the success of technology transfer can also be seen across the United Kingdom, where the transformation of knowledge into innovation is largely supported by the Government Office for Technology Transfer (GOTT) through the development of knowledge produced in academic institutions and the identification of possible solutions with the potential to reach the market.

A key element of any country innovation ecosystem is the academic technology transfer offices (TTOs) that are responsible for passing technologies and knowledge from the laboratory to the market within research institutions and universities.

In Portugal, TTOs' activity is less recognized and developed in comparison with United States and some European countries, as the United Kingdom. Therefore, the question here is what is missing in Portugal to advance the activity of these offices. Considering the culture, size, and financial resources of the country, is it even possible?

This study then tries to answer these and other questions related to the performance of the academic TTOs in Portugal in comparison with the American and British ones.

1.1 Innovation

1.1.1. Economic competitiveness in Europe

Economic competitiveness has been a key factor in improving innovation in European Union (EU) countries. In 2000, a meeting of the European Council including all the 27 Heads of State/Government of the member states of the EU created a Development Plan for Europe whose purpose was ‘’to become Europe by 2010 the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion’’ [1]. This action plan was entitled Lisbon Strategy.

However, the goal of the Lisbon Strategy was not achieved due to several factors, including the global economic crisis of 2008. The Lisbon Review 2010 (final report of the Lisbon Strategy) evaluated the performance of each one of the 27 member countries[1] (Table 1) in transforming Europe into the most competitive economy in the world and drew attention to many differences among the member countries performance in the eight assessed indicators: Information Society; Innovation and R&D; Liberalization; Network Industries; Financial Services; Enterprise Environment; Social Inclusion and Sustainable Development [2].

Table 1. Rankings and Scores of Competitiveness for the EU countries and comparison with the United States and the East Asia in 2010.

Economy	Rank 2010	Score
Sweden	1	5.83
Finland	2	5.72
Denmark	3	5.61
Netherlands	4	5.51
Luxembourg	5	5.43
Germany	6	5.39
Austria	7	5.39
France	8	5.22
United Kingdom	9	5.15
Belgium	10	5.15
Ireland	11	5
Estonia	12	4.96
Cyprus	13	4.83
Slovenia	14	4.79
Czech Republic	15	4.71
Portugal	16	4.7
Malta	17	4.58
Spain	18	4.53
Slovak Republic	19	4.45
Lithuania	20	4.39
Hungary	21	4.28
Latvia	22	4.21
Greece	23	4.18
Poland	24	4.07
Italy	25	4.03
Romania	26	3.96
Bulgaria	27	3.77
EU 27 Average	-	4.81
United States	-	5.27
East Asia	-	5.28

Source: World Economic Forum, 2010

[1] In 2010, the 27 member countries of the EU included the United Kingdom and excluded Croatia.

Table 1 shows the performance of each European member country in comparison with the United States and East Asia, in a score from 1.0 to 7.0 points. The European average stayed 0.46 points below the United States and 0.47 below East Asia. However, the TOP7 EU countries of the ranking, composed by Sweden, Finland, Denmark, Netherlands, Luxembourg, Germany, and Austria were above the average of these two country/regions, with the highest value being 5.83 points, represented by Sweden, the leader for two consecutive years. The UK presented also positive results of competitiveness, staying among the TOP10 countries with the best performance, in the 9ª position with a score of 5.15.

The Lisbon Strategy was succeeded by the Europe 2020 Strategy, also a 10-year approach (2010-2020), that aimed to continue the efforts started in 2000. During this period, the achievements were related to develop a knowledge-based economy, to improve sustainability, and to increase employment. The European Commission established five measurable targets for 2020: a) 75% of the population aged 20-64 should be employed; b) 3% of the gross domestic product (GDP) should be expended on Research and Development (R&D); c) 20% of the total consumption of energy should originate from renewable energies, 20% of the energetic efficiency should be higher, 20% of the greenhouse effect should decrease; d) less than 10% of early school leavers and at least 40% of younger people with a tertiary degree and e) 25% reduction in the number of people living below the national poverty line [3].
Despite the improvement in all the established targets, the main goal was not achieved: Europe still did not become the most competitive economy in the world. Recently, the European Commission published the New European Innovation Agenda which is focused on transforming Europe into the “Leading Innovation Region” through a financial access increase for start-ups, the stimulus for innovators to set up innovative ideas, and the investment in qualified human resources [4].

1.1.2 Definition of innovation

According to the Oslo Manual, an innovation is “a new or improved product or process (or a combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)” [5]. Innovation is also defined as ‘’the process of implementation of a new or significantly improved product (good or service), process, new marketing method, or new organizational method in business practices, workplace organization or external relations’’ by the Organization for Cooperation and Economics Development [6].
Innovation moves economies forward by creating the constant necessity to generate new knowledge through improved products, processes, or methods to face competition. Within a country’s economy, the major players in developing innovations are academic institutions and the industry. Academic institutions are responsible for discovering and developing the fundamental and applied knowledge that allows the creation of new products, processes, or methods, whereas the industry is responsible for bringing these products into the market or for implementing of these processes or marketing/organizational methods within their organizations. As such, a nation’s competitiveness, and consequently economic growth, depends largely on the capacity

of its academic and industry ecosystems to innovate and upgrade [7]. The competitiveness also varies within the sector of activity: some sectors are more innovative by nature, whereas others present more difficulties in developing innovations. Companies can be competitive by having a unique, more efficient, or differential product or service, attractive prices, or attending to clients' needs.

1.1.3 Characterization of innovative companies in Europe

The investment in R&D constitutes a good measure of a company's innovation level. In Europe, in 2019 and 2020, the "Automobiles & Other Transports" was the sector presenting the higher amount of investment in R&D (€bn), whereas the "Health Industries" presented the higher one-year growth rate in 2020 with 10.3% (Fig. 1). The investment in R&D contrasts in some sectors among the countries/regions analysed in Fig.1. For example, the US presents a dramatic difference in the value of these investments in the sectors "Automobiles & Other Transports," "Health Industries," and "Health and Information and Communication Technology (ICT) Services and Producers" [8].

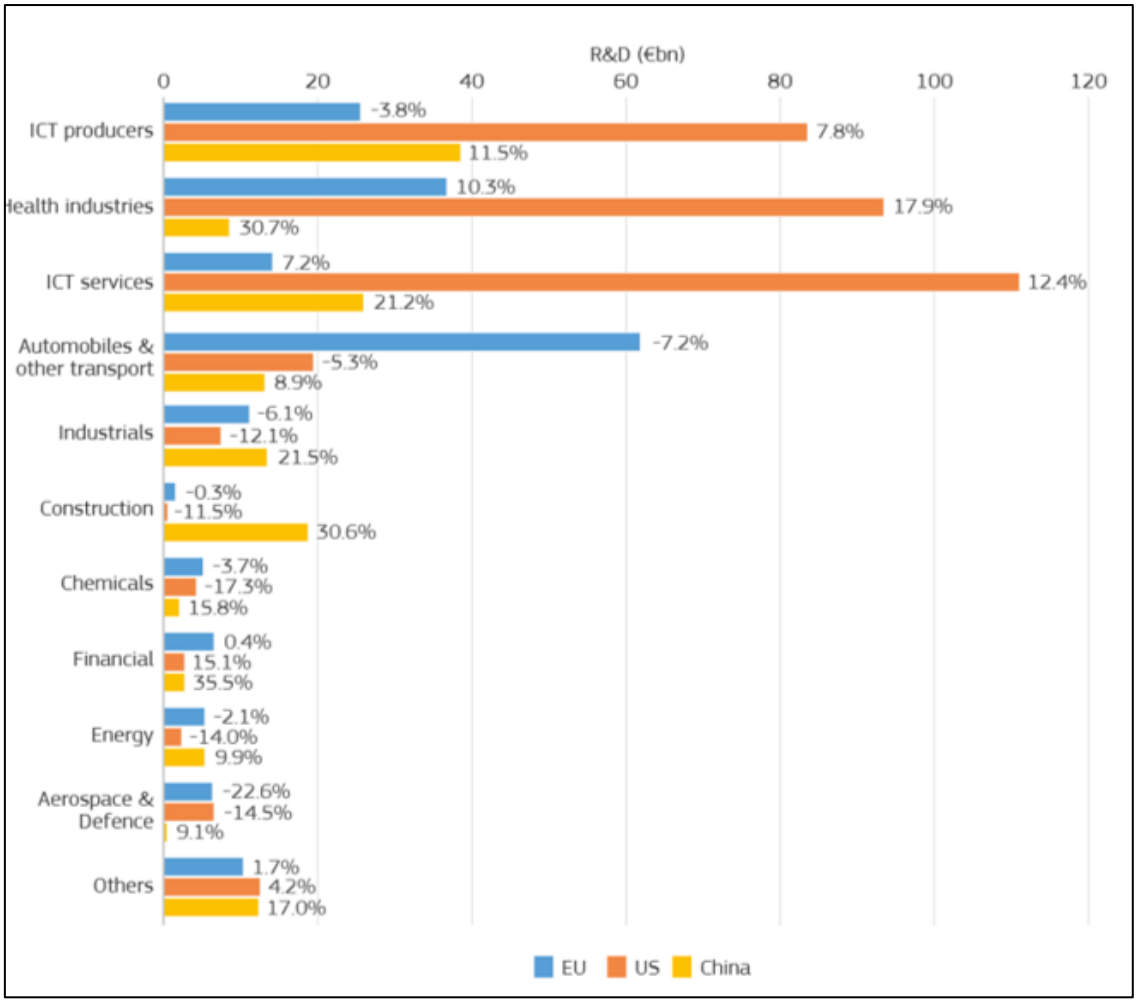

Figure 1 *– R&D investment represented in €bn and the one-year growth rate represented in percentage in 2020 by sector and region/country. R&D investment growth rates have been computed for 399 EU, 776 US, and 597 Chinese companies with data*

available for the years 2019 and 2020. Source: The 2021 EU Industrial R&D Investment Scoreboard, European Commission. JRC/DG RTD.

The Covid-19 crisis negatively affected many industrial sectors, directly impacting the national economies and the global one. However, this occurrence also positively impacted some industries that saw their market grow due to the pandemic such as the "Health Industries", specifically in the Biotechnology sector [9]. With the emergence of Covid-19, the urgent development of therapies and vaccines became essential for minimizing the disease effects and the virus dissemination. Many pharmaceutical companies needed to accelerate the production of these products to deliver a fast solution to the market on behalf of public health, pushing the economy in this sector. Gilead Sciences, Pfizer, Moderna, and BioNTech were examples of companies that had their stock prices increased [10].

Also, the pandemic situation was a particularly good example of how the national economies are connected and dependent on each other. A vaccine based on the Ribonucleic Acid messenger (mRNA) technology produced by Moderna, an American biotechnology company, was used by European countries to immunize their population. The same mechanism of action was used by other United States company, such as Pfizer in partnership with the German company BioNTech. These international collaborations were fundamental for bringing solutions to SARS-CoV-2 and tackling this health emergency.

In addition, the updates in the biopharma industries were not only the results of investors and specialists in the area but also of the general population. With the help of modern social media, people were informed and many of them consciously realized the importance of therapies and vaccines, to the point that they started to discuss biotechnology in their day-to-day lives. At the same time, this engagement also brought negative reflexes, the discussion about a complex theme by people who do not have advanced knowledge set precedents for the dissemination of incorrect information. However, the Covid-19 pandemic still has contributed to the knowledge, visibility, and promotion of the sector, nationally and internationally.

For innovation analysis purposes, it is also important to characterize the type of companies existing in Europe: Small and Medium Enterprises (SMEs) "represent 99% of all businesses in the EU'' [11]. To be considered an SME, the company needs to meet requirements regarding ceilings in the staff headcount and the turnover volume or total balance sheet (Table 2).

Table 2. Definition of a Small and Medium Enterprise (SME) according to the European Commission.

Category	Staff Headcount (number of persons expressed in annual work units)	Turnover volume	or Total balance sheet
Medium	<250	≤€ 50 million	≤€ 43 million
Small	<50	≤€ 10 million	≤€ 10 million
Micro	<10	≤€ 2 million	≤€ 2 million

Source: Definition of a Small and Medium Enterprise (SME) (European Commission, [12])

In 2022, the micro-sized enterprises represented ~93% of the total number of SMEs in the 27 countries of the European Union (EU27), followed by the small- and medium-sized enterprises), as observed in Fig. 2.

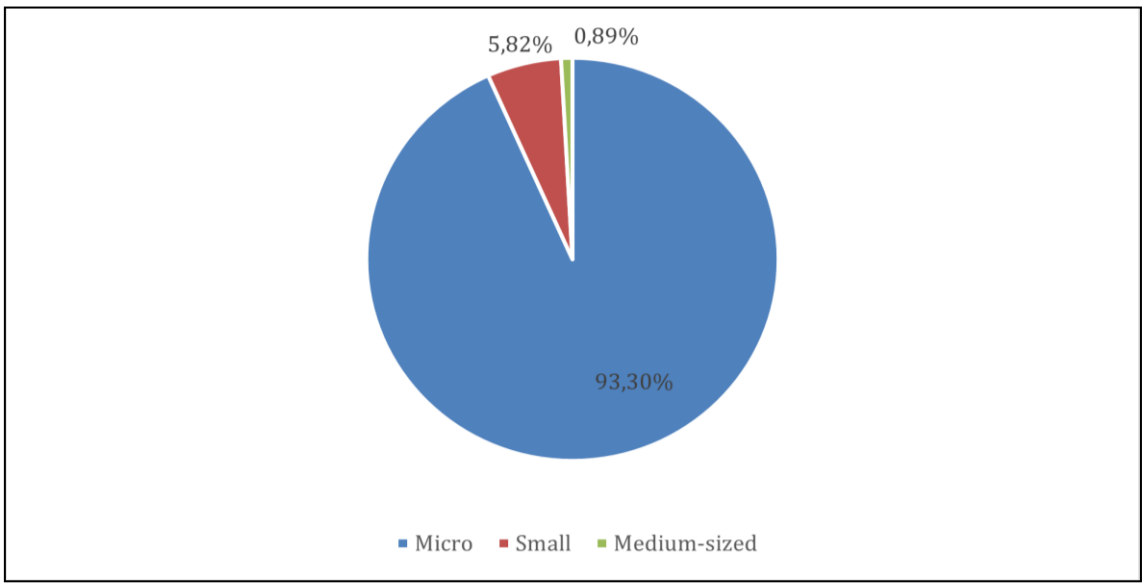

***Figure 2** – Characterization of the small and medium-sized enterprises (SMEs) in the 27 countries of the European Union in 2022. Source: (Statista, 2022). Accessed on 2023-07-2023.*

1.2 Characterization of innovation in EU countries vs Portugal

R&D expenditure is also a key indicator to measure the level of innovation of a country. Fig. 3 shows the gross domestic expenditure (GDP) on R&D for each member country of the EU27 in 2021.

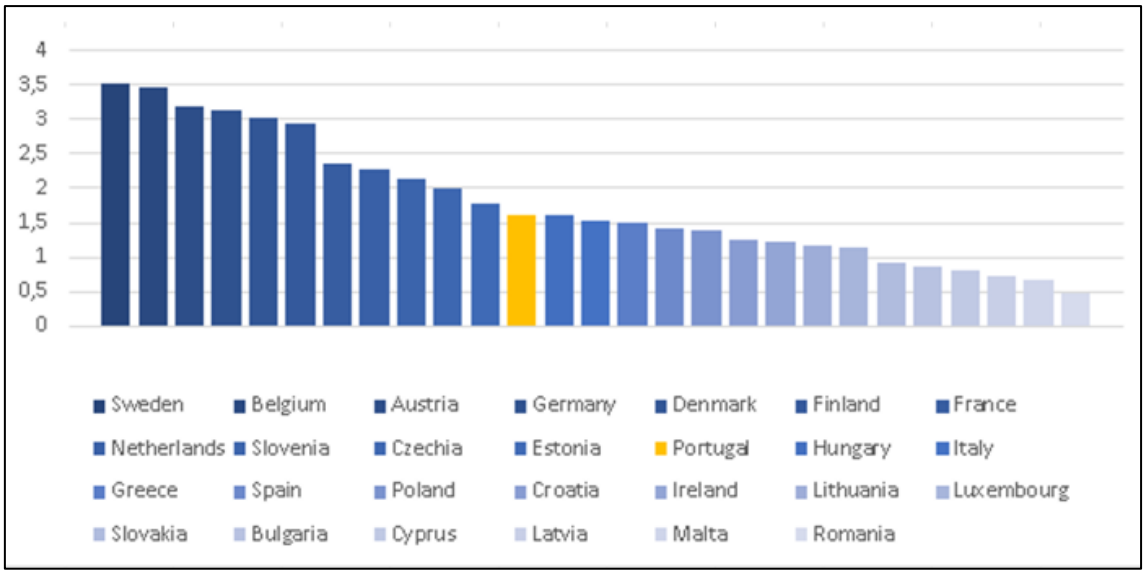

Figure 3 *- The gross domestic expenditure on Research and Development (R&D), in percentage, in 2021 by the EU27 countries [13].*

R&D statistics are compiled for four institutional sectors of performance: business enterprise (BES); government (GOV); higher education (HES) and private non-profit (PNP). These sectors are defined based on the System of National Account (SNA), with the difference that higher education has been established as a separate sector because of its policy relevance and households have, by convention, been merged with the private non-profit (PNP) sector. Source of data: (Eurostat, 2022).

The European R&D expenditure in 2022, on average, was 1.78% of the GDP. Sweden was the country with the higher expenditure of 3.53% of the GDP. Portugal is represented in yellow in the 12ª position with 1.62% of the GDP expended in R&D, below the European average but in the first half on the distribution of EU27. Table 3 presents Portugal's expenses in R&D from 2015 to 2021.

Table 3. Portugal's Expenses in R&D from 2015 to 2021.

Years	Expenditure in research and development activities as a % of GDP
2015	1.24%
2016	1.28%
2017	1.32%
2018	1.35%
2019	1.40%
2020	1.61%
2021	1.68%

Sources: INE, DGEEC/ME-MCTES, PORDATA. Updated in 2023-06-15. [14]

These data show the efforts that Portugal has done to improve innovation, with a consistent growth in the R&D expenditure over the last 7 years. However, this evolution was not enough to put the nation among the most innovative countries in Europe. In 2022, Portugal kept its innovation performance as a "Moderate Innovator" [15] categorized by the European Innovation Scoreboard (EIS), as it was categorized in 2021 [16].

The innovation indicators used by the EIS 2021 were taken from the Community Innovation Survey of 2018 (CIS 2018) [17], a document that analyses the innovative behaviour of companies and provides criteria to characterize them. One of these innovation indicators where Portugal presented less performance was the ''Innovation Profile'', which presented seven types of profiles in the EIS (table 4).

Table 4. Characterization of the innovation indicator “Innovation Profile.”

Innovation Profiles	Definitions
a) In-house product innovators with market novelties	All companies that introduced a product innovation that was developed by the company and that was not previously offered by competitors.
b) In-house product innovators without market novelties	All companies that introduced a product innovation that was developed by the company but that is only new to the company itself.
c) In-house business process innovators	All companies that introduced a business process innovation that was developed by the company.
d) Innovators that do not develop innovations themselves	All companies that introduced an innovation of any kind but did not develop it themselves (companies without significant own innovation capabilities).
e) Innovation active non-innovators	All companies that did not introduce any innovation but that either had ongoing or abandoned innovation activities.
f) Non-innovators with the potential to innovate	All companies that did not introduce any innovation, and which had no ongoing or abandoned innovation activities but that did consider innovation.
g) Non-innovators without a disposition to innovate	All other companies, those that neither introduced an innovation nor had any ongoing or abandoned innovation activities nor considered to innovate.

Source: European Innovation Scoreboard, (Hollanders e Es-Sadki, Nordine, 2021)

In comparison with the EU, the Portuguese companies are below average on the indicators c) In-house business process innovators and d) Innovators that do not develop innovations themselves with 4.7% and 4.1% less, respectively. These results point to a necessity of national companies to potentiate efforts in introducing novelty in their organization through innovative processes and by developing themselves more innovations.

1.2.1 Characterization of Small and Medium-Sized Enterprises in Portugal

In Portugal, the characterization of SMEs follows the same pattern observed for the EU. In 2021, they represented 99.9% of the total companies of the country, where 96% were micro-sized, followed by small-sized (3.3%), and medium-sized enterprises (0,6%) [18]. Nevertheless, the number of SMEs related to the Human Health and Social Work Activities has been rising uninterruptedly since 2011. In 2020, they already represented 8.06% of the total SMEs in Portugal [19].

1.2.2 Biotechnology Sector

In 2021, Portugal's Biotechnology Industry Organization (P-BIO) published a survey started in 2016 with 98 Portuguese biotech companies showing that the Human Health area represents 36% of their main target markets [20].

In 2022, the website Labiotech EU that brings news about the biotechnology industry in Europe, updated an article (originally published in 2019) about the 15 Portuguese Biotech Companies driving innovation in this sector. The companies are associated with distinct areas such as Cancer, Diagnostic Tests, Cell therapies, Antibiotic Resistance, Immunology, Marine Microbiology, Artificial Intelligence, Synthetic Biologic, Machine Learning, and Agriculture and Food [21]. Six of them (nearly half) were born in academic institutions, being identified as spin-offs (a concept that will be discussed further ahead).

1.2.3 Support for Small- and Medium-Sized Enterprises in Portugal

The creation and growth of SMEs in Portugal are in line with the objectives of Europe 2020 in contributing to qualified employment, developing innovation, and promoting entrepreneurship. To achieve these goals, Portugal and the European Commission are working through the national entities to support national SMEs and, in this way, to promote Portugal's progress.

The Institute of Support for Small and Medium Enterprises and Innovation (IAPMEI) is one institution that promotes incentives for national and international entrepreneurs to create and develop their businesses, including support initiatives for incubators, financial subsidies, tax benefits, and access to funds for risk capital, business angels, and credit lines. The IAPMEI cooperates also as a financier of public risk capital funds in Portugal. Risk capital is one financial resource that SMEs can search to raise money to develop their companies. Normally the SMEs that apply to receive this financial resource are new-born companies with a high potential of commercial revenue, but also with a considerable risk of failure. For SMEs, the accessibility to risk capital is beneficial because the capital-associated risk is totally on the investor side, the SME does not need to reimburse the investment to the Venture Capitalist independently of the results achieved, and the Venture Capitalist also provides useful insights into the SME business. The SMEs may also find funding through business angels, anonymous individuals with a high financial capacity who invest their capital and expertise in companies on the initial step of development. Another entity responsible for supporting the economic activity of Portugal is Compete 2020, created for improving competitivity and internalization of Portugal through government initiatives at a financial level.

Within these institutions, there are also initiatives for complementing the economic and social development of the nation. Portugal 2020 is an agreement that facilitates access to capital through a set of national public funding programs targeting the different country regions, supported by the five European Structural and Investment Funds (ESIF), whose objectives are ‘’to invest in job creation and a sustainable and healthy European economy and environment’’[22].

1.3 Academic institutions as drivers of innovation

As explored in section *1.1 Definition of innovation*, the constant generation of new knowledge is essential to foster a country’s economic growth. As privileged centres for this generation, academic institutions position themselves as pillars to the advent of a knowledge-driven economy. With a highly competent teaching staff, appropriate infrastructure, cutting-edge equipment, and easy access to the community, they produce high-quality research, training, and education. However, society will only benefit from the generation of this qualified knowledge when transformed into innovation. Companies are one of the main agents responsible for materializing innovative ideas, while academic institutions are responsible for generating knowledge. To connect these two players of innovation, technology transfer comes into the picture.

Today, knowledge production is particularly important, but not enough to raise awareness about the great responsibility of the TTOs. The creation of partnerships between academic institutions and companies can facilitate the materialization of the knowledge produced, where the exchange of expertise is favourable to learning new ways of transferring knowledge, the possibility of access to alternative available resources and technologies, and access to international markets that would not otherwise be possible.

A study from 2021 showed that, among the world's most innovative universities of the world, the TOP6 were based in the United States, namely Stanford University, Massachusetts Institute of Technology (MIT), Harvard University, University of Pennsylvania, University of Washington, and University of Texas System [23]. All these institutions already have many years of creation that contributed to their experience in developing solutions that reach the market. However, for transferring knowledge, not only does experience count, but also high-quality research is essential. According to Al-Youbi et al. [23], the United States continues to invest in research, and, because of that, the number of academic discoveries should continue to increase.

Following the TOP6, two European universities were on the ranking as most innovative universities of the world, the KU Leuven Belgium in the 7ª position and the Imperial College London in 8ª position [24]. The research performed in these universities is also a contributor to the country’s development [24].

Therefore, producing innovation is a concern for all competitive economies, and so, a concern for many universities around the world. But it is also important to spread the importance of produce innovation in countries that are emerging in technology transfer, such as Portugal. Despite an increase in innovation, our country can still benefit from international experience on applying knowledge and thus collaborating to produce innovation.

2. The Applicability of Knowledge

2.1 Technology Transfer

2.1.1 Definition of Technology and Technology Transfer

The creation of innovation usually involves distinct players of society such as academic institutions, government bodies, companies, and/or financial institutions. This process is called technology transfer. Before the discussion of the definitions of technology transfer, it makes sense to clarify what is the object to be transferred. What is a technology? According to the Britannica dictionary, technology is ‘’the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment’’ [25]. Technology Transfer has distinct definitions: Elisabet del Valle defined it as the process of creating value from knowledge, making it applicable and available for economic or social use, and transforming it into new business services or processes [26]. It can be said that technology transfer is the process of developing practical applications from the research results or also the process of scientific and technological knowledge transfer from one organization to another to grasp and explore research results in favour of science, economy, and social development. Here, it is presented the definitions of technology transfer, described in the Cambridge dictionary. Three of them were chosen since were considered more applicable to the scope of this dissertation (Table 5).

Table 5. Definitions of Technology Transfer.

Definition 1	Definition 2	Definition 3
(The study and knowledge of) the practical, especially industrial, use of scientific discoveries.	The use of scientific knowledge or processes in business, industry, manufacturing, etc.	The methods for using scientific discoveries for practical purposes, especially in industry.

Source: (Cambridge Advanced Learner’s Dictionary & Thesaurus [27]*). Accessed in 2023-07-08.*

2.1.2 The role of the universities

The valorisation of technologies became recognized through the Bay-Dole Act [28]. The introduction of this law allowed entities such as small businesses and non-profit organizations (e.g., universities), to hold ownership of the technologies they developed using government funds (United States Patents Trademark Office). In this way, academic institutions began to transform the knowledge produced on their facilities into a practical utility with a commercial potential. This transformation assured them proper merit, through visibility and prestige, and an increase in competitivity between them, leading to a bigger effort to produce better innovations and, consequently, to have a bigger socio-economic impact. The Bay-Dole Act changed the technology transfer in the United States and awakened other economies to the importance of knowledge industrialization, but it was not the first law. According to the United States Patent Trademark Office (USPTO), the Stevenson-Wydler Technology Innovation Act of 1980 (Pub. L. 96–480) (94 Stat.

2311) [29] was the first major U.S. technology transfer law, approved on October 21, 1980 (two months earlier to the Bay Dole Act), and it was responsible for the introduction of the technology transfer offices (TTOs) as we know them today.

In Portugal, the initiative of creating Technology Transfer Offices (TTOs) occurred in 2001, by the National Institute of Intellectual Property (Instituto Nacional da Propriedade Industrial; INPI), to promote innovation and dissemination of Intellectual Property knowledge to citizens.

2.1.3 Academic Technology Transfer Offices

The role of an academic TTO is to support the transfer of technologies with commercial potential developed inside the R&D institutions and universities to the market. According to the World Intellectual Property Organisation (WIPO), an invention is explained as a ‘’new solution for a specific technical problem of any technological field’’ [30]. To do that, TTOs provide services mainly related to Intellectual Property (IP) management, establishment of e academic-industry collaborations, and valorization of IP through selling or licensing to existing companies or to new ones created for this purpose (spin-offs).

Fig. 4 illustrates, in detail, the distinct stages that a technology must go through and what are the activities conducted in each of them, so that they can be transferred to the industry.

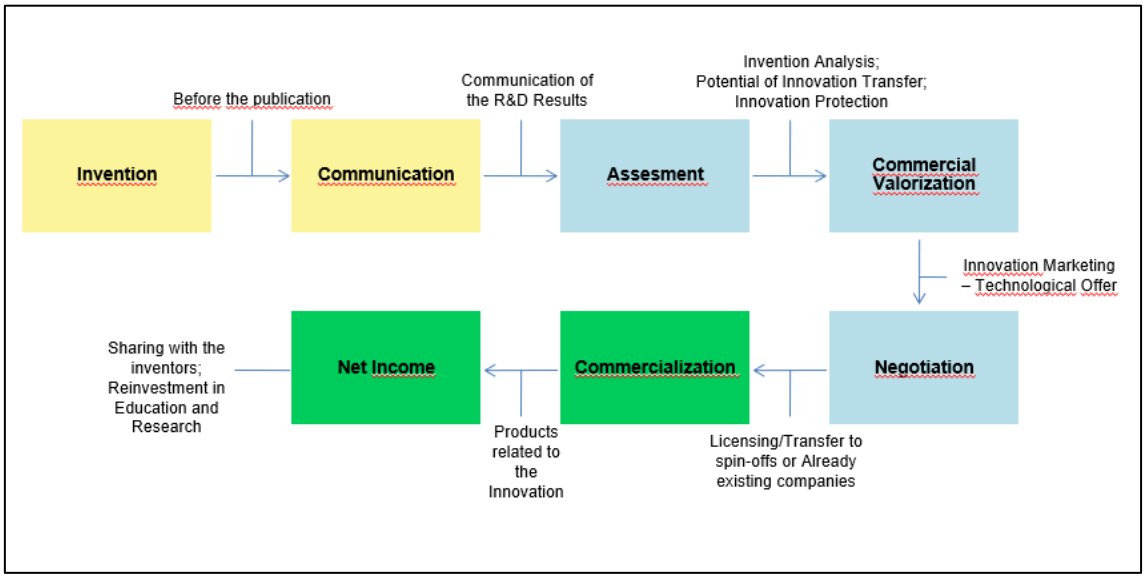

Figure 4 *- The seven steps of the Technology Transfer. (Adapted from UC Business, [s.d]). Accessed on 2023-06-16.*

The fig. above exemplifies the seven steps of Technology Transfer. The two first steps in yellow represent the stage focused on the inventors; the following three steps in grey symbolize the relationship with external partners, and the last two in green are related to the industry phase.

The Inventors stage covers the discovery of an invention and its communication to the TTO. In this step, the involvement with researchers is strong, therefore, it should be a trusty relationship between both parties. Normally, this process happens from the initiative of the researchers. For the office to assess the innovative potential of that

technology, researchers must complete a document describing the entire technology, the so-called Invention Disclosure Form (IDF). It is a document describing all the information about the invention that will be used as a base to evaluate the technology and to submit an IP application, if applicable, by the TTO. Each university has its model of IDF, as well as the name of the document varies consonant with the institution, but all of them request similar information. It should contain: the personal information of all researchers involved; an abstract explaining shortly, but with a wealth of detail the technology; the technological domain, which is the market necessities that the technology will supply; the development stage of the technology; predicted disclosures, for example if there is an expectation to publish the technology; commercial advantages; competitors' limitations and signatures of all the researchers involved.

Using the IDF, the TTO should analyze the research results and evaluate, for example, if the technology has the potential to be commercialized. For that, it is necessary to classify the technology according to its maturity level. This level will define the development stage of the technology, and, consequently, the amount of development needed to ingress in the market. This type of measure is called Technology Readiness Level (TRL), as demonstrated in Fig. 5.

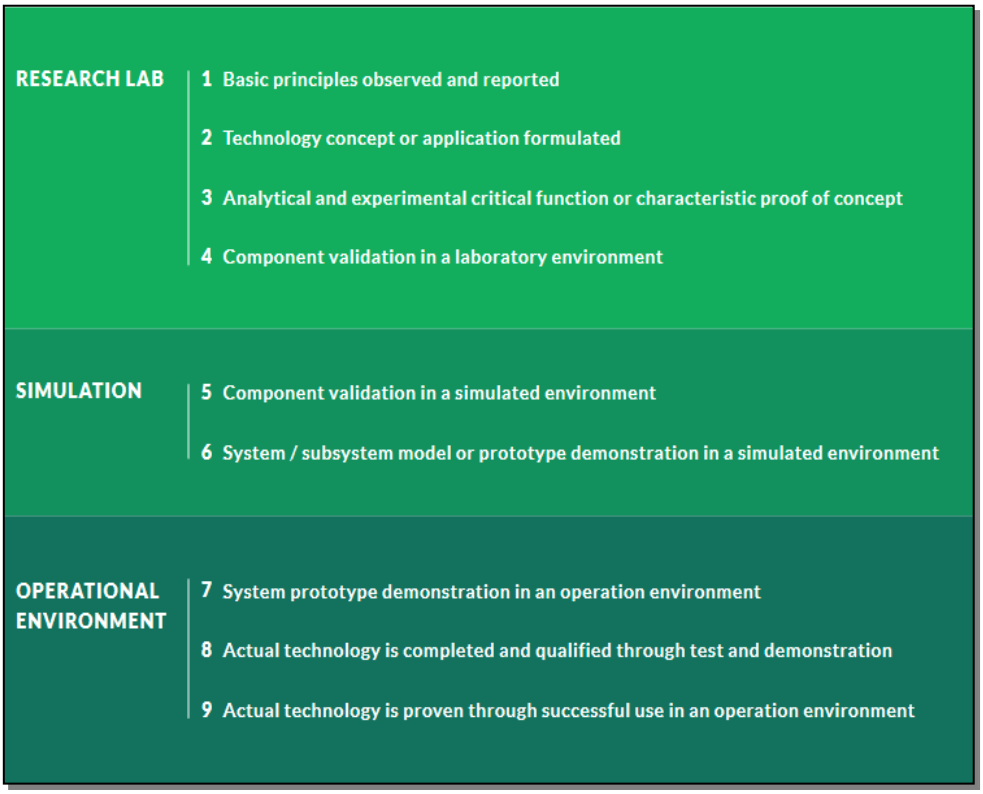

Figure 5 *- Technology Readiness Level and its meanings. TRL 1 constitutes the lowest level of the scale and TLR9 constitutes the highest level of the scale. Source: (NOVA Impact Office, [31]).*

The lower the TRL, the less mature the technology is, and the more research will be needed to develop it. For a technology to be considered for IP protection, the ideal is being at least in TRL 4, a phase that normally represents the technology proof of concept [32] .

In parallel to the commercialization potential, the TTO will verify if the technology follows the patentability requirements to delineate and proceed with an IP protection strategy. These assessments initiate the Partners stage. The second step of this stage refers to commercial valorization, whereby the technology will be offered to interested partners that could transfer it to the market. This offer is performed within the adequate technological sector and can be done through direct contact with companies, technology transfer events, technology match platforms, and funding call opportunities originated by the industry. If a partner is interested in the invention, negotiation step initiates. In this phase, an exploration license can be agreed with an already established company or through the creation of a spin-off. When the technology is licensed, it can be commercialized, and the net income of this licensing is usually shared by the academy and the researchers. From this economic benefit, the university can invest further in R&D activities.

2.1.4 Protecting a technology through patenting

It was mentioned before that IP protection is one of the first steps of technology transfer. Usually, technologies developed in academic institutions are protected by patents or (much more rarely) by trade secrets. In this dissertation, only the protection by patents will be detailed.

Human creations of the mind are under the guardianship of Intellectual Property Rights. They assure that those who created or developed something have the right to be considered owners of their production. Intellectual Property Rights are categorized into Copyrights, protecting everything originating from the human brain within the "literary, scientific and artistic domain'' [33] - books, musical compositions, photography, paints, and sculptures are examples of creations that can be protected by copyrights - and Industrial Property Rights, protecting trademarks, designs, secrets, inventions, and others produced by the humankind [34] . The trademarks are used for ''differentiating the products or services of a company or organization'' [35], the designs for ''protecting the apparent characteristics of a product'' [36], the secrets for protecting confidential information, and the patents for protecting inventions, including technologies developed in a laboratorial setting.

2.1.4.1 Patents and Utility Models

A patent, according to WIPO is “an exclusive right granted for an invention, which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem.''

Therefore, having a technology protected by patent means that those who identified a solution inside the academy have the safeness of exploring and developing it without the influence of thirds that do not possess the authorization for it. So, the process of protecting an invention is essential to initiate a successful technology transfer. In this first step, the patent application must come from the person or people that developed the invention, in the academic context involves a researcher or a group of researchers that develop a technology with commercial potential in the laboratory.

For a technology to be considered an invention, it needs to present three mandatory requirements:

1. Novelty - the technology cannot be part of the state of the art, meaning, any information about it cannot have been disclosed, either in publications, papers, scientific meetings, or other meanings that are under public domain.

2. Inventiveness - technology cannot be the result of an obvious conclusion.

3. Industrial applicability – it can be made or used in some kind of industry.

In alternative to patents, creations can be protected through utility models. They differ from patents in respect of the inventive activity (1), scope (2), and duration (3).

1) In utility models, an invention must only provide a technical or practical advantage for its production or its use, whereas for patents, there is inventiveness when the invention does not arise from an obvious conclusion of the state of the art.

2) While the patent encompasses all the fields of knowledge, the utility models do not cover anything related to the ‘’biological material, substances or chemical process and pharmaceuticals, food products or processes for the preparation, obtention or confection of these products’’ [37].

3) The patents have a period of 20 years of protection for their owners to explore the invention without competition, whereas utility models have a time limit of 10 years.

In Portugal, the patenting process is performed by the INPI, responsible for assuring and informing about Industrial Property Rights and for providing training on the IP subject. A patent or a utility model can be applied through the INPI website. There, the applicant(s)—the person(s) or entity(ies) that is(are) entitled to be the owner(s) of the patent or utility model—find (s) all the necessary information about the process of each application’s type. The application process for patents can be performed through distinct routes (Fig. 6).

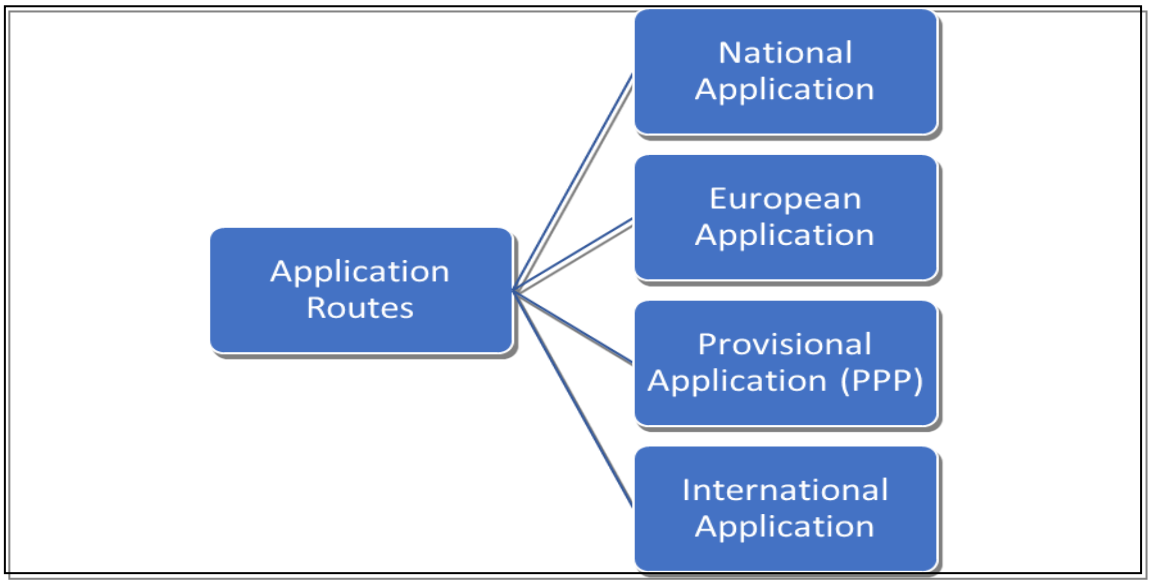

Figure 6 *- Types of Applications for Patents.* Source: *INPI – How to present a Patent Submission Application [38].*

Patent applications can occur through four distinct routes: the National Patent Application; the European Patent Application; the Provisional Patent Application (PPP) and the International Patent Application. The routes for the application will depend on the applicant(s).

2.1.4.2 National Application

When the applicant only wants to protect the invention in one single country, the better option is to go forward with a national application, through the office of the country of interest. Within this type of request, the applicant can extend the protection to other countries until 12 months after the application date, called the priority date. The priority date is so-called because in case they want to submit patent applications for the same invention in other countries, they benefit from the date of the first request, excluding the necessity of filling other applications in different periods, and assuring that the technology is part of the state of the art in the regions of the following requests since the first submission [39].

2.1.4.3 European Application

When the applicant wants to protect the invention in more than one country in Europe, it can request a European Patent (EP) through the INPI website or directly through the European Patent Office (EPO)[3], responsible for analysing, granting, and searching European Patents. The EP can be applied through the national offices when it is the first application for that technology and through the EPO website, when the inventors want to use their national priority date to extend the protection for other countries, or when the person or group is resident out of their country of origin. In this option, the countries where the patent applications are submitted need to validate the request in the national offices of the countries of interest, otherwise, it is not granted. The EP gives the applicant the right to submit a patent application in one or more countries that are part of the European Patent Organization[2].

2.1.4.4 Provisional Application

Instead of filling a patent application, the applicant has the option to submit a Provisional Patent Application (PPP), a simplified document used mostly when the inventors do not have all the documents needed to request a definitive patent, but also as strategy protection, once it is cheaper than the definitive application, and gives the applicant 12 months to raise money for the next steps of submission and patent maintenance. The

[2] The European Patent Office (EPO) constitute the European Patents Organization, responsible for granting patents, and the Administration Council, which manages the activities of the EPO. The members of the European Patents Organization are all the member states of the EPO (the contracting states) and countries with an extension protection for them (the extension and validation states) [40].

PPP could also be an alternative in cases that the patent is threatened by third parties, accelerating the protection request.

2.1.4.5 International Application

Besides the previous three types of applications, there is still a possibility of submitting a patent file in many countries of the world. This can be done by two routes: 1) after a national submission, there are 12 months during which is possible to request protection for technology in other countries and 2) through the Patent Cooperation Treaty (PCT)[3]. Both options are described in Fig 7.

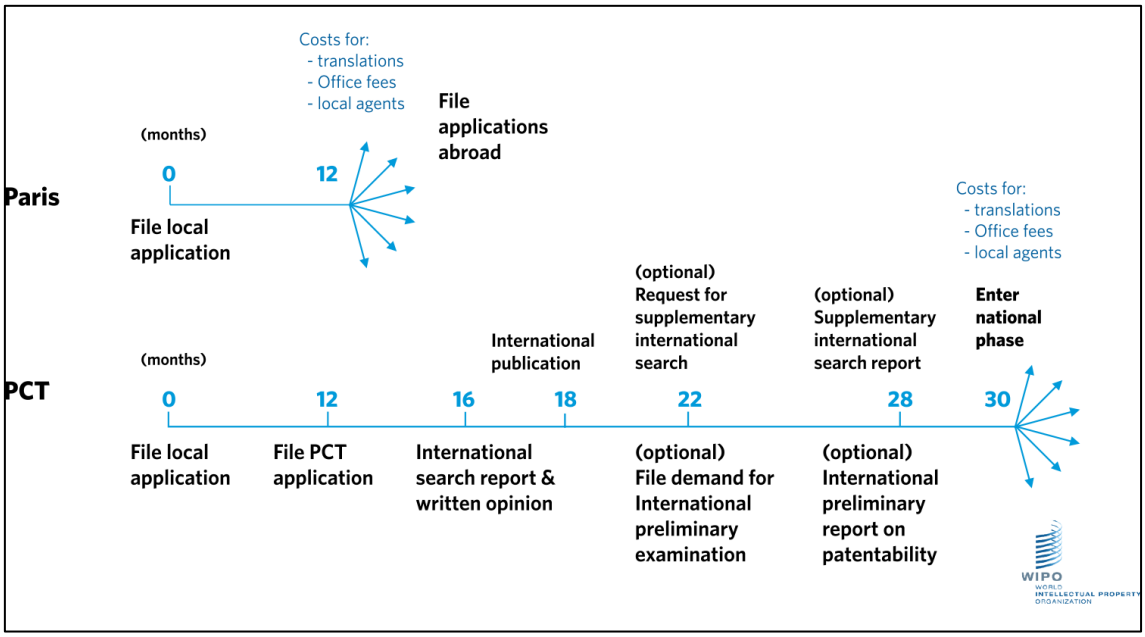

Figure 7 *- Comparison between the route of the Paris Union Convention[4] and the route of the Patent Cooperation Treaty. Source: World Intellectual Property Organization, PCT – The International Patent System, July/2022 [41].*

The route 1) is submitted following the National Patent Application route, whereby the applicants have 12 months to decide if they want to go forward with an International Application. If so, they will proceed with applications in each country they decided, with expenses and translations paid individually. While in route 2) the International Application is submitted just one time, in one language, until after 12 months from the first application date, whereby the applicant can decide in which countries that are part of the PCT they want to protect their technology. In this route, the applicants have 30 months to prepare themselves for the national individual taxes. During this period, the applicants benefit from the WIPO feedback regarding the patentability potential of the invention, so that they can make an informed decision in going forward with its protection in the interested countries [41].

[3] The Patent Cooperation Treaty (PCT) is a route of international patent application. Through this route, the inventors can apply for a patent protection in many member countries covered by PCT by one single application.
[4] The Paris Convention was an international agreement signed in Paris that established the protection of Intellectual Property of the member countries outside of its territory. Today, there are 176 member countries covered by this agreement.

2.1.4.6 Costs of Patent Application

As seen before, the types of patent applications vary consonant if it is done nationally or internationally. In the same way, the costs will change depending on the location in the world. A survey conducted by the European Commission in 2011 that counted the participation of the 40 Patent Offices worldwide assessed the costs of patent applications in each location (Table 6).

Table 6. Patent Costs Structure 2011.

Patent Costs Structure 2011 (€)				
Patent Office	**Administrative**	**Maintenance**	**Process**	**Translation**
Austria	660	12300	12199	1718
Belgium	350	4340	12331	1798
Bulgaria	411	6547	4963	1991
Croatia	812	5207	7519	2020
Cyprus	546	4263	9889	2039
Czech Republic	370	6870	8047	1942
Denmark	2179	6807	15143	2256
Estonia	320	5362	7703	2142
Finland	1020	8635	13332	2448
France	712	5608	12414	1798
Germany	550	13170	11443	1718
Greece	590	7325	10188	2039
Hungary	725	8311	6502	2108
Ireland	550	4628	12159	0
Italy	1935	6620	11294	1798
Latvia	333	5201	7320	2020
Lithuania	220	4407	6679	2020
Luxembourg	270	2842	13318	1718
Malta	196	2400	8207	0
Netherlands	914	11040	12224	2110
Poland	182	3552	6507	1991
Portugal	200	5475	9224	2020
Romania	690	5920	5599	1991
Slovakia	402	5157	7473	1983
Slovenia	460	5143	9193	2129
Spain	737	4903	10368	1734
Sweden	925	6193	14361	2260
UK	323	5244	11827	0
Iceland	471	2578	12179	2020
Norway	1206	7906	16926	2020
Switzerland	689	3499	17161	0
Brazil	611	11288	9298	2019
Canada	1090	3489	13248	0
China	379	9162	5736	0
India	407	2959	3423	0
Israel	244	6950	11656	0
Japan	2124	13971	14236	0
Russia	907	1716	6242	2020
South Korea	881	9233	8153	0
USA	3453	5446	10573	0

Source: Patent costs and impact on innovation (European Commission, 2014, [42)

2.1.4.7 National Patent Applications in Portugal

A lot is said about the importance of patenting and the efforts that academic institutions and companies have done to produce an elevated level of knowledge. In Portugal, in 2022, there was an improvement of 7,6% in the national patent applications in comparison with 2021 [43]. Within the fields with most Portuguese applications are Computer Technology, leading the ranking, followed by Medical (2º position) and Pharmaceutical Technologies (3º position).

By analyzing the number of patent applications in Portugal from 2009-2019, overall, they have increasing over the years. This impact is more realized in areas with a higher commercial potential, huge necessities for supply, and high technical-scientific knowledge. One example would be the pharmaceutical sector (Fig. 8).

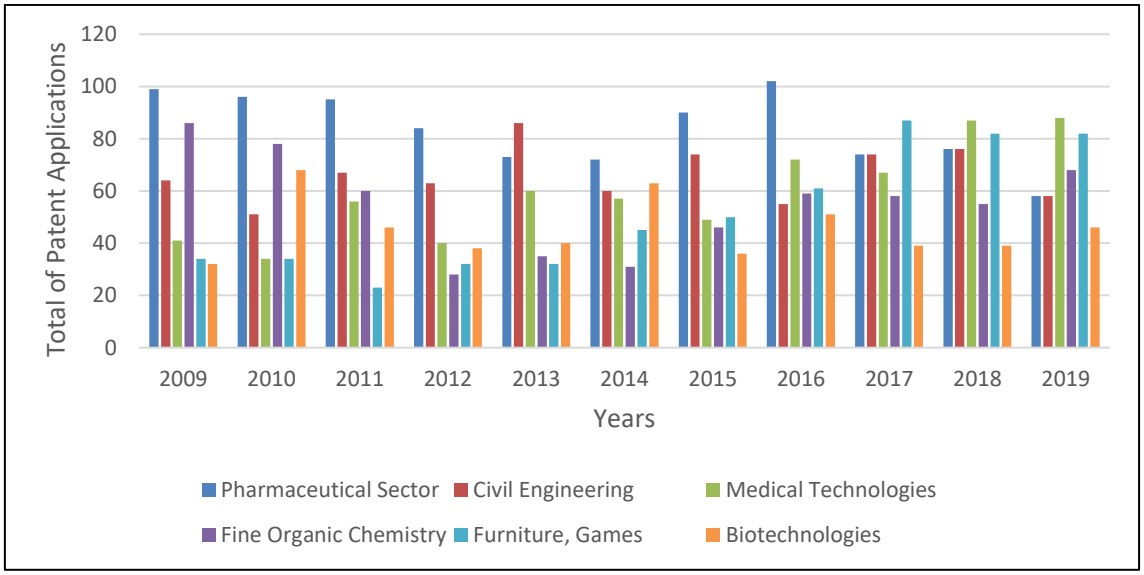

***Figure 8** – TOP6 sectors of the patent applications in Portugal from 2009 to 2019. Source: Barómetro Inventa – Patents Made in Portugal|Statistics and Indicators – 2001 to 2020 [44].*

The pharmaceutical sector presents consistently the higher number of national patent applications from 2009 to 2019, except in the year 2013, with a total of 1126 patent applications in these 10 years. Of noting, three from the six TOP sectors belong to the life sciences field (Biotechnologies, Medical Technologies, and Pharmaceutical sector).

2.1.5 Valorisation

After the patent application submission, it starts the commercialization stage, in which the inventors and applicants have three routes to follow: forming partnerships with companies within the invention sector to further develop it; exploring the invention through the establishment of a spin-off or licensing or selling the invention to already existed third parties.

2.1.5.1 Licensing Agreements

Fostering industry innovation through patents is always beneficial: for society, since the invention will provide some solution to an existing need; and for the patent owner(s),

since they have the right of being compensated for their effort. As inventors, the researcher(s) can explore the invention and receive recognition monetarily. The responsible for conceding the license is the research institution (licensor) and those to whom the license rights are granted are companies (licensees). The first owns the scientific knowledge and expertise that conferred to it the property rights of the technology. Whereas the second has the necessary resources (materials, laboratories, equipment) and the practical expertise of the sector, to further develop the technology according to the market needs and put it in the market, obtaining profit from it. A license is, therefore, understood as an authorization of exploration and development of an invention provided by the owners of it, whereby they keep the Intellectual Property Rights (IPR) ownership. Among the diverse types of commercialization strategies of a technology, licensing is the most used and sustainable way of doing it [45]. The relationship licensor-licensee is described and agreed upon in the form of licensing contracts, covered by the Code of Industrial Property, Article 31°, in Portugal.

The conditions of a license agreement vary consonant with the needs and objectives of the involved parties. A license can be granted:

a) In a total or partial form [33] – regarding the total or partial concession of the Intellectual Property Rights.

b) Against payment or free of charge [33] - if the use/exploration of the license will be unpaid or it will have costs.

c) For all the territories or for specific ones [33] – if the license is valid for all or only some (and which) of the countries where the patent application was submitted.

d) For the time of its duration or a brief period [33] – for a patent, the licensor can choose if the agreement will last until its expiration date (20 years) or if will have a short duration.

e) Of an exclusive or non-exclusive way – in case the licensee is the only one who will usufruct of the benefits of exploring the technology, it is an exclusive license, in case that exists a possibility for another licensor to participate in that technology, we are in front of a non-exclusive license.

f) With the possibility of a sublicenses [46] – if it is in the interest of the licensor, it may allow the direct licensee to grant the exploitation of the invention to third parties.

2.1.5.2 Other Agreement Types

Regarding the agreements between research entities and industry, besides licensing agreements, there are two types of it: Agreement of Regulation of Titularity of the Results of I&D and Agreement of Technological Development. The first is related with an I&D collaboration agreement involving an academic organization and a company, with the common aim of developing research activities, and defining the ownership of the results arising from this research and the sharing of the proceeds from it [47]. The second is an agreement initiated by the company, whereby this one looks for institutions of R&D that

are capable to develop a technology that solves a company demand, staying the company the titular of the invention [48].

In 2022, the Community Innovation Survey (CIS) published a survey analysing the Portuguese companies' performance in R&D and/or another innovation activities in the year 2020, and its comparison with the year 2018 (Fig. 9).

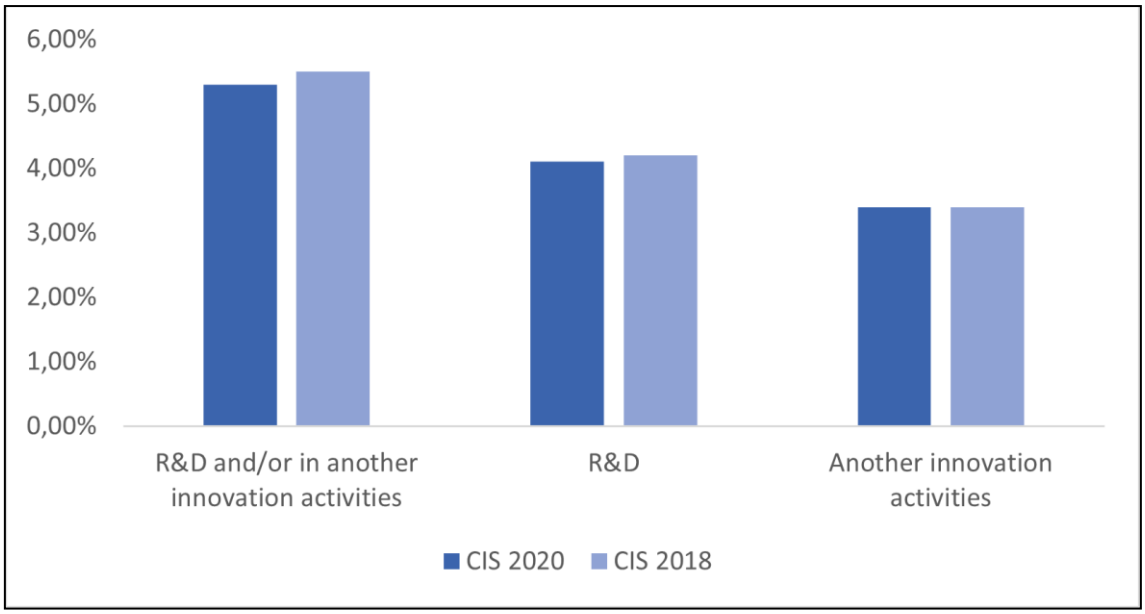

Figure 9 *– Percentage of Portuguese companies (Innovative companies) that cooperated with other companies or organizations in R&D activities and/or another innovation activities in the years 2018 and 2020. Source: DGEEC e INE, Inquérito Comunitário à Inovação (CIS), 2022 [49].*

When comparing the participation of the Portuguese companies in collaborative R&D and another innovation activities individually, he participation of Portuguese companies in R&D activities was higher than the participation of these companies in another innovation activities. Regardless, the percentage of companies that cooperate with other organizations in innovation activities in Portugal is reduced, demonstrating the presence of few innovative companies in Portugal.

2.1.5.3 Shared Benefits from Licensing

Just as there are requirements for a contract essay, the sharing of the generated profits also follows a pattern of payments, which can be done through:
1. Royalties – a percentage of the product sales.
2. Lump-Sum – only one high payment value.
3. Milestones – the payment is done every time the goals of the technology development are achieved.
4. Stock payment – done through the participation of the licensor in the capital of the licensee [46].
5. Upfront payment – a paid value in the initial stages of the agreement in a manner that the licensor has the assurance of the commitment of the licensee in honoring the agreement.

6. Cross licensing – When a license is conceded by the licensor to the licensee in exchange of a license conceded by the licensee to the licensor.

2.1.5.4 Patent Sale

Selling a patent does not bring many benefits to the academic organization. This alternative is only performed in cases where the technology is not relevant for the research entity, or there is no financial possibility for the applicants to valorize it in another way, therefore, the transmission of the IPR is the single viable solution.

2.1.5.5 Technology Based-Companies: The Creation of Spin-Offs

The licensing of the exploration rights of a patent to an existing third party is one of the forms of commercializing the research results from academia. It also can be done through spin-offs creation.

A spin-off is a company coming from an academic institution that benefits from its technical and scientific resources. Algieri *et Al* defined a spin-off as a ‘’new technology-based firm whose intellectual capital originated in universities or other public research organizations’’ [50]. According to Clarysse and Moray, 2004, the concept of a spin-off is interpreted as ‘’a technology transfer mechanism for the commercialization of a technology developed at an R&D institution or university’’ [51].

Many researchers define the concept as a new company that exploits research results proceeding of the academy. It is different from a start-up company. According to the Harvard Business Review, a start-up is ‘’a temporary organization designed to search for a repeatable and scalable business model’’. In other words, a start-up is also a company established to develop a product, but that does not have necessary any relation with R&D institutions.

In this type of commercialisation, the TTO helps the entrepreneur(s) to raise funding to, in the first stage, institutionalise the company, endow it with the necessary equipment and human resources and to progress with the technology development. Namely, commercialisation through partnerships with a company has the challenges of finding interested partners in the developed invention. But, once this is achieved, commercialisation is financially assured. In respect of the spin-off establishment, the threat of maintaining it is permanent, since there is not a financial source established for the remaining years of the spin-off. If there is no investment, the company does not have the conditions to sustain itself. In the meanwhile, sometimes, exploring the technology through a spin-off is the only alternative that the entrepreneur(s) have, because developing an early-stage technology constitutes a high risk for already established (third) companies [52]. Entrepreneurship has been the target of incentives by the European Council and national economies for some years now. But even today, the image we have of entrepreneurship is closely related to the creation of start-ups. Little is known about the creation of academic-based technological companies.

Pursuing an entrepreneurial career has its drawbacks, and anyone thinking of doing so is aware of this, but there are also many advantages when the process is successful. According to Araújo Rochel M Lago *et al*.(2005), the benefits of creating a spin-off, directly and indirectly, impact the local and national economy, by creating jobs,

increasing the commercialization of technologies, involving researchers in entrepreneurship, and boosting the mission of universities. When establishing a company, highly qualified people with highly specialized knowledge are employed [53]. Typically, these are the people involved in the invention process, but it may be necessary to hire market-oriented collaborators. The commercialization of technologies that meet market needs is also beneficial, since, in a spin-off, the entrepreneur(s) are actively working on their products, which speeds up the entry of the invention on the market. Finally, the involvement of researchers in the creation of a company is a key point. They are the most suitable people to develop the technology, because they know it in depth. On the other hand, they lack business knowledge.

According to Festel, the Biotechnology sector is quite suitable for creating spin-offs, and one of the reasons is that this is an area characterized by frequent developments of high technological value coming from R&D institutions [54].

Being aware that the valorisation of academic knowledge is a mobilizing factor for the economy, national governments and universities have guided their employees to entrepreneurship, through idea competitions, support to SMEs, courses, and scientific events in the area, among many other initiatives.

2.2.1 Importance of TTOs as we know them today

Universities are leading organizations when it comes to promoting research activities. Therefore, studying technology transfer activities in these institutions is quite relevant. Technology transfer offices, as academic TTO departments are known, are responsible for making the entire process of moving technologies to the market. And even having such large participation in the activities of universities and, consequently, in the socio-economic impact, they are still little known, even by the academic community. This finding goes in the opposite direction of commitment to disseminating and promoting knowledge in the area. In this study, we aim to understand why this happens, in addition to making known the TTOs, their services, and their importance in supporting the economic development.

3. Methods

3.1 Portuguese Academic Technology Transfer

3.1.1 Analysis of the activities of the Technology Transfer Offices

For having a more comprehensive understanding of what is performed inside the universities of Portugal for promoting technology transfer, we used a list created by ANI in 2018 containing all the activities and services executed by the Offices and Infrastructures of Knowledge Transfer. This list includes TTOs (organic units inside of the academic institutions responsible for promoting the transfer and knowledge valorisation), centres of the technological interface, science and technology parks, technology-based incubation centres, and all entities responsible for promoting knowledge valorisation and transfer [55]. Focusing only on the activities and services of the TTOs mentioned in this list of ANI, interviews were performed with professionals of eight TTOs in the North, Centre, and Lisbon and Tagus Valley regions of Portugal (that will be furtherly mentioned in section 3.5) to assess the execution of each of these activities and services.

The list presented in Table 7 indicates all the activities and services performed by TTOs mentioned by the ANI. We organized these activities and services into four different groups for analysis purposes: Researcher's Support; Partnerships; Spin-off Creation and Others, this last group contains the activities and services that do not fit into the other groups.

Table 7. Services and activities performed by the Portuguese Technology Transfer Offices divided in groups according to areas within the Technology Transfer subject. The activities in red represent the ones further analysed in the context of this study.

Group of Services/Activities	Services and Activities performed
Researcher's Support	Prepare application for incentive/subsidies
	Evaluation of the potential of patentability of inventions
	Patent submission
	Support on Intellectual Property management
	A search for new Intellectual Property and innovative technologies
	Diffusion of information about Intellectual Property Rights and entrepreneurship
	Training for researchers and students
Partnerships	Negotiation of licenses of use of Intellectual/Industrial Property
	Negotiation of research contracts
	Management of Material Transference or Confidentiality Agreements
	Management of seed fund
	Management of funding for proof of concept
	Coordination of business angels' networks
Spin-off Creation	Creation and support to spin-offs/start-ups
	Support on banking acquisition by spin-offs/start-ups
	Incubators management
Others	Management of science and technology parks
	Support to the recruitment and selection of human resources

Source: (EY-Parthenon, 2020 [55]*)*

3.1.1.2 Analysis of the Training for Researchers and Students Activity

To evaluate the activity "Training for Researchers and Students" of the group 'Researcher's Support'' of the ANI list, we created an anonymous survey aimed at researchers associated with any national research centre/academic institution in any field of knowledge. This questionnaire presented 25 questions, varying between multiple-choice and short-answer options. To facilitate the interpretation of the results, this survey was segmented into three parts: patent strategy protection; valorisation and raising of financing and spin-off creation (Annex 1). The questionary counted with the participation of 40 researchers in total.

3.1.1.3 Analysis of the Creation and Support to Spin-offs/Start-ups Activity

To evaluate the activity “Creation and Support to Spin-offs/Start-ups” of the group ‘’Spin-off Creation’’ of the ANI list, we analysed initiatives to support entrepreneurship promoted by educational institutions, and we chose one of them, the ideas’ contests, that aims to identify ideas with commercial potential coming out of the laboratory through business mentoring guided by professionals in the sector.

To observe deeply how the ideas contest works, we contacted the winning teams of the ideas contest of different institutions: the University of Minho, the University of Porto, the University of Beira Interior, the University of Coimbra, the University of Aveiro, and the two TTOs of the New University of Lisbon. Among them, the respondents were from the University of Minho, the University of Porto, the University of Beira Interior, the New University of Lisbon, and the University of Coimbra.

3.2 Foreign Academic Technology Transfer: A comparison with the Portuguese landscape

3.2.1 Interviews with the National and Foreign Technology Transfer Offices

The interviews were performed using the online Zoom platform for approximately 1h30 hours due to the practicality of this approach, especially regarding the foreign offices. With exception of one, all interviews were recorded with the previous authorization of the participants, for exclusive use in this dissertation. The interviews included the list of activities and services provided by the TTOs from the ANI list (see section 3.1.1) and a questionnaire with 27 questions related to operations, intellectual protection strategies, licensing processes, and entrepreneurship support (Annex 2).

To choose the participant entities, we reached the Portuguese, American, and British universities with the highest score in innovation indicators. In the case of Portugal, we also considered the distinct regions of the country for this selection, even though not all institutions contacted have answered. Of the 23 TTOs contacted, 12 accepted to participate in the interviews: eight Portuguese; two American and two British.

In Portugal, we interviewed professionals from eight technology transfer offices in the North, Centre, and Lisbon and Tagus Valley regions (Fig. 10):

- University of Porto Innovation (UPIN), representing the University of Porto (city of Porto);
- TecMinho, representing the University of Minho (city of Braga);
- TTO of the Catholic University of Porto (city of Porto);
- TTO of the Center for Neurosciences and Cell Biology (city of Coimbra);
- UBINNOVATIVE, representing the University of Beira Interior (city of Covilhã);
- UA Coopera, representing the University of Aveiro (city of Aveiro);

- TTOs of the Nova Impact (city of Lisbon) and the FCT Nova (village of Monte da Caparica, south of Lisbon), representing the New University of Lisbon.

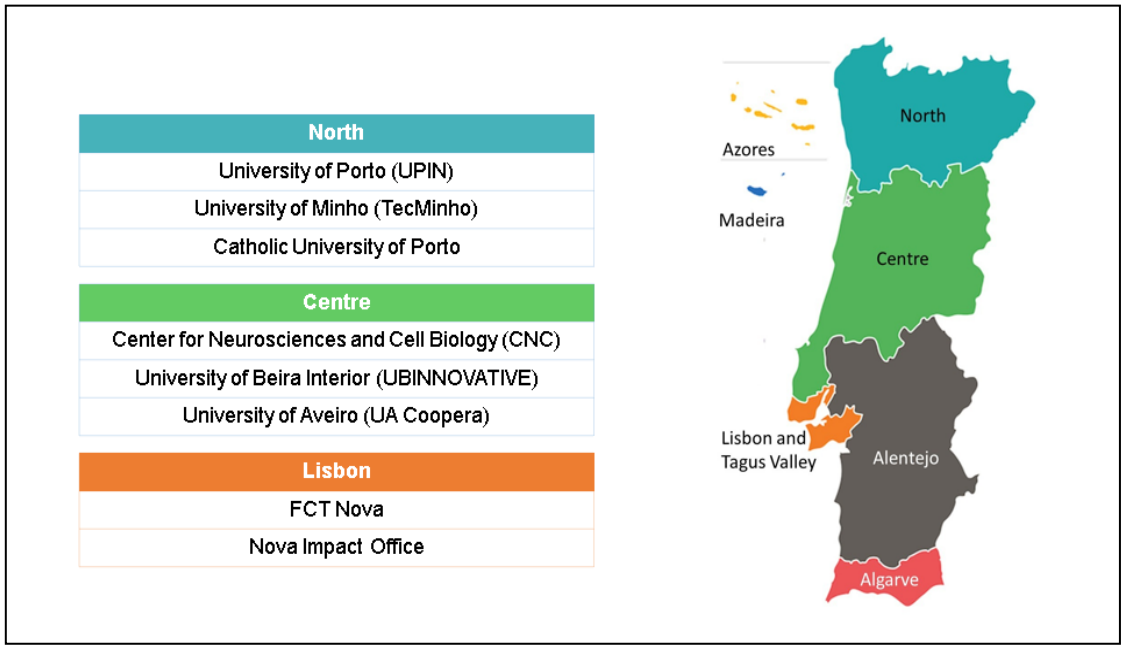

***Figure 10** – The Portuguese Technology Transfer Offices interviewed by region. (Adapted from INPI, 2021* [56]*).*

In the United States, the TTOs were from the University of Pennsylvania, in the city of Philadelphia, Pennsylvania, and the University of Stanford, in the city of Palo Alto, California. In the United Kingdom, we interviewed TTOs from the University of Oxford, in the city of Oxford, and the University of Bristol, in the city of Bristol.

4. Results

4.1 The Activities of the Portuguese Technology Transfer Offices

To evaluate the performance of the academic technology transfer in Portugal, we started by questioning eight Technology Transfer Offices (TTOs) using as base a 2018 ANI list that contains a set of standard activities and services to make a successful technology transfer possible (see section 3.1.1 of Methods). Fig. 11 indicates all the activities and services most performed and less performed by the TTOs.

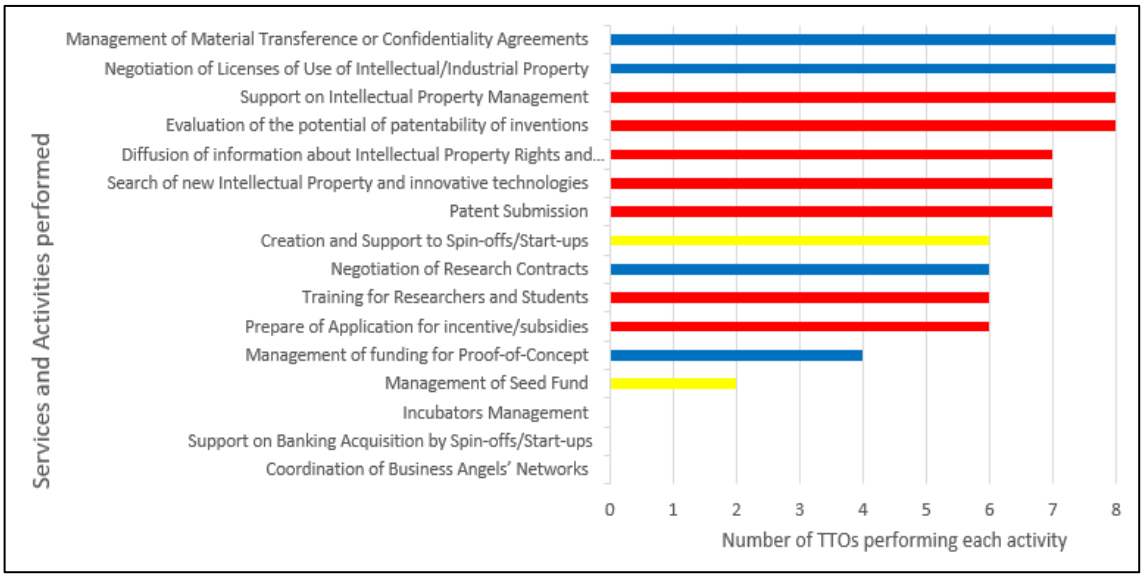

Figure 11 - *The activities/services performed by all the TTOs. The activities of the Researchers´s Support group are represented in red; the activities of the Partnerships group are represented in blue, and the activities of the Spin-off Creation and Maintenance are represented in yellow.*

In Fig. 11, the most performed activities are related with the Researchers' Support group, being followed by the activities of the Partnerships group, and the less performed activities are related to the Spin-off Creation and Maintenance group.
Regarding the activities in the Researchers' Support group, most of the TTOs (six out of eight) perform all the activities related to this group (Fig. 12).

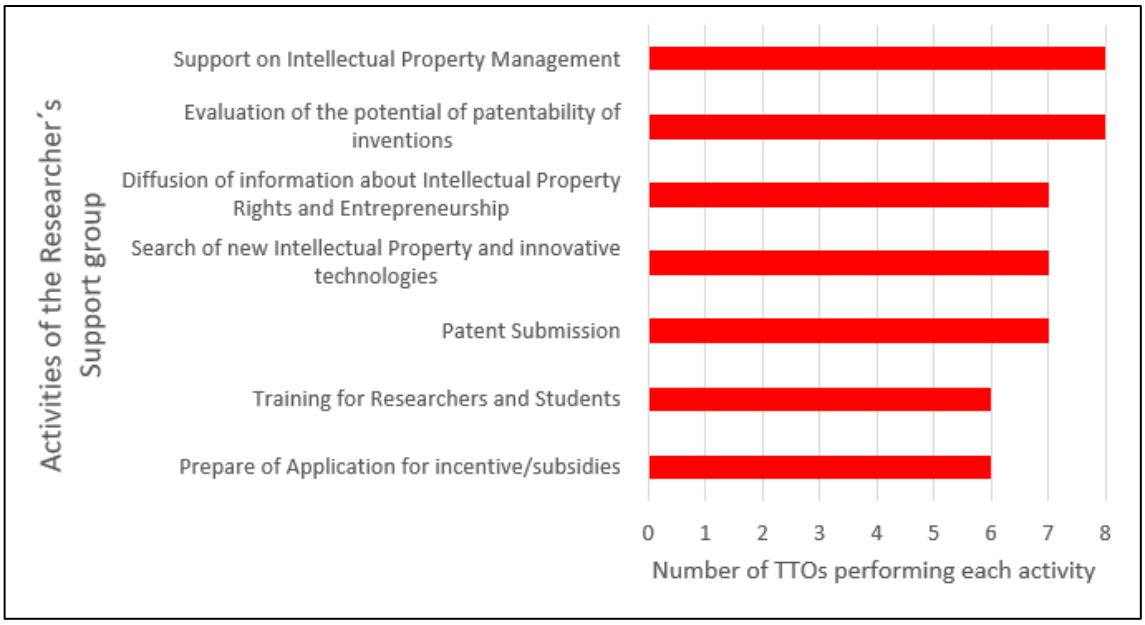

Figure 12 - *The activities/services performed in the ''Researchers' Support'' group.*

Within the ''Researchers' Support'' group, ''Support on Intellectual Property management'' and ''Evaluation of the potential of patentability of inventions'' are the most performed services, while the ''Training to Researchers and Students'' and ''Preparation of application for incentives/subsidies'' are the less performed services.

Regarding the activities in the ''Partnerships'' group, there is a concern about valorising IP since all TTOs affirmed to participate in the negotiation of license agreements. Comparing with the Researchers' Support group, there is an activity that is not performed by any TTO and the there is a decrease in the number of TTOs involved in all the remaining activities from six to four, but still there is a great support from them, as can be observed in Fig. 13.

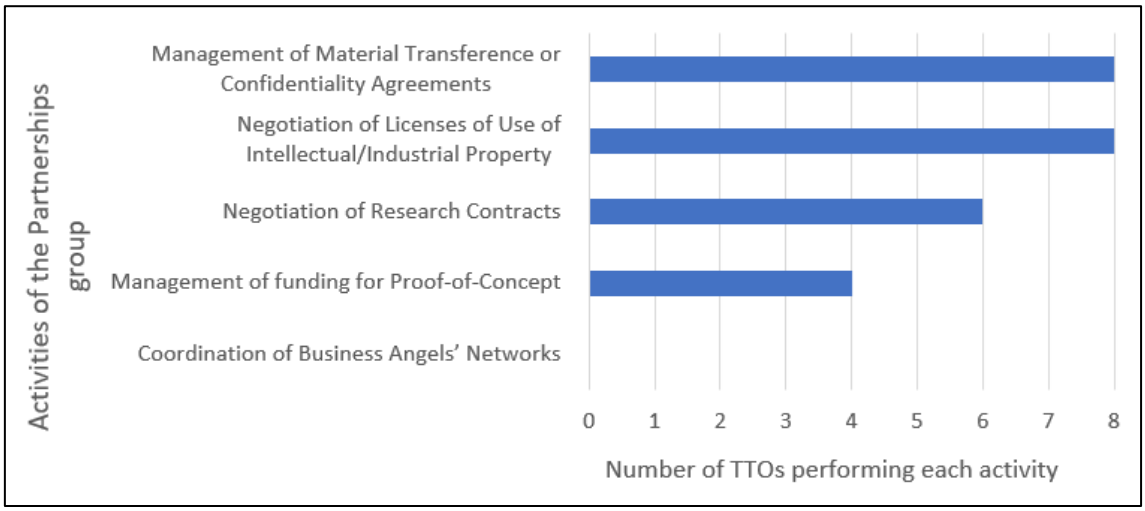

Figure 13 *- The activities/services performed in the ''Partnerships'' group.*

Regarding the "Spin-off Creation and Maintenance group*''*, the discrepancy in the support provided is higher when compared to the two previous groups. Of the four

activities of the “Spin-off Creation and Maintenance group’’, only two of them are being performed by the TTOs as indicated in Fig. 14.

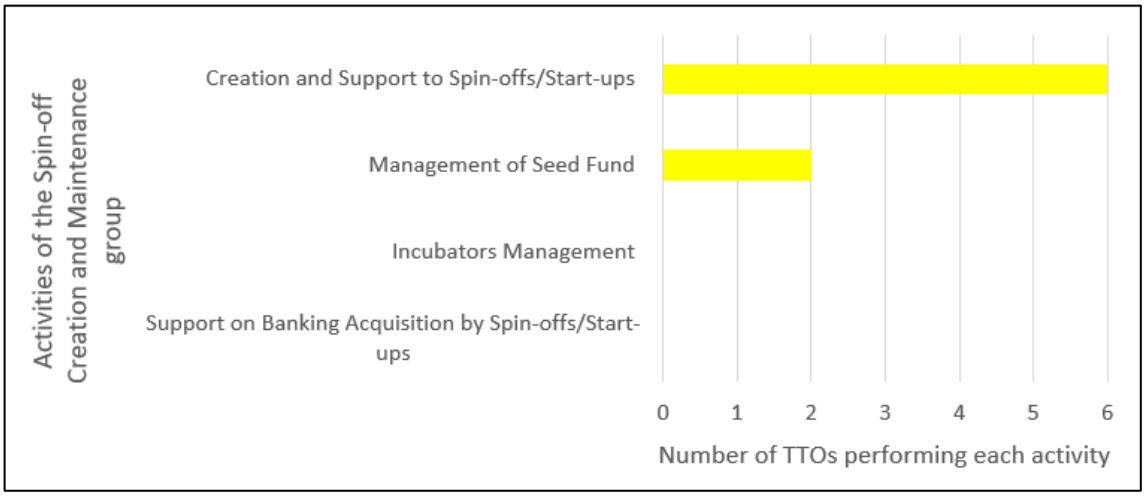

Figure 14 *- The activities/services performed in the* “Spin-off Creation and Maintenance group*”.*

We see a high number of TTOs performing the “Creation and support to spin-offs/start-ups” activity (six out of eight) but this number is not observed in other activities of this group that are also essential for the maintenance of spin-offs and start-ups. This could mean that the researchers may be looking for funding on their own, a process that could be even more difficult without the TTO’s support since at the stage of creating a new spin-off or startup, the bridge between researchers and investors would be essential. Regarding the “Incubators management” activity, no TTO claimed to conduct activities of this type. However, more than half of them have an incubator associated with their university or within the technology park of their university.

When comparing the three groups, the "Researchers’ Support", the "Partnership", and the "Spin-offs/Startups", we see that there is an extremely high prevalence of support in the first group comparing with the other two, where there is a decrease in the number of TTOs performing these functions.

We chose to not evaluate the activities and services within the “Others” Group because we do not consider that present relevant activities for this study.

4.2 Analysis of the Training of Researchers and Students Activity

Technology transfer starts with research results. Therefore, it makes sense to assess the degree of knowledge, awareness, and motivation of the people who work directly on the laboratory bench regarding Knowledge Valorisation and Technology Transfer (KVTT). As such, we designed a questionnaire targeted to researchers in Portugal through a questionnaire regarding their understanding of the possibility of transferring an invention from the laboratory to society, as well as the existence of a responsible department for performing the functions related to that.

Fig. 15 shows the affiliation of the 40 researchers that participated. They are distributed among seven distinct academic institutions, the majority belonging to the Center for Neuroscience and Cell Biology (CNC) or the University of Coimbra (UC), both located in Coimbra. It is important to reinforce the limitation of this survey regarding the coverage of researchers among the country and an easier access to the entities that I belong (CNC and UC).

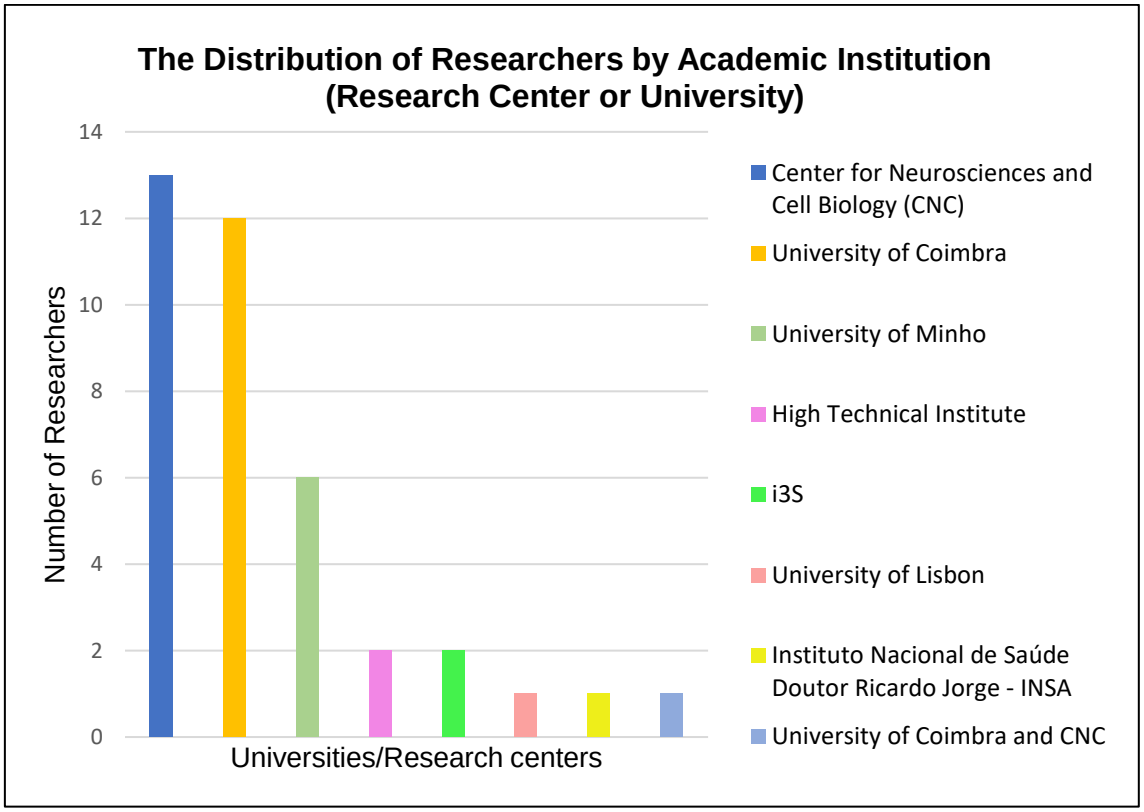

Figure 15 *- The Distribution of Researchers by Academic Institution (Research Center or University).*

4.2.1 Researchers 'awareness about Technology Transfer

Regarding the scientist's awareness of the KVTT process, only nine (22.5%) affirmed that had never heard about the subject (Annex 2). The remaining 77.5% that affirmed to know about it were informed from distinct sources according to Fig. 16.

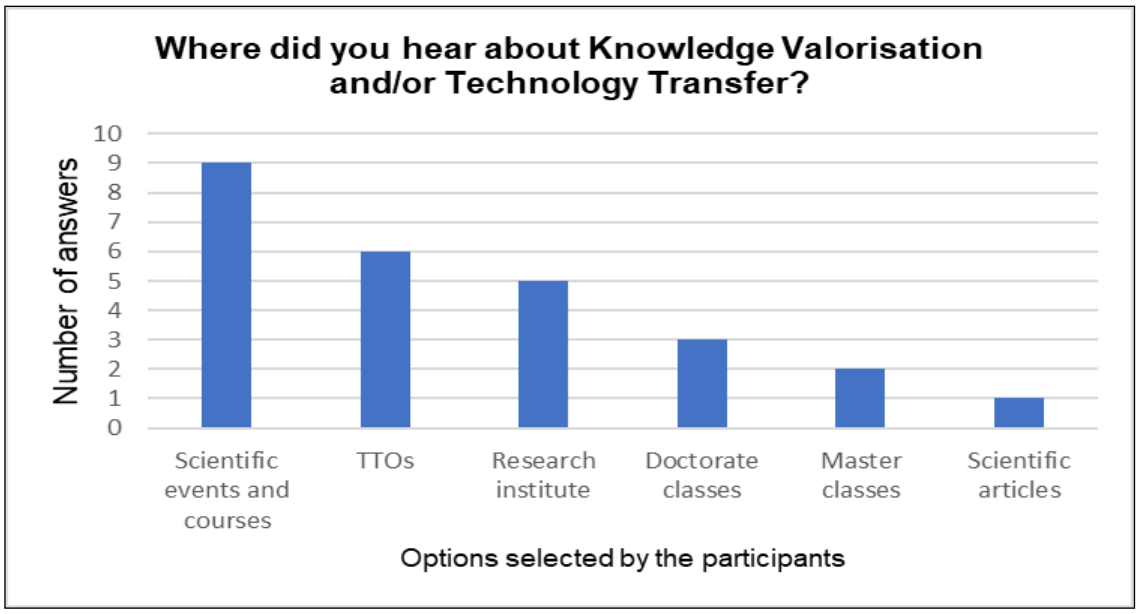

Figure 16 *– Sources for the participants awareness about knowledge valorisation and/or technology transfer.*

The ‘’Scientific events and courses’’, the ‘’TTOs’’, and the ‘’Research institute’’ were the most mentioned resources by the researchers, meaning that the research centers and universities have been the main source responsible for making the researchers aware about technology transfer.

Regarding their level of knowledge in KVTT, in a scale of 1 to 5 half of the researchers reported having any (1) or little knowledge (2) in this area (Fig. 17), which demonstrates still the significant number of researchers that lack knowledge in KVTT.

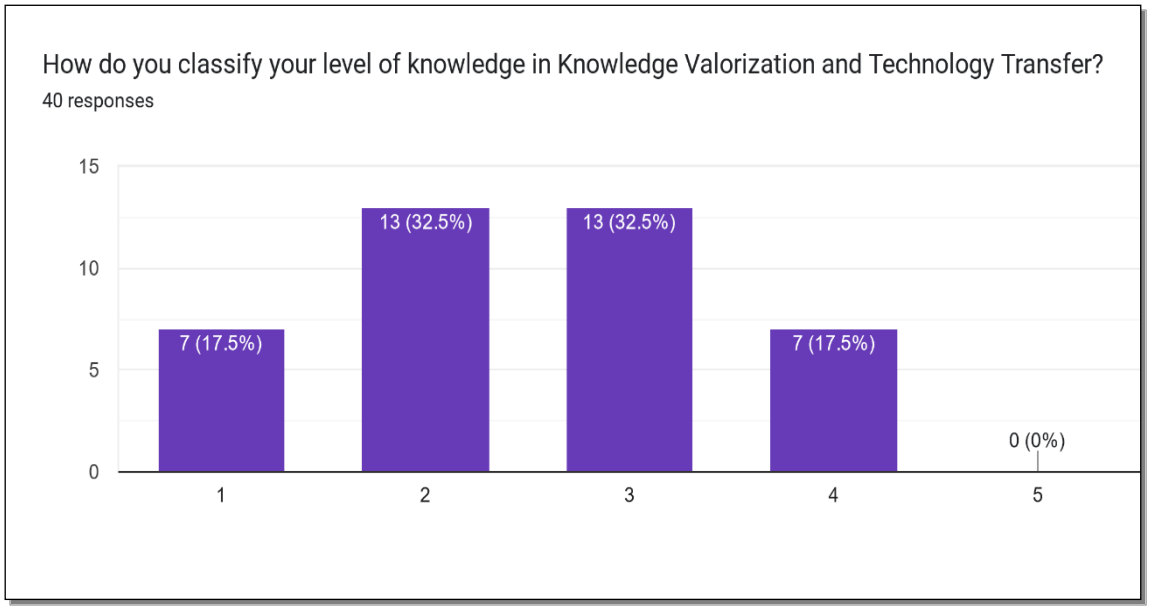

Figure 17 *– Knowledge of researchers in the Technology Transfer field. The scale 1 to 5 represents* any knowledge, few knowledge, a considerable knowledge, a great knowledge, and an expert, respectively (represented by the x-axis). The y-axis represents the number of researchers who answered this question.

4.2.2 Researchers 'awareness about Technology Transfer Offices

Subsequently, the researchers were questioned about the purpose of transferring technology from the laboratory to the market. The results indicated that most of them (70%) never think about the industrial applicability of something found/developed on the bench (Annex 2). Also, it would be relevant to know if they are aware of who is responsible for this role in their institution. For that, it was asked if they knew about the existence of a department or technology transfer office at their institution. Again, a relevant group of researchers (30%) confessed not knowing about the presence of an office (Annex 2). To those that answered be aware of it, it was questioned about their level of knowledge of the services and initiatives that the department provides (Fig. 18).

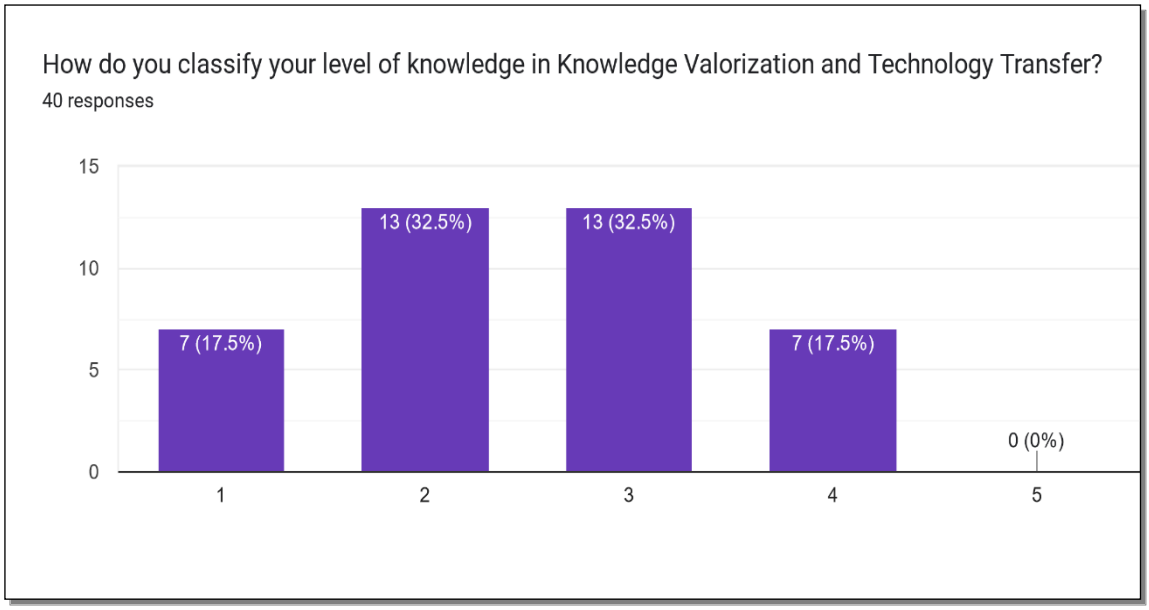

Figure 18 *- Knowledge of researchers in the Technology Transfer Offices activities.* The scale of 1 to 5 represents any knowledge, a few knowledge, some information about it, solid knowledge, and expert on the subject, respectively (represented by the x-axis). The y-axis represents the number of researchers who answered this question.

The findings reveal that, 63.3% of the researchers answered (scale 3 to 5) to be aware of the responsibilities of the TTOs. Only one person affirmed not having any knowledge of it.

Afterwards, the researchers were questioned about their motivation to understand better the roles and services provided by the TTOs. The results are shown in Fig. 19.

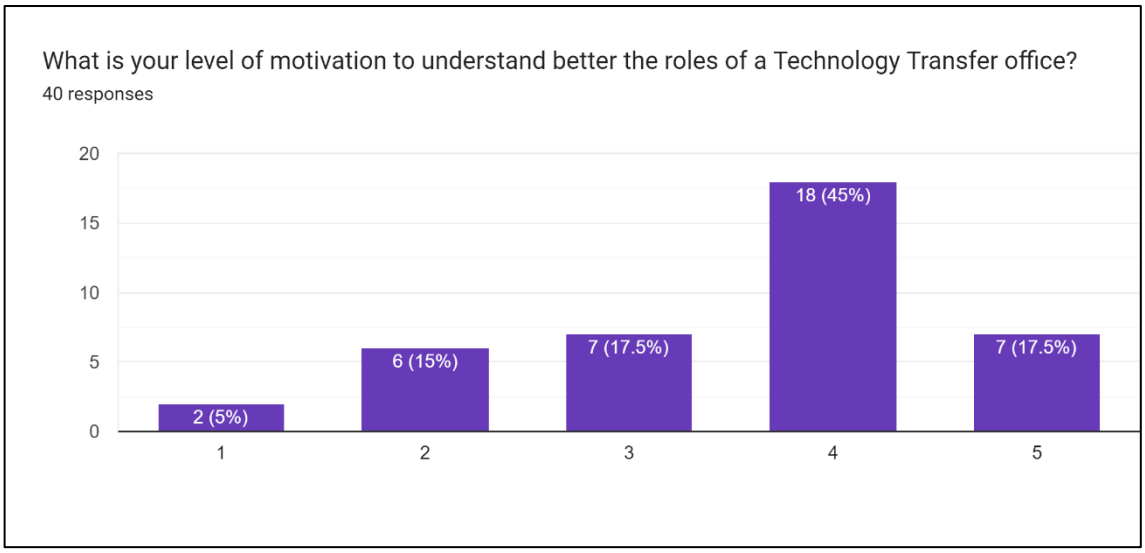

Figure 19 *– Researchers motivation to understand the roles of a Technology Transfer office.* The scale of 1 to 5 represents no motivation, little motivation, some motivation for it, solid motivation, and extremally motivated, respectively (represented by the x-axis). The y-axis represents the number of researchers who answered this question.

Positively, 25 researchers (62.5% that answered 4 or 5) have the motivation to understand better the roles of the TTOs, being that seven of them are extremally motivated. Still, 20% of the researchers answered having no or little motivation (scale 1 and 2) to understand better these roles.

4.2.3 Researchers´ awareness in patenting process

Regarding the patenting process, most of the researchers never submitted a patent. Among the 10 researchers who had a patent application, eight of them mentioned having one granted patent, one researcher mentioned having two granted patents, and one researcher mentioned having six granted patents (Annex 2).

In addition, it was a concern to know if the researchers had a patent application rejected. In this case, 100% of them never had a patent request refused (Annex 2).

4.2.4 Researchers´ awareness in licensing and partnerships

Regarding the Valorisation of the Technology step, the participants were questioned about technology financing. The first question formulated referred to their experience in getting financing from an industrial third party: 70% mentioned never had a project, either individually or in a team. For those who had at least one sponsorship (12 researchers), 11 of them confirmed that was through company support, and one chose the option ‘’Other’’. None of them had sponsorship from investors or business angels. Regarding the option “Other”, the answers mentioned financing from a research foundation, which does not constitute an industrial third party.
Among the participants who answered ‘’No’’ to the question ‘’Did/Do you have a project, individually or in a team sponsored by an industrial third party?’’, 22 of them never tried

to get any type of funding, and the other five of them answered that they already had tried to get a funding before but did not reach it.

4.2.5 Researchers´ awareness in spin-off creation

Finally, the researchers were questioned about the possibility of creating a spin-off. Of the 40 researchers, the majority mentioned never considering starting a company. Of the 16 researchers (40%) who answered that already thought about this possibility, two of them have one spin-off at least.
After, the researchers were questioned about their level of awareness of the process of creating a spin-off (Fig. 20).

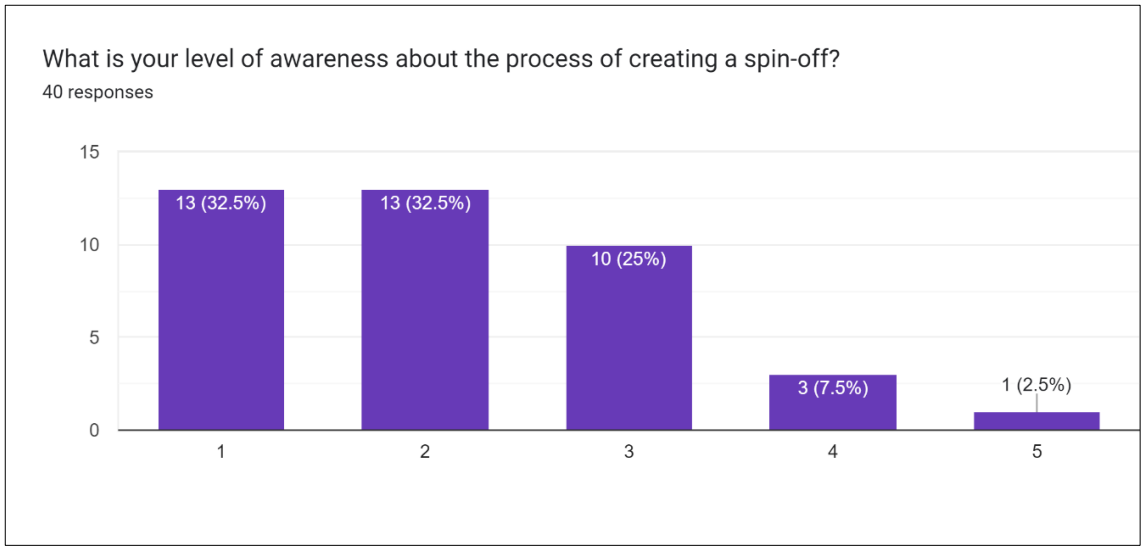

Figure 20 *- Researchers awareness to create a spin-off.* The scale of 1 to 5 represents no awareness, little awareness, sufficiently aware, strong awareness, and complete awareness, respectively (represented by the x-axis). The y-axis represents the number of researchers who answered this question.

The results indicate that more than half of the inquired researchers have no or little awareness about the process of creating a spin-off (scale 1 and 2). Only one researcher confirmed having full awareness of it. These results could demonstrate that the lack of knowledge in the process of creating spin-offs could be affecting the researchers´ willingness for creating a spin-off.

In respect of knowing the advantages of creating a spin-off, the answers changed with more researchers being aware of the benefits that could arise from creating a spin-off (Fig. 21).

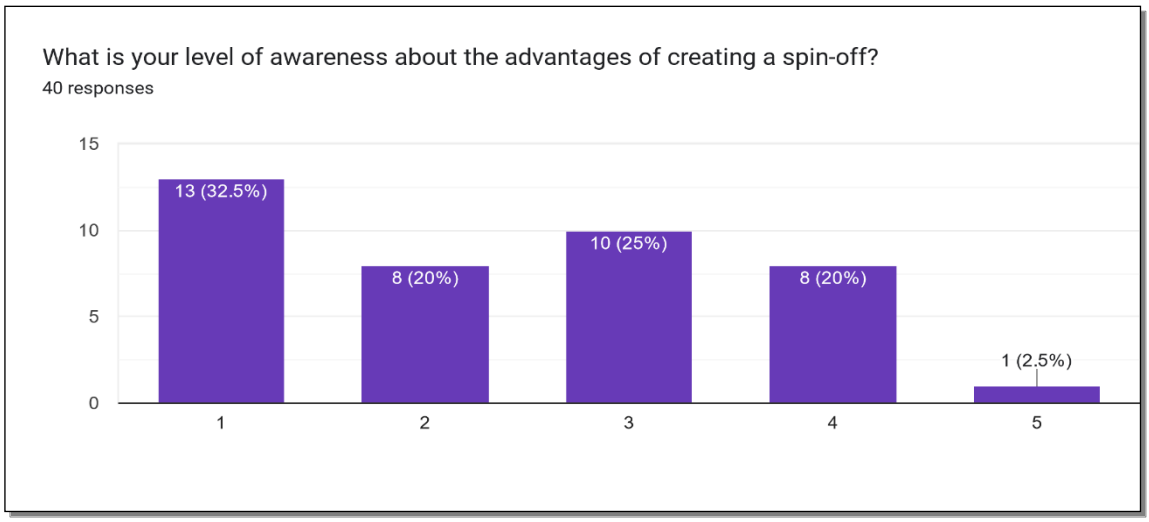

Figure 21 *- Researchers knowledge about the advantages of about creating a spin-off.* The scale of 1 to 5 represents no awareness, little awareness, sufficiently aware, strong awareness, and complete awareness, respectively (represented by the x-axis). The y-axis represents the number of researchers who answered this question.

Finally, Fig. 22 presents the results for motivation of the researchers to follow the entrepreneurship path with 13 of them motivated to create a spin-off (responses 4 and 5)

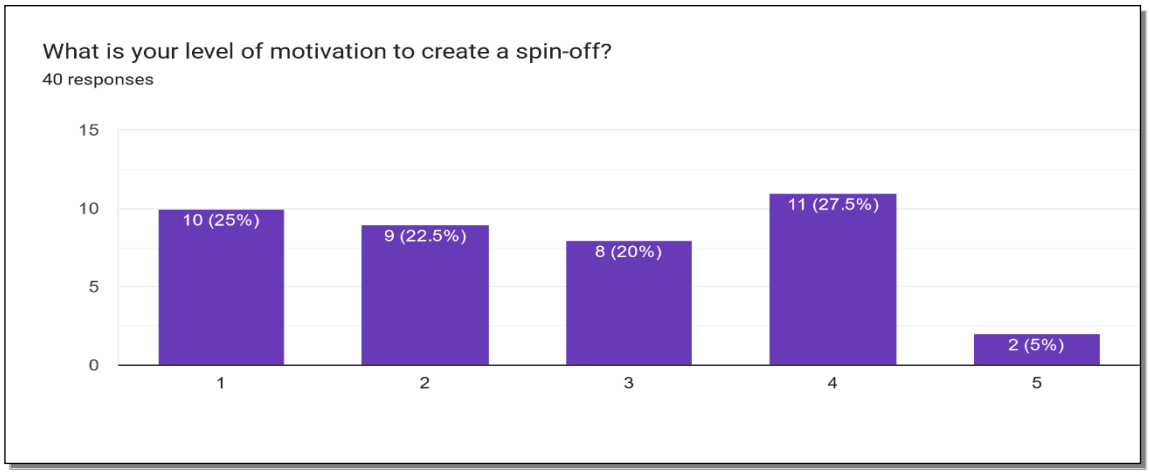

Figure 22 *– Researchers openness to create a spin-off.* The scale of 1 to 5 represents no motivation, little motivation, some motivation for it, solid motivation and extremally motivated, respectively, represented by the x-axis. The y-axis represents the number of researchers who answered this question.

For those who chose the options 1-3 (no motivation, little motivation, and some motivation for it), the reasons for it are demonstrated in Fig. 23.

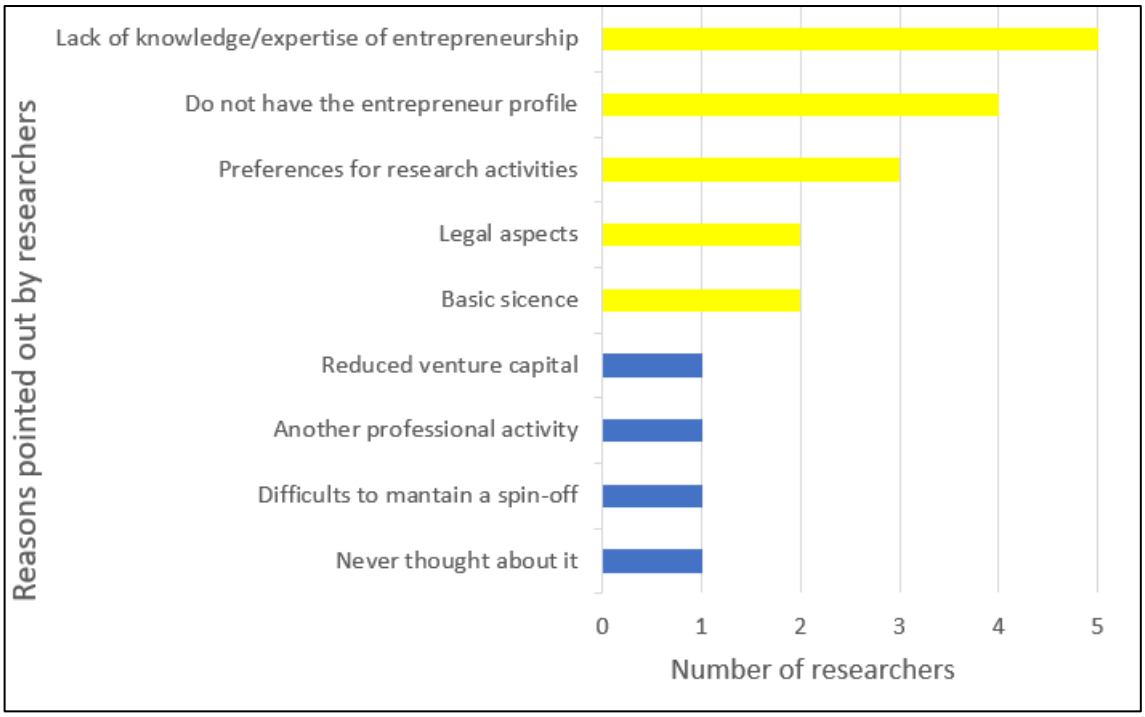

Figure 23 *- Reasons for less motivation for creating spin-offs.*

The answers were many, but a considerable number of researchers consider not having knowledge or expertise in entrepreneurship or not having the entrepreneur profile. To prepare researchers to develop skills in this field, trying to change their point of view about their profile could be a path to increase their motivation to be an entrepreneur.

In resume of the “Training of Researchers and Students” activity, still a significant part (in our survey half) of the researchers have little or no knowledge of KVTT. Among these who already know about the TTO, most are relatively aware of the services and activities provided by them, but there are still many who have little/no knowledge about it. When we asked researchers who were already familiar with the KVTT process, the most cited source of information was scientific events (meetings, seminars, webinars, congresses) and courses followed by the TTOs. Regarding awareness in patenting and licensing and partnerships, most of the researchers do not have patent submissions and 70% of them never had financing from a third industrial party. These results indicate an immaturity of our national technology transfer ecosystem. Regarding spin-offs creation, more than half have no or little knowledge on this subject, although more researchers are aware of the advantages of creating a spin-off and the motivation for it. This leads to the conclusion that maybe more training in this subject could make a difference for the creation of more start-ups by researchers.

4.3 Analysis of the Creation and Support to Spin-offs/Start-ups Activity: The incentives for spin-offs creation through the ideas contest

To evaluate the”Creation and Support to Spin-offs/Start-ups” Activity , we chose to analyse initiatives to support entrepreneurship promoted by educational institutions. Among the activities developed by the universities interviewed, we note that there was a common initiative among all of them, which is the ideas’ contests - an initiative that aims

to identify ideas with commercial potential coming out of the laboratory through business mentoring guided by professionals in the sector. Candidate teams of researchers with the best ideas are selected, in general, according to criteria of originality, degree of innovation, maturity of idea development, and the potential for socioeconomic impact. At the end of the competition, the teams that best developed their project are chosen to receive the monetary prize - the amount varies depending on the institution - to create a spin-off. To observe deeply the support of this type of initiative for researchers, we contacted the winning teams of the ideas' contests of the Nova University of Lisbon, University of Minho, University of Porto, University of Beira Interior, and University of Coimbra.

4.3.1 The contest idea of the Nova University of Lisbon

The Nova Impact Office, the office of the Nova University of Lisbon has the ''Nova Impact Challenges'' idea contest, whereby the 10 selected teams to participate in this contest receive an initial monetary award of 500€ to develop a proof of concept or prototype. During the three weeks of the contest, the participants are trained in workshops. At the end of the three weeks, they present a final pitch, and the winning team receives more 2000€ to move forward with the project development [57]. The Ebreathie team is composed by three people with academic background in Medicine, Nursing, and Engineering. None of them had any experience in entrepreneurship or had think about creating a company before, the closest was the participation of one of the members in the foundation of a junior enterprise. However, they consider that all the members had what was needed: an "entrepreneur spirit, meaning, we had participated in previous projects that, although had not been successful, it had the aim of creating innovation, creating value from the technology" (Entrevista Ebreathie, 2022).

4.3.2 The contest idea of the University of Minho

The University of Minho promotes "SpinUM'', an idea contest that offers 11.500€ to the teams with the best ideas [58]. The most innovative projects that could cover market needs and bring social benefits are selected. The same happens with the ideas contest ''Sustenta UC'', from the University of Coimbra TTO.

Within the University of Minho, we contacted two winning teams of the idea contest SpinUM. The TopoSEM won the 10º edition of the idea contest, in 2018, with a product with the same name, a software to construct three-dimensional models from the scanning electron microscopy (SEM) technique. This winning team created a company to develop the TopoSEM product, called Electron SoftView. The Mag2Clean team won the 11º edition of this contest, in 2019 [59]. In both cases, the interviewees mentioned the difficulty to raise funding, not only at the beginning of the project to be developed, but also to keep the spin-off active. The difficulty of financing is independent of the stage of the project. The TopoSEM and the Mag2Clean teams are both composed by a group of researchers who worked at the University of Minho.

The creation of both spin-offs came from different paths. The entrepreneurs of Electron SoftView are a team of experienced researchers with knowledge about entrepreneurship, they already had a submitted patent in the Netherlands and

publications and aimed to go forward with their software to reach potential users. In contrast, the team from MAg2Clean is a group of researchers at the beginning of their careers, both taking a master's degree at the time of the contest in two different areas (Biophysics and Environment Technologies) and with no inspiration to follow the entrepreneurship path. In that case, they were incentivized by a professor who saw potential in their technology and in them as a team.

Both teams mentioned the support of the TecMinho, the TTO of the University of Minho. They said that was essential to guide and give them the necessary tools to develop their business plan. Both mentioned the accessibility and the willingness to help the employees, and one of them mentioned the satisfactory level of knowledge of the collaborators. Also, both teams indicated support for research activities, despite the team TopoSEM realizing they did not usufruct this kind of service since a considerable part of their technology had already been developed at the University of Groningen. One of the teams mentioned the decent quality of the laboratories available to work. In addition, both teams highlighted the support of TecMinho on the network with investors or people who, somehow, could collaborate on their project.

For Mag2Clean, the SpinUM was the first idea contest in which they had participated. The entrepreneurs were incentivized by a professor who was accompanying the thesis project of one of them, from where it came the idea of Mag2Clean. The entrepreneurs were exposed to knowledge in market analysis, business plans, preparation, and presentation of a pitch, knowledge they did not have before as researchers.

Another important item mentioned by one of the teams was the development of skills oriented to the business field. One of them considered that these skills provided them with a differential background from other researchers who were not exposed to this type of initiative.

Besides these positive aspects, there were three limitations to point out. The first one is about one of the rules of the contest. In the contest of the University of Minho, for winners to access the money award, they need to create a company. Creating a company may not be the best idea, because they are obligated to spend the money they won in that process and not on the development of the idea. Not to mention the great costs at the beginning of the process in the employment of accountants, purchase of equipment, and the technology development itself. The second issue pointed out by them is the conservative attitudes of investors they contacted. One of them described that investors want to invest in companies already on the market, already with clients, which is contradictory, because at that phase the entrepreneurs do not need huge investments. They questioned the lack of capital risk. The third issue was pointed out by one of the winners of the University of Minho, which is about the limitations to researchers being entrepreneurs due to their employment contract. According to the Regulatory of the University of Minho, there are three modes of service provision. One of them is the regime of exclusive dedication, typically, the regime where researchers are submitted and, in the case of the interviewed member, applicable to him. This regime excludes functions or rewarded activities, including the exercise of the liberal profession besides the responsibilities of research activities. This exclusion is not compatible with the incentives of the University of Minho for entrepreneurship, since limits researchers to

practice the company activities, which make them choose between a career in research or a career in entrepreneurship. And so, many of them opt to keep their jobs in research, giving up on entrepreneurship.

The Electron Soft View is a 4-year company and one of the main challenges to keep the start-up active, according to one of the members, is still related to raising money ‘’to keep their people working and doing activities in the framework of the project’’. The activities of the company are focused on conception, development, modification, testing, and assistance to informatics programs, according to the customer’s needs.

In the case of Mag2Clean, the process of creating the spin-up was compromised due to Covid-19, whereby the team was already in conversation with investors to maintain the development of the project, but the Covid situation ended up delaying the investments, and now the project stands on-hold. However, they are still developing the project in the lab with the hope to find a new opportunity soon. Also, today they are part of the House of the Impact (Casa do Impacto) community, which is an online space dedicated to entrepreneurial projects with social or environmental motives.

4.3.3 The contest idea of University of Porto

The fourth winner team represents the University of Porto with the project Audio-GPS, which was created in 2016, and is integrated by collaborators of the Faculty of Engineering of the University of Porto (FEUP). At the time of the spin-off creation, they were all researchers at FEUP. This project aims to facilitate the location of people in inner spaces only using a sound system that issues signals that can be captured by smartphones and function as a GPS.

The University of Porto promotes a series of activities that meet the entrepreneurial potential of students not only from academia but also outside of it. The U. Porto Inovação, technology transfer office of the University of Porto, developed the ideas contest Iup25K in 2010, aimed at students in any study cycle, researchers, collaborators, or alumni of the University of Porto. This contest provides support in the scope of intellectual property, in the construction of a business plan, and offers a pre-incubation period at the Science and Technology Park of the University of Porto [60]. For the top 10 teams classified in the iUP25k, the University of Porto provides access to another competition for ideas, the Business Ignition Programme, an initiative with an essential focus on the creation of spin-offs [61].

As happened with one of the teams of the University of Minho, the iup25K (the idea contest of the University of Porto) was the first contest in which they had participated. However, they were experienced researchers and aware of the criteria of novelty in an invention. The Audio-GPS project came from a technology developed in the PhD of one of the members, and from that, they decided to follow with the iup25K contest.

To this team, the way the contest was organized was essential to prepare themselves as researchers, and they did not have the training for that. The interviewee said that was important to his maturity on the business subject and to get the necessary experience to be able to defend the business idea to the investors.

Also, the Audio-GPS team believes that the iup25k act to them as a precursor to the business world to investigate if their idea would be a business opportunity. And according to him, they were not the only teams to think like that. ‘’ Even when I was on the UPIN, a lot of people attended this contest and they did not know if they would go forward on the business idea, and, with the success of the feedback from the jury and the people involved, they think that the idea could progress’’ (Audio-GPS interview, 2022).

Besides that, the team recognizes that participation in the iup25K contest resulted in good mediatic exposure and opened doors to take part in following contests and initiatives of entrepreneurship promotion.

However, one of the biggest difficulties of that team was the unavailability of funding. The Audio-GPS team, despite winning the iup25K contest and the award of the edition of 2016 of the initiative ‘’Ideas – Born from Knowledge’’ as the Best Business Idea of the Year (a technology that has the advantage of allowing and facilitating the location in inner spaces through a smartphone or tablet), failed to gain the trust of the investors. The team was surprised with the fact that, even a team with so many recognized and acclaimed conditions to move forward, still was not possible to get funding to develop and materialize the project. Also, they did not think that the necessary steps to implement the project were complex. For them, the unavailability of funding was due to a conservative attitude from the investors, who do not take risks on new investments.

The last limitation mentioned by the team was the impossibility of them to look for opportunities in international markets once the national market turned up unavailable. Consequently, the financial availability was not enough, they were forced to give up on the project.

Even today, one of the members of the Audio-GPS team does not set aside an entrepreneurial career, just says that if so, it would be necessary to use a technology with huge potential of innovation and in the right timing to find investments.

4.3.4 The contest ideas of the University of Beira Interior

The fifth team to be analysed was DyShip, formed by researchers of the University of Beira Interior with backgrounds in Computer Engineering and Economics.

The UBI ideas competition is aimed at the university's academic community and aims to reward the teams with the best ideas with a monetary prize of €5000, which can be used in the creation of prototypes, market studies, marketing, marketing plans, support for the protection and management of the respective industrial property, such as trademark registration, or incorporation into the share capital of the commercial company, which must be set up within 6 months after the award delivery.

The DyShip project consists of a tool to detect the canine hip dysplasia disease before it is diagnosed. One member initiated this team. At the time this member was a researcher, he had already been inspired to create a company before the technology had been developed. And so, the ideas contest came up as the first opportunity for him to try the entrepreneurship career. All the members of the DyShip team had already knowledge in the business field.

This team was one of those who highlighted the support of the technology transfer office. According to them, the office provided materials and facilities for them to build up the software for a nominal fee per month.

He also recognized the gain of exposition they reached after the UBI contest, besides realizing that this participation brought them skills that another group without being involved in any of these programs did not have, even having a project with technical interest. Also, in this contest, the team had the opportunity to contact counsellors directly on the creation of one of the pitches, each one of them with a different counsellor, and according to the DyShip team, this was enough to learn more than they had learned in books.

4.3.5 The contest idea of the University of Coimbra

The sixth team analysed participated in the contest idea of the University of Coimbra, Arrisca C, in 2018. The team is composed of three elements with different backgrounds: one is a Mechanical Engineer, the other has a background in Mechatronics Engineering and marketing, and the last is a Speech Therapist.

Arrisca C is a contest idea that has been running for 10 years and aims to contribute to the creation of spin-offs in the Region Center, rewarding teams with the best business ideas in the areas of Natural Resources and Bioeconomy, Energy and Climate, Materials, Tools and Production Technologies, Culture, Creativity and Tourism, and Health and Wellness [62].

Applications for the competition must fit into one of the following categories: Social Innovation, Innovation, and Junior Innovation. In each category, the top 3 winners win €3500, €2500, and €1000, respectively. In addition, the winners can also benefit from other monetary awards, access to resources, courses, and training related to the development of the business model.

3DPrint4good is a project that turned into a company that builds personalized tools for people with disabilities, adapting them to the specific anatomical characteristics of the person using 3D modeling and printing. The idea came from one of the members when, while working in a social institution in the city noted a need faced by people with disabilities. The member also knew a company that could help in practice with the tools they used, so the union of a need with the tools used was what brought them together as a team.

Two of the members had already expertise in business: they had a company dedicated to build mobile robotics before the third member joined the team. For this member it was its first contact with entrepreneurship.

At the time the team participated in the contest, they never thought about the possibility of the project being successful and, consequently, formalizing a team. They thought it would be an isolated partnership and that it would come to nothing.

The team did not benefit (by choice) from the support of the University of Coimbra. The university offered the possibility of having a person working for them during the initial three months, but they did not consider it necessary.

Like some of the other teams, 3DPrint4good recognized a gain of exposition after participating in the contest idea. They mentioned having been contacted to appear on a television channel that, if not for the contest, it would not have happened. They also mentioned that participating in the contest helped them to mature and make the idea viable as a project, and not just as an isolated case.

Today, 3Dprint4good completes five years of existence, and after creating a website with its tools, the objective of the team is to establish partnerships with an institution to increase the number of tools they make available.

4.3.6 The Comparison between Teams

The teams that participated in the contests were asked about how was the process of creating a spin-off and how was the TTOs supportive after this establishment process, including the following questions:

a. How was the participation in the ideas contest?
b. Were you incentivized to participate in the contest?
c. What did you do after winning the contest? Did you already have an idea about what steps to follow next?
d. Did the university support you after the contest? If the answer is yes, how?
e. Do you think that participating in the contest facilitated you in some aspect?

Also, we wanted to see if there were patterns in the projects that were successful, as well as similarities within the projects that were not successful. The main questions are presented in Annex 3.

For making a comparison with the teams, common issues among them were found and we highlighted what we considered to be the most relevant questions for the analysis. Concerning the six analysed teams, three of them had already thought about creating a spin-off or had already a spin-off before participating in the contests. Of these three, all of them had already business knowledge before participating in the contest. Also, the involvement of the three teams started from their initiative. Of all the teams, three of them still have the active spin-off.

About the teams that still have the spin-off working – the 3DPrint4Good, the Ebreathie, and the Electron SoftView - we were looking for a pattern that crosses the three of them. And so, based on the interviews, we observe that these three have a well-structured team. In those cases, the project's ideas originated before the team's formation, and then, with the support of the right people, a team was built according to the needs of the company, which it was structured with the complementary skills of each member. Among them, the 3DPrint4Good and the Electron SoftView had already considered/had created a spin-off before, and within the same two, both teams had previous knowledge in the business field. The team without previous business knowledge - EBreathie - consider

that all the members have a particularly important characteristic that may supply the lack of market experience: an entrepreneur profile, that, according to them, is enough to turn the project successful. Also, the 3DPrint4Good and the Electron SoftView decided to be involved in the contests by their initiative, while the Ebreathie team had incentives from external people.

We also noted that the 3DPrint4Good, the Ebreathie, and the Electron SoftView did not receive the support of the academic TTOs after the companies have been created. In the case of the 3DPrint4Good, this was due to a previous partnership between the team and a social institution in Coimbra, through this partnership, they won a monetary reward destined to the non-profit-organizations that develop initiatives promoting the social development of people with disabilities, and mental diseases, and other diseases. So, they opted to advance the company out of the university [63].

Regarding the Electron SoftView team, they mentioned great support of the TTO of the University of Minho before the spin-off establishment. As well as the 3DPrint4Good team, the Electron SoftView did not need the resources provided by the TTO, once their technology had already been developed at the University of Groningen. However, they also said that today, the company works as a ‘’hobby’’ due to difficulty to get funding to continue with the technological improvements.

Finally, concerning the Ebreathie team, for now, the support of the TTO is related to the promotion of initiatives that could help them to boost the company.

Regarding the main challenges faced by them, the 3DPrint4Good indicated the difficulty to fit their project idea into a business model. For Ebreathie and considering the recent establishment of the company, aligning the expectations of the members, being that they did not know each other and are people in different life stages was a challenge in the initial phase of the project. And, for the Electron SoftView team, attracting funding was and still is a challenge for them to continue the progress of their software.

To the teams that the spin-offs were not successful – the DyShip, the Audio-GPS, and the Mag2Clean - it was possible to note that, among them, the Audio-GPS and the Mag2Clean never thought to create a spin-off before the contest participation, while the DyShip team was already thinking about creating a company, but they still did not know in which area and with which product to establish it, and, according to them, the participation in the contest raised the business idea that culminated into the DyShip project. The DyShip presented reasons related to discrepancies of the members as a team for the failure of the spin-off.

Regarding the TTO support, only the DyShip team benefited from it. Given the adversities of the entire process, the Audio-GPS and the Mag2Clean teams never had the opportunity of creating their companies, and so, they are not in a position of talking about the TTO support after the spin-off launch. The Mag2Clean team mentioned that, in the process previously to the spin-off phase, the support of the TTO was better. According to them, TecMinho was essential to provide their space with a good structure to develop their technology.

We also asked the three teams about the main challenges that they had faced, and the most mentioned factor (by two of the teams) was the difficulty of accessing financing. In the case of Mag2Clean, getting investments became unfeasible due to the Covid Crisis, which started at the same time they were negotiating with investors. About the Audio-GPS team, they mentioned the unavailability of the investors to concede funds, even with all the technology potential, besides mentioning that, in Portugal, the risk culture regarding investments is low. For these two teams, the investment issues are at the core of the reasons why their companies failed. Even the Electron SoftView that had launched the company mentioned the difficulty to get investments as a limitation to continuing the business activities. At last, the DyShip team considered the location of their company, the lack of market, and the initial fixed costs for creating it as the main challenges they faced.

Following the analysis of the successful and not successful spin-offs, we found three topics there are present in all teams.

1. First, any of them had participated in an idea contest before.
2. The team's participation in the contests was always incentivized by people associated with the universities, and with direct contact with the member(s), except in cases where the members had already knowledge about this type of initiative.
3. For the teams, the contest succeeded as an identifier of ideas with commercial potential, and from that, they started to trust in their technologies, and not worked as well as predecessors of the spin-off creation.

All the teams confirmed the importance of involvement in the ideas contest initiatives. Almost all teams are made up of people involved, at some level, in research activities. Even so, half of the teams had never thought of creating a company or had already formed a company before participating in the competitions. This makes us think that, although the creation of spin-offs is directly related to the academy, and this is clear to professionals working in technology transfer, the research is still seen as an activity separated from the market.

The ideas contest is an initiative to promote entrepreneurship. As mentioned by most of the teams interviewed, the contests were exceptional in forming researchers for business. During the training, they are taught by investors and people from the industry sector how to prepare a business model, providing them with the techniques and skills to prepare their technology the better as possible to get financing. This type of formation differentiates them as researchers since these valences are not present in their work. However, the participants of these contests considered that this initiative functioned for them to advance a project that in another manner they would not have advanced, but not as a company generator. In general, the contests are predecessors of companies' creation, the difficulty lies in their maintenance.

4.4 The Technology Transfer Offices Interviews

The way of transferring technology, despite following a standard procedure, may vary depending on the experience of TTOs in commercializing technologies created at the laboratory, as well as the resources available in each academic institution. As we have seen, the implementation of TTOs in the United States and the United Kingdom took

place about 20 years before Portugal. That said, we went to analyze the activities and services provided by the TTOs of the three countries to understand the differences and similarities of this process among them, and to analyze if it is possible to improve the procedures that are carried out in Portugal. From the questions asked in the interviews, we focused specifically on the organization of the TTOs, patent submission processes, granting licenses, and creating spin-offs. The results obtained are organized by country.

4.4.1 The Portuguese Technology Transfer Offices

The Portuguese TTOs are inserted into the academic institutions and present autonomy to manage their activities. To make the results easier to understand, a prior comparison was made between the Portuguese TTOs themselves, to have an overview of the Portuguese scenario, and then with the foreign TTOs. To complement the information provided in the interviews, we also use data available on the websites of the analysed academic institutions.

4.4.1.1 The Organization

In the TTOs of Portugal, the number of employees and workgroups organization varies according to their experience and longevity. We note a higher number of collaborators in the TTOs with more years of existence and a small number of collaborators in the most recent ones. To make this comparison, we used the information provided by the TTOs in the interviews.

The UC TTO team is composed of 23 people, organized into 10 workgroups:

1. Coordination, with 2 people.
2. Innovation, with 5 people.
3. Technology and Service Platforms, with 1 person.
4. Intellectual Property, with 5 people.
5. Entrepreneurship, with 1 people.
6. Provision of Specialized Services, with 2 people.
7. Non-Profit Private Associations, with 3 people.
8. Marketing, Events and Communication, with 2 people.
9. UC Gest, with 1 person.
10. Center for Neurosciences and Cell Biology, with 1 person.

The UA Coopera TTO team is composed of 11 people, organized into 5 workgroups:

1. Coordination, with 1 person.
2. Knowledge Transfer and Technology, with 5 people.
3. Entrepreneurship, with 2 people.
4. Intellectual Property, with 2 people.
5. Secretariat, with 1 person.

The TecMinho TTO is composed of 9 people, organized into 3 workgroups:

1. Intellectual Property, with 3 people.
2. Entrepreneurship, with 3 people.
3. Commercialization and Science & Technology, with 3 people.

However, there are in total 22 people working in TecMinho, besides the technology transfer area.

The UPIN TTO is composed of 10 people, organized into 8 workgroups:

1. Coordination, with 1 person.
2. Science and Technology Management, with 1 person.
3. Intellectual Property Management, with 1 person.
4. Technology Management, with 4 people.
5. Project Management, with 2 people.
6. Business Management, with 1 person.
7. Entrepreneurship Management, with 1 person.
8. Communication and Image, with 1 person.

In this TTO, there are employees that work in more than one workgroup. Therefore, the number of employees in each workgroup is higher than the number of total employees.

The Ubinnovative TTO is composed of 11 people, organized into 2 workgroups:

1. Project Support Sector, known as GAPPI.
2. Program and Project Management Sector, known as GGPP[5].

The Nova University of Lisbon IRIS TTO is composed of 9 people, organized into 3 workgroups (Technology Transfer, with 4 people, Projects, with 3 people, and Impact, with 2 people), while the Nova Impact TTO is composed of 4 people, divided into Knowledge Transfer and Intellectual Property and Entrepreneurship (in the case of this TTO people are not divided by workgroups, they work in everything that is needed). Regarding the Ubinnovative TTO, the distribution of employees by workgroups is not available.

Being represented also through a workgroup of the UC Business TTO, the CNC has its own TTO. The CNC TTO is composed of 3 people, the Catholic University of Porto TTO is composed of 4 people.

As we can see, the number of collaborators varies considerably among the TTO, but, on average, the Portuguese TTOs present eight employees.

Regarding the activities performed by them, in the majority of the TTOs, the workgroups are divided in three, associated with Intellectual Property/Patents, Knowledge Valorization, and Creation of Spin-offs. In the bigger TTOs, it is possible to allocate a specific number of people for each workgroup, in the smaller TTOs, the collaborators perform all the necessary activities among themselves.

4.4.1.2 The Process of Communication of the Research Results

All Portuguese TTOs mentioned that the process of communicating research results is initiated by researchers. This is the standard procedure for communicating inventions, except for one of them. In this TTO, the institutionalized procedure is to establish periodic meetings between TTOs and researchers to understand better the work that is being developed by researchers on the laboratory, to identify projects with commercial potential. Some also highlighted a less used procedure initiated by the TTO when they

[5]All interviews were performed based on the same questions that were placed into a survey. In the case of Ubinnovative TTO, the questions were mostly answered as a survey (and not mostly as an interview) due to the preferences of this TTO. One of the questions answered in the survey was the organization of TTO, whereby the distribution of employees by workgroups was not answered by them.

identify a technology developed in the laboratory with commercial potential or when there is interest from companies.

All communications of research results culminate in the completion of a form by the researchers, the Invention Disclosure Form (IDF), which contains all the information on the technology developed, in a way that the TTO can assess if the research results are likely to be protected by Intellectual Property.

4.4.1.3 The Patenting Step

Using the IDF, TTOs assess whether the technologies in question have the potential to be protected. If so, a protection strategy is defined that best suits the characteristics of the technology. The TTOs assist in the process of writing patent applications (most used intellectual property type in the academic setting) to be submitted to the INPI.

4.4.1.4 The academia-industry communication

Regarding academy-industry communication, TTOs were questioned if they had any type of strategy that could facilitate this communication (Fig. 24).

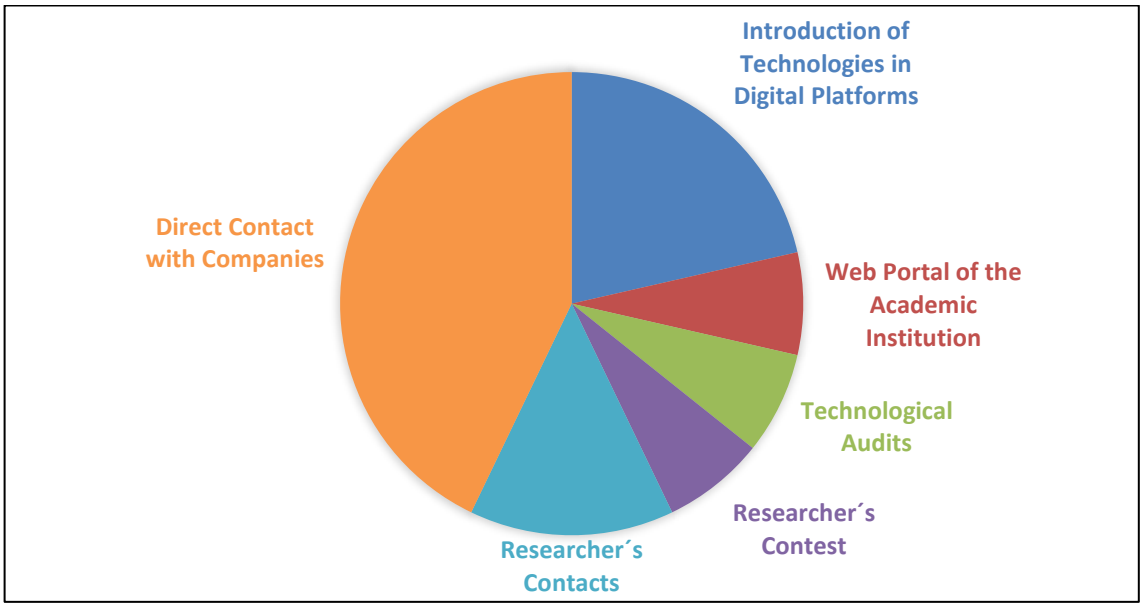

Figure 24 *- Different approaches to companies mentioned by the Technology Transfer Offices.*

4.4.1.4.1 Direct Contact with Companies

When a university has technologies to be licensed, the most common for the TTO is coming into direct contact with companies that are part of the invention's ecosystem and that, therefore, may be interested. TTOs then make a technological offer, informing companies in the sector about the technologies they have available for licensing. However, this practice is not very efficient, as TTOs usually contact one company at a time. As such, this disclosure does not reach many companies, making it difficult to find interested partners.

4.4.1.4.2 Introduction of Technologies in Digital Platforms

Another approach identified by the university offices, which, according to the graph, is the alternative most used after direct contact with companies is the introduction of technologies in digital platforms, a way to overcome the low match that occurs in individual disclosure. The use of this type of platform is the easiest way to disseminate technologies from the laboratory and to find partners for further scientific and technological development. Regarding the use of this approach, we had input from three different TTOs. One of them mentioned that many of the companies that are on these platforms are American companies and highlighted the advantages and disadvantages of their location. According to the TTO, the platform they use has two types of procedures: the first occurs when one of the parties is interested in an available technology, and from there, a meeting is scheduled; the second procedure can occur when one of the parties is interested or would like to have some clarification about the technology, and then they get in touch to suggest improvements in the technology description form that can benefit the match of interested partners. According to this TTO, the use of this platform is positive, since there is the possibility of contacting multinational companies and, even if they do not show interest in the inventions, the TTO always benefits from favorable input in terms of better writing proposals in terms of offering value. The disadvantage is that being foreign companies, and at the level of the United States, the market is very different from the Portuguese market, which makes it difficult to formalize collaborations. This difficulty was also pointed out by two other TTOs. One of them also highlighted the occurrence of expressions of interest in technologies they disclosed, but which never resulted in a license agreement.

4.4.1.4.3 Researcher’s Contacts

The third most commented strategy was the contact with companies through the researchers. According to the TTOs, when looking for partners to licensing, one option is to ask the researchers if they know of any companies that may be interested in the technology, as they know the environment better and may be aware of an opportunity. Or they may have already worked in another organization in the invention sector and be aware of what they are looking for.

4.4.1.4.4 Web Portal of the Academic Institution

Despite being mentioned by only one TTO, the dissemination of technologies on the institution's portal is a commonly used approach and is employed by most respondents.

4.4.1.4.5 Technological Audits

The next alternative was mentioned by only one TTO, and it comes in a different line from the ones already mentioned. The companies conduct technological audits to analyse their innovation activities, to assess their degree of innovation, and to identify flaws and/or improvements in their procedures. By this way, it can draw the company's attention to the technologies available at the university and to increase the possibilities for finding licensing partners.

4.4.1.4.6 Researcher’s Contest

The last-mentioned approach constitutes the ideas contests that were mentioned in section 4.3. This approach is useful to licensing technologies to spin-offs. Despite being

a strategy mentioned by only one TTO, all the interviewed TTOs perform ideas contests aimed to the researchers.

4.4.1.5 The Licensing Step

As a rule, when a patent application is submitted, TTOs seek partners who may be interested in licensing it. But establishing a licensing contract is a complex process that depends on factors such as the technology area and maturity, whether there is already an interested company or whether it is necessary to search for one, and the researchers' interest in this process. According to one of the TTOs, "many researchers want to proceed with patent applications to be included only in the curriculum, and not with the idea of the economic valorisation of the technology" (UPIN Collaborator, 2022). In addition, in cases where TTOs must report the possibility of patenting technology to the university's rectory, there is still the added time for the return to the TTOs.

The period from the communication of the invention to its licensing varies greatly depending on the TTOs. There is no standard time that characterizes them all. Normally, this process takes about 2 to 3 years, but it can take less (considered a quick process) or more time (considered a slow process).

4.4.1.7 The Process of Spin-offs Creation

Exploring technologies through the creation of spin-offs is one of the ways to commercialize inventions from the laboratory. For most TTOs, creating a spin-off is not a procedure that happens often. According to two of the interviewees, this process is directly related to the motivation of the researcher(s), and many of them do not have this interest, often making this process unfeasible: ''There aren't many who are dedicated to entrepreneurship and creating a spin-off company, because this requires a lot of work, a lot of dedication, and many of them already have a position, a teaching career, and often it's not very compatible'. (UA Coopera interview, 2022). Another TTO also recognized that researchers at the beginning of their careers demonstrate more entrepreneurial spirit than researchers with a consolidated career: ''Deep down, for them, the main objective is fundamental science, creating projects, and developing technology. It's the younger ones, typically doctoral students, who have this spirit associated with entrepreneurship''. (FCT Nova interview, 2022).

On average, Portuguese TTOs create around three spin-offs per year, with five being the maximum number mentioned, and two as the minimum number mentioned.

4.4.2 The American Technology Transfer Offices

As observed in the Portuguese TTOs, the offices of the United States work inside the universities but present autonomy concerning their initiatives. Regarding the implementation of these offices, they started about 20 years before Portugal, shortly after the Bayh Dole Act. Ten years after it, there were already about 200 TTOs spread over the country.
To understand better the activities performed by the international TTOs, the interviews were constituted by questions about the office organization and the processes of the

technology transfer. We compared the University of Pennsylvania and the University of Stanford.

4.4.2.1 The Organization

In the University of Pennsylvania, the TTO named Pen Center for Innovation (PCI) is organized into 15 workgroups:

1. The PCI Leadership, compounded by eight people.

The Technology Licensing is organized into faculties:

2. The School of Medicine Licensing, with five people.
3. The School of Engineering and Applied Sciences, School of Arts and Sciences, Stuart Weitzman School of Design, and Wharton School Licensing, with five people.
4. The Penn Dental Medicine, Penn Nursing, School of Veterinary Medicine, Graduate School of Education, Law School, Social Policy & Practice, and the Annenberg School of Communication Licensing, with two people.
5. The Special Projects, Life Sciences, with two people.
6. The Corporate Alliances, with eight people.
7. The PCI Ventures, with four people.
8. The Penn Medicine Co-Investment Program, with one responsible person.
9. The Marketing Communications and Programs, with four people.
10. The Seas Corporate Outreach, with one responsible person
11. The Corporate Contracts, with seven people.
12. The Intellectual Property and Operations, with 10 people.
13. The Legal Affairs, with five people.
14. The Finance, with six people.
15. The Executive Support, with one responsible person.

Overall, the PCI is composed of almost 70 people.

In the TTO of Stanford, the Office of Technology Licensing (OTL) is organized into four workgroups:

1) The Intellectual Property Management, with four people.
2) The Industrial Contracts Office, with 11 people.
3) The Business Development & Strategic Marketing, with 8 people.
4) The Business Operations Director, with 11 people.
5) The Internship Program Managers, with three managers and three interns.

The collaborators of both TTOs come from diverse backgrounds. In the case of PCI, the group responsible for writing the contracts (Workgroup 11. The Corporate Contracts) is composed of lawyers.

4.4.2.2 The Process of Communication of the Research Results

As occurs in Portugal, in the United States, the communication of the research results is initiated by the researchers. When we asked the American TTOs about the researcher´s awareness in KVTT, both TTOs considered that exists a general understanding by researchers about this whole process, and this may be associated with the culture and experience of these universities in technology transfer. According to Stanford TTO, their

“researchers are more aware that other from other universities because Stanford tends to be pretty entrepreneur…not all faculties of Stanford know about this, so we do try to do some outreach, talking to faculties, talking to departments about our project…but we are at an advantage here, because it’s kind of part of the culture of Stanford” (Stanford TTO interview, 2022). However, we need to consider that not all-American universities have the same experience in technology transfer, therefore, we cannot affirm that the researchers of other universities have the same awareness and easiness on this process.

In PCI TTO, after the communication step, the researchers have access to the PCI Inventor Portal, where they could submit disclosures and monitor their status while working in parallel with the TTO to observe if their technologies could be protected. In the OTL, there is a website where the researchers can find and fulfill the Invention Disclosure Form and report their inventions there. After this, the TTO starts working actively with the researcher through meetings and assesses the technology to determine what is the best strategy for Intellectual Property protection.
The PCI mentioned that when they found a technology with commercial potential, they organize meetings with the researchers involved, weekly or monthly, to keep a close relationship with them, so the TTO could monitor the progress of development of the technologies and maintain the involvement of the researchers on it.

4.4.2.3 The Patenting Step

The OTL looks at the attractiveness of the involved sector, the potential for the technology to be protected, and their confidence as a TTO in the transfer of this technology. This TTO presents inventions protected in the Life Sciences field, focusing on Gene Therapy, Cell therapy, and Therapeutics, Diagnosis and Medical Devices (Stanford interview, 2022).

To patent technologies, the PCI look mostly for competitive patents in the involved sector and affirmed to have a conservative attitude about what they patent, going forward with the process only if they are certain that it will succeed. And still, they only license about 30% of what is patented. In most cases, they only submit patent applications inside the United States due to the high costs of applying, additionally, in other territories. Only when they consider a patent to have worldwide applicability, they submit an international application. PCI presents inventions in, at least, ten different areas: oncology; nanotechnology; software; bioengineering; immunology; drug delivery; infectious disease; Covid-19; electronic materials and neurodegenerative diseases [69].

To both TTOs, the decision of patenting a technology is closely related to the licensing opportunities. They only patent what they consider possible to license.

4.4.2.4 The academia-industry communication

For the TTO of Stanford, two main strategies are used: the first strategy refers to the use of a technological platform, in which the TTO makes a brief description of the technology to be licensed and the companies make a description of the technology they want to

license. If there is a link between the keywords described by the TTO and the company, they establish a first connection. The second strategy is carried out with the help of the researchers themselves, who often know of partners who might be interested and inform the TTO. Based on these two strategies, the team aiming to establish partnerships with third parties tries to schedule meetings with the possible interested parties to better understand their interests, their pipeline, and what technologies they are looking for.

In PCI, there is a specific department that takes care of the partnerships of PIC with third parties. There are many types of partnerships that can be included in R&D partnerships or partnerships for commercial purposes.

4.4.2.5 The Licensing Step

For PCI, finding a partner to license can take six months to one year and writing the license agreements takes a significant long time until nine months, although the TTO states that these agreements could been done in few weeks. The entire process from communicating an invention to licensing can take almost two years.

For OTL, finding a partner to license depends a lot on the maturity level of the technology. This TTO affirmed to receive many early-stage technologies, and in these cases, it takes longer to find an interested partner. If the technology is inserted into a “hot market”, a field that is receiving a huge amount of investment, or if the technology is addressing a particular disease indication, the licensing occurs quickly. The entire process from communicating an invention to licensing, in average, takes six years.

4.4.2.5 The Process of Spin-offs Creation

Regarding the number of spin-offs created per year, both TTOs said that is difficult to give an annual average because it varies enormously. The number of companies created in 2022 was 21 for PCI. The OTL did not give a number, but they have informed us that normally 10% to 15% of the technologies culminate in the creation of spin-offs.

PCI presents a series of initiatives to promote entrepreneurship. There is a whole technological environment in this institution to support students and researchers who want to create a spin-off that counts with incubators, accelerators, and competitions to find innovative solutions for the university technologies.

In both TTOs, there is an initiative called the Entrepreneurs in Residence, where researchers with technologies presenting commercial potential receive support of successful entrepreneurs in training and counseling, so they can learn from the experience of those who have already gone through the challenges of creating a spin-off.

4.4.3 The British Technology Transfer Offices

In the case of the interviews that took place in the United Kingdom, although our initial proposal was just to ask the questions we had, we noticed an openness of the collaborators to talk more about the transfer of technology in their academic institutions. And so, in these cases, we decided to extract the most relevant information for this study.

4.4.3.1The Organization

The TTO of the University of Oxford is organized into 10 workgroups:

1) The Cx0 (including the Chief Executive Officer and Chief Operating Officer), with two people
2) The Investment & New Ventures, with five people
3) The Operations, with 12 people
4) The Clinical Outcomes, with four people
5) The Consulting Services, with eight people
6) The Finance, with five people
7) The Human Resources & Reception, with four people
8) The Licensing and Ventures, with 45 people
9) The Marketing, with six people
10) The Startup Incubator, with one person

The TTO of Bristol is not organized into workgroups, but by position:

1) Head of Impact Development
2) Economic Development Manager
3) Knowledge Transfer Partnership Specialist
4) Business Development Manager
5) Consultancy Services Manager
6) Junior Contracts Associate
7) Impact Development Administrator

They have two people responsible for requests of the Faculty of Arts, two people responsible for the Faculty of Engineering, four people responsible for the Faculty of Health Sciences, four people for the Faculty of Life Sciences, three people for the Faculty of Science, and four people for the Faculty of Social Sciences and Law.

4.4.3.2 The Process of Communication of the Research Results

At the Universities of Bristol and Oxford, the communication of the research results is similar to the Portuguese and American approaches: the researchers communicate the technology to the TTO, that then the TTO starts to evaluate the commercial potential of the technology.

The University of Bristol mentioned that in institutions where the researcher's knowledge about technology transfer is reduced, the TTO should give more active support, observing the laboratory's activities and monitoring the technologies development. According to this TTO, this proactive type of communication is not commonly done due to its reduced capacity. Regarding researchers' awareness to technology transfer, the University of Bristol provides training for researchers in Intellectual Property on the

university´s website, as well as information about how they should proceed if they have a technology with commercial potential [70].

The Oxford University Innovation (OUI) is a subsidiary of the University of Oxford (fully owned by it), meaning that all the processes are reported to the university. For them, the usual is also to perform a reactive type of communication (the contact is initiated by researchers). Nonetheless, inventions may rise through a specific initiative for researchers, called the "Translation Funding"[6]. Through this funding program, the TTO can act proactively by evaluating the technology protection and commercial potentials. Regarding awareness to technology transfer, OUI confessed that depends on the field the researchers operate. In the Engineering, Chemistry, and Computer Sciences fields, few researchers know something about it or know someone who knows the process. In the Social Sciences and Humanities fields, there is no awareness to the KVTT process. OUI tries to raise researchers' awareness through talks in the distinct university departments.

4.4.3.3 The Patenting Step

As occurs in Portugal, the submission of a patent application takes place with the support of TTOs that uses the technology characteristics mentioned by the researchers. A possible difference is the usual use of patent attorneys to prepare patent applications and procedures that precede the granting of a patent. Some universities have patent attorneys to perform these activities, but the American and Portuguese TTOs interviewed do not consider this as a requirement.

4.4.3.4 The academia-industry collaboration

As well as the American TTO, establishing partnerships through the contacts brought by researchers is a widely used way of getting in touch with interested companies. In addition to this strategy, they also believe to benefit from the work done at the Translate Research Office in Oxford. They explained that the Translate Research Office manages university research funds, so when a researcher is developing a project, they can apply to receive this fund and if they are selected, the amount used will be for technology development purposes.

For Bristol, the TTO believes there is no fixed strategy, but the application of all of them is what can establish a successful partnership: there must be an incessant search for partners. However, for them, we also must consider that if the company is genuinely interested, it will establish the initial contact with the university.

4.4.3.5 The Licensing Step

The OUI emphasized the difficulty of getting a license with companies. The high risk associated with early-stage technologies is a major obstacle to the development of more partnerships. To try to overcome this barrier, both Bristol and OUI TTOs referred that a good strategy for approaching the companies is through the researcher's contacts, in which they could have knowledge about the company's sector, or they could have

[6] In this support initiative, researchers apply their early-stage technologies for funding to further development towards commercialization.

participated in a previous collaboration agreement with a company that could be interested in their technology.

Also, the OUI declared that they count on the support of other research departments spread over the University of Oxford. One of them is the Medical Sciences Division, which, in turn, possesses a Translational Research Office, which also helps to transfer the research to the industry [64].

4.4.3.6 The Process of Spin-offs Creation

Bristol TTO reported difficulty to give an average of how many spin-offs are created per year. However, they reported the creation of more than 50 spin-offs until the end of 2022. They support entrepreneurship through an idea competition that aims to incentivize the establishment of new companies. This competition is divided into three levels of technology development. The first one is related to researchers that need to test their business idea. The second one is related to the development of the business idea. The third one is related to the growth of the business. In each level, participants win a monetary award.

The OUI is also alert for the spin-off creation process. According to them, the University of Oxford creates about 20 to 30 spin-offs annually and provides support to the post-establishment of them. The entrepreneurs benefit from 30 days per year to focus on the activities of the new company, and now they are working on the implementation of an initiative called entrepreneurial sabbatical, that will allow the researchers to take time off their research activities to focus on the development of the company (OUI TTO interview,2022).

5. Conclusions

5.1 Evaluation of Portugal

Focusing on Portugal, the dissemination of the technology transfer area by the TTOs has had positive effects on the researchers' understanding of this process. Therefore, TTOs have a great responsibility to continue to inform about transferring the knowledge produced by the academy to the industrial sector. In addition, most of the researchers seem interested/very interested in knowing more about the work that is done by TTOs.

In our country, usually, the researchers are the ones who initiate the contact with the TTOs. But this approach presents a limitation: Researchers know about technology transfer when they developed an invention with commercial potential and, consequently, when they meet the TTO. So, in the case of researchers who do not know the possibility of commercializing technology, they will not contact the TTO, and the communication of the research results will never happen. The focus of TTOs, therefore, should be on:

1. Reach out to researchers at their academic institutions who are not aware of the technology transfer.

2. Improve the knowledge of researchers who already know the processes, but who can still learn more.

A high percentage of researchers had thought about creating a spin-off at some point. However, most of them revealed to know nothing/little about the process of creating a company. The lack of knowledge and expertise in creating companies was the reason most mentioned by the researchers to their little or no motivation to create a company, followed by the lack of an entrepreneurial profile, and the preference for laboratory activities.

5.1.1 Lack of expertise to create a spin-off

To exploit a technology that came out of the laboratory, use licenses are established for companies interested in developing it or for new companies (spin-offs). According to what was discussed in the interviews, we can infer that this last alternative seems not so well known by researchers. There is a lot of talk about entrepreneurship, but what is communicated is more associated with the creation of start-ups than spin-offs. Instituting training in technology commercialization could be an option to internalize the idea to researchers and inform them about this possibility.

5.1.2 Researchers' Profiles

We also observe that there are professionals who prefer to maintain their careers in research than embark on the creation of companies, and this has several reasons:

I. **Preferences for researcher work**

Some researchers simply prefer to exert laboratory activities than change to a business career.

II. **Creating a spin-off is opening a door for a career change**

Managing a company and making it grow demands time, effort, and great availability of workers. Therefore, at a certain point in the company's maturity, entrepreneurs must choose between keeping their work as researchers or focusing only on the spin-off. Some people simply prefer to carry out laboratory activities, leaving aside the life of entrepreneurship.

III. **Research career stability**

Other researchers do not even rule out about the possibility of becoming an entrepreneur. Having an established career in research prevent the researchers to follow the entrepreneurship. For them, it does note makes sense to change the route after many years of work in laboratory.

IV. **Do not fit in an entrepreneur profile**

Entering the business field requires some basic skills that can convert researchers into entrepreneurs. Some studies analyse the personality of people who start a business. A study performed to evaluate how personality affects the success of entrepreneurs concluded that the "conscientiousness type of personality has a significant correlation with successful entrepreneur" [65]. But there are a lot of other skills associated with an entrepreneur profile that may include independence, creativity, initiative, self-confidence, leadership, team spirit, assiduity, responsibility, solidarity, and perseverance" [66].

In the meantime, the mentioned skills are also present in the researchers' profiles. However, when referring to a business profile, the researchers may be associating to an entrepreneur profile the resilience for dealing with difficulties and the courage to take risks. An entrepreneurial career is, usually, unstable, due to the constant need for investment to maintain the company. And many people choose to be in jobs that don't offer so many uncertainties. According to answers received in the questionnaire done to the researchers, they can be divided according to their availability to embark into an entrepreneurship career:

I. Researchers that are unaware of the possibility to create a spin-off.

II. Researchers that have a brief knowledge about the creation of a spin-off and are not opposed to entrepreneurship.

III. Researchers who never thought about starting a business**.**

These three reasons pointed out lead us to think that indeed, creating a spin-off is not an option for all researchers. On the other hand, there are researchers that could be open to create a spin-off and may just need motivation and more information to advance on an entrepreneurial route. Therefore, one of the responsibilities of the TTOs should be focus on motivating researchers with openness to create a spin-off to turn this process more successful.

Regarding the ideas contests analysis, the difficulty to get funding is associated with the low-risk culture in Portugal. A study performed in 2015 by Erin Lindsey Burton

demonstrated that Portugal is characterized by high levels of risk aversion mostly due to the 35 years of dictatorship Salazar regime, which structured a rigid individual expression, and limited nonconformist ideas and the entrepreneurial spirit [68]. Another study that aimed to evaluate the diagnostic of investors profile in Portugal interviewed four types of them: the private equity, the venture capital, the business angels, and the family offices. They were asked about the limitations for them to invest. The reasons raised are concerned with the institutional, tax, and community funds, public agents for investments, the companies' profiles, and the Portuguese scenario issues [68]. For this dissertation, we will approach only the concerns regarding the companies' profiles and the Portuguese scenario that applies to our study, focusing on the information given by venture capitalists and business angels, professionals that invest in early-stage companies. Regarding the constraints of the companies' profile and according to the venture capital and business angels, the entrepreneurs are less prepared than they think for the business world, retracting the financing from these investors. Regarding the constraints only mentioned by the business angels, there is the low potential of start-ups, the low quality of Business Plans, presented with few details and bad structure, and the overestimation of the value of start-ups by the researchers, which create unrealistic expectations due to their lack of experience. All these factors negatively influence the investment's accomplishment (Table 9).

Table 8. The low funding explained by investors.

Concerns	Type of Investors	Constraints
Companies' profile	**Venture Capitals/Business Angels**	Unprepared Entrepreneurs.
	Business Angels	Few start-ups with high potential.
		Low quality of Business Plans.
		Overestimation of the value of start-ups.
Portuguese scenario	**Private Equity/Venture Capitals**	The small dimension of the Portuguese companies.
		Shortage of capital for investment in series A and pre-series A phase.

Source: Diagnóstico ao perfil dos investidores em Portugal [68].

However, as discussed earlier, in this case, entrepreneurship is associated with start-up creations, and not with spin-offs (with an academic base creation). Concerning this last one, the universities are working to improve the training of new entrepreneurs, with market-oriented skills, so that these limitations are overcome. In the idea competitions, the participating teams are submitted to the preparation of Business Plans by the mentors of the area. There are also some competitions in which two Business Plans are prepared, one without the support of mentors, and another with the support of mentors. According to the interviews, this type of training has produced positive results. One of the participating teams had their Business Plans highly praised by some of the contests' investors.

Regarding the constraints of the Portuguese scenario, our country is characterized by a huge concentration of micro-enterprises, and investments in this type of company have

low returns. At last, the investments in early-stage companies are too high in monetary value for Portuguese investors, but the value of the Portuguese market is too low for international investors, creating a barrier for the companies to grow. This scenario makes it difficult to change the national environment, but it is important to understand it better through future studies to improve our entrepreneurial ecosystem.

5.2 The comparison among the three countries

According to what was said by the TTOs of the three countries, we can say that despite the particularities of each one, the procedures for transferring technologies are similar.

In all three countries, reporting of research results is typically initiated by researchers. And while the different TTOs are aware of the benefit of initiating communication with investigators themselves, the British TTOs appear to be more prepared to improve this approach than the Portuguese and American TTOs. In the United Kingdom, the process of communicating research results is reactive, however, in some circumstances, this process can be proactive, when the functions of technology transfer were recently implemented in an institution and the researcher´s awareness about these functions is reduced.

When asked about the researchers' knowledge about transferring technologies, the answer of the TTOs was the same as that given by the Portuguese TTOs: some have knowledge about the subject, and therefore already know how to proceed in these cases, but some have no knowledge on the subject, and so, the university's mission should be to provide support to these researchers. In the United States, we can observe that there is a greater link between the technologies that are patented and licensed, the universities prefer to patent less, to have greater certainty that they will be able to commercialize them. Despite this, the number of patents submitted and granted in a year in foreign universities is much higher than in Portugal. This leads us to think that the number of members in the TTOs team can have a direct influence on patenting activities. Table 10 shows the number of TTOs members in Portugal and the average.

Table 09. The Portuguese Technology Transfer Offices employees.

Technology Transfer Offices	Team Composition
Center for Neurosciences and Cell Biology	3
Nova Impact Office	5
IRIS FCT Nova	7
TecMinho	9
UA Coopera	11
Catholic University of Porto	4
UPIN	9
Average	**7**

Subsequently, we have the team of some American TTOs (including the ones interviewed in this study) in Table 11.

Table 10. The American Technology Transfer Offices employees.

Technology Transfer Offices	Team Composition
University of Pennsylvania	52
University of Harvard	69
Massachusetts Institute of Technology	51
University of Stanford	65
Columbia University	58
Yale University	36
University of California	21
Average	**50**

And, finally, the number of collaborators from some British TTOs (including the ones interviewed in this study) is in Table 12.

Table 11. The British Technology Transfer Offices employees.

Technology Transfer Offices	Team Composition
University of Oxford	84
University of Bristol	10
Cambridge University	33
University College of London	47
University of Manchester	40
University of Liverpool	2
University of Birmingham	12
Average	**33**

According to the tables above, the largest number of employees are in the American TTOs, followed by the British ones, and finally, by the Portuguese TTOs. The big number of employees in foreign universities could suggest a higher focus on intellectual property management, since there are more people available to perform the work.

Unfortunately, the British TTOs were unable to provide an average time between the communication of the research results and their licensing, so, it is impossible to compare it with the time provided by the other TTOs. Regarding the partnerships for licensing, one of the British universities also highlighted the difficulty of finding a partner to license the available technologies due to the considerable risk that companies must take.

Finally, the United States has an advanced entrepreneurship ecosystem, which certainly reflects in the number of spin-offs that are created per year. In addition, both universities interviewed have a group of people who work specifically in external partnerships, which can facilitate both the creation and support of new companies.

Concerning the American and British TTOs, a huge effort in the creation and maintenance of spin-offs is observed. In both countries, exist a specific group of people working exclusively in external partnerships and contacting investors, which is not the case in Portugal. In the United States, for example, Osage University Partners (OUP) is

a venture capital firm that works exclusively with universities and finances spin-offs fresh out of academic institutions [69].

To improve the financial support to spin-offs, partnerships could be formed between universities and investors as a way of facilitating the search for funding by researchers. Regarding the support for the spin-off creation and maintenance, the American and British interviewed universities present an initiative called Entrepreneurs in Residence (EIR), in which the universities have a team of associated entrepreneurs whose objective is to foster the culture of entrepreneurship, through contact with students and researchers inserted in the teaching institutions. Entrepreneurs share their experiences and, at the same time, teach and instill interest in the world of business and academics. The EIR initiative could be easily implemented in Portuguese universities since they already have experience in training entrepreneurs.

A lot can be learned from looking at the American and British technology transfer processes. However, it is worth noting that in a context such as Portugal, where the economic situation, the number of employees, and the risk culture are very different from the other two countries, TTOs have played with merit the role of supporting the generation of innovation in our country, which is increasingly confident in a knowledge-based economy.

5.3 Final considerations

In the literature to date, some studies compare the US technology transfer model with the UK one, and these models with other not studied here, such as the Germany, Switzerland and Brazil models [70] [71] [72] [73] [74]. However, there are no studies comparing the Portuguese technology transfer model with the American and British ones.

The American and British models of technology transfer have been in place for many years being, therefore, considered examples to be followed. We believe that this comparison with Portugal could be useful for our country to assess the major differences and similarities between the whole process of transferring technology - focusing on the activities performed on the TTOs - to evaluate what is being well performed nationally and what can be improved, but also the characteristics and cultural way of working of each country.

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6.1 Annexes

6.1.1 ANNEX 1 – Questions for the TTOs interviews

The interviews are organized into questions related to the TTO organization, the different stages in the technology transfer, and concerned with the possible improvements in this area:

1. TTO Organization
2. Communication and Protection Strategy
3. License Contracts
4. Spin-off Creation
5. Challenges and Opportunities faced by the TTO

1. TTO Organization

a) What is the size of the TTO?

b) Which are the careers of the employees? Are they multidisciplinary? What is their background?

2. Communication and Protection Strategy

c) When it is identified a technology that can be patentable, how is the communication process with the office?

d) What is the first step to take after the research results?
e) How much time does it takes between technical communication and licensing?
f) How do you decide to protect the new technology?
g) Does the University have international patents?
h) What is the support law? (nós, código da propriedade industrial)

3. License Contracts

i) How the office gets to the companies?

j) What are the licensing types most done?

k) Usually how much cost licensing values?

l) How much time last the licensing contracts? (On average)
m) What are the licensing conditions? (Examples: royalties, upfront payment, milestones...)?
n) Typically, do you sell the research results?
o) Do you usually do co-development contracts?
p) If the answer is yes, how are results and profit shared?

4. Spin-off Creation

q) Are the researchers incentivized to entrepreneurship?

r) Are the research results taken to the creation of a new company?
s) Are there advantages to spin-offs created?

5 Challenges and Opportunities faced by the TTO

t) In your opinion, what are the essential good practices to do a successful transference?

u) In your opinion, which are the most important factors for the success of its university in technology transfer?

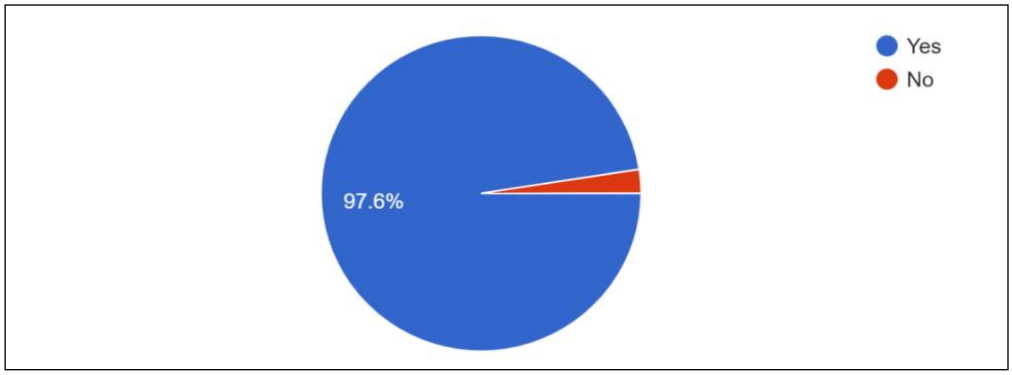
v) Do you think the location of this university has an impact on the innovative environment?

6.1.2 ANNEX 2 - The Understanding of Technology Transfer by Researchers (Questionaire)

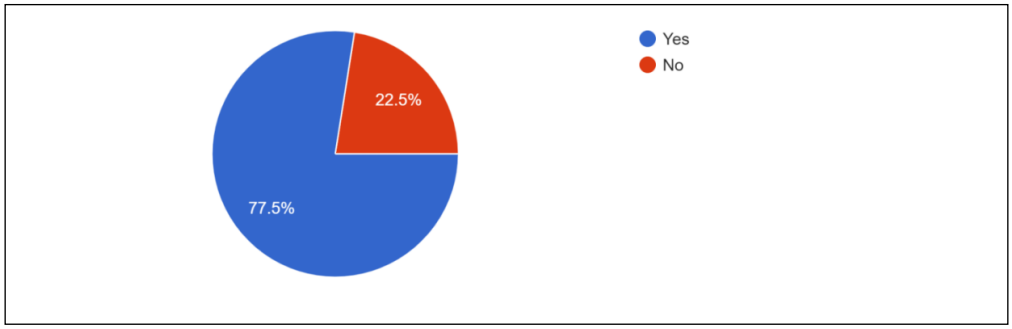
Total of responses: 40

The following questions cover the processes of Patent Strategy Protection; Valorisation and Raising of Financing, Spin-off Creation and evaluate the researcher´s awareness in Technology Transfer.

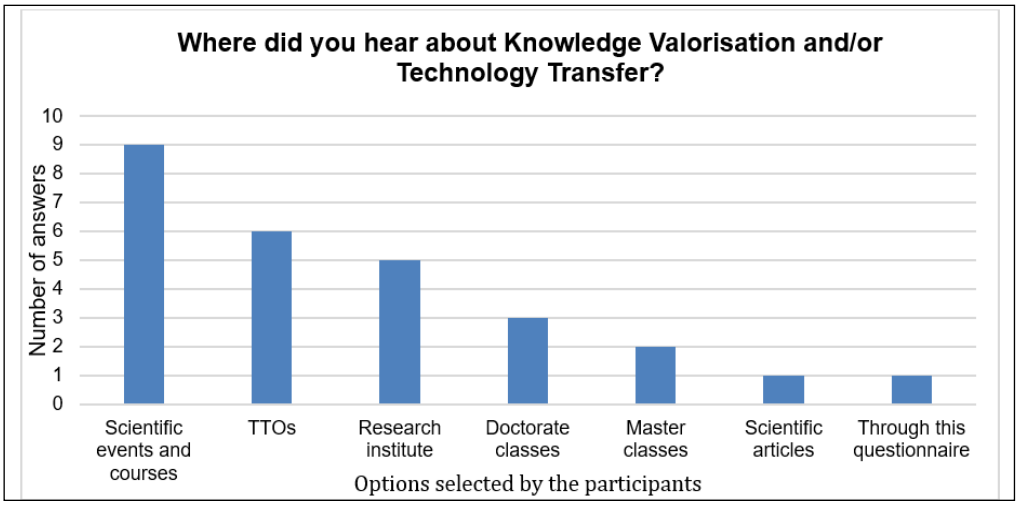
1) Do you are a researcher integrated into any academic institution/research center in Portugal



2) Did you hear about Knowledge Valorisation and/or Technology Transfer before?

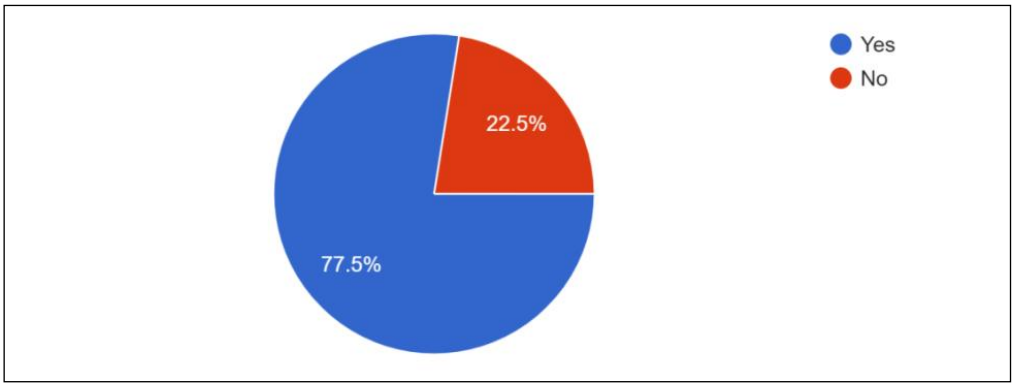


If you answered Yes in the previous question, where did you hear about it?

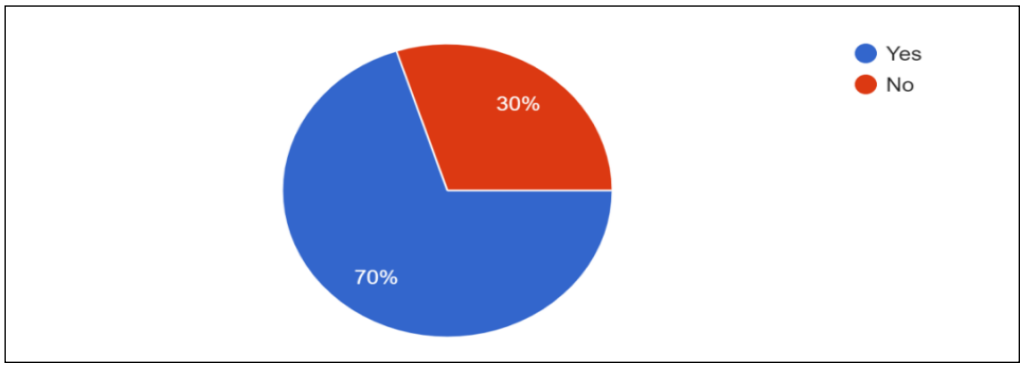


3) How do you classify your level of knowledge in Knowledge Valorisation and Technology Transfer?

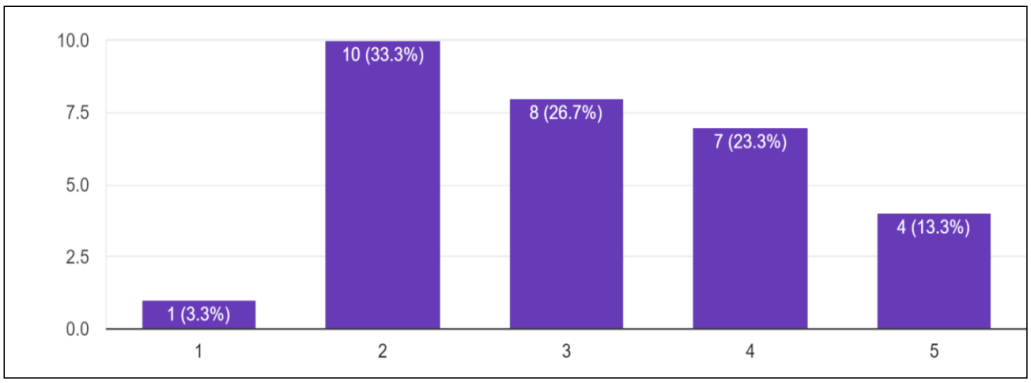
4) Did you ever think about the industrial applicability of something that you found/developed in the lab?



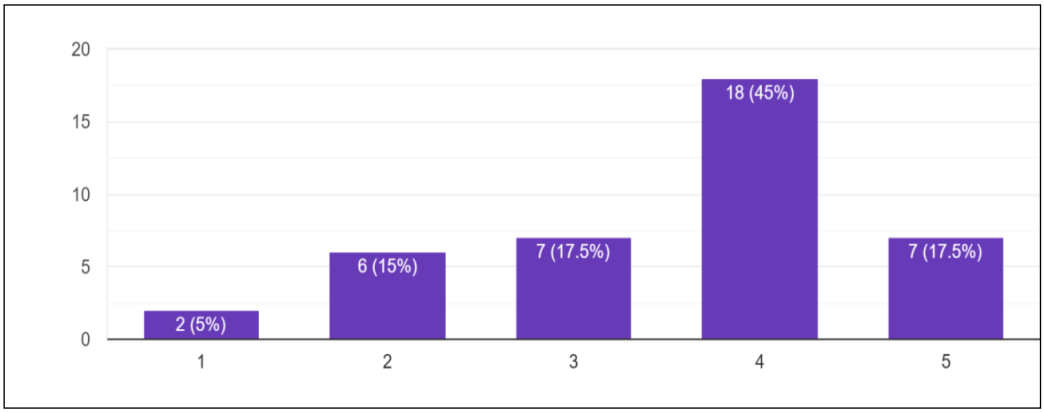
5) Do you know about the existence of a department or technology transfer office at your institution?



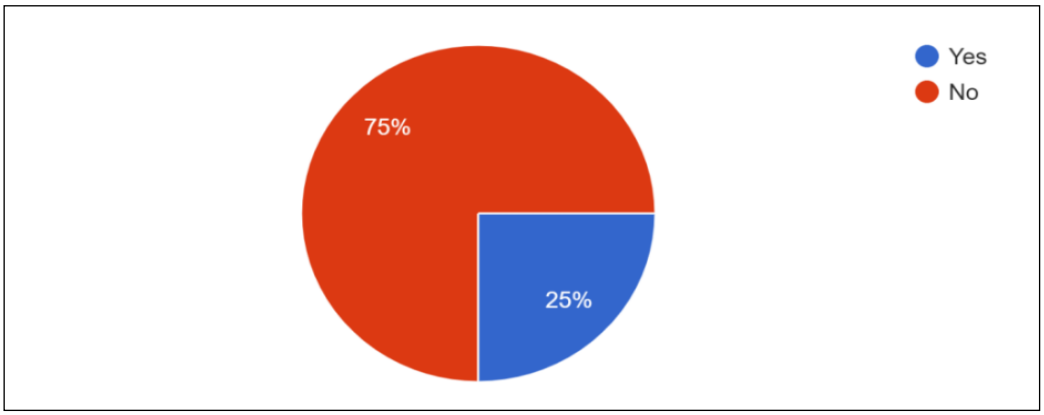
If you answered Yes to the previous question, what is your level of knowledge in the kind of services and initiatives this department provides?



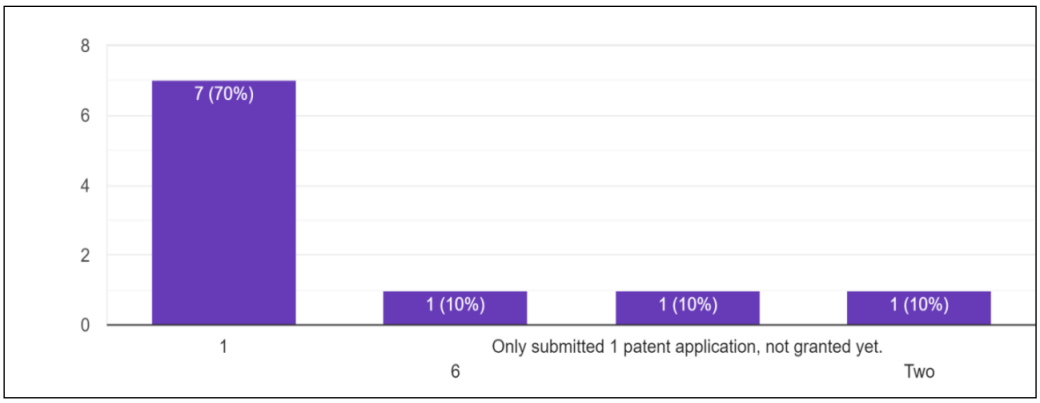
6) What is your level of motivation to understand better the roles of a Technology Transfer Office?



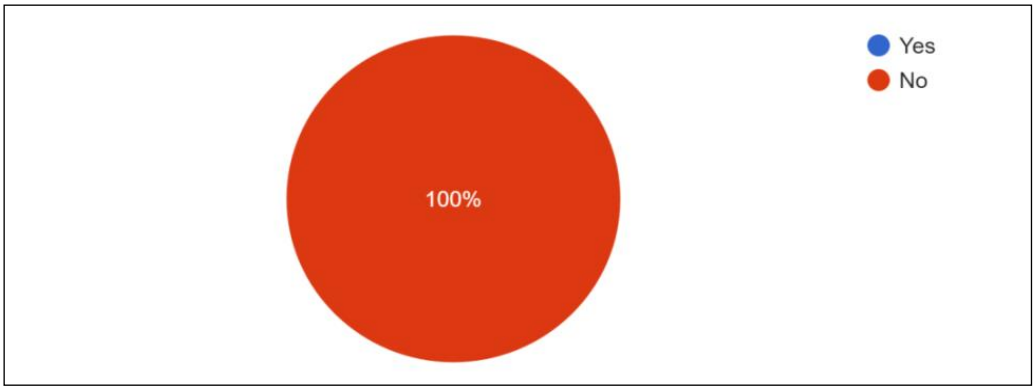
7) Do you have any submitted patent?



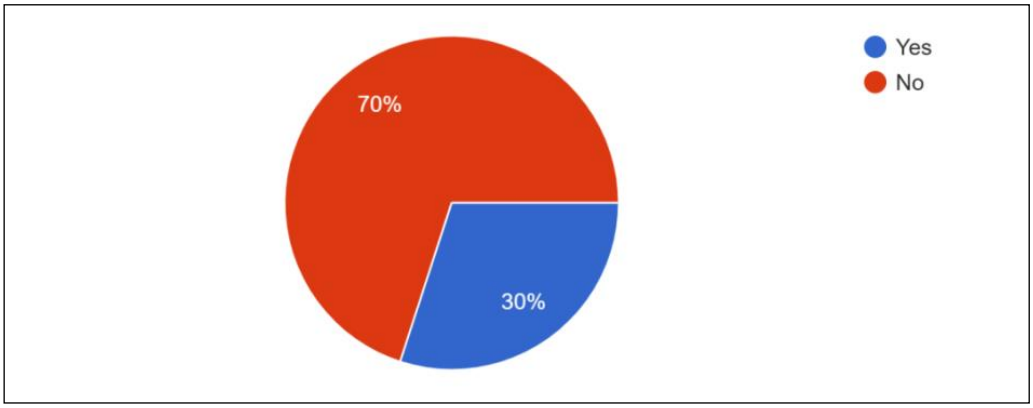
If you answered yes in the previous question, how many of them are granted?



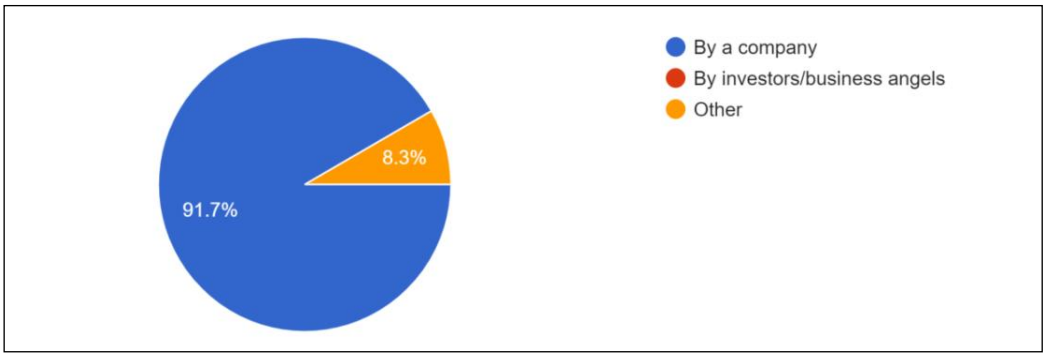
8) Did you have a refused patent request?



9) Did/Do you have a project, individually or in a team sponsored by an industrial third party?



If you answer Yes in the previous question, the project was sponsored by whom?

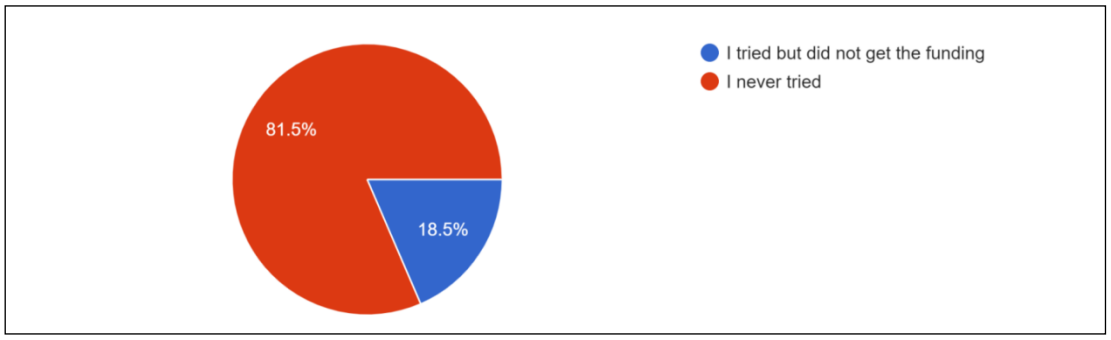


If you answer Other in the previous question, could you say what kind of funding entity it is/was?

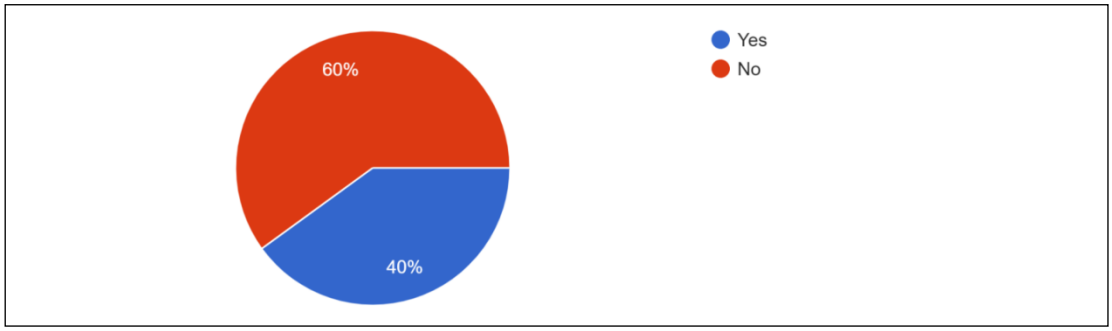
national ataxia foundation
FCT/ La Caixa Foundation
Pharmaceutical industry grant on an Investigator Initiated Research (IIR) project

If you answer No in the question “Did/Do you have a project, individually or in a team sponsored by an industrial third party?‘, please choose one of the options:

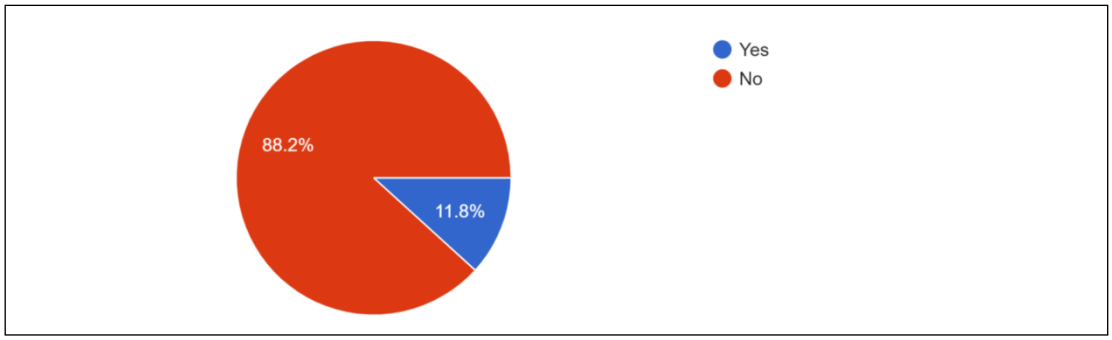
a) I tried but did not get the funding
b) I never tried



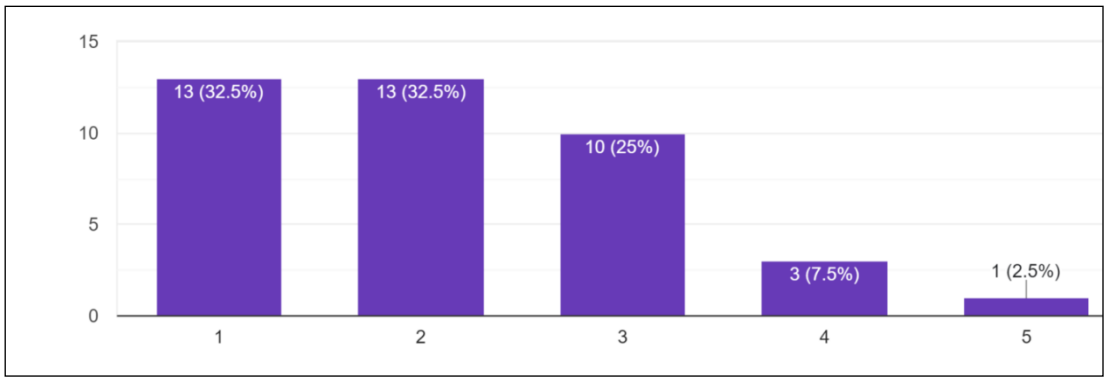
10) Did you ever think about creating a spin-off?



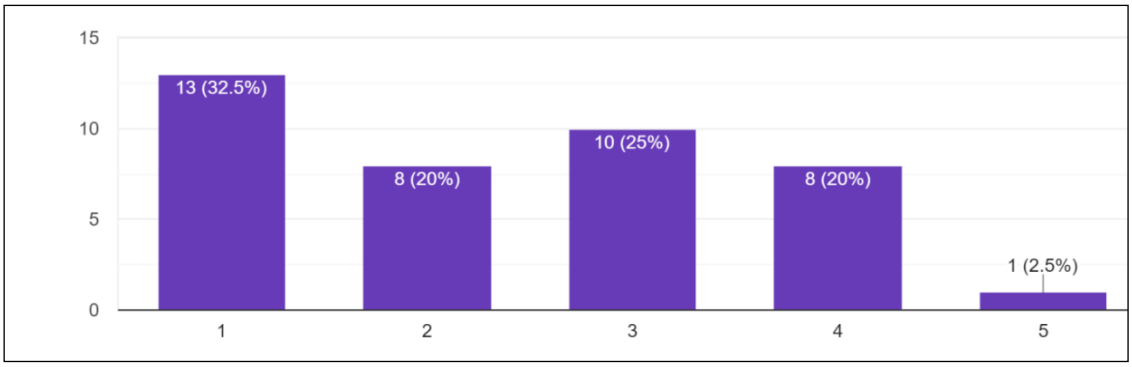
If you answered Yes in the previous question, do you have one or more spin-offs already?



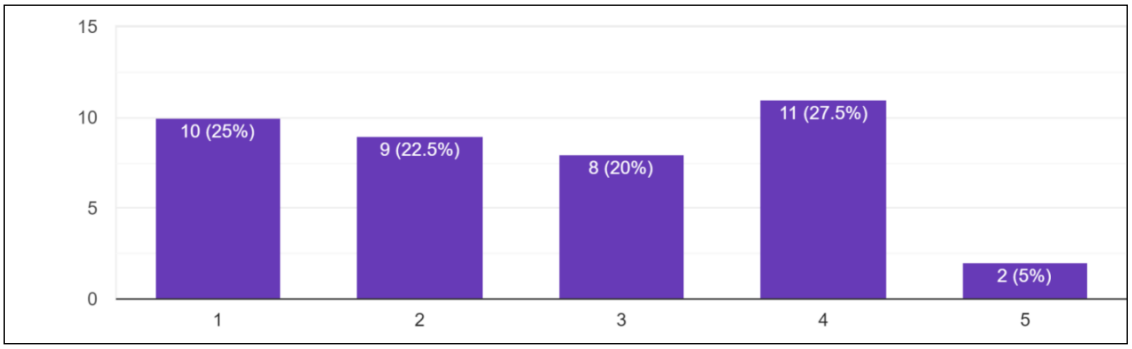
11) What is your level of awareness about the process of creating a spin-off?



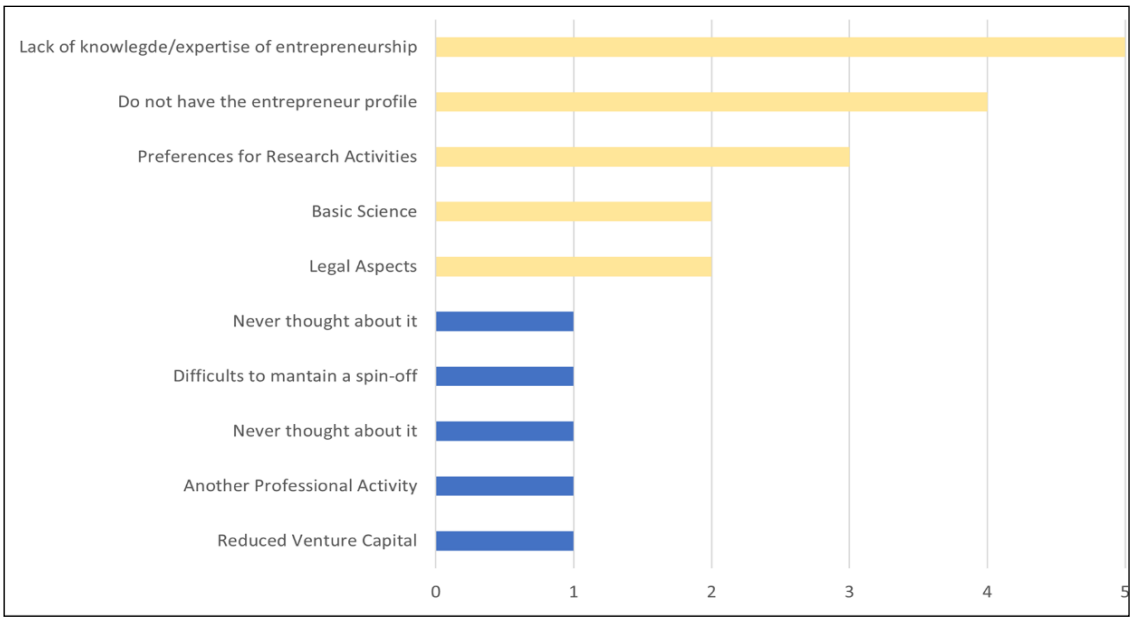
12) What is your level of awareness about the advantages of creating a spin-off?



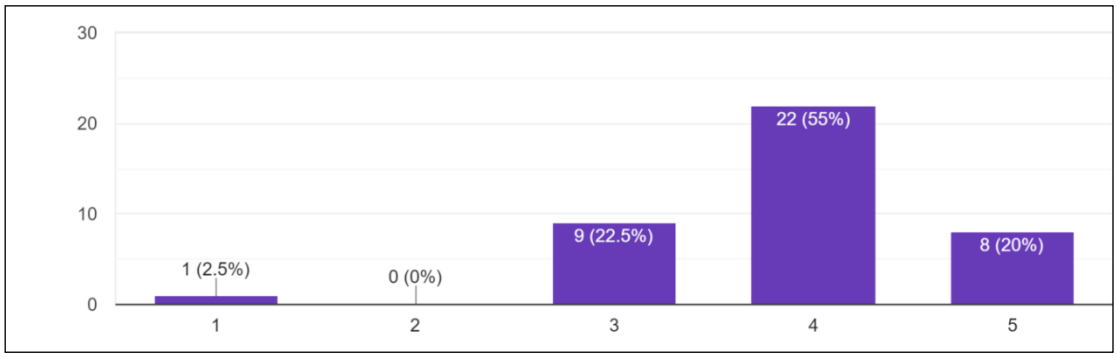
13) What is your level of motivation to create a spin-off?



If you answered 1 to 3 in the previous question, tell us about the reason.



14) What do you think is the level of relevance of these questions for you as a researcher?



15) What is your academic institution?

Academic institution	Number of researchers by institution
University of Coimbra (UC)	15
Center of Neurosciences and Cell Biology (CNC)	14
International Institute for Innovation (3i)	1
Faculdade de Farmácia da Universidade de Lisboa (FFUL)	1
Instituto Superior Técnico (IST)	2
Instituto Superior de Engenharia de Coimbra (ISEC)	1
University of Minho	6

16) Years of experience as a researcher

Number of years in Research	Number of researchers
From less than one year to 5 years	19
From 5 to 10 years	3

From 10 to 15 years	8
More than 15 years	10

17) Your area of expertise

Area of expertise	Number of researcher by area of expertise
Biochemistry	1
Biomedicine	2
Molecular and Cell Biology	10
Clinical Research, Epidemiology, Pharmacovigilance	1
Construction and Maintenance of Mechanical Components	1
Earth Sciences	2
Engineering	2
Extracellular vesicles, Nanotechnology, Bioengineering	1
Gene therapy	1
GeoSciences	3
Materials Science	1
Metabolism	2
Molecular Medicine	1
Natural products	1
Neurodegenerative diseases	10
Oncology and immunotherapy	1

6.1.3 ANNEX 3 – The comparison between teams

Questions	3DPrint4Good	Ebreathie	TopoSEM	DyShip	AudioGPS	Mag2Clean
Have the team ever thought about creating a spin-off before?	Two of the members already have a company.	Anyone had thought about it before.	Yes.	Yes.	No.	No.
Have you ever participated in a contest before?	No.	No.	No.	No.	No.	No.
How did you find out about the contest?	We knew people who already had been participated in the Arrisca C course.	Through a teacher's incentive.	We were researchers at the university of the contest, and we were aware about these types of initiatives.	He was student at the contest university and was aware about this type of initiatives.	Through a doctoral advisor.	Through a master advisor.
Did you already have business knowledge before the contest?	Two of the members had it, and just one member had not.	No.	They were aware about the entrepreneurship.	Yes.	No.	No.
Did the department support the team after the spin-off was launched?	We chose to create the company outside of the university, so they did not benefit from some possible TTO support.	For now, we benefit from the ''spin-off'' statute of the university.	It was very good, and they are still in contact, but we did not need the support because our technology had already been developed.	Yes, besides the monetary price, they had available space with all the needed resources, as materials, equipment at a very low price.	Unfortunately, the project never turns into a spin-off.	Unfortunately, the project never turns into a spin-off.
Which was/are the main challenges that you face(d)?	To fit the company in a business model since we want to go forward the social entrepreneurship.	In the beginning, to align expectations of all the members.	Difficult to attract funding.	Interiority, the lack of market, and the initial fixed costs.	The funding availability.	The difficult for fundings due to the Pandemics, the Regulatory of the university Intellectual Property.

Was the decision to participate in the contest yours or were you encouraged?	The team's decision.	We were encouraged.	The team's decision.	The team's decision.	We were encouraged.	We were encouraged.
Is the spin-off still active?	Yes.	Yes.	Yes.	No.	No.	No, only in laboratory activities.
What fails?	-	-		There were not fulfilled the requirements of equity among the members anymore.	The lack of national funding, the impossibility for us to invest in the international markets.	The access to the inventors.