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Technology Transfer

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1 INTRODUCTION

Knowledge, or technology, transfer is defined by the World Intellectual Property Organization (WIPO) as "a collaborative process that enables scientific discoveries, knowledge and intellectual property to flow from creators, such as universities and research institutes, to public and private users" (WIPO, [n.d.]). This is a crucial step in bringing the results of Research and Development (R&D), often publicly funded, to society.

The United States (US) ecosystem pioneered the growing wave of knowledge transfer from academia to industry and society as of the 1980s (MOWERY et al, 1999). This phenomenon coincided with the coming into force of the University and Small Business Patent Procedure Act, better known as the Bayh-Dole Act, in the US in 1981, which transferred intellectual property rights designed with funding from funding agencies to Higher Education Institutions (HEIs) (STEVENS, 2004). This allowed institutions to commercially exploit the results of their research (THURSBY; THURSBY, 2003).

Prior to the implementation of the Bayh-Dole Act, few universities sought protection through patent, as protection had a high fixed cost and commercialization of government-funded technologies was limited. The Bayh-Dole Act opened new possibilities for HEIs to explore technology transfer more broadly (RAFFERTY, 2008). For this reason, the US innovation ecosystem is a reference for comparative analyses of operational models that favour the transition of knowledge produced in academia to society (MOWERY; SAMPAT, 2004; GRAFF et al., 2004; SO et al., 2008; GORES et al., 2021).

This change allowed HEIs to have more control over the results of R&D activities and, consequently, greater commercialization capacity (MOWERY et al, 2001; THURSBY; KEMP, 2002; MOWERY et al, 2015). With the possibility of making profits from the commercial exploitation of their innovations, HEIs began to have incentives to seek patent protection and invest in knowledge transfer to the private sector (LINK; VAN HASSELT, 2019).

Next, a brief literature review is presented on the history of innovation policies established by the US central government in order to promote interaction between academia and industry. Such policies had a direct impact on the establishment and maturation of *Technology Transfer Offices* (TTO) in HEIs and national laboratories, which will be the reference for the analysis dealt with in this chapter.

Subsequently, the methods applied to compare the knowledge transfer practices adopted by TTOs of reference HEIs in the United States and Portugal are presented. The results achieved include the assessment of quantitative and qualitative aspects, in addition to a discussion on the implications for the activities of Portuguese TTOs.

1.1 The influence of public policies on knowledge transfer strategies in US and Portuguese universities

The implementation of the Bayh-Dole Act provided a more advantageous environment for collaboration between academia and industry in the USA. Companies began to have access to innovative technologies developed in HEIs, through licensing and technology transfer agreements (SCHACHT et al., 2009). In turn, HEIs benefited from the transfer of knowledge and financial resources from partnerships with the private sector (GRIMALDI et al., 2011).

Another important aspect of the Bayh-Dole Act was the promotion of the dissemination of knowledge generated in academia to society in general. Through technology transfer, the innovations developed in HEIs could be transformed into products and services that benefit the population, generating economic and social impact (SARPATWARI; KESSELHEIM; COOK-DEEGAN, 2022).

Moreover, the Bayh-Dole Act also had a positive impact on the entrepreneurial culture and the promotion of innovation in the US. By allowing HEIs to seek economic exploitation of their innovations, the legislation encouraged the creation of university startups and spin-offs, which have become important drivers of innovation and job creation in the country (GRIMALDI et al., 2011). According to studies by AUTM (ASSOCIATION OF UNIVERSITY TECHNOLOGY MANAGERS, 2012) and Tseng et al. (TSENG, RAUDENSKY, 2015), the number of patents issued by US universities grew from less than 250 in 1980 to 4,700 in 2011, a nearly 20-fold growth.

However, it is also important to highlight that the implementation of the Bayh-Dole Act has raised debates and criticisms in some aspects. For example, several authors argue that the commercialization of technologies born in academia may have led to an increase in access costs to these innovations, harming the dissemination of knowledge to society in general (LITAN; MITCHELL; REEDY, 2007; RYAN; SCHUSTER; KENNEY; PATTON, 2009; KUMAR, 2010; FRYE, 2023). In addition, there are concerns about the potential conflict of interest between academia, society and industry, especially when it comes to research funded by government agencies (SAMPAT, 2006; EISENBERG; COOK-DEEGAN, 2018).

Another point of discussion is the fact that not all technologies created in academia are marketable or have immediate profit potential (THURSBY; THURSBY, 2011). The Bayh-Dole Act has encouraged universities to focus on patent protection and commercialization of technologies that have clear economic potential, to the detriment of other equally important research areas, but which may not generate immediate financial returns (SHANE, 2004; KENNEY; PATTON, 2009).

In addition, the implementation of the Bayh-Dole Act also raises questions about equity and access to the benefits of publicly funded research. The legislation states that HEIs have the right to retain the intellectual property of technologies developed with public funding, which may result in economic benefits for these institutions. However, some critics argue that the economic benefits generated from academic innovations should be shared more equitably with public funders and society at large (BOETTIGER; BENNETT, 2006).

Despite these criticisms and debates, the Bayh-Dole Act has been considered an important milestone in promoting the transfer of knowledge and technology from academia to industry and society in the United States. The legislation opened new possibilities for HEIs to commercially exploit the results of their research, encouraged collaboration between academia and industry, stimulated entrepreneurial culture and promoted innovation and economic growth (SARPATWARI; KESSELHEIM; COOK-DEEGAN, 2022).

Following the Bayh-Dole Act, more than two hundred and fifty US HEIs established technology transfer offices (TTOs) to deal with the increase in technology transfer activities (STEVENS, 2004; ANDERSON, DAIM, LAVOIE, 2007). Technology Transfer Offices or related entities, in HEIs, play a central role in the transfer of knowledge and technology produced in academia to society (MASCARENHAS et al, 2019). According to the Association of University Technology Managers (AUTM), spin-offs from US academic institutions between 1980 and 1999 contributed 280,000 jobs to the US economy.

The TTOs have become increasingly important, given the concern of universities to maximize the returns on their intellectual property, especially the patents they own (MACHO-STADLER; PÉREZ-CASTRILLO; VEUGELERS, 2007). Currently, the TTOs present themselves as an important actor intermediary in absorbing the effects of public policies aimed at encouraging the insertion of knowledge generated in academia in the North American innovation ecosystems (HAYTER, 2016; HOLGERSSON; AABOEN, 2019).

In the three decades that followed the Bayh Dohle, about 20 other policies to encourage innovation were established in the USA, at the national level, both to strengthen the ecosystem as a whole and to stimulate specific segments (SHAPIRA and YOUTIE, 2010). Also in the 1980s, the Stevenson-Wydler Technology Innovation Act, among other aspects, introduced the figure of the TTO (at the time called *Office of Research and Technology Applications*) in federal laboratories, which also had the mandate to reserve funds for investment in technology transfer (JOLLY, 1980).

Created in 1982 through the Small Business Innovation Development Act, the Small Business Innovation Research (SBIR) program was established within the Departments of Defense, Energy and Health and Human Services, the National Space Administration (NASA) and the National Science Foundation. These federal agencies were mandated to invest significant amounts of money in small business R&D. Today, SBIR remains the nation's largest small business innovation program, distributing upwards of $2 billion per year (NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE et al, 2016).

In 1984, the National Cooperative Research act additionally encouraged the approximation among companies and of these with federal laboratories and educational institutions. The legislation represented a public policy to encourage research and development (R&D) consortia, establishing a legal framework for examining lawsuits against R&D consortia under the Antitrust Law and determining a list of softened penalties (SCOTT, 1989).

In addition to these two important programs, the period up to 1989 also included the establishment of the Economic Recovery Tax Act, which established tax benefits for R&D activities; the Small Business Innovation Development Act, which provided for the funding of R&D by federal agencies; the Federal Technology Transfer Act, which authorized national laboratories to enter into R&D and licensing agreements; and the National Competitiveness Technology Transfer Act, which extended the authorization of previous legislation to all federal laboratories (SHAPIRA and YOUTIE, 2010).

The 1990s were a period of reinforcement and extension of the policies of the previous period. In particular, the enactment of the Small Business Technology Transfer Program (STTR) in 1992 further consolidated the institutional framework of support and funding for the US innovation ecosystem (BARON, 1993).

STTR was intended to expand opportunities for collaboration between small businesses and non-profit research institutions. In the STTR program, a small company receiving an award was required to formally collaborate with a research institution. Along with SBIR, STTR is a landmark in encouraging R&D cooperation between small businesses and academic researchers, has distributed annual resources in excess of US$200 million (NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE et al, 2016). The SBIR and STTR programs have led to the formation of successful companies such as KelaHealth, Biopsy Science, and Genzyme Corporation (DIRKHIPA et al., 2023).

More recently, during the Covid-19 pandemic, caused by the SARS-CoV-2 coronavirus in 2020, the central US government again channeled resources to develop solutions leveraged by the interaction between business and academia. Different funding agencies of the US federal government invested massively in private R&D programs for vaccines that helped control the global health crisis. However, the decades of basic research that supported the development of such vaccines had already counted on government support since at least the 1960s (LALANI et al., 2022).

Given the impressive results, in terms of vaccines and equipment to combat and control Covid-19, achieved by the emergency programs, the U.S. government decided in 2021 to create an agency with an allocation of $ 6.5 billion to accelerate innovations in health and medicine (TOLLEFSON, 2021). The new entity, called ARPA-H (Advanced Research Projects Agency for Health) would have the agile bureaucracy model of the Defense Advanced Research Projects Agency (DARPA), specialized in conducting projects of high technological risk to meet the interests of the Department of Defense (SOMANI, 2022). DARPA's operational model originated in 1958, when the US Department of Defense, during the Cold War, created a special division to finance the development of technologies (AZOULAY et al., 2019).

A striking aspect of the institutional goal for innovation in the United States is the perennially of state strategies. Instruments and programs that endure for decades support the long periods necessary to transfer scientific knowledge to the market. In a way, the Portuguese ecosystem fits a similar scenario, since in terms of research, development and innovation (R&D+I) policies, the local framework is strongly linked to regional policies established at the European Union (EU) level, which have a long-term perspective.

The institutional framework for stimulating R&D+I that governs the European community bears similarities to the North American context in terms of the provision of financial support and long-term strategic orientation. The EU Science and Technology Policy, established in the Maastricht and Amsterdam Treaties, aims to make research in Europe a transnational activity where appropriate. The joint policy focuses on sharing costs and resources for the implementation of large-scale projects, particularly those that allow solutions to problems affecting all of Europe (KIM; YOO, 2019).

The EU's work is implemented through different programs and instruments, the *Framework* Programs being the largest, oldest and most important of these. The first Framework Program (FP) was established in 1983 for a period of four years. During the following decades, successive FPs have provided financial support for the implementation of EU R&D+I policies. Their aim has evolved from supporting cross-border research and technology collaboration to encouraging genuine European coordination of activities and policies.

The ambitious goals of the FPs have been matched by the evolution of the budget made available, from just over €3 billion in 1983 to almost €100 billion in the ninth FP, which started in 2021 under the name Horizon Europe. In addition to the FPs, the cohesion policy and other EU satellite programs offer research-related opportunities, among which are the European Structural and Investment Funds, COSME, Erasmus+, the LIFE program, the Connecting Europe Facility and the EU health programs (EUROPEAN PARLIAMENT, [n.d.]).

In Portugal, the internal programs for stimulating innovation have been linked to the EU instruments and strategies since 1986, when the country joined the Community. At that first moment, the operationalization of the objectives and distribution of EU resources within Portugal were mediated by what became known as the "Previous Regulation", valid until 1988. Since then, the different FPs of the European Community were consolidated in the country by similar programs, which included the Community Support Frameworks (CSFs) I, II and III, the National Strategic Reference Framework (NSRF) and Portugal 2020 (GAMA; FERNANDES, 2016; DA SILVA, 2022).

Between FP1 and Horizon 2020, about 9,000 projects developed by Portuguese universities, research institutes and companies were contemplated, receiving a total of € 2 billion in funding (EUROPEAN COMMISSION, [n.d.]). Currently, the EU objectives and instruments, embodied in the current version of the FP - called Horizon Europe, are implemented in Portugal through the "Portugal 2030" instrument, consisting of 12 programs that will distribute, between 2021 and 2027, more than € 20 billion to national projects and initiatives.

Portugal 2030 encompasses 4 thematic programs, 7 regional programs and 1 technical assistance program. The instruments aim at implementing the strategic guidelines of Horizon Europe in Portugal, namely:

- *Open Science*: continues the "Science of Excellence Pillar" introduced by Horizon 2020.
- *Global Challenges and Industrial Competitiveness*: addresses European industrial competitiveness and implements EU-wide research missions to address specific societal challenges; and
- *Open innovation*: aims to make Europe a pioneer in market-creating innovations by developing an innovation ecosystem to promote the integration of business, research, higher education and entrepreneurship (EUROPEAN PARLIAMENT, [n.d.]).

The Portugal 2020 and 2030 programs were designed under the concept of Smart Specialization, a form of organization of the National Innovation System that favors the interaction of geographically close actors with the purpose of building capacity in strategic themes and favoring regional economic development (MORAIS, 2019). The innovation ecosystems of the regions of the Lisbon Metropolitan Area, North, which includes the city of Porto, and Centre, which includes the city of Coimbra, stand out, with some institutional robustness, including the capacity to lead international projects. (SANTOS et al., 2020).

The system of financial incentives for innovation in Portugal comprises three main funding lines with specific purposes, these are the incentive systems for business innovation and entrepreneurship (SI Inovação), for the qualification and internationalization of Small and Medium Enterprises (SI Internacionalização), and for business R&D (SI I&D) (MORAIS, 2019). For the context of encouraging R&D+I and the relationship between HEIs and companies, the Innovation and R&D Sis hold the most relevant roles.

The objectives of the SI Inovação, whose budget and strategies are formulated and managed by the Agency for Competitiveness and Innovation (IAPMEI), are to reinforce business investment in innovative activities and contribute to the internationalization of the Portuguese economy and to the creation of qualified employment. There are three fostering instruments in IAPMEI's arsenal, namely: Productive innovation in non-SME companies, Qualified and creative entrepreneurship, Productive innovation in SMEs (MORAIS, 2019).

The SI R&D, administered by the National Innovation Agency (ANI), promotes partnerships and synergies between companies, R&D centers, HEIs and other organizations through smart specialization. Its objectives are to provide an increase in business investment in R&D+I, strengthen the connection between companies and technological infrastructures, increase the number of knowledge-intensive companies and develop new products and services in the most knowledge- and technology-intensive activities (MORAIS, 2019).

However, a striking aspect differentiates the US and Portuguese innovation ecosystems. The former was built on a robust legal and institutional framework of incentives for R&Di and the transfer of knowledge from academia to companies, being, still, strongly financed by public resources. The second, despite being inserted in a strategic context that seeks the integration between the various member countries and actors of the European community, relies essentially on public funding instruments.

Next, it seeks to illustrate how North American academic institutions have structured their TTOs to act in the innovation ecosystem and the results achieved in terms of transfer of the knowledge produced by their research groups to the market. Finally, a contrast is drawn with the models practiced by Portuguese HEIs in order to verify common practices and points of possible improvement in the Portuguese model.

2 METHODOLOGY

This article will analyse the practices and strategies adopted by leading American academic institutions with regard to the management, valorisation and transfer of knowledge produced by associated research groups. The aim is to draw a parallel with what is practiced in Portuguese universities, observing the similarities and differences between the American and Portuguese realities. In a complementary manner, key indicators are presented, such as the number of invention notifications received, license agreements signed and spin-offs created, as well as the volume of income earned by negotiated technologies.

As references, three US HEIs were selected for their recognized reputation and leading role in technological development and knowledge transfer to society, namely: the Massachusetts Institute of Technology (MIT), the University of Texas and Carnegie Mellon University (CMU). The Portuguese context will be represented by an overview of the practices adopted by the universities that most publish academic work and most file patent applications, namely: Universities of Lisbon, Porto, Aveiro and Nova de Lisboa.

MIT, a prestigious teaching and research institute located in Cambridge, Massachusetts, has been the birthplace of over 280 companies and is an absolute reference in technology transfer to the market. It is estimated that start-ups originating from MIT generate over $200 billion in sales per year for the US economy (O'Shea et al, 2005, 2007). In 2022, the institution invested almost $1.9 billion in research, filed over 311 US patent applications and promoted the creation of 27 new start-ups from technologies conceived within the Institute's domains.

Another major US university selected to feature in this comparative exercise is Carnegie Mellon University. Located in Pittsburgh, Pennsylvania, Carnegie Mellon is known for its strong emphasis on research and innovation, with specialisms in areas such as computer science, robotics and engineering. The university's technology transfer office, called the Technology Transfer Center, has an impressive track record of partnering with industry and commercializing technologies developed by the university.

In the Portuguese context, the analysis will be conducted on models, strategies and results of a set of institutions representative of the ecosystem as a whole. To this end, it is inferred that the institutions responsible for the largest volumes of academic publications and patent deposits in Portugal will be considered, as well as the technology transfer efforts of these institutions. This analysis will enable a comparison between the North American scenario, with its renowned universities and established technology transfer models, and the

Portuguese scenario, with its own specific characteristics and challenges concerning the transfer of knowledge and technology from academia to society.

In conclusion, technology transfer is a collaborative process that aims to bring scientific discoveries, knowledge and intellectual property generated by academia to public and private use. The North American academic ecosystem, driven by perennial state policies, has been a reference in the transfer of knowledge to industry and society, with examples of renowned universities such as the Massachusetts Institute of Technology (MIT), Carnegie Mellon University and the University of Texas.

In the Portuguese context, it is important to analyse representative institutions of the academic ecosystem and their technology transfer efforts in order to understand the particularities of this scenario. The comparison between these two contexts can provide valuable insights for the development of effective knowledge and technology transfer strategies in academic environments.

3 TECHNOLOGY TRANSFER MODELS FROM MIT, CARNEGIE MELLON UNIVERSITY AND THE UNIVERSITY OF TEXAS

MIT, Carnegie Mellon University and the University of Texas are internationally recognized for their significant contributions to innovation in various technological fields. Each of these institutions adopts a set of approaches that have in common the purpose of encouraging collaboration between researchers and companies, facilitating the commercialization of inventions and scientific discoveries and promoting the transfer of knowledge to society.

The driving force behind the contributions of these institutions to technological innovation lies in the inventive capacity that each of them cultivates with its faculty and students. The generation of potentially innovative solutions is illustrated by the volume of invention notifications received by the technology transfer offices of these institutions. As shown in figure 1, MIT research groups generated an average of almost a thousand inventions in the 6 years between 2015 and 2021. In the same period, the technology transfer offices at Carnegie Mellon and the University of Texas received an average of close to 400 inventions per year.

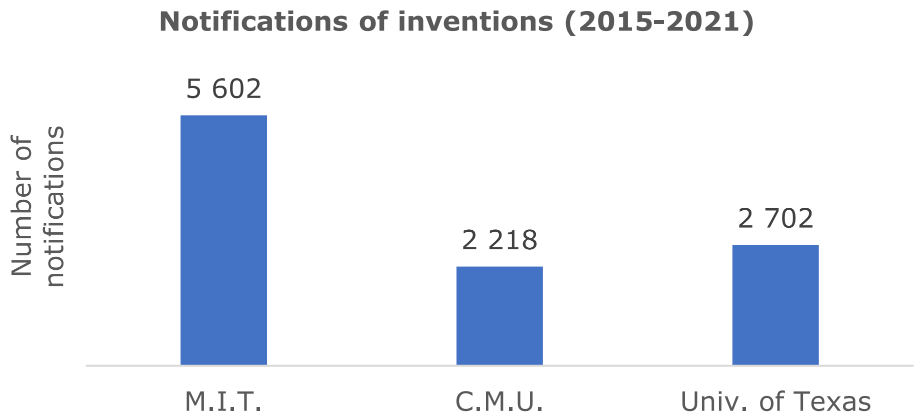

Figure 1: Number of invention notifications received by the technology transfer offices of the selected US universities.

Source: Universities' websites; own preparation.

The large number of inventions generated translates into a significant volume of deals signed involving intellectual assets of the respective institutions. Between the years 2015 and 2021, MIT, CMU and the University of Texas together signed more than 3,000 agreements, for a general average of about 500 technology-based transactions negotiated per year (Fig. 2).

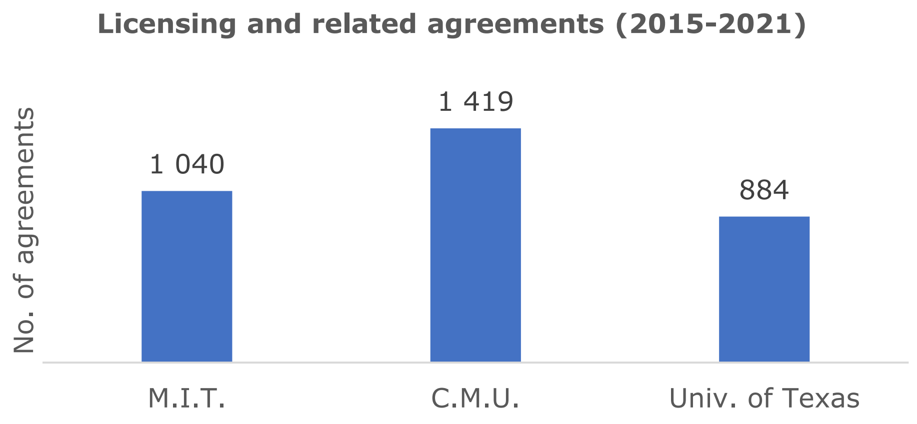

Figure 2: Number of agreements signed in the period between 2015 and 2021, including licences and licensing options.

Source: Universities' websites; own preparation.

Part of the licensing negotiated by MIT, CMU and the University of Texas resulted in the creation of *spin-offs* - technology-based companies created specifically to explore a business model centered on a university asset or technology. In the period 2015-2021, the three institutions together have enabled the creation of more than 300 companies (Fig. 3). Among the 3, MIT stands out as possibly the most entrepreneurial environment, creating almost 200 *spin-offs*.

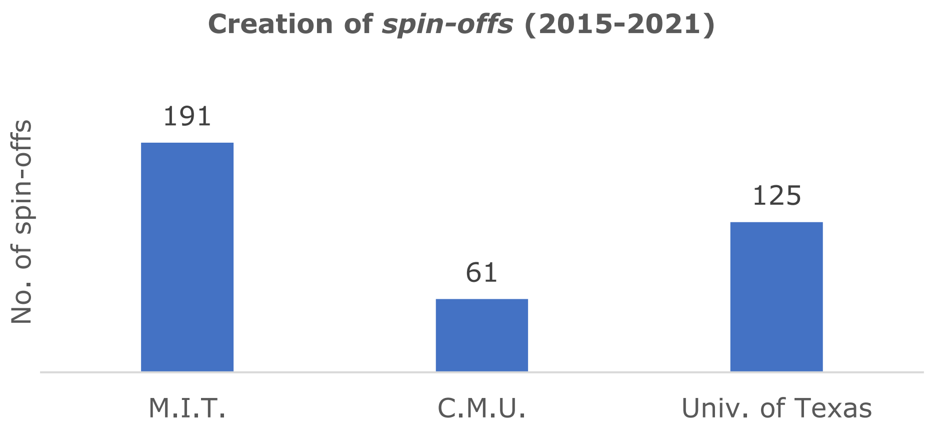

Figure 3: Number of spin-offs created from technologies developed at universities indicated between 2015 and 2021.

Source: Universities' websites; own preparation.

Ultimately, technologies generated within the domains of MIT, CMU and the University of Texas jointly generated more than $600 million in revenue for the three universities between 2015 and 2021 (Fig. 4). MIT's licensed assets returned just over $400 million, an impressive average of almost $70 million per year. CMU and University of Texas had financial benefits of around US$90 and US$130 million, respectively.

The financial revenues from licensing contribute to the perpetuation of a virtuous cycle of academic R&D. Resources invested in cutting-edge scientific research are transformed into new technologies that, consequently, provide the basis for new transactions which, in turn, mediate the transfer of high value-added knowledge to society and bring more investment to the institutions involved.

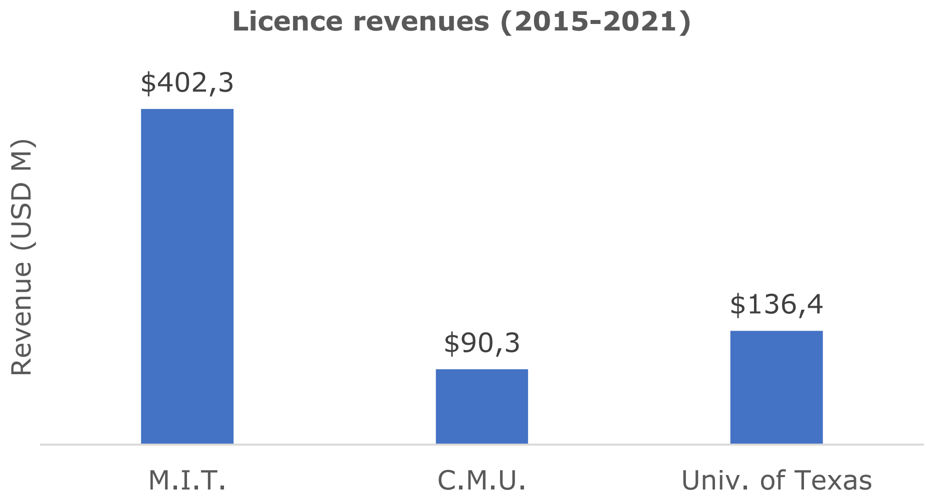

Figure 4: Revenues received between 2015 and 2021 derived from traded technologies.
Source: universities' websites; own preparation.

The following details the practices of the technology transfer offices associated with each of the aforementioned institutions, which have enabled them to achieve the aforementioned marks.

3.1 Massachusetts Institute of Technology - MIT

Massachusetts Institute of Technology's (MIT) TTO connects companies with cutting-edge research and innovations from the university. This program has successfully facilitated collaborations and partnerships between various companies and MIT researchers, resulting in numerous innovative technologies and products. The ILP takes advantage of resources such as the MIT Startup Exchange, where startups can access mentoring, funding and networking opportunities.

MIT has a strong focus on technology transfer and entrepreneurship, making clear and legally grounded such intent already in its IP policies. As the Institute states, the aim of the policy on patents, copyright and other intellectual property is to make the Institute's technology available to industry and others for public benefit, while at the same time providing recognition to individual inventors and encouraging the immediate and open dissemination of research results.

The Institute's Intellectual Property Policy has specific chapters dealing with ownership, mandatory disclosure of inventions, licensing of IP rights, the possibility of return of ownership of an asset to inventors, among other IP administrative aspects. The MIT maintains a public record of updates to its IP Policy since 2007, ensuring transparency and explaining the evolution of its IP practices.

The process of admitting a new technology to the MIT portfolio begins with the submission, by a researcher or research group, of an Invention Disclosure Form to the TTO. At this point, the technology is evaluated for commercial potential and patentability, particularly considering: (1) solved problems or unmet needs addressed by the technology, (2) potential market-sized applications, (3) potential competitors/partners, and (4) potential challenges to patenting and commercialization; all with support from internal collaborators and external experts.

When an intellectual property asset owned by MIT is licensed and generates revenue, the TTO distributes the amounts, after all operating and patent expenses of the TLO are reimbursed, among (a) inventors, authors and collaborators of such intellectual property (as applicable); (b) co-owners of the IP (as applicable); (c) relevant MIT departments, laboratories and centers; and (d) the MIT General Fund to be used for educational and research purposes.

In its entire history, the MIT TTO has received over 22,000 invention notifications and signed over 3,000 technology licensing agreements. That is, almost 15% of the technologies developed by MIT have already been licensed. In addition, the Institute's TTO has contributed to the creation of more than 500 companies, including Akamai Technologies, 3Com Corporation and Genzyme Corporation. MIT's involvement in founding the Cambridge Innovation Centre (CIC) has also contributed to the growth of the ecosystem of start-ups in the Boston area.

One of MIT's many initiatives is the Deshpande Centre for Technological Innovation, which has successfully commercialized more than 30 projects, including advanced materials, biotechnology and energy solutions. One example is A123 Systems, a company developing advanced lithium-ion batteries and energy storage systems. Currently, MIT has annual revenue derived from licensing IP assets in the range of $80 million.

3.2 Carnegie Mellon University - CMU

CMU's Technology Transfer and Enterprise Creation Centre (CTTEC) has been successful in commercializing technologies and supporting start-ups.

CMU's IP Policy is also grounded on purposes of generating knowledge and transmitting it to the wider society, ensuring the sharing of benefits with those involved. Specifically, the objectives of the IP Policy are (1) to create a university environment that encourages the generation of new knowledge by faculty, staff and students; (2) to facilitate the broad transfer of useful inventions and writings to society; (3) to motivate the development and dissemination of intellectual property by providing appropriate financial rewards to creators and the university and administrative assistance to creators (CARNEGIE MELLON UNIVERSITY, [s.d.]).

A rather interesting point of the pillars of CMU's IP Policy is the intention to ensure that the financial return from the development of intellectual property does not distort the university's decisions and operations in a manner contrary to the university's mission - to produce and disseminate knowledge. Still, the policy provides that there should be incentives for all parties to seek financial rewards together, consistent with the expressed objectives of the policy. The distribution of these rewards should reflect, as far as possible, the creative contributions of the creator and the resources contributed and risks taken by the creator and the university in developing the intellectual property (CARNEGIE MELLON UNIVERSITY, [n.d.]).

As usual, the process of admission of a technology in CMU's portfolio also begins with the disclosure of a creation, by a researcher or research group, to the technology transfer office of the university - called CTTEC (*Center for Technology Transfer and Enterprise Creation*). Then, the matter is evaluated as to its possibility and protection modality (*e.g.* by patent).

Next, CTTEC, with support from internal collaborators and external experts, conducts a rigorous market viability assessment to design a commercial strategy. When, at the end of this exercise, the research group decides to create a company to exploit the creation, CTTEC assesses resource needs and administrative tasks, helps identify resource needs for prototyping and proof-of-concept execution, provides advice on regulatory requirements, and assists in the development of the business plan (CARNEGIE MELLON UNIVERSITY, [n.d.]).

Over the past 5 years, more than 350 licenses, options and other agreements have been signed and 50 spin-outs have been successfully established. CMU has a strong focus on robotics, artificial intelligence (AI) and computer science, which has led to the creation of successful companies such as Uber's autonomous car division (formerly known as Uber Advanced Technologies Group) and Duolingo, a popular language learning platform (CARNEGIE MELLON UNIVERSITY, [n.d.]).

3.3 University of Texas

The University System of Texas, referred to only as the University of Texas, comprises 8 academic institutions of higher learning and 5 research and health service delivery entities. Each of the academic arms has an independent office for knowledge management and commercialization. However, all meet a common rulebook, built to be adaptable to the highly varied circumstances that characterize the private sector and research portfolio at U. T. System institutions (THE UNIVERSISTY OF TEXAS SYSTEM, [n.d.]).

The fundamental principles governing the University of Texas' relationship with its intellectual property assets highlight the role of technology transfer in fulfilling the University's mission and place businesses at the heart of the strategy of transforming academic knowledge into well-being within reach of the broad public (THE UNIVERSISTY OF TEXAS SYSTEM, 2015).

The University of Texas system has implemented several initiatives to promote technology transfer and entrepreneurship (THE UNIVERSISTY OF TEXAS SYSTEM, [s.d.]). Inventors and entrepreneurs in the system rely on an ecosystem of support for innovation and entrepreneurship that includes:

- *Office of Industry Engagement*: charged with negotiating all research contracts sponsored exclusively by industry.
- *Office of Sponsored Projects*: Supports teachers and researchers in their efforts to secure and ensure the proper administration of external funding.
- *Innovation Center*: Helps create and foster a culture of entrepreneurship in support of technology commercialization. Provides coworking space; wet lab space; workshops and marketing support training; connections to incubators, accelerators, mentorships and investors.

- *Incubator*: supports university entrepreneurs in efficiently commercializing innovations in local and global markets.

In addition to the support structure, the University of Texas System has the *UT Horizon Fund*, a strategic investment fund that supports the commercialization of technologies developed at UT institutions. The fund was created in 2011 to help System-related companies create social and financial wealth. The UT Horizon Fund has committed US$50 million to date, ranking among one of the leading university-sponsored strategic investment vehicles in the United States (THE UNIVERSISTY OF TEXAS SYSTEM, [n.d.]).

In sum, the US HEIs taken as reference present a clear process of monitoring, reception and analysis of the intellectual creations derived from the research activities they sponsor. In the three cases described here, there is an explicit focus on taking the knowledge produced academically to the wider society, with private initiative as the main vehicle of this trajectory. The main elements offered by each of the afore mentioned HEIs to support, stimulate and finance inventiveness and entrepreneurship are summarized in Table 1.

Table 1: Summary of frameworks for IP asset management and knowledge transfer maintained by MIT, the University of Texas system and CMU.

Attribute	MIT	University of Texas	CMU
Internal and external structures for knowledge and IP management	Yes	Yes	Yes
Specialised technical areas	Yes	Yes	Yes
Competitive monitoring	Yes	Yes	Yes
Ownership of the research and results	100% institution	100% institution	100% institution
External audit of TTO	Yes	Yes	Yes
International presence	Yes	Yes	
Policy to encourage researchers	Yes	Yes	Yes
Incubator	Yes	Yes	Yes
Accelerator	Yes	Yes	Yes

Attribute	MIT	University of Texas	CMU
External advice (Business, finance, IP, etc.)	Yes	Yes	Yes
Investment and conflict of interest committee	Yes	Yes	Yes
Provides support for business model creation and commercialisation	Yes	Yes	Yes
Provides training advice and business benchmarking	Yes	Yes	Yes
Possibility of TTO participation in spin-offs	Yes	Yes	Yes
Forms of TTO participation in *spin-offs* (*e.g.* equity)	Case by case	Case by case	<50%
Private funding	*VC and MIT fund instruments*	*VC Seed Fund* *UT Horizon Fund*	*VC Venture Bridge program*

Source: Own preparation based on information disclosed by the institutions.

4 TECHNOLOGY TRANSFER MODELS FROM PORTUGUESE UNIVERSITIES

As with their American counterparts analysed in the previous chapter, Portuguese Higher Education Institutions (HEIs) recognize technology transfer as one of the main pillars for valuing the institution's intellectual property, the possibility of a return, even if partial, on the investment made in R&D activity and its protection by IP rights, the stimulation of business relations and the promotion of entrepreneurship for the creation of economic value for the country.

Technology transfer is a complex process and depends on several factors, including the nature of the technology, the interest of the business sector, the ability to negotiate and the availability of resources. Thus, the technology transfer model implemented in the different Portuguese HEIs may vary, since each institution may have its own specific policies and approaches to promote technology transfer. However, in a more global analysis we can infer that there are common aspects in the technology transfer model adopted by many national HEIs.

Technology Transfer Offices: Most Portuguese universities have a Technology Transfer Office (TTO) or a similar structure dedicated to the management and promotion of technology transfer. These offices act as intermediaries between academia and the business sector, facilitating the licensing of technologies, the creation of spin-offs and other forms of collaboration.

Patents and Intellectual Property: Universities encourage the protection of intellectual property, through obtaining patents and other intellectual property rights, for the innovations developed by their researchers. There is a strong incentive for the licensing, often on an exclusive basis, of IP rights to new companies, academic spin-offs, allowing them to develop and commercialize future products arising from these technologies.

Collaboration with Companies: Portuguese universities seek to establish research and development partnerships with companies, aiming at transferring knowledge and technology. These collaborations may involve joint research projects, consultancy contracts, internships in companies for students and other forms of interaction.

Creation of Spin-off Companies: Universities in Portugal have increasingly encouraged the creation of spin-off companies, which are technology-based companies originated from research and technologies developed within higher education institutions. These spin-offs receive institutional support for their creation and development, including access to infrastructure, mentoring and financial resources.

Funding Programs: There are several funding programs available in Portugal, both at national and European level (see point 1.1), which aim to support technology transfer and collaboration between universities and enterprises. These programs offer funding for joint research projects, prototype development and technology transfer activities.

5 TECHNOLOGY TRANSFER MANUAL

5.1 Management of R&D projects and internal dissemination

R&D project management refers to the management of research and development projects to ensure their successful execution from inception to completion. Managing R&D projects involves overseeing the planning, coordination, execution and monitoring of activities aimed at achieving specific research and development objectives. In this sense, project management can be divided into the following phases.

Initiation phase. In the initiation phase, the project should be clearly defined, including the expected objectives, the scope and resources of the project, and the role of each team member required. Clarifying what the expectations of the project are, and what exactly the project aims to achieve (and why) will give the project and the team a clear direction. At this stage, it is necessary to communicate with project investors or sponsors and understand the desired outcomes, define SMART (Specific, Measurable, Attainable, Relevant and Time-bound) objectives, clarify resources such as budget and people, define roles and determine checkpoints for the project.

This is a crucial phase for project success, because without clarity about what needs to be achieved and why, the project runs the risk of not achieving the final objectives.

Planning phase. In the planning phase, it is necessary to determine the steps to achieve the project objectives. It is necessary to establish budgets, deadlines, milestones, source materials and necessary documents. This stage also involves calculating and forecasting risks, implementing change processes and defining communication protocols. At this stage, NDAs and RFPs can be created. The end of planning is marked by a kick-off meeting.

Execute and complete tasks. During this phase, you need to keep the action plan on track, which means tracking and measuring progress, managing quality, mitigating risks, managing budget and checking project status. GANTT and burndown charts can be used to track the progress of tasks.

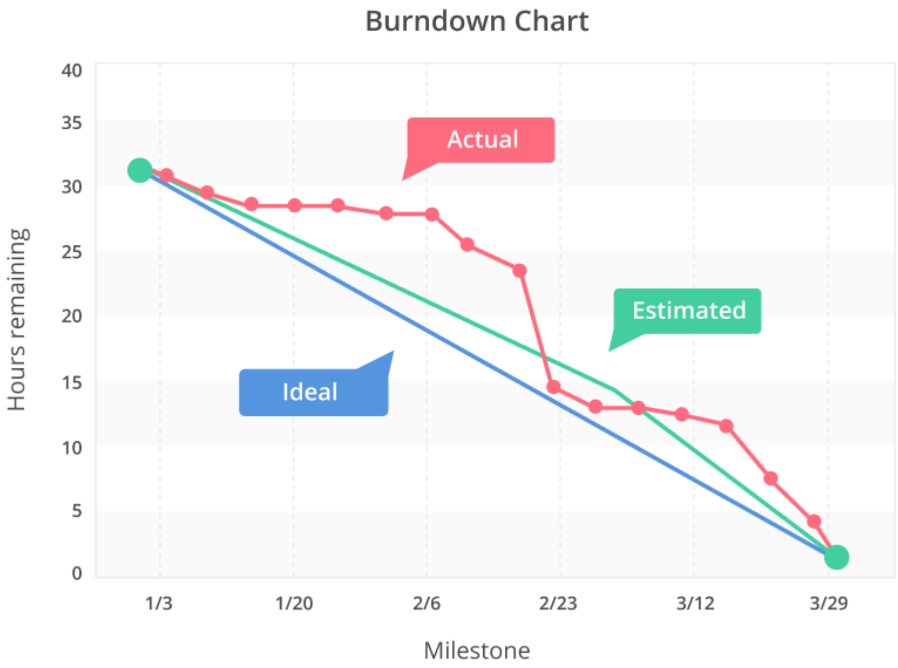

Figure 5Burndown chart.

Source: https://backlog.com/wp-blog-app/uploads/2020/01/burndown@2x.png.

Closing phase. In the closing phase of the project management life cycle, it is necessary to complete project activities, deliver the finished product or service to its new owners, and assess areas of opportunity for the project. It is recommended to conduct retrospectives and take notes of changes that can be implemented in the future, to communicate with the new owners of a project and to create a project closure report.

5.1.1 Open innovation

Open innovation is a collaborative approach to innovation that involves seeking and using external ideas, technologies and resources, as well as sharing internal ideas and technologies with external parties. The concept was first introduced by Henry Chesbrough in his book "*Open Innovation: The New Imperative for Creating and Profiting from Technology*" in 2003.

In contrast to traditional closed innovation, where firms rely primarily on their internal R&D efforts to generate new ideas, open innovation recognizes that valuable ideas and technologies can come from a variety of sources, including customers, suppliers, competitors and academic institutions. Open innovation seeks to harness this external knowledge and expertise to accelerate innovation, reduce R&D costs and increase the likelihood of commercial success (Chesbrough et al., 2006). By connecting to an external pool of knowledge and ideas, firms can continue to innovate and thrive. Proctor & Gamble's "Connect & Develop" and Philips' "High-Tech Campus Eindhoven" are some examples of successful implementation of Open Innovation.

Therefore, open innovation refers to a business management model based on the belief that a company can benefit from collaborations with external sources. This collaboration can take many forms, such as strategic partnerships, joint ventures, licensing agreements, crowdsourcing and innovation challenges. It requires a culture of openness, collaboration and trust, as well as effective communication and intellectual property management to protect the interests of all parties involved.

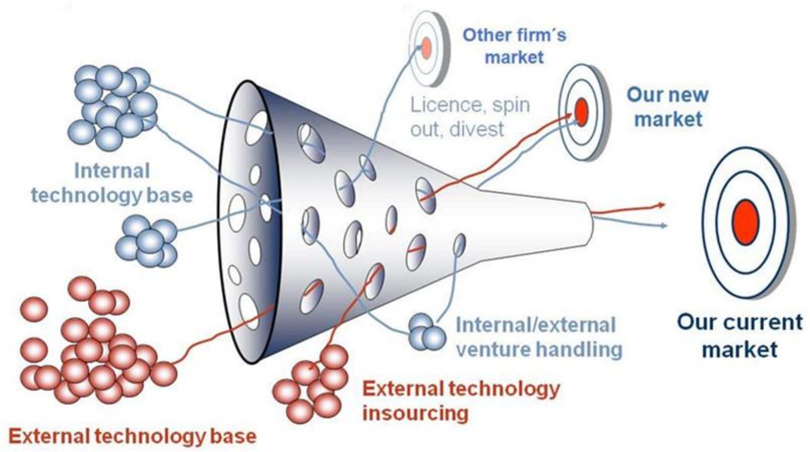

Figure 6: Open innovation.

Source: https://www.eoi.es/blogs/imsd/innovation-what-is-open-innovation.

5.1.2 Definition of Technology Scouting

At the heart of open innovation is the ability of a firm to identify technologies that are in tune with its goals and objectives. Competitive advantage is largely determined by the adoption of innovative technologies and therefore early identification of these technologies is critical.

There are different methods to identify future trends and reduce uncertainty by analyzing new and emerging technologies. These methods can be called *External Technology Searches* (ETS) and aim at bringing new technologies to a company. There is much research in this field; however, authors use different formulations and terminology to describe their methods, namely *Technology Forecasting*, Technology *Foresight*, *Technology Intelligence* or

Technology Scouting. All these terms have different meanings, but their research has been correlated over time, as shown in the following figure:

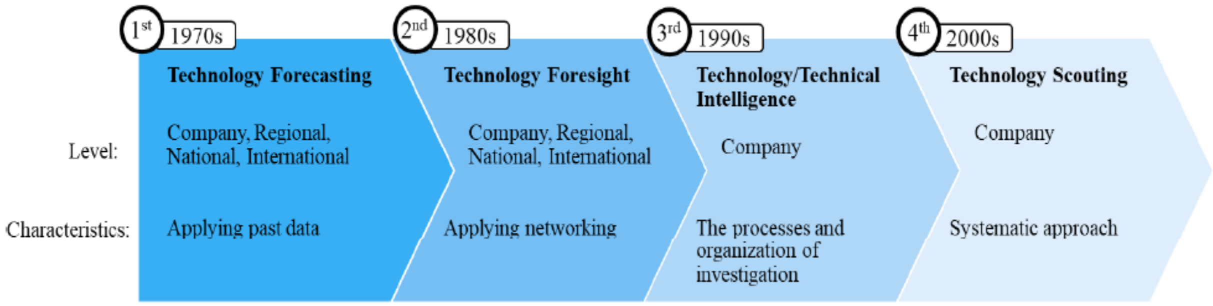

Figure 7: Evolution of ETS terminology.

Source: " External technology searching methods - a literature review " (2019), based on Chan and Daim (2012) and Gudanowska (2016).

Therefore, the concept of ETS has evolved over time, with a broader scope, as described in figure 8:

- ***Technology Forecasting*** is the process of forecasting future technological advances and trends based on current and historical data as well as expert analysis and input. The goal of technology forecasting is to help individuals and organizations stay ahead of the curve by identifying emerging technologies and trends that may impact their industry or domain.
- ***Technology Foresight*** is a broader term. It comprises a systematic and participatory approach to forecasting future technological developments and their potential impacts on society and the economy. It involves a wide range of stakeholders, including researchers, policy makers, industry representatives and civil society organizations, working together to develop a shared understanding of the future of technology and its implications. It therefore includes aspects of networking at broad levels, as well as preparation for decision-making.
- ***Technology Intelligence*** refers to the process of gathering, analyzing and using information about new and emerging technologies to gain a competitive advantage in a particular market. This may involve tracking trends, monitoring competitors, assessing the potential impact of new technologies and developing strategies to implement or invest in those technologies.
- ***Future Analysis***, on the other hand, take a longer-term view, looking at the broader social, economic and environmental factors that are shaping the future of technology. Future studies often involve scenario planning, in which various possible futures are

envisaged and analyzed, and can draw on a range of disciplines such as sociology, economics and political science.

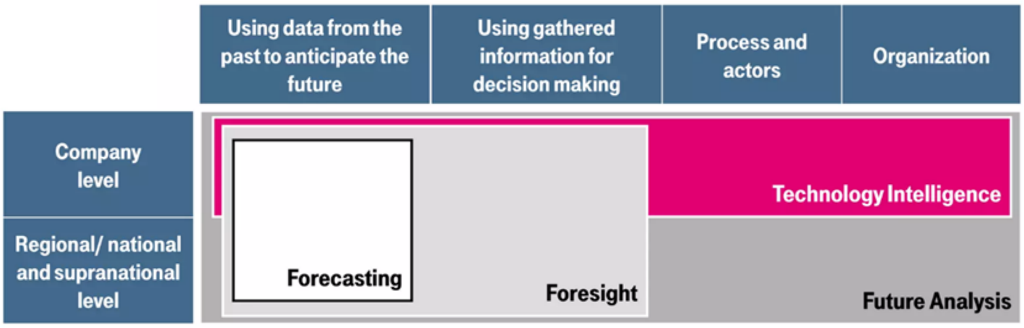

Figure 8: Scientific classification of ETS-related terms.

Source: "External technology searching methods - a literature review" (2019), based on Rohrbeck (2007).

What is technology scouting?

Technology scouting is the systematic process of searching for and identifying external technologies and innovations that can be integrated into a company's product or service offerings, as well as identifying new market opportunities and potential partners for collaboration.

In an open innovation context, technology scouting involves actively seeking external sources of innovation, including start-ups, research institutions, suppliers and customers. The aim is to identify new and emerging technologies that can help solve business challenges, improve the characteristics of products or services, or create new market opportunities. Technology scouting often involves a combination of online research, participation in industry events and conferences and networking with potential partners.

Technology scouting is important for companies and organizations that want to stay ahead of the curve and remain competitive in their sectors. By identifying and integrating external technologies and innovations, companies can improve their products and services, reduce R&D costs and accelerate time to market. In an open innovation context, technology scouting can also lead to new business models, strategic partnerships and collaborations that can drive growth and long-term success.

Technology scouting can provide a variety of benefits for organizations, including:

I. ***Competitive advantage***: By keeping up to date with the latest technologies and identifying emerging trends, organizations can gain a competitive advantage over their rivals.

II. ***Innovation***: Technology scouting can help organizations identify new and innovative ideas that can be used to improve their products or services.

III. ***Cost savings***: By identifying technologies that can streamline operations or reduce costs, organizations can save money in the long term.

IV. ***Improved decision making***: By gathering information on emerging technologies and industry trends, organizations can make more informed decisions about their future strategies.

V. ***Partnerships and collaborations***: Technology scouting can also help organizations identify potential partners or collaborators who can help them develop new products or expand their business.

VI. ***Risk management***: By monitoring emerging technologies and trends, organizations can identify potential risks and take action to mitigate them before they become serious problems.

Overall, technology scouting can help organizations stay competitive, drive innovation and make better decisions about their future strategies.

Relationship between technology scouting, technology intelligence and technology management

The concept of technology scouting is closely related to technology intelligence and technology management. Rohrbeck's Figure 9 (2007) helps to understand the synergies between these three elements.

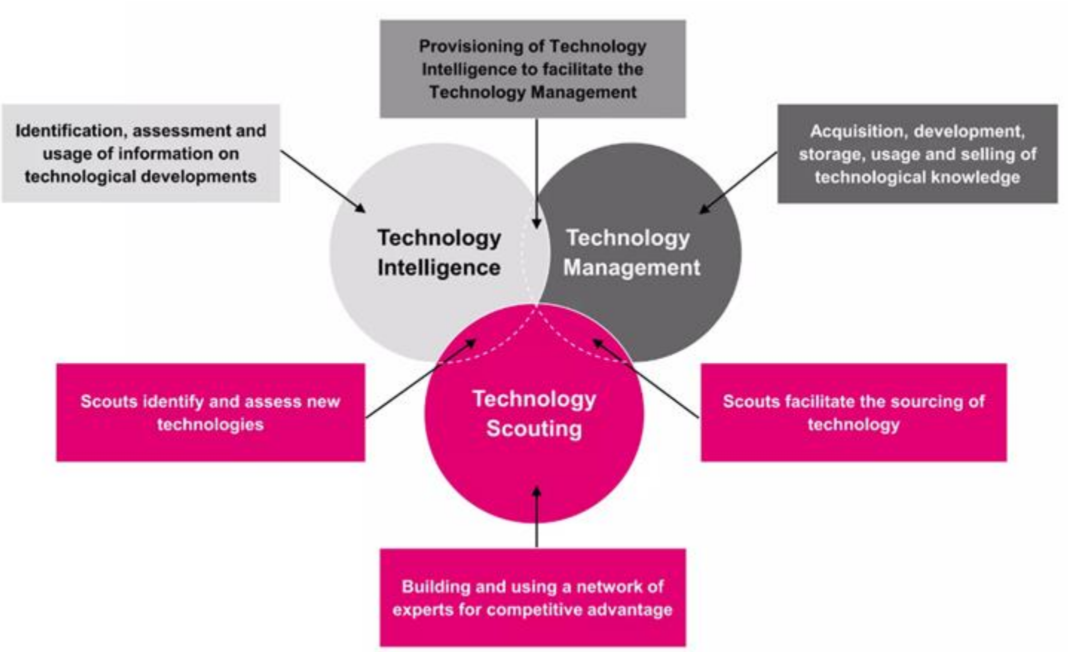

Figure 9: The scientific classification of technology scouting.

Source: "External technology searching methods - a literature review" (2019), based on Rohrbeck (2007).

While Technology Intelligence refers to the process of collecting, analysing and disseminating information about technological developments, trends and emerging technologies in a particular domain or sector, technology scouting refers to the process of identifying and assessing new technologies with the potential to increase an organization's competitive advantage.

On the other hand, Technology Management refers to the process of planning, organizing and controlling the development, implementation and maintenance of technology within an organization. It involves the management of technology resources, including human resources, financial resources and physical infrastructure, to maximize their impact on organizational performance. Technology management includes R&D strategy development, product development, project management and innovation management.

Therefore, management includes the integration of strategies to obtain more intelligence, find opportunities, develop and implement technological capabilities and planning in the company. It can be said that technology scouting is a means to increase technology intelligence and facilitate technology management. In summary, Technology Intelligence, Technology Scouting and Technology Management are three important concepts that are crucial for organizations to remain competitive and innovative. They are interconnected and organizations must use them in an integrated manner to attain their strategic objectives.

The process of technology scouting

The methodology for technology scouting can vary depending on the organization's objectives and resources, but some common steps include:

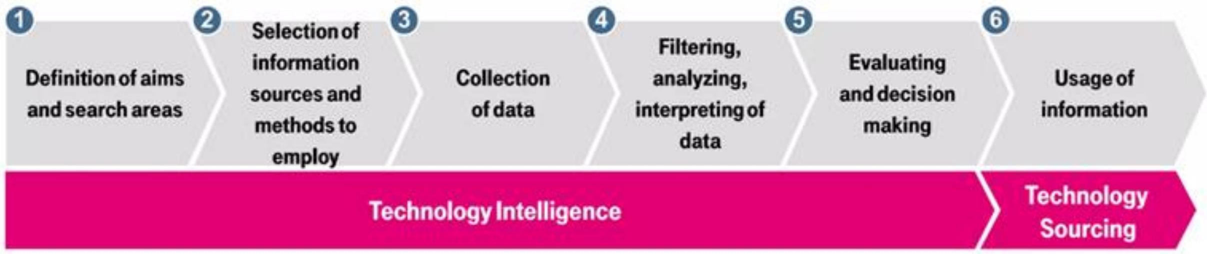

Figure 10: Stages of technology scouting.

Source: "Technology Scouting - a case study of the Deutsche Telekom Laboratories" (2007), Reger (2001) and Ashton/ Stacey (1995).

I. **Define the objectives and research areas**: The first step is to define the focus area and scope of the technology scouting effort. This involves identifying the key business challenges or opportunities facing the organization and the technology domains that are relevant to solving them.

II. **Selecting sources of information**: Once the scope is defined, the next step is to identify potential sources of new technologies and innovations. This may include academic research, start-up companies, industry conferences and publications, patent databases and other sources.

III. **Data collection**: Once potential sources have been identified, collecting data from a variety of sources is critical to building a comprehensive understanding of technology trends and emerging new technologies and their impact on the organization.

IV. **Filter, analyze and interpret data**: the next step is to select and prioritize data based on criteria such as the maturity of the technology, the potential impact on the organization and the alignment with the organization's strategic objectives.

V. **Assess**: the most promising technologies in more depth. This may include conducting pilot projects, analyzing technical feasibility and market potential, and assessing the intellectual property landscape. Based on this assessment, the organization can select the technologies to pursue.

VI. **Use information**: When a technology is selected for further development, the organization may seek partnerships and collaborations with technology providers, such as licensing agreements or joint development projects.

The technology scouting process requires continuous monitoring of the technology landscape and adapting the methodology to changing business needs and emerging technologies. This involves regularly searching for new technologies and innovations, re-evaluating existing technologies and refining the criteria used to prioritize and select technologies.

Technology scouting tools

There are many tools and resources that can be used for technology scouting, depending on the scope and needs of the project. Here are some of the most commonly used technology scouting tools:

- *Patent databases*: Patent databases such as the United States Patent and Trademark Office (USPTO)[1] , the World Intellectual Property Organization (WIPO)[2] and the European Patent Office (EPO)[3] can be used to search for technologies that have been patented in specific areas. In general, they provide a wealth of information on new and emerging technologies, and the companies and individuals developing them.
- *Research article databases*: Research article databases such as IEEE Xplore[4] , ScienceDirect[5] , Google Scholar[6] , Scopus[7] and Web of Science[8] can be used to search for new technologies being developed in academic institutions.
- *Technology news Internet*: Technology news websites such as TechCrunch[9] , Wired[10] and The Verge[11] can be used to keep up to date with the latest technology trends and developments.

[1] https://www.uspto.gov/patents/search

[2] https://patentscope.wipo.int/search/en/search.jsf

[3] https://www.epo.org/searching-for-patents.html

[4] https://ieeexplore.ieee.org/Xplore/home.jsp

[5] https://www.sciencedirect.com/

[6] https://scholar.google.es/

[7] https://www.scopus.com/home.uri

[8] https://clarivate.com/products/scientific-and-academic-research/research-discovery-and-workflow-solutions/webofscience-platform/

[9] https://techcrunch.com/

[10] https://www.wired.com/

[11] https://www.theverge.com/

- *Databases of start-ups, accelerators and incubators*: Databases of start-ups, such as Crunchbase[12] and AngelList[13] , can be used to identify emerging start-ups developing new technologies. In addition, start-up accelerators and incubators provide a way to connect with early stage companies that are developing new technologies. These organizations can provide access to resources, guidance and investment opportunities.
- *Innovation poles and clusters*: Innovation poles and clusters are geographic regions where several companies, academic institutions and other organizations are focused on innovation and technological development. These regions can be a valuable source of information and opportunities for collaboration.
- *Industry events*: Industry events such as fairs, conferences and seminars can be used to network with experts in a particular field, learn about new technologies and see demonstrations of cutting-edge products and services.
- *Innovation management platforms*: Innovation management platforms such as IdeaScale[14] , Brightidea[15] and Spigit[16] can be used to collect and evaluate ideas from employees, customers and other stakeholders.
- *Market information platforms*: Market information platforms, such as CB Insights[17] and Gartner[18] , can be used to track technology trends and identify potential disruptors in a particular sector.
- *Open innovation platforms*: Open innovation platforms, such as InnoCentive[19] and NineSigma[20] , can be used to connect with external experts and solve specific technological challenges.

[12] https://www.crunchbase.com/

[13] https://www.angellist.com/

[14] https://ideascale.com/

[15] https://www.brightidea.com/

[16] https://www.ideaconnection.com/software/spigit-273.html

[17] https://www.cbinsights.com/

[18]https://www.gartner.com/reviews/market/competitive-and-market-intelligence-tools-for-technology-and-service-providers

[19] https://www.wazoku.com/challenges/

[20] https://www.ninesigma.com/

- *Technology scouting software*: There are many software platforms available that can help simplify and automate technology scouting processes, such as Cipher[21] , PatSnap[22] and Innography[23]. These tools use artificial intelligence and machine learning algorithms to analyze large amounts of data and identify potential technologies and trends.
- *Consulting firms and experts*: Finally, consulting firms and experts can provide expertise and experience in specific technology areas, as well as help with scouting strategies and technology implementation.

Among the technology scouting tools, the *Technology Radar* solution deserves special mention. This solution was proposed by the Deutsche Telekom Laboratories (Rohrbeck et al., 2006) and brought major contributions to innovation and technology management. The Technology Radar is essentially a visual tool used for technology scouting, which was developed and applied in industry by ThoughtWorks, a global software consulting company, based on the idea of a radar chart that visualizes the distance of various technologies from the center (the most promising and widely adopted) to the extremities (the least mature and least adopted).

The *Technology Radar* is originally divided into four quadrants, centered on the software sector:

I. ***Techniques***: This quadrant includes methodologies, practices and processes that can help organizations improve their software development processes and delivery capabilities.

II. *Tools*: This quadrant includes software tools and frameworks that can help organizations create better software, automate processes and improve collaboration.

III. ***Platforms***: This quadrant includes platforms and technologies that provide infrastructure for software creation and deployment, such as cloud computing, containers and serverless computing.

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21 https://cipher.ai/

22 https://www.patsnap.com/

23 https://clarivate.com/products/ip-intelligence/patent-intelligence-software/innography/

IV. ***Languages and Frameworks***: This quadrant includes the programming languages and software development frameworks that can be used to create software applications.

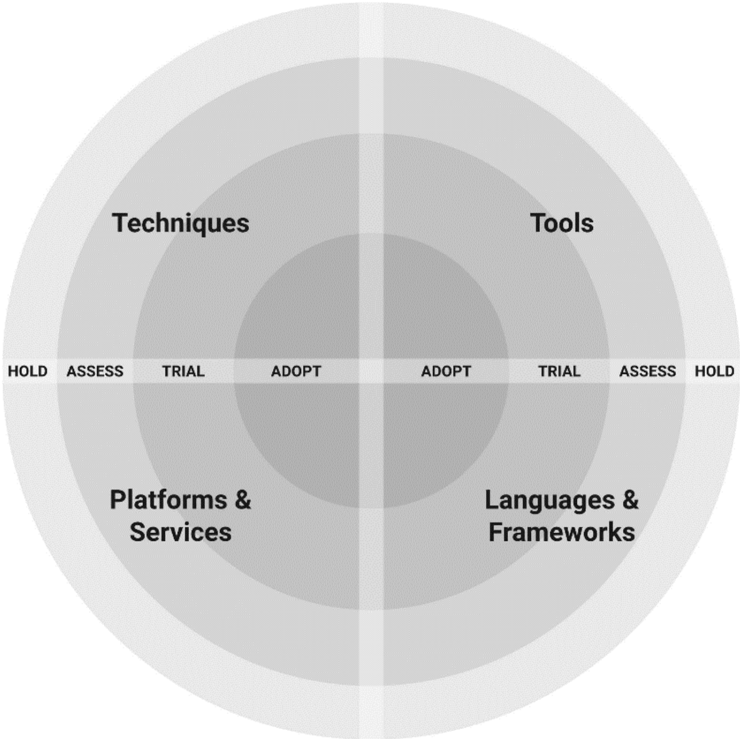


Figure 11: Technology Radar.

Source: ThoughtWorks.

These quadrants can be modified and adapted to different sectors. Then, the various technologies are categorized by their level of adoption and relevance to the organization. In that sense, some common categories that are often included in a technology radar include:

- *Adopt*: Technologies that are already in use and have proven to be successful.
- *Trial*: Technologies that are being tested or piloted to assess their potential impact.
- *Assess*: Technologies that are being researched and assessed for potential future use.
- *Hold*: Technologies that are no longer relevant or useful to the organization and should be phased out.

The *Technology Radar* is often updated on a regular basis, with new technologies being added or removed based on changes in their adoption or relevance to the organization's strategic objectives. This helps organizations stay up to date with the latest trends and innovations in technology and make informed decisions about which technologies to invest in or explore further. Overall, a technology radar can be a valuable tool for organizations looking to remain competitive and innovative in today's rapidly changing technology landscape.

5.1.3 Internal dissemination tools

Communication between research teams and technology transfer offices is very relevant to promote the effective transfer of knowledge and technologies from academia to the business sector. Researchers generate innovative ideas and discover technologies that may have significant commercial potential. By maintaining fluid communication between stakeholders, the intellectual property associated with these breakthroughs, such as patents, designs, trade secrets, copyrights or trademarks, can be readily identified and adequately protected.

There are several communication mechanisms between research teams and technology transfer offices, these ensure effective collaboration and information exchange, maximizing the impact of academic research and promoting practical applications and encouraging innovation, which leads to significant economic and social impact.

Regular meetings between research teams and TTOs to discuss ongoing projects, potential commercialization opportunities and updates on intellectual property protection are a very effective way to keep up-to-date information on R&D projects. These meetings provide an opportunity to exchange ideas, address concerns and ensure alignment between research activities and technology transfer objectives.

Project Survey Forms: These disclosures provide detailed information about your inventions, innovations or research results and serve as a basis for assessing the commercial potential and determining appropriate strategies to protect and transfer the technology.

Online platforms, formats and portals can be used to simplify communication and information sharing. These options serve as centralized repositories to present technology releases, track progress, access resources and facilitate collaboration between research teams and technology transfer professionals.

Effective communication between research teams and technology transfer offices relies on a combination of face-to-face interactions, formal agreements, evaluation processes, training initiatives and digital platforms. These mechanisms promote collaboration, knowledge exchange and successful technology transfer from academia to the commercial sector.

Clarke Modet

Technology | Technologies on the rise

- Will it work, how will it expand productively (its productive scale)?
- Will it become obsolete?
- Will I be free to commercialize it or what are the barriers to entry?
- Will it need more research and development?
- With whom to collaborate?

Market | Products on the rise

- What are the needs?
- What´s the market like?
- What will be the market penetration percentage?
- How fast the market is changing?

5.2 Preliminary assessment of the technology's potential and market viability

The research activities of higher education institutions (HEIs) often lead to discoveries and inventions that may have commercial applicability.

The first step to evaluate the developed technology and its viability in the market is to fill out and send to the TTO a **Result Communication Form**, to be filled out by the researchers with all the relevant information of each project.

In this initial phase, researchers must formally communicate their discoveries and inventions through this form, whose purpose is to collect and structure information on the technology, and not just contain a summary or technical publication. The TTO, together with the research teams, can then analyse and preliminarily assess the invention's potential and develop an adequate protection and commercialization strategy.

The assessment of the potential and commercial viability of a technology by the TTO should take into account aspects related to both the technology under development and the relevant market.

This assessment involves a considering number of factors that determine whether a technology is likely to be technologically and economically feasible, with a view to its implementation and adoption by the target market.

This involves assessing the strengths of the developed technology and comparing it with similar existing technologies.

Market factors such as demand, potential customers and competitors should also be taken into account to assess whether the technology has a realistic chance of market and commercial success.

In summary, the process of preliminary assessment of the technology's potential and market viability should assess the following aspects:

- **Technology viability:** whether the technology can be successfully developed and implemented. It includes assessment of factors such as availability of required resources, collaborative development needs, required skills, infrastructure and potential challenges or constraints.
- **Value proposition:** The value proposition of the developed technology is essential for its commercial viability. It involves identifying the main benefits and advantages offered by a development in comparison with existing alternatives. It includes consideration of factors such as cost-effectiveness, efficiency, scalability, sustainability and potential return on investment for customers.
- **Intellectual property:** Assessment of the intellectual property landscape is important to determine whether the technology is already protected. This involves conducting a thorough analysis of existing IP rights (prior art), potential infringements (FTO reports based on prior art) and the possibility of obtaining and maintaining exclusive rights over the technology.
- **Market** demand**:** Assessing market demand is key to determining whether potential customers need or want the technology developed. This requires research and analysis of the target market, identification of weaknesses or problems that the technology can solve and whether the market size and growth potential is sufficient.
- **Competitive** landscape**:** Assessing the competitive landscape helps identify existing solutions or competitors in the market. This analysis involves studying their strengths and weaknesses, their market share and their pricing and differentiation strategies. It helps to assess whether the technology has a competitive advantage or a unique selling proposition.
- **Financial considerations:** Assessing the financial viability of the technology involves examining the estimated costs of development, production, commercialization and distribution. It also includes evaluation of potential revenue

streams, pricing models, profit margins and the overall financial sustainability of the company.

- **Risk assessment:** It is essential to identify and assess the potential risks and challenges associated with the technology. This includes considering technical risks, market risks, regulatory risks and any other factors that could impede the successful adoption and commercialization of the technology.

In view of the above, it will be necessary to develop a **technology viability plan** for each R&D technology/project, which should be regularly updated as the R&D project develops, and relevant experimental results are obtained.

5.2.1 Technology viability plan:

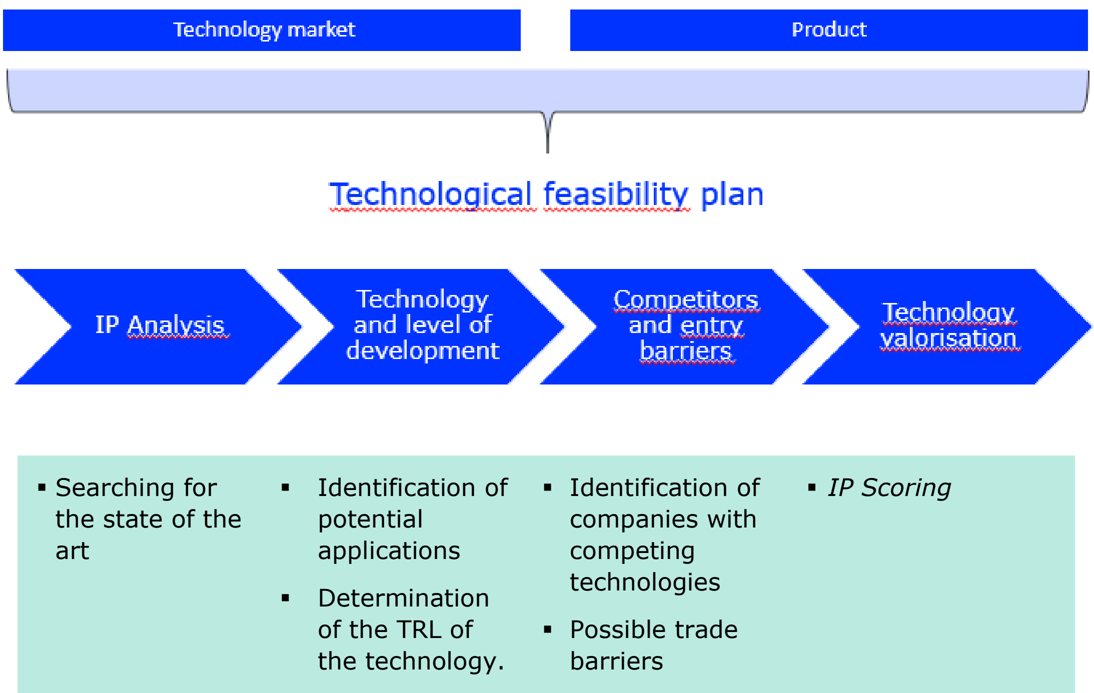


Figure 12: Steps to consider in a technology viability plan.

Source: Elaborated by ClarkeModet.

A.1 IP Analysis: Survey to the state of the art.

The state of the art, also known as the state of the art or state of knowledge, refers to the body of existing knowledge, techniques, technologies and practices that are recognized and accepted as a reference or starting point for future research, innovation or development in the field.

It should be borne in mind that 300,000 patent applications are rejected worldwide each year for lack of novelty, which represents 30% of investment in research and development in Europe. Therefore, knowing the state of the art is essential during R&D processes as it provides a solid basis for avoiding redundant R&D. Currently it is estimated that at European level €60 billion is lost each year due to redundant research.

To begin a **search for the state of the art**, it is necessary to clearly identify the area of interest on which the research is to be carried out.

The most common official public databases that can be used to carry out these searches are:

- EPO (European Patent Office) (https://www.epo.org)
- Patentscope (WIPO) (https://patentscope.wipo.int)
- Espacenet (https://worldwide.espacenet.com)
- USPTO (United States Patent and Trademark Office) (https://www.uspto.gov/patents-application-process/search-patents)

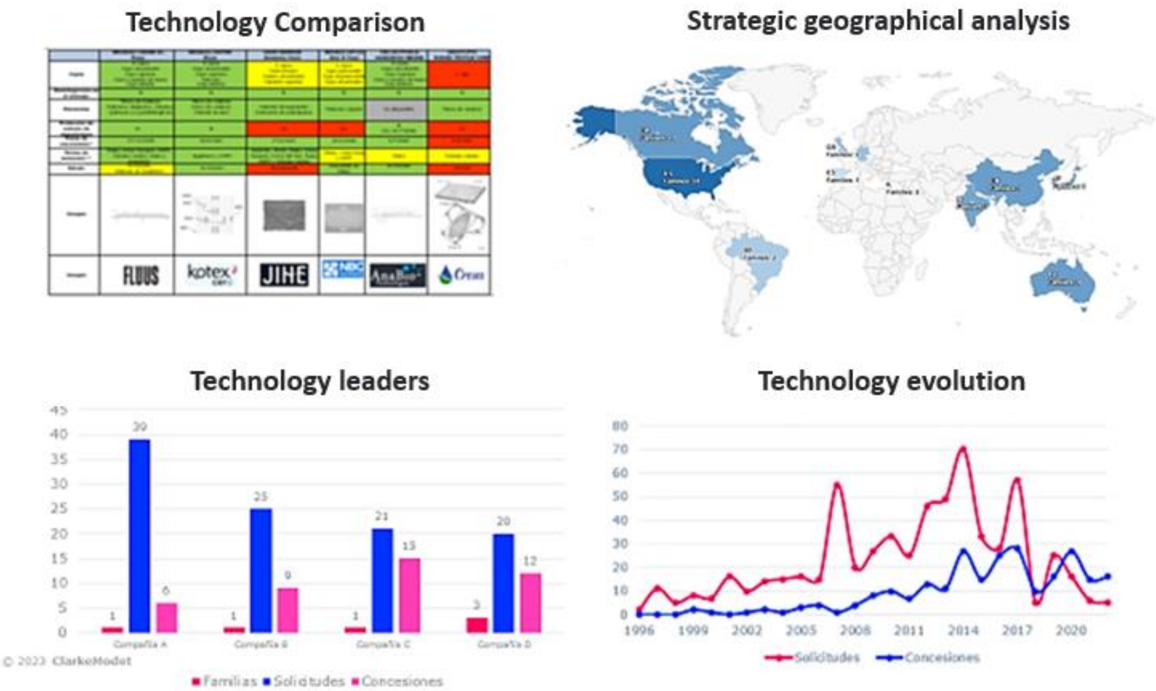
The search should be conducted using keywords related to the technology under analysis, which may be referenced in relevant technical documents (patents or patent applications), in the title, abstract, description or claims. In the search strategy synonyms or equivalents should be considered, and Boolean operators (AND, OR, NOT) may be used to refine the results.

Additionally, it is very important to use the international classification codes (IPC-CPC) that group patent documents into subgroups, dividing technological knowledge into nine (9) main areas (sections):

- Section A - Human necessities
- Section B - Performing operations; Transporting
- Section C – Chemistry; metallurgy
- Section D – Textiles; paper
- Section E - Fixed constructions
- Section F - Mechanical Engineering; Lighting; Heating; Weapons; Blasting

- Section G - Physics
- Section H - Electricity
- Section Y - New technological developments

Once the search results are obtained, the results must be filtered by analysing the titles and



abstracts of the patents to determine their relevance and proximity to our development, discarding those patents that are not relevant.

In **filtering the information**, it may be useful to review the cited patents to determine those that may relate to prior art.

The information that the state-of-the-art survey can identify relates to:

- The evolution of the technological area over time and its degree of maturity.
- Identification of the patent documents with the greatest impact, for comparative analysis of the distinctive features and the different applications of the technology.
- What are the emerging technologies and the most recent lines of research?
- Which markets are the most strategic.

A.2 Technology and level of development:

Identification of potential applications

It is very common for technologies to be developed for a particular purpose, to solve a particular problem of the state of the art. However, each technology, depending on its characteristics, may have applicability in different technological domains.

Identifying all possible applications of the technology increases commercialization opportunities and as such has an impact on valuation.

Different uses of the technology can be sought:

- Brainstorming with researchers
- State of the art: keyword search in patent databases
- Online search: Public databases can also provide a wealth of information.

State of technological development

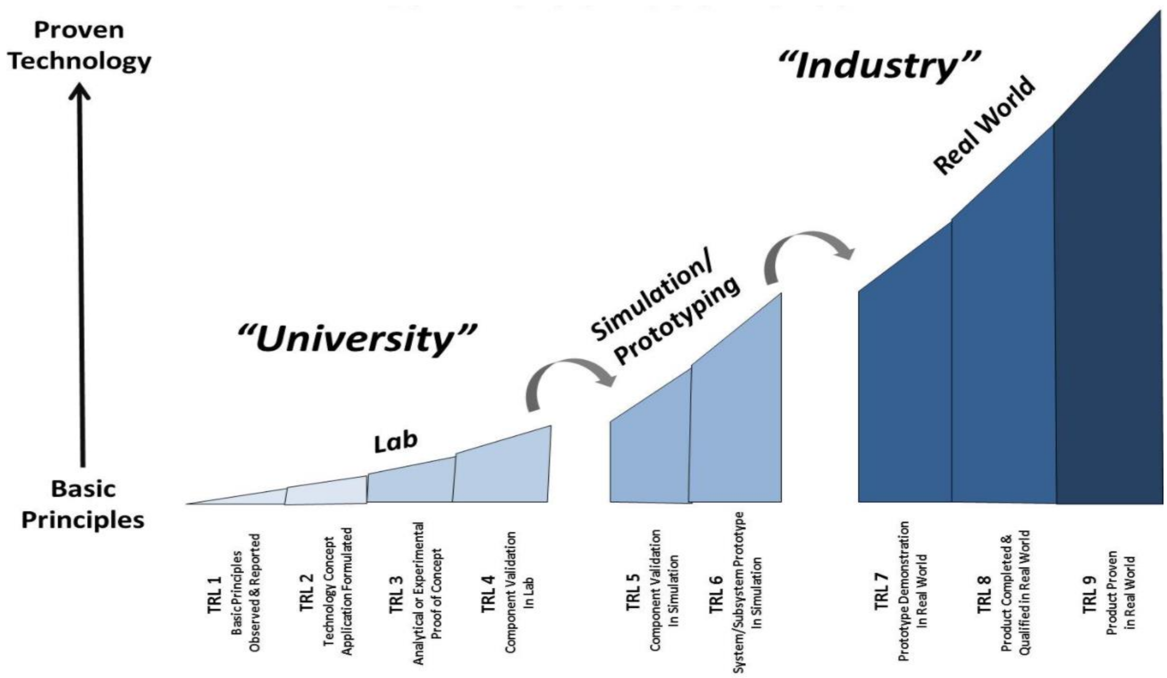
The development of a technology goes through several phases depending on its robustness and complexity.

The **Technology Readiness Level (TRL)** scale indicates the maturity of the technology. The TRL scale was developed by NASA to write down the stages of technology development or readiness and has become a reference and has been widely adopted in the context of European funded R&D projects.

Similar, but tailored to the pharmaceutical and medical sector, the US Department of Health and Human Services created the integrated TRLS for medical countermeasure products.

TRLs are determined using a scale of 1 to 9, with 9 being the most mature technology:

TRL	Description
1	Basic principles observed
2	Concept and/or technological application formulated
3	Experimental proof of concept
4	Laboratory validated technology
5	Technology validated in a relevant environment
6	Proven technology in a relevant environment
7	Prototype of the system demonstrated in an operational environment
8	System completed and certified through testing and demonstration.



9	System successfully tested in real environment

Figure 13: TRL scale.

Source: https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level.

Figure 14: Representation of the stages of development level.

Source: https://alopexoninnovation.com/.

When assessing the potential of a technology and its commercial viability, it should be borne in mind that a technology at an early stage of development involves higher risks, more time and higher development costs.

A.3 Competitors and possible barriers to entry

Main competing technologies

Through searches of the state of the art, it is possible to identify the most relevant patent documents in the technological area related to the technology of interest.

The identification and selection of these documents allows the comparative analysis of technical characteristics and the possibility of what the competitive technological advantages of the R&D project are in comparison with existing ones.

Additionally, through the results obtained from the survey it is possible to identify which are the **competitors of our technology**, which allows us to analyse the entities involved in the technological domain of interest, their relative and absolute position and their nature (companies, R&D institutes or universities or individual inventors), in order to understand the profile and competitive dynamics of the domain of study.

The analysis of the participating entities allows us to identify:

- Who are the main companies and institutions active in the technological field analysed?
- What the most active competitors with the greatest technological impact are doing, detailing the R&D lines undertaken by each of them.
- With whom do the main competitors cooperate?
- What are the inter-relationships between the main companies and institutions?

N. Patente	Título	Área tecnológica	Principais Vantagens	Solicitante	País Pub.	Año Pub.

Possible barriers to entry

Closely related to the previous step, to evaluate the entry of our technology into the market, we will have to take into account the information obtained on existing technologies in the market that occupy the same niche and what the value proposition of our technology is, situating our technology in relation to the existing one and evaluating the different applications of our technology.

Moreover, it must be borne in mind that commercializing an invention involves a considerable investment of time and resources. The risk of being blocked for manufacturing, using, selling or importing a new technological solution is increasingly high, especially in IP-intensive sectors.

It is therefore desirable to minimize the risk of infringement of third party IP rights. To this end, it is advisable to have a **Freedom to Operate (FTO) report** that provides a technical-legal opinion on the risk of infringement of third party IP rights, in a particular jurisdiction and time period.

The FTO's opinion is reasoned and calculated on technical grounds, as to whether the production, use, sale or import of a product in a given geographical area may infringe the intellectual property (IP) rights of third parties.

The following steps should be followed for the preparation of an FTO report:

1. An **advanced patent search in the IP databases** in the territory of interest.
2. **Analyse its legal and technical status to** assess the potential for infringement if the new technological solution is marketed.
3. **Strategic commercialization decisions**: in case the search concludes that one or more patents exist that limit the free exploitation of our technology, commercial decisions must be taken: requesting an invalidity search to analyse the possibility of invalidating the blocking patent(s), initiating design and research activities to make changes to the product or process to avoid infringing the patent(s) held by others, acquiring the patent license or negotiating cross-licenses, i.e. exchanging licenses to be able to use certain patents of the other party.

It is desirable that the FTO report be prepared by a legal expert in IP matters, given its complexity.

A.4 Technological valorisation

IP Scoring

IP Scoring is a graphical representation that aims to assess a technology through relevant parameters, namely IP protection and legal strength, potential market applications, existing competitors or partners, legal barriers to market entry and distance to market, which together characterize the technology qualitatively, providing a global vision to potential buyers/licensees.

Thus, considering the information presented in the previous chapters, the technology is assessed qualitatively from 1 to 5 according to its performance in each of the referred parameters, where '5' is the best classification in terms of perspectives regarding a given parameter.

The relative positions obtained for the five dimensions analysed are as follows:

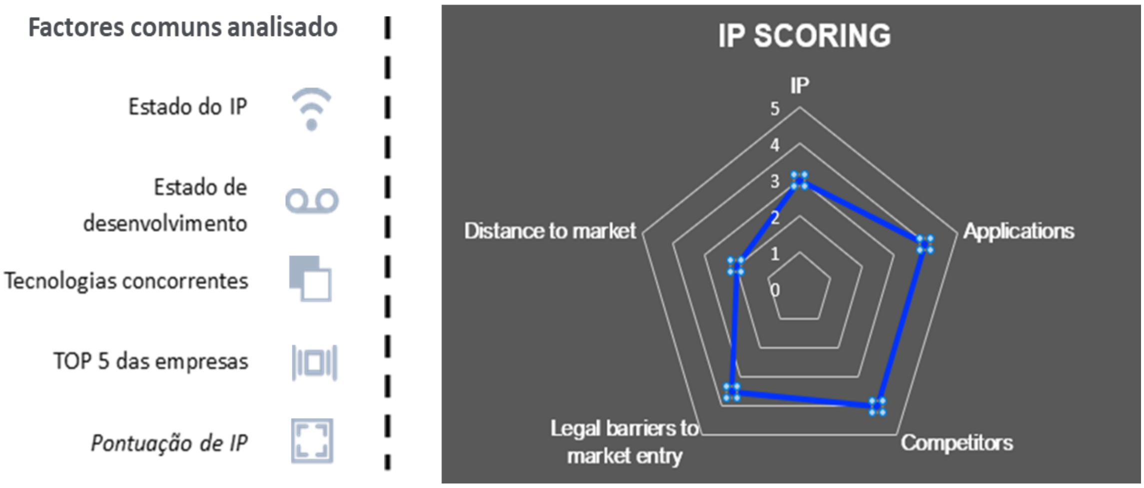


Figure 15: IP Scoring Model.

Source: Elaborated by ClarkeModet.

5.3 Protection of intellectual assets

Intellectual property refers to the legal rights granted to individuals and institutions over the creations of their minds. These creations can be literary, artistic, musical works, inventions, industrial designs, trademarks or distinctive signs used in commerce (WIPO, [n.d.]). The main objective of intellectual property is to encourage innovation and creativity by providing creators with the necessary protection and incentives to benefit from their creations.

An institution's IP portfolio consists of different intangible assets generated and recorded by the institution, the most common of which are as follows:

- **Patents:** According to the EPO definition, a patent is a territorial legal title that gives its holder the right to prevent third parties from commercially using an invention without his authorization for a limited period of time. Like other forms of intellectual property, the rights conferred by a patent do not allow the holder to commercialize the protected invention, but they do allow him to prevent others from doing so, for example, in the case of pharmaceutical inventions, authorization must be obtained from health authorities to commercialize the invention in the country.

Before granting a patent right, local IP offices conduct a formal and substantive analysis to define compliance with the characteristics of novelty, inventive step and industrial application, which are essential requirements to recognize the contribution of the invention. An invention is considered new when it is not part of public knowledge accessible to the population, by any means, including written, oral and any public demonstration of the invention. Inventive Activity refers to the fact that a person with knowledge in the technical field can easily deduce the invention considering his own knowledge of his information and all the information published on the date of registration of the invention. Industrial Application refers to the ability to generate a commercial product from the invention, which excludes all theoretical inventions or those that contribute only in an academic sense to the technological field and have no capacity to be directly exploited in a commercial product.

The rights conferred by a patent are limited to the countries where the patent was registered and granted and normally last for 20 years from the first registration of the patent.

- **Utility models:** Utility models are used to protect inventions involving minor improvements or adaptations of existing products, usually tools or equipment, and are also useful for products that have a short commercial life because of the lower registration costs compared to patents. Many countries allow the conversion of a patent application into a utility model application, however, in some countries there is a time limit for doing so. If a patent application is rejected, some countries allow the patent application to be converted into a utility model within a certain period after rejection.

  The rights conferred by a utility model are limited to the countries where it was registered and granted and its duration varies between 6 and 15 years, according to local legislation.

- **Designs:** Designs are a figure of intellectual property that protects the appearance of a part of a product resulting from the characteristics of, in particular, the lines, contours, colours, shape, texture and/or materials of the product itself and/or its ornamentation. This figure does not protect any technical feature of the invention and the protection is limited to the appearance of the invention.

Like patents, design protection is limited to the countries where the design was filed and granted, and its validity is limited to a specific period of time ranging from 10 to 25 years according to local legislation.

- **Trademarks: Trademarks** are signs capable of distinguishing the goods and services of one company from those offered by others. A word or combination of words, letters and numbers may constitute a trademark, although they may also consist of designs, symbols, three-dimensional features such as the shape and packaging of goods, non-visible signs such as sounds or scents, or colour tones used as distinguishing features.

  Like patents, the rights conferred by a trademark are limited to the territories where it was registered and granted. Unlike patents, trademarks can be renewed for an unlimited period, provided there is an interest on the part of the owner in maintaining its rights.

- **Copyright:** El Copyright is a legal term used to describe the rights that creators have over their literary and artistic works. Copyrighted works range from books, music, paintings, sculptures and films to computer programs, databases, advertisements, maps and technical drawings.

  In general, the law does not contain exhaustive lists of materials that may be protected by copyright. However, in general terms, works commonly protected by copyright around the world include literary works, such as novels, poems, plays, newspaper articles, computer programs, databases, films, musical compositions and choreographies, artistic works, such as paintings, drawings, photographs and sculptures, architecture, and advertisements, maps and technical drawings. Copyright protection extends only to expressions and not to ideas, procedures, methods of operation or mathematical concepts as such. Copyright may or may not be available for a number of objects, such as titles, slogans or logos, depending on whether they contain sufficient authorship.

- **Trade Secrets: Trade secrets** are intellectual property (IP) rights over confidential information that can be sold or licensed. In general, any confidential business information that gives a company a competitive advantage and is unknown to third parties can be protected as a trade secret.

  Trade secrets cover both technical information, such as information relating to manufacturing processes, pharmaceutical test data, software designs and drawings, and commercial information, such as distribution methods, supplier and customer lists and advertising strategies. A trade secret may also consist of a combination of elements, each of which is in the public domain, but where the combination, which is kept secret, provides a competitive advantage. Other examples of information that may be protected by trade secrets include financial information, formulas, recipes and source codes.

5.3.1 Definition of a protection strategy

Intellectual property is of great importance for higher education institutions as it promotes innovation, protects research investments, facilitates technology transfer and collaboration with industry, generates income and contributes to the prestige and reputation of the institution:

- **Fostering innovation:** Intellectual property protects the results of research and the development of new ideas and technologies. By securing exclusive rights over these assets, higher education institutions can foster innovation and creativity among their teachers, researchers and students. This drives the generation of new knowledge, discoveries and scientific breakthroughs.
- **Investment protection:** Higher education institutions invest significant resources in research, development and knowledge creation. Intellectual property protects these investments by granting exclusive rights to the results obtained. This motivates institutions to continue investing in research and development activities as they know they will benefit from the fruits of their labour.
- **Technology transfer and collaboration with industry:** IP facilitates technology transfer and collaborations between higher education institutions and industry. Through licensing agreements, institutions can grant rights to third parties to use their inventions or technologies, which can lead to the creation of new products, services and businesses. This contributes to economic development and the progress of society in general.
- **Revenue generation:** IP can generate revenue for higher education institutions through different mechanisms such as commercialization of patented technologies, licensing, copyright sales, among others. These revenues can be reinvested in new research and development activities, improve the institution's infrastructure and resources or fund academic programs and scholarships.
- **Prestige and reputation:** Protection of intellectual property and recognition of a higher education institution's research and development contributions enhance its

prestige and reputation, both nationally and internationally. This can attract talented teachers, researchers and students, as well as partnerships and collaborations with other academic institutions and research entities.

Through their IP contributions, HEIs support the economic development of the nation by generating new research, which can lead to scientific and technological breakthroughs, new discoveries, inventions and innovative developments. Knowledge generated in higher education institutions can be transferred to industry and other areas of the economy, driving innovation and improving productivity.

The development of an appropriate strategy for the protection of the innovations generated by the institution is of vital importance to avoid misuse of the information and to ensure the highest possible return on investment. The development of a protection strategy is not a one-off activity; the strategy must evolve in conjunction with the institution to ensure that it is always aligned with the institution's objectives. WIPO has developed a **general guide for the development of protection strategies** that includes the most relevant points to consider during their development:

Phase I. Conception of the idea

- **Does the invention have an industrial application?** This evaluation allows you to define if there will be a commercial product associated with the invention, otherwise it will not be possible to obtain a patent right on the invention and it will have to be evaluated if the knowledge should be protected as an industrial secret or if it should be considered as a scientific contribution to the field.
- **Identification of IP assets,** it is recommended to confirm whether the institution has processes in place to identify its own IP assets, such as IP audits, due diligence and use of IP checklists.
- **IP asset capture,** monitoring of the institution's procedures for IP asset capture.
- **Confidential information,** monitor the institution's procedures to prevent disclosure of the invention (confidentiality agreements, trade secrets, restricted access, other agreements)

- **Likelihood of IP protection,** determine the likelihood of obtaining IP protection through preliminary searches for patents, designs, trademarks, copyrights, domain names, plant breeders' rights and any other applicable.
- **Alliances,** identify potential partners with whom to collaborate in the development and commercialization of the idea/concept. In case of collaboration with third parties, it is necessary to define the ownership and access to IP assets.
- **Identification of competition,** identify potential competitors and the likelihood of infringement of third party rights when implementing the idea/concept**.**

Phase II. Development of products and services

- **Freedom to Operate (FTO) studies,** conduct a freedom to operate study to identify the IP landscape, freedom to operate and the presence of competitors in the territories of interest.
- **IP Surveys,** conduct periodic IP and technology surveys to determine the likelihood of obtaining protection for innovations, as well as to identify technological trends and possible further improvements to the invention.
- **Third party rights,** Define the scope of the right over the IP assets of third parties involved in the product development (traders, investors, R&D collaborators and licensing agreements).

  It is recommended to review the right on the use of third party research results, as well as the possible use of IP assets from entities outside the institution.
- **Commercialization tools,** define the most appropriate commercialization model (manufacturing, selling, licensing, etc.).
- **Definition of the IP strategy,** definition of the protection strategy by an internal technical commission, considering the information obtained in the previous points.

Phase III. Protection of IP

- **IP protection strategy,** implementation of a protection strategy covering possible patents, trade secrets, designs, trademarks, open source, plant breeders' rights and copyright.

- **Prioritization of IP protection,** monitoring of deadlines and filing requirements for each of the defined IP rights. The correct definition of a protection calendar will allow the submission of national phases and different modalities of rights properly and without interferences.
- **Control of ownership,** control of the scope of recognition of IP rights for the institution and potential third parties involved in the development of the technology.
- **Non-registerable protection of IP assets,** protection of non-registerable forms of IP, such as know-how, trade secrets or business models.
- **IP advice,** advice from IP experts is suggested to ensure the correct processing of the applications generated as well as compliance with the requirements of the local IP authorities.
- **Adjustment of the IP strategy,** if necessary, make any appropriate adjustments to the IP strategy. These adjustments may include changing the protection values, modifying the scope of protection, adjusting the territories where invention protection will be sought, adding new IP values.

Phase IV. Commercialization of IP

- **Valuation of IP assets,** valuation of IP assets, in particular those licensed as part of the business model or product pricing strategy (e.g. planning claims against competing products/services).
- **Competition tracking,** monitoring competitors' activity, new developments introduced in the market and strategy for enforcing their IP rights.
- **Brand image,** proper identification of the image of the product or service (brand, packaging, websites, domain names).
- **Review of IP assets,** monitoring the status of IP rights, renewals, annuity payments, oppositions and any other applicable.
- **IP auditing,** procedures for periodic audits of IP assets, portfolio optimization and cleaning and possible disposals.

5.4 Economic valuation of IP assets

Intellectual Property (IP) assets are intangible assets that constitute, from an economic point of view, one of the fundamental elements of the competitive advantages of one before the competition. From the perspective of Higher Education Institutions (HEIs), the knowledge produced by them and embodied in an IP asset represents the possibility of attracting resources for the maintenance and expansion of their most elementary activities - teaching, research and extension. The **adequate measurement of its financial value** enables the owner of the asset to account for it, manage it and negotiate it with third parties.

This chapter seeks to present a brief review of the methodologies available for estimating the value of IP assets, making, at the end, considerations as to a methodology possibly applicable to the reality of the TTOs of the different HEIs.

To value an IP asset, it is essential to adequately define and delimit them. Due to their intangible nature, IP assets cannot be described by the metrics and references universally used to delimit the attributes of tangible assets, i.e., those physically represented in the material plane. Thus, the evaluation of IP assets must always pay attention to the peculiarities of this type of asset.

However, intangible assets of any kind must be capable of reasonably direct specification and be associated with a set of essentially private property rights. Additionally, for intangible assets to retain value, from an economic perspective, some elements must be present. In essence, the asset in question must generate some measurable economic benefit to its owner, whether in the form of increased revenues or decreased costs (REILLY; SCHWEIHS, 1998, p. 9). Still according to Reilly and Shweihs (1998, p. 5), the classification of an asset as intangible depends on the occurrence of a series of attributes, namely:

1. Be subject to specific identification and recognizable description;
2. Being subject to legal existence and subject to protection;
3. Being subject to private property rights and therefore legally transferable;
4. Be represented by some tangible evidence, such as, for example, a contract, a license, a registration document, a set of financial statements, among others;
5. Result from an identifiable event, at a specific time;
6. Being subject to destruction or termination at a specified time or as a result of an identifiable event.

Such characteristics are embodied, for example, in the most common forms of protection for intellectual creations, such as trademarks, patents, industrial designs and copyrights. In addition to scoping aspects, other characteristics impact the potential value of an intangible asset, particularly those concerning the asset's potential to generate revenues. Some of the key factors affecting their value are:

1. The nature of the asset (brand, patent, etc.), revenue realized and potential for future revenue generation;
2. The current level of exploitation of the asset and its correspondence with the income obtained (if any);
3. The capital costs and investments necessary to exploit the intangible asset;
4. The economic climate in general and the relevant market in particular;
5. The risk involved in the investment, related to the stability of results, competition and market potential, implicitly included in the update of expected returns.

Roughly speaking, valuation methods can be classified into two broad groups according to whether or not target market elements are used to assess an intangible asset. Market-based methodologies comprise cost-based (involved in the development of the technology), market-based (industry standards) or income-based (perspective of) approaches (NI et al., 2015; REILLY; SCHWEIHS, 1998; STEVENS, 2016, p. 34). Methodologies are generally essentially quantitative, underpinned by a combination of financial valuation techniques (DISSEL et al., 2005).

Cost-based valuation approaches may consider two distinct perspectives. On one hand, it is possible to associate the value of a technology to the amount invested up to the moment of negotiation. Alternatively, it is possible to associate the value to the future benefit of holding the property over the asset. From this perspective, the volume of resources required to reproduce the object in question or to develop a substitute product for the one under analysis is calculated. However, despite the alternative, the cost approach fails to capture the commercial performance to come, besides being highly subjective (PITKETHLY, 1997; POTTER, 2007, p. 806).

On another front, market-based approaches aim to estimate the value of assets through direct comparison with the prices of similar objects already traded in the market. It corresponds to a direct methodology, which uses industry or target segment standards to determine the price of an intangible asset. However, the application tends to be limited to cases where already established markets have a similar product available to serve as a reference. For example, the *benchmarking* method is unlikely to be appropriate to the valuation of technologies with disruptive potential (RAZGAITIS, 2007, p. 820-821; NI et al., 2015). However, it is possible to include market standards in approaches by revenue, forming hybrid methodologies that enable more accurate results (POTTER, 2007, p. 807).

Methodologies that allow the projection of future revenues are perhaps the main strategies to estimate the value of a technology under development. The Discounted Cash Flow (DCF) method is the standard usually employed to determine the current value of an immature technology based on its potential to generate future revenues. This methodology is governed by two central premises: first, that a unit of money has more value in the present than in the future since the holder is free to invest the resource to obtain income over time. Second, for the interpretation of the analysis result, it assumes that if the present value of future revenues exceeds the investment required to develop the technology, then the project is viable (RAPPAPORT, 1981; VILLIGER; BOGDAN, 2006).

DCF methodologies compare the potential future returns of a given investment and estimate the present value of the asset considering a rate of return required by the investor when giving up the resource in the present in favour of a future gain. In addition to the influence of time on asset value, DCF models can incorporate aspects of uncertainty, resulting in "Risk-adjusted Present Value" or "Expected Present Value". Further refinements, such as the association of DCF with decision tree analysis, can also estimate the impact of different scenarios throughout the project on the expected present value (VILLIGER; BOGDAN, 2006; POTTER, 2007, p. 806; NI et al., 2015).

However, the DCF method has limitations that may acquire greater importance depending on the purpose of the analysis. For instance, when applied to the evaluation of technologies in stages of maturity that are still incipient, the DCF method returns, with good frequency, negative present values, even though the revenue potential is extremely significant (BOGDAN; VILLIGER, 2007, p. 7). This occurs because the immaturity of the technology implies in (1) high risk and (2) long period until it reaches the market, aspects that impact the present value of a future flow of receipts.

Furthermore, the assumptions used in DCF models are fixed numbers, which therefore capture to a limited extent how project value varies with risk mitigation as technology development advances. In contrast, project maturity reveals characteristics of the asset that can impact its market value. Thus, a new evaluation process would have to be conducted in the transition between development phases (SHOCKLEY et al., 2002; VILLIGER; BOGDAN, 2005).

A more refined methodological alternative, capable of overcoming the shortcomings of DCF models, is materialized by evaluation methods based on Real Options (RO). These are methods that allow estimating the value of the technology at the point where it reaches the market and then weighting the probabilities of success along the development path. The RO technique arose from the concept used in financial investments, where an option corresponds to the right to buy or sell an asset for a fixed price by a certain date (POTTER, 2007, p. 809).

The elegance of OR protocols is in incorporating the dimension of rapid abandonment of an R&D project as soon as some aspect of unviability is diagnosed. This flexibility of reacting quickly to the development dynamics adds value by avoiding losses, however, it is not perceived by other evaluation methods. However, it is a methodology of extreme complexity, hardly applicable to the evaluation of intellectual assets of academic institutions, on a large scale and with adequate speed (PERLITZ; PESKE; SCHRANK, 1999; KELLOGG; CHARNES, 2000; SHOCKLEY et al., 2002; SCHWARTZ, 2004; HARTMANN; HASSAN, 2006; VILLIGER; BOGDAN, 2006; RODRIGUES et al., 2013).

Among the various options for valuation methods, the protocol for estimating value by analysis of *Royalty Relief* or, in free translation, "royalty savings", figures as an alternative of simple application, technically robust and accountingly accepted. The central premise of this technique is that the value of the asset valued is equivalent to the sum of the present value of the flows of *royalty* payments that the asset holder would have to make if it were not the owner of the technology. Hence, the name "royalty economics" (REILLY, 2022).

The advantage of this methodology is that it is based on commercial practice and business reality. It considers the estimate of probable future sales associated with the asset under analysis, to which it applies an appropriate royalty rate to be paid to determine the annual royalty value over an estimated period, which after capitalization translates into the current economic value of the IP asset (REILLY, 2022).

The *Royalty Relief* valuation protocol is, therefore, a combination of elements from the market approach - since the appropriate royalty rate is estimated from transactions that already have taken place involving assets similar to the analysed asset - and the income approach - since the revenue generation potential of the analysed asset needs to be estimated before the royalty rate can be applied. This combination of factors provides the *Royalty Relief* method with a realistic profile, since the value calculated for the analysed asset derives from a royalty rate already practiced in previous deals and, commonly, publicly available for verification purposes by third parties (HÜBSCHER; EHRHART, 2021).

The most important point of this methodology is, therefore, the identification of the most adequate royalty rate for the asset under evaluation. To this end, we resort to previous transactions involving assets considered similar, publicly registered, for example, at the US *Securities Exchange Commission* (SEC). Then, the royalty values established in the identified transactions are analysed. In general, the estimation of the value of an IP asset through the *Royalty Relief* method comprises the following essential steps:

1. Identification of market transactions (executed) relating to assets comparable to the one under review and identification of the *royalty* rate applied in those transactions (in addition to the minimum, maximum, average and median royalty);
2. Application of the *royalty* rate found on sales projections of products/services associated to the asset being valued, over a given period of time;
3. Calculation of the net annual flows attributable to the asset, using the market *royalty* rate;
4. Determination of the net present value of flows and calculation of the economic value of the asset.

The complexity of estimating the value of an IP asset is evident, particularly those that involve a potentially innovative technology in a very early stage of development. Nevertheless, the difficulty of the task does not remove the need for, nor obscure the advantages of establishing a routine for valuation of the IP assets in a portfolio. Whether through simplified measures - just for managerial decisions - or using more robust methods - for the factual negotiation of an asset - knowing the potential value of the IP assets in a portfolio is a crucial step in the maturing of the activities of a technology transfer office in a HEI.

5.5 Commercialisation of IP assets and technology transfer

Technology transfer (TT) is a collaborative process that enables scientific discoveries, knowledge and IP to move from creators, such as universities and research institutions, to the marketplace. Its aim is to transform inventions and scientific results into new products and services that benefit society. Technology transfer is closely related to knowledge transfer. In the context of the present study, technology transfer can be narrowly defined as "the process by which inventions or IP resulting from academic research are licensed or transmitted through rights of use to industry" (Association of University Technology Managers (AUTM), 2000).

Technology transfer supports the life cycle of technology, from conception to diffusion and commercialization in the market. In the context of HEIs, stimulating the flow of ideas and inventions from university laboratories to the market aims to benefit society through new products, processes, jobs and ideas.

In the context of transfer between HEIs and industrial sectors, at least three stakeholders are identified: HEIs, Technology Transfer Offices (TTOs) and industry. These stakeholders have their own motivation when they carry out the negotiation among themselves, which are presented in the following figure:

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Organizational Culture
Scientist in HEIs	Discovery of new knowledge and technology	Recognition within the scientific community – publication, grants	Financial gain and desire to secure additional research funding	Scientific
Technology Transfer Office	Works with faculty members and firms/entrepreneurs to structure deals	Protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firms or entrepreneurs	Commercialize new technology	Financial gain, market creation	Access to competency, maintain control of proprietary technologies	Business – entrepreneurial

Figure 16: Main actors in technology transfer from HEIs to industry.

Source: Siegel et al. (2004).

5.5.1 Types of technology transfer

A) Licensing of intellectual property (IP):

Licensing in technology transfer for HEIs involves the process of transferring IP rights developed within the institution to external entities, usually for the purpose of commercialization. HEIs often engage in research and development activities that result in innovative technologies, inventions or discoveries. Licensing these technologies offers HEIs an opportunity to promote innovation, drive economic development and translate their research into real applications, maximizing the social and economic impact of their research and fostering collaboration with industry stakeholders.

There are some key considerations specific to licensing for HEIs:

- *Licensing strategies*: HEIs can adopt different licensing strategies based on their objectives and the specific technology to be transferred. These strategies may include exclusive or non-exclusive licenses, domain-specific licenses, regional or global licenses, formation of startups or spin-off companies. The chosen strategy should be aligned with the institution's objectives and maximize the technology's commercialization potential.
- *Negotiating licensing agreements*: HEIs enter into negotiations with potential licensees to establish mutually beneficial licensing agreements. These agreements specify the terms and conditions under which the licensee may use, develop or commercialize the technology. Licensing terms, financial considerations (e.g. royalties, upfront fees), performance milestones and IP rights are typically addressed in the agreement.
- *Compliance and legal considerations*: HEIs must comply with relevant laws, regulations and policies governing technology transfer and IP. These may include export control regulations, conflicts of interest, ethical considerations, and compliance with funding agency requirements. HEIs must ensure that licensing activities comply with these legal and regulatory frameworks.

C) Sale of IP rights or technology rights:

The direct sale of IP rights or technologies developed in the institution to external entities, usually industrial partners or commercial organizations, offers HEIs an avenue to monetize their IP assets and promote technology commercialization, stimulating economic growth and maximizing the impact of their research results.

The key factors for HEIs when engaging in technology sales are:

- *Technology assessment*: Assess the technology's commercial potential, market demand and value proposition. Assess its competitive advantage, scalability and potential for successful commercialization. Consider factors such as market size, target customers and the suitability of the technology for the industry landscape.

- *Marketing and promotion*: Develop a marketing strategy to reach potential buyers and showcase the benefits and applications of the technology. Create marketing materials, such as technology brochures, presentations and case studies, highlighting the technology's unique selling points, benefits and potential market impact. Leverage *networking* events, conferences and industry platforms to connect with potential buyers.
- *Negotiation and agreement*: Engage in negotiations with stakeholders to finalize the sale. Define the terms and conditions of the technology sale, including the payment structure, transfer of intellectual property, warranties and after-sales support, if applicable. Engage legal professionals to ensure that the sale agreement is comprehensive, protecting the interests of both parties.
- *Valuation and pricing*: Determine the value of the technology or IP rights based on factors such as market potential, stage of development, competitive advantage and revenue projections. Define a pricing strategy that is competitive and reflects the value proposition of the technology. Consider factors such as upfront payment, royalties or revenue sharing arrangements.
- *Technology transfer and support*: To facilitate the transfer of the technology to the buyer. Provide any technical support, documentation or training necessary to ensure the successful adoption and use of the technology by the buyer. Define the scope of the transfer, support services and any ongoing assistance necessary to ensure the successful integration of the technology into the purchaser's operations.
- *Compliance and legal considerations*: Ensure compliance with relevant laws, regulations and institutional policies associated with technology sales. Address any licensing requirements, export control regulations, or intellectual property rights considerations. Maintain proper records and documentation throughout the technology transfer process.
- *Post-sales monitoring*: Monitor and evaluate the performance of the technology and the buyer's compliance with the agreed terms. Address any issues or concerns that may arise during the post-sales phase. Maintain communication with the buyer to ensure a successful technology transfer and address any support needs.

D) *Joint ventures:*

Joint ventures are a popular form of technology transfer for HEIs. They typically involve two or more entities coming together to pool resources, expertise and capital to develop and commercialize a new technology or product, and can be an effective mechanism whereby, by leveraging their research capabilities and skills, HEIs can create new commercialization and societal impact opportunities while fulfilling their research and teaching mandates.

However, HEIs should carefully consider the different situations when engaging in joint ventures:

- *Strategic partnerships*: Joint ventures can be a powerful way for HEIs to establish strategic partnerships with industry actors to develop and commercialize their technologies. HEIs can leverage their research capabilities and expertise to develop new technologies, while industry partners can provide funding, commercialization expertise and market access.
- *Licensing and royalty* agreements: Licensing and royalty agreements shall be negotiated between the joint venture partners to ensure that both parties receive adequate compensation for their contributions to the joint venture. These agreements should define the scope of the license, the royalty rates and other financial considerations.
- *Governance and management*: Joint ventures require clear governance and management structures to ensure that the interests of both parties are protected. HEIs should establish appropriate decision-making mechanisms, such as a joint venture board, and define the roles and responsibilities of each partner.
- *Allocation of resources*: The HEIs shall commit resources, such as staff, funding and research facilities, to the Joint Undertaking to ensure its success. The HEIs shall ensure that they have adequate resources at their disposal to fulfil their commitments to the Joint Undertaking and to meet their research and teaching obligations.
- *Conflict of interest*: HEIs should be aware of potential conflicts of interest when participating in joint ventures. They should have policies and procedures to manage these conflicts and ensure that their research activities and academic independence are not compromised.
- *Compliance and legal considerations*: Joint ventures must comply with relevant laws and regulations governing technology transfer, competition law and intellectual property. HEIs should ensure that their joint venture activities respect these legal frameworks.

E) Research and development (R&D) partnerships:

R&D partnerships are a valuable approach to technology transfer. These partnerships involve collaborative efforts between HEIs and external parties, such as industry, government agencies or non-profit organizations, to jointly conduct research and develop innovative technologies. Through these collaborations, HEIs can advance their research, accelerate technology development and increase the likelihood of successful commercialization. R&D partnerships can enhance the technology transfer capabilities of HEIs by taking advantage of external expertise, resources and market knowledge.

The effective management of R&D partnerships requires special attention to the following areas

- *Objectives of the collaboration*: Clearly define the objectives and scope of the R&D partnership. To determine the common objectives, the research areas and the desired results. Align the objectives of the partnership with the technology transfer objectives of the HEI and the strategic priorities of the partner.
- *Partner selection*: Identify suitable partners that have complementary skills, resources and capabilities to support R&D efforts. Consider factors such as industry reputation, technical know-how, financial stability and shared research interests. Look for partners who have a strong commitment to technology transfer and a track record of successful collaborations.
- *Sharing resources*: Defining the resources that each partner will contribute to the R&D partnership. This may include financial resources, research facilities, equipment, technical expertise and access to data or samples. Clearly define the roles and responsibilities of each partner to ensure an equitable sharing of resources.
- *Project management*: Establish effective project management mechanisms to ensure smooth coordination, communication and accountability. Define project deadlines, milestones, deliverables and reporting requirements. Regularly monitor progress, evaluate results and resolve any issues arising during collaboration.
- *Funding and financial considerations*: Determine the funding model for the R&D partnership. Explore funding opportunities, such as government grants, industry contributions or philanthropic support. Establish clear financial arrangements, including cost sharing, reimbursement mechanisms and sharing of intellectual property revenues.
- *Publication and dissemination*: Establish guidelines for publication and dissemination of research results. Balance the need for open dissemination of knowledge with

intellectual property protection considerations. Address publication rights, confidentiality obligations and the timing of public disclosures to maximize scientific impact and commercialization opportunities.

- *Technology transfer mechanisms*: Identify potential technology transfer pathways at an early stage of collaboration. Explore licensing options, creation of spin-offs, *joint ventures* or other commercialization strategies. Develop a proactive approach to identify and protect potentially valuable IP generated through the partnership.
- *Legal and compliance considerations*: Comply with the legal and regulatory requirements relevant to the R&D partnership. This includes compliance with intellectual property laws, research ethics guidelines, export control regulations and any contractual obligations associated with the partnership. Ensure that appropriate agreements, including non-disclosure agreements and material transfer agreements, are in place to protect confidential information and manage the transfer of materials.

F) ***Spin-offs* and *start-ups:***

Spin-offs and *start-ups* involve the creation of new companies that commercialize the IP and technologies developed at the HEI. Spin-offs are usually based on research or inventions originating from the institution, while start-ups may include wider business ventures. Spin-offs from HEIs have the potential to translate research results into real applications and economic impact.

HEIs can facilitate the successful creation and growth of *spin-offs* and *start-ups* by promoting technology transfer and innovation, paying particular attention to the following aspects:

- *Entrepreneurship culture and support*: Promote an entrepreneurial culture within the institution to encourage researchers, faculty and students to explore commercialization opportunities. Provide resources, mentoring programs, incubators and support mechanisms to facilitate the creation and growth of *spin-offs* and *start-ups*.
- *Technology identification*: To identify promising technologies or inventions at the HEI that have commercial potential. Assess their marketability, competitive advantage and viability for start-ups. Prioritize technologies that align with market needs, have strong intellectual property protection and demonstrate scalability.
- *Business planning*: Helping researchers and entrepreneurs develop comprehensive business plans for their spin-off or start-up companies. This includes defining the value proposition, target market, revenue model, competitor analysis and growth

strategies. Business plans should address financing needs, market entry strategies and risk mitigation measures.

- *Funding and investment*: Helping spin-offs and start-ups obtain funding to support their initial operations, research and development efforts. Explore various funding sources such as government grants, venture capital, angel investors or strategic partnerships. Help entrepreneurs navigate the funding landscape and connect with potential investors.
- *Management and team building*: Support the recruitment and development of competent management teams for spin-offs and start-ups. Help bring together experienced executives, advisors and mentors who can contribute to the growth and success of the company. Encourage collaboration between the entrepreneurial team and researchers to bridge the gap between technical knowledge and business acumen.
- *Incubation and support services*: Provide incubation programs and support services to help *spin-offs* and start-ups establish their operations. Offer access to shared facilities, labs, office space, mentoring programs, business development support, legal and accounting services and networking opportunities.
- *Collaboration and partnerships*: Promote collaborations between *spin-offs*, start-ups and HEIs. Encourage researchers to maintain links with their academic counterparts, facilitating knowledge exchange and potential collaboration opportunities. Explore strategic partnerships between the institution and business to leverage expertise, resources and industry links.
- *Monitoring and support*: Continuously monitor and support the progress and growth of *spin-offs* and start-ups. Provide ongoing mentoring, guidance and business support services to help address challenges and seize opportunities. Provide access to a network of industry experts and contacts to help with market penetration and business development.

G) Consultancy work by HEI staff and staff exchanges between institutions and industry:

Experienced staff can provide a wide range of services and expertise to industry and government projects, providing solutions to real-world problems. Among others:

- Technical and scientific skills.

- Identification, valuation and commercialization of intellectual property.
- Business development and marketing expertise to help companies introduce new products or services to the market. This can involve market research, product development, pricing and distribution strategies.
- Experience in regulatory compliance, ensuring that industrial and government projects meet legal and ethical requirements. This can include compliance with environmental regulations, health and safety requirements and data protection regulations.
- Training and education programs for industry and public administration professionals on a wide range of topics, promoting knowledge transfer and innovation.

Each mode of technology transfer has its own advantages and disadvantages, and the best approach will depend on the specific objectives and circumstances of the organizations involved.

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