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Présentée par :

Sarah TUNG

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Multiple Intermediaries, Different Roles? Understanding the Functions, Evolution and Skills of Intermediaries in Science-Industry Links

Sous la direction de : **Julien PENIN (directeur)**, Professeur des universités, HDR, Université de Strasbourg et **James BOYER (co-encadrant)**, Maître de conférences, Université Catholique de Lille.

Membres du jury:

Isabel-Maria BODAS-FREITAS	Full Professor, Grenoble Ecole Management	Rapportrice
Aldo GEUNA	Full Professor, University of Turino	Rapporteur
Alessandro NUVOLARI	Full Professor, Scuola Superiore Sant'Anna	Examinateur
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To my beloved grandparents 阿公 (a-gōng) 阿嬤 (a-má)

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All errors or omissions are my sole responsibility.

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GENERAL INTRODUCTION: Multiple Science-Industry Links, Multiple Intermediaries?

What do Stanford, Cambridge, KULeuven, and the University of Strasbourg all have in common? Beyond their academic excellence, these institutions are renowned for their remarkable ability to transform research into groundbreaking innovations through science-industry collaborations. In the United States, Stanford is among the top universities[1] in technology transfer and commercialization (DeVol et al., 2017). In Europe, KULeuven and Cambridge hold top positions, ranking with 1st and 4th respectively among Europe's 100 most innovative universities.[2] The University of Strasbourg, although ranked 60th at the European level, is a notable player in the French innovation landscape with a long history of technology transfer (Olivier-Utard, 2003).

Of course, there are many factors which can explain the success of technology transfer. A combination of sustained entrepreneurial culture, strategic initiatives, and synergy with the local and regional environment can provide a fertile ground for success (Acworth, 2008; Lenoir, 2014; O'Shea et al., 2007). While these explanations prevail, one factor plays a fundamental role in facilitating this process: the roles of support organizations, often referred to as "intermediary organizations" (Villani et al., 2017).

By taking Stanford as an illustration, we can rapidly identify that this university, which stand at the epicenter of Silicon Valley, relies on over a dozen support organizations. For example, the university's *Office of Technology Licensing* (OTL) manages the university's intellectual property and operates with regional venture capital firms. Complementing the OTL's efforts, Stanford also hosts a range of specialized initiatives such as *StartX*, a non-profit accelerator which nurtures Stanford-affiliated startups, and the *Stanford Venture Studio,* which offers resources and mentorship for student entrepreneurs. Stanford also relies on outside

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[1] 5th out of the 225 institutions studied. Stanford scores highest on patents and licensing income.
[2] https://www.reuters.com/graphics/EUROPE-UNIVERSITY-INNOVATION/010091N02HR/ (2019)

organizations in the Sillicon Valley such as *TiE Silicon Valley* which also foster entrepreneurship. The university's commitment to innovation extends to specific sectors, with many research-industry programs such as *SPARK* focusing on biomedical research translation, or the *TomKat Center* supporting technology transfer in sustainable energy solutions. Stanford also fosters collaborative research with industry through centers such as the *Standord SystemXAlliance* which focuses on advancing system-level research in information technologies and electronics systems. The *Stanford Research Park*, one of the world's first university-affiliated research parks, also offers an interface for university-industry collaboration.

This multi-faceted approach to technology transfer is not unique to Stanford; similar arrangements exist in the aforementioned universities and other parts of the world. The observation is the same: a myriad of organizations exists to support science-industry interactions.

1. Science-industry links: from impact to challenges

Science-industry links[3] encompass a diverse range of collaborative activities and knowledge exchange mechanisms between academic institutions and private sector companies (Ankrah & AL-Tabbaa, 2015; Bodas Freitas et al., 2013; Perkmann & Walsh, 2007; Vick & Robertson, 2018). The relationship between science and industry has a long history, dating back to the 19th century when scientific research became more institutionalized within universities (Layton, 1971; Wengenroth, 2000).

Throughout history, there have been numerous examples demonstrating the fundamental role of science and how its translation has led to groundbreaking advancements: from Thomas Edison's Menlo Park laboratory in the late 19th century, leading to the inventions of the phonograph and the electric light bulb, to the development of nylon at DuPont in the 1930s showing how industry could push the boundaries of material science, to the birth of the biotechnology industry in the 1970s and 1980s fueling close collaboration, leading to the production of insulin and other breakthrough therapies, or even the recent global response to the COVID-19 pandemic. All these examples serve as a palpable reminder of how science-industry collaboration has repeatedly proven its power and necessity in driving innovation,

[3] In this thesis, we will also refer to university-industry interactions (UII).

tackling major societal challenges, and transforming multiple sectors, from energy and materials to healthcare and agriculture.

However, the nature and strength of these connections have evolved over time, particularly since the 1980s, due to changing policies and economic contexts. The linear model of innovation proposed by the Bush Report in 1945 which depicted a one-way flow of knowledge from basic research to applied research and commercialization, implied a clear separation and division of labor between these two spheres. This model was challenged as it failed to capture the complex, iterative nature of the innovation process. Instead, innovation studies emphasized the crucial role of interactive and collaborative processes between different actors for strengthening competitiveness in national innovation systems (Freeman, 1995; Kline & Rosenberg, 1986; Lundvall, 1992).

Simultaneously, universities faced increasing pressure to contribute to economic development by expanding their missions beyond education and basic research to include knowledge and technology transfer (Etzkowitz, 1998). The reduction in government involvement and limited public funding for research compelled universities to collaborate more closely with industry (Geuna & Muscio, 2009). For firms, university collaboration became a promising approach to enhance innovation capabilities and competitiveness (Wright et al., 2008), particularly as many shifted towards "open innovation" models that leverage external knowledge and networks to complement their internal R&D efforts (H. Chesbrough, 2006; Perkmann & Walsh, 2007).

Collaboration between academic institutions and industrial partners has since been recognized as a key determinant for economic growth and essential for addressing complex societal issues (OECD, 2023). It has grown substantially across various regions in the world (Ankrah & AL-Tabbaa, 2015) with joint patent applications, academic start-ups, and licensing activity, all increasing significantly. For example, joint patenting between academic research institutions and industry have grown faster than solo applications by universities, accounting for 24% of all EPO (European Patents Office) patents in 1992, and increasing up to 43% by 2014 (OECD, 2019b). Academic start-ups in the OECD countries[4] have also become more prominent, making up 14-15% of all start-up activity between 2001 and 2016 (OECD, 2019). Additionally, the number of licenses granted by US universities underwent a significant increase over the

[4] The study accounts for 20 countries including 16 OECD nations plus Brazil, China, India, and Russia.

1990s, from about 300 in 1980 to 2,000 in 1995[5]. This trend continues nowadays with the 26.5% increase from 2015 to 2020 (AUTM, 2020). Science-industry links now cover a wide range of activities, beside joint research projects, licensing of intellectual property, and the creation of spin-offs, these also include consulting, contract research, mobility of staff between the two spheres, joint supervision of students..etc.[6]that also constitute pathways that bridge industry and academia.

Despite recognized benefits and growing trends, science-industry collaboration also faces significant challenges. It would be overly simplistic to assume that successful collaboration merely requires bringing the two actors together.

From the issues surrounding the impact of science and the difficulties of transferring and valorizing it - referred to as the metaphoric “Valley of death” (Branscomb & Auerswald, 2002), to the challenges stemming from differences in objectives, time horizons, and operational cultures (Bruneel et al., 2010; Perkmann et al., 2013), science-industry is marked by paradoxes, tensions, and challenges. Significant gaps persist between the world of scientific research and industrial application. The open nature of academic science can conflict with the companies' need to protect the technologies they use while universities’ longer-term focus and bureaucracy can clash with industry’s fast-paced, project-driven R&D.

Forging successful and sustainable partnerships requires carefully navigating a range of organizational, cultural, and institutional barriers (Albors-Garrigós et al., 2014; Gilsing et al., 2011; O’Dwyer et al., 2022; Rossoni et al., 2023) which emphasize the need for intervention, that is an intermediary. These obstacles will therefore be a fundamental aspect of this research and will be developed further in the thesis.

While research has given much focus on science and industry actors both at institutional and individual level (Perkmann et al., 2021), this thesis proposes a shift in focus towards the less visible, yet equally critical, actors that operate behind the scenes (Clayton et al. 2018) to support these links.

[5] https://news.mit.edu/1998/nelsen-0926 (last visited October 2024)
[6] See following chapter for full review.

2. Science-industry intermediaries: a brief overview

The notion of intermediation has developed in various disciplines from economic science and management, with an emphasis on innovation but also environmental science, geography. In the context of economics and business, "intermediation" initially refers to the process by which banks or brokers, facilitate transactions between two other parties (e.g., lenders and borrowers or buyers and sellers). The notion of “intermediation” comes from the latin root “intermediārius”, which itself derives from inter, meaning "between," and medius, meaning "middle" or "midway." It refers to the act of standing between two parties, mediating or facilitating exchanges, and goes back to the idea of acting as a "middleman" in a variety of contexts. These organizations, whether public or private, are neutral entities which serve as 'institutional bridges' (Mokyr, 2002), or as the 'glue' that holds various actors together (Iturrioz et al., 2015), working “behind the scenes” (Clayton et al., 2018) to facilitate different aspects of innovation (Howells, 2006). Their role is multifaceted encompassing the dissemination of information, fostering connections, and catalyzing collaborations that might not otherwise occur (Howells, 2006). In the University-Industry Interactions (UII) context, intermediaries can be defined as *“organizations that facilitate the exchange (scientific and technological) knowledge between universities and industry by creating two-way value-added relationships”* (Santos et al. 2023, p. 1).

The general increase in science-industry collaboration in the late 20th was accompanied by the rise of support organizations. Although intermediaries have arisen organically, most of the common intermediaries that we know of today, have been institutionalized through government policies.

The role of research in fostering innovation became of critical concern for policymakers (European Commission, 2024; Mazzucato et al., 2018). Policies like the *Bayh-Dole Act* (1980) in the U.S. aimed to accelerate the translation of publicly funded research into commercial applications, enabling universities to protect intellectual property (IP) and license research to the private sector. This law required universities to set up technology transfer offices (TTOs), thus marking the beginning of the history of intermediary organizations[7]. Universities across the U.S. rapidly established TTOs, with their numbers growing from just 25 in 1980 to over 200 by 1990 (Mowery et al., 2001). This trend soon spread globally, with countries in Europe

[7] See Chapter 2 for historical analysis of intermediaries before 1980.

adopting similar policies and establishing their own TTOs throughout the 1990s and 2000s. For instance, the UK saw a significant increase in TTOs following the 1985 British Technology Group privatization and subsequent policy changes. In Continental Europe, the growth of TTOs was notably influenced by the 1998 Flemish decree on universities and the 1999 Professors' Privilege abolition in Germany. In France, universities equipped themselves with internal structures, called "SAIC" after the 1999 Law on Innovation and SATT (TTOs) created only in 2010, with 30 years difference with the US.

Academic incubators which support academic entrepreneurship also began around this time[8], growing from approximately 40 academic incubators in the US in the 1980s, to over 100 by the mid-1990s and over 1000 by 2010 (Mian et al., 2016). The 1990s and 2000s saw a global expansion of the academic incubator model. In Europe, the European Business and Innovation Centre Network (EBN), founded in 1984, supported the development of incubators across the continent, many of which linked to universities (European Comission., 2002).

The concept of science parks, pioneered by Stanford Research Park in 1951 (Castells, 2014), inspired similar initiatives worldwide. In the United Kingdom, the first science park was established at Heriot-Watt University in Edinburgh in 1965, marking the beginning of the science park movement in Europe (Bakouros et al., 2002). Science Parks aimed to create a symbiotic relationship between universities and high-tech companies, fostering innovation and technology transfer (Link & Scott, 2003). In the United States, the number of university research parks grew from 12 in 1980 to 200 by 2012 (Mian et al., 2016), while Europe, had about 400 science parks in 2014 (Lecluyse et al., 2019).

3. The current landscape

Over time, many different types of organizations have emerged to facilitate science-industry links (Joint Research Centers, Research and Technology Organizations, Competitiveness Clusters, Innovation Agencies...etc) and continue to multiply in number and in diversity (fab-labs, living-labs, Proof-of-concepts centers etc.)[9]

The contemporary landscape of intermediary organizations has become increasingly complex, with each intermediary type characterized by distinct focus, methods, and strengths. While

[8] The concept of business incubators first emerged in the 1950s, but academic incubators, specifically tied to universities, have a more recent history.
[9] See Chapter 1 for full review.

these intermediaries serve various functions and engage in different activities, there have overlaps in their roles (Good et al. 2019) when it comes to facilitating University-Industry Interactions (UII). This complexity can present challenges for stakeholders, including researchers, companies, investors, entrepreneurs, and policymakers, in understanding the specific roles and responsibilities of each intermediary type.

This issue has been raised by policies, particularly in the French context. The proliferation of support structures for research and innovation in France began as early as in the 1990s and has increasingly become a subject of policy concern, particularly since the 2010s. This multiplicity of actors, while initially intended to boost collaborative research and innovation, has been identified by several official reports (over 20) as a significant issue requiring attention and reform (Oumohand, 2020). In the seminal report from the IGAENR[10] in 2013, authors identify a lack of strategic coherence across support mechanisms, exacerbated by fragmented administration across multiple governmental bodies and emphasizes that successive policy schemes since 2000 have resulted in the creation of new tools that overlap with previous ones, rather than replacing them. Consequently, the authors argue that this landscape presents a significant barrier to innovation, particularly for small and medium-sized enterprises (SMEs) that may lack the resources to navigate such a complex system effectively (Thiard et al., 2013, p.15-16). This redundancy is also highlighted in the following extract from the Cour des Comptes' report published in the same year: *"Public mechanisms aimed at supporting research and innovation and the valorization and transfer of research results, are numerous, some redundant, and clearly call for an effort of simplification"* (Cour des Comptes, 2013, p.171).

These examples illustrate the complexity of the "*millefeuille*", a term used to describe the layered and intricate nature of the French research and innovation support system, recognized as specificity of the French system (OCDE, 2014). The aforementioned reports along others[11] consistently identify the issue of complexity and lack of readability in the system and the

[10] The IGAENR (General Inspectorate of the Administration of National Education and Research) is a high-level French government body that oversees and advises on education and research. It evaluates institutions and policies, advises ministers, conducts studies to improve efficiency, and recommends reforms in these sectors. Its report merits particular attention in the discourse on French innovation policy because it has been frequently cited as it represents one of the first comprehensive analyses. Moreover, prior reports don't include Technology Transfer Offices (TTOs) which were created in 2012 in France.
[11] see Oumohand, 2020 for full description of reports from 1998 to 2018.

accumulation of institutional devices without a coherent overall vision and call for a more streamlined approach to support research and innovation in France.

Although this perspective prevails today, recent policy discourse also indicates a more nuanced approach. For instance, the 2018 report for the government on innovation aids proposes a more balanced approach to improving the existing system. While acknowledging the need for simplification, as illustrated by recommendations such as merging some structures or eliminating others, the report emphasizes the importance of maintaining system stability and explicitly cautions against precipitous restructuring. The authors underscore the risks associated with excessive homogenization, which could potentially disregard regional specificities and the multifaceted nature of innovation processes (Lewiner et al., 2018, p.27). Rather than proposing reduction in institutional structures, they recommend improving the system's overall transparency and accessibility. Similarly, the most recent report published in June 2023 by the Ministry of Higher Education, Research and Innovation points out that the existing diversity may be necessary to be in alignment with the needs of each territory. This report challenges the idea that the primary focus should be on clarifying the roles and responsibilities of actors (including intermediary structures themselves) and improving coordination among them, rather than simplifying the system or creating new structures (Gillet, 2023, p.65).

In the literature, research has also identified the challenges of having too many structures and started to call for further research to take action in this regard. The literature on innovation intermediaries, which focus on the roles of intermediaries in broader collaborations beyond just science-industry partnerships, acknowledges that these organizations have become increasingly numerous and diverse over time, making them a somewhat fuzzy concept to define and study. As Caloffi et al. (2023) pointedly note, the expansion of research on intermediaries has paradoxically led to a less clear understanding of their characteristics and functions. This confusion stems from the plethora of terms used to describe intermediaries (e.g., brokers, matchmakers, boundary spanners) and the focus on various highly heterogenous and redundant organizations (e.g., knowledge-intensive business services, technology transfer agencies, science parks, incubators, virtual platforms) (Kanda et al., 2018).

The entrepreneurship literature has also begun to acknowledge the potential drawbacks of an overabundance of support structures within entrepreneurial ecosystems (e.g. incubators, accelerators, science parks, maker spaces). The lack of differentiation and targeting makes it difficult for entrepreneurs to find the most suitable support organization for their needs, creating the perception of a “cluttered landscape” (Hruskova et al., 2022). Despite recognizing this problem, the literature has failed to adequately address it, with most studies remaining siloed and examining specific support forms in isolation rather than considering them as a broader category (Bergman & McMullen, 2022).

The literature on technology transfer and commercialization of science draws similar conclusions. While intermediaries are numerous (Santos et al., 2023), the again atomistic approach (Good et al. 2018), with each component (intermediary) being studied as a separate unit of study, has severely limited our understanding of their comparisons and synergies (Clayton et al., 2018). Recent research urgently calls for a holistic approach to grasp the interactions, potential overlaps, and synergies among intermediaries (Good et al. 2019). Clayton et al. (2018) advise to consider the "fuller institutional picture" and institutional diversity in a defined setting, rather than myopically focusing on identifying a single best intermediary.

The study of intermediaries in science-industry links as a category is a relatively new phenomenon (Villani et al., 2017, Santos et al. 2023), and the lack of an overarching framework on the roles of science-industry intermediaries is where this research stands by. In fact, this thesis aims to cut through the confusion both in practice and theory by investigating at once the roles of multiple intermediaries in multiple channels of U-I. By opting for a holistic approach—that is, by simultaneously considering all intermediaries, their functions, and their synergies—we argue that this complexity and diversity can be justified.

4. General problematic and research approach

4.1 Problematic, objectives of research, specific research questions

The previous contextual elements and the current literature led me to question this multiplicity of actors, and depart from the idea that it may be wrong to assume to simplify the landscape considering that links between science and industry have become complex. Hence, this thesis will focus on this principal following question:

How can we explain the multiplicity of intermediaries in the science-industry context?

The general research question calls for investigating more deeply science-industry links from a relational perspective, the intermediaries, their functions in its organizational and micro-perspective, their emergence and evolution, but also relationships between the two and between them. In doing so, I asked myself what theory and real cases could tell us about this phenomenon but also what history and micro level-data could additionally bring to our research inquiry. In fact, I addressed these following questions such as:

- How U-I intermediaries complement each other and collaborate by leveraging different barriers ? (Q1)
- When did first intermediary forms emerged, how did they evolve and why? (Q2)
- How are the functions of intermediaries translated with the skills of individuals working in these organizations, and how do these skills differ? (Q3)

This thesis draws upon the economic, management and historical literature in the field of innovation and entrepreneurship. Due to the emergence of science-industry links and of U-I intermediaries in the Western World and its particularity in France, this thesis specifically focuses on these areas.

4.2 General research methodology and main research results

The strength and originality of this research lie in its holistic analysis of intermediaries but also the employment of diverse methodological strategies across its chapters.

The decision to employ multiple methodologies is motivated by several factors. First, given the exploratory nature of the research question and the lack of comprehensive datasets, this thesis merits the use of diverse methodological tools to support its arguments. All data used in this thesis have been collected specifically for this research. The second reason stems from the literature on University-Industry (U-I) intermediaries, which, to my knowledge, has been limited in its adoption of some of the methodologies developed in this thesis. Finally, the third reason is motivated by my curiosity, coming from a background in statistical and econometric analysis in the social sciences, I have always wondered about other ways of conducting research.

This dissertation is structured to systematically address our research question(s) and is organized into four chapters with each chapter employing a distinct theoretical and empirical methodological approach. First and foremost, to answer our main research question, we adopt a theoretical and conceptual approach. **Chapter 1** serves as the cornerstone of this thesis, providing a robust theoretical and conceptual framework that underpins the entire research. This chapter is pivotal as it elucidates the fundamental link between science-industry relationships and intermediary organizations. Through in-depth analysis of the literature university-industry interactions, and innovation intermediaries, this chapter develops an overarching conceptual model of the roles of intermediaries in facilitating different science-industry interaction. The theoretical lens and perspectives developed here serve as a guiding and common thread throughout the thesis, ensuring coherence and depth in our analysis.

Building upon this theoretical foundation, **Chapter 2** takes a historical perspective and gives evolutionary insights on science-industry intermediaries. This chapter focuses on tracing the evolution of intermediary organizations through three distinct periods, from the prehistory of science in the 12th and 13th centuries to the early 20th century. By identifying key historical trends and turning points in the development of these intermediaries, this chapter provides evidence of the first existing intermediaries and their evolution throughout history. This historical perspective enriches our understanding by revealing the long-term dynamics and transformations in the field of science-industry intermediation. Together, Chapters 1 and 2 allow for a comprehensive understanding of the link between types of science-industry relationships and types of intermediaries.

The final two chapters of the thesis, Chapters 3 and 4, transition from theoretical analyses to empirical investigations in the field. **Chapter 3** uses a qualitative study with in-depth exploration of specific cases and provides an empirical demonstration and extension of the model constructed in Chapter 1 through 33 interviews of 8 case studies in the health sector in the region of Hauts-de-France. As such, Chapters 1 and 3 should be considered as twin chapters in this thesis, with Chapter 3 validating and potentially refining the theoretical propositions of Chapter 1.

Chapter 4 provides a broader and generalizable data using a novel quantitative survey developed during this research of 214 employees working in different intermediary organizations. Therefore, this chapter takes a micro-level approach, shedding light on the competences of employees working within these intermediary organizations. This chapter adds a crucial dimension to our understanding of intermediaries by focusing on the human capital that enables these organizations to function effectively.

The structure of this thesis therefore follows a logical progression, moving from establishing theoretical foundations to providing historical context, and finally conducting empirical investigations at both organizational and individual levels. Moreover, each chapter is built upon the insights of the previous ones, creating the narrative of the thesis. The conceptual framework from Chapter 1 informs the historical analysis in Chapter 2, and provides context for the empirical study of Chapter 3. The insights emerging from the cases studies, lead to the problematic approach of Chapter 4. The empirical findings from the later chapters can also feed back into the theoretical framework of Chapter 1, allowing for refinement and expansion of the initial concepts.

The principal findings of the thesis defend the existence of multiple intermediaries due to their complementarities both at organizational and individual level (Chapter 1, 3 & 4), their coordinated efforts (Chapter 3) and the dynamic evolution of their functions in response to changes in science-industry relationships and historical contexts (Chapter 2). This thesis provides conceptual and empirical evidence supporting a multiple-intermediary model in which intermediaries co-exist within the science-industry ecosystem.

The multiple approach adopted in this thesis is also reflected in the diverse ways the research results have been disseminated. The findings have been valorized through multiple channels: scientific articles submitted in peer-reviewed journals, presentation and exchanges with peers in conferences, dissemination of research results to practitioners (University, Innovation Agency, general public) and engagement in workshops with the University. Throughout this thesis, I gave particular attention to how my findings could be translated to have practical relevance and impact beyond academia and took initiatives to propose the possibility for participants in the study to gain insights of the findings. In fact, two workshops organized by the Lille Catholic University allowed me to share results in this way.

5. Structure of the thesis

This thesis started with an introduction in which we contextualize our research, as we have seen, the concept of multiple intermediaries have animated different political debates. The chapters of this manuscript and how they address our main research question and the different sub-research questions is structured as depicted in **Figure 1**. Finally, we provide a discussion section for mentioning limitations especially investigating future paths of research and highlighting the modest contributions of this thesis.

This thesis manuscript is derived in research articles. More specifically, Chapter 1, 2 and 3 are structured into research articles that have been submitted to conferences and later on in journals, receiving first rounds of revisions. A detailed summary is provided in **Table 1.**

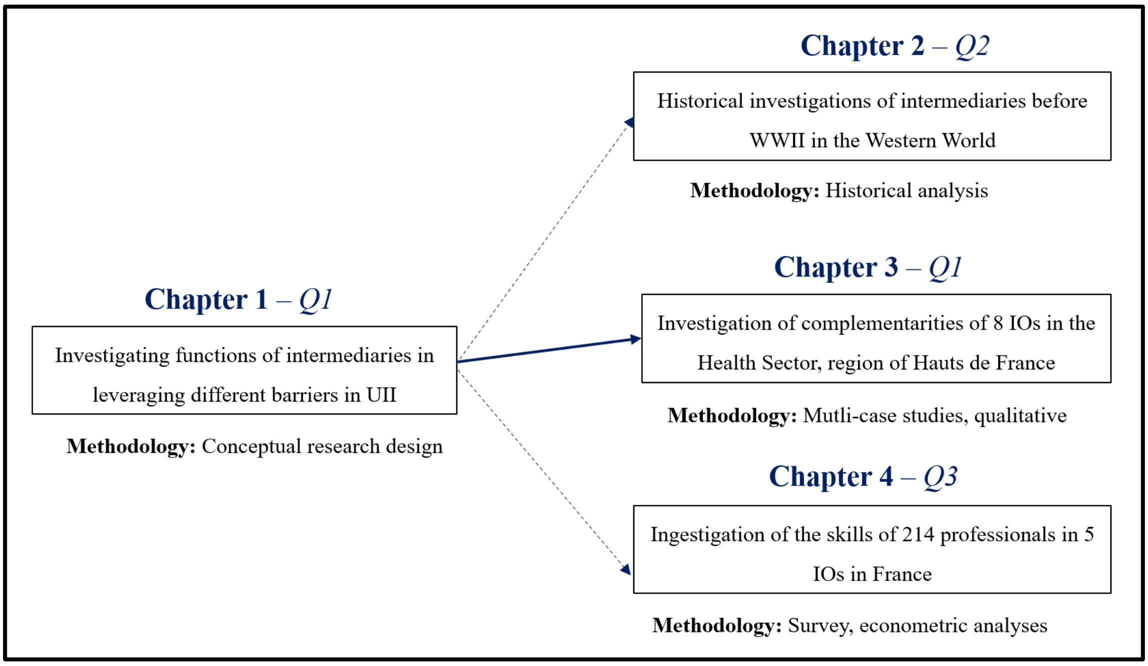

Figure 1: Thesis Overview

- ***Chapter 1 – For One Problem, One Solution: Unpacking the Diversity and Roles of U-I intermediaries***

Chapter 1 lays the theoretical and conceptual groundwork for the entire thesis, offering a structured framework for understanding the existence of multiple U-I intermediaries. Through the development of a conceptual framework and model, it justifies the multiplicity of intermediary organizations (IOs) in diverse university-industry interactions (UII). More specifically, the particularity of this model is its use in the concept of barriers in science-industry relationships. Through a comprehensive literature review on interactions, barriers, and intermediaries, the chapter identifies two barriers "Williamson-type barrier" and "Merton-type barrier" and introduces a novel "Polanyi barrier". This work shows that some intermediaries are better at tackling some barriers than others in specific UII. This work resulted in an article version which was submitted in July 2023 and in July 2024 with revisions in the journal of *Industry & Innovation*.

- ***Chapter 2 – The History of Science-Industry Intermediaries until WWII, a functionalist view***

Chapter 2 delves into the historical emergence and evolution of science-industry intermediaries in the Western world. Challenging the common perception that science-industry links began post-WWII, this chapter traces the roots of intermediation to much earlier periods. Using a neo-Schumpeterian or evolutionary economics framework, the Chapter examines how intermediaries evolved in response to changing historical contexts and the evolution of science and industry links, especially their institutionalization. The chapter identifies three distinct periods of intermediary development and uses the conceptual framework developed in Chapter 1 to show that different forms of intermediaries appeared throughout history to address specific barriers. The first period (pre-19th century), intermediaries focused on reducing Williamson barrier, while later periods show a shift towards reducing Polanyi and Merton-type barriers. This historical analysis reveals the long-term dynamics of the functions of intermediaries. By identifying and examining approximately ten distinct forms of intermediation throughout history, the chapter provides a comprehensive understanding of how these structures have always existed to overcome barriers in science-industry links. This work is intended to be adapted in article version to be submitted in the *Journal of Evolutionary Economics* on the 31st of October 2024.

- ***Chapter 3 – How Do U-I intermediaries Work Together: Insights from a Leading Health Sector Region in France***

This chapter presents an empirical investigation into the roles of intermediary organizations (IOs) in facilitating university-industry interactions (UII). Chapter 3 is structured on the basis of an article submitted in the journal *Technovation* in October 2023 and underwent a first round of revision which are included in this version. On the basis of 33 interviews conducted in eight types of IOs in the health sector of the Hauts-de-France region, this chapter aims to empirically explore the conceptual model developed in Chapter 1 and further explores how these intermediaries collectively facilitate UII. This empirical demonstration of the conceptual framework from Chapter 1 highlights the specific roles of each IO and emphasizes that various IOs collaborate to overcome different barriers. Different coordination patterns among IOs are identified which are influenced by the type of interaction channel and the nature of barriers. Amidst this process, we identify another barrier that we name "Arthur-type barriers". Beyond the exploration of the conceptual model, this chapter emphasize that some IOs collaborate or act independently.

➢ ***Chapter 4 – One Step Beyond: An exploration of Skills and Background of U-I Intermediary Professionals?***

Chapter 4 plays a crucial role in the thesis by shifting the focus to a micro-level analysis of U-I intermediaries, examining the individual characteristics of employees within these organizations. This approach complements the earlier chapters' exploration of organizational aspects, functions, and historical evolution of intermediaries by addressing a significant gap in the literature on individual-level characteristics of U-I intermediaries. The chapter presents the first survey-based study of these professionals in the French context, providing novel empirical insights into the skills and backgrounds of employees across five types of IOs (TTOs, Academic Incubators, Clusters, RTOs, and FabLabs). The chapter sheds lights on the balance between generic and specific technical skills and how it varies across different intermediary types and activities. Each intermediary type shows distinct preferences in skills and educational backgrounds that align with their core functions.

The following Table presents an overview of the main submissions of the chapters in conferences as well in peer-review journals.

Chapters	Title and description	Details of submissions	Co-authorships
1	***For One Problem, One Solution: Unpacking the Diversity and Roles of U-I intermediaries*** Development of a conceptual framework and a model explaining the diversity of U-I intermediaries.	Presented at R&D Management 2023, Trento. Submitted in Industry & Innovation in July 2022 (2nd Revise and Resubmit)	No

2	***The History of Science-Industry Intermediaries until WWII, a functionalist view*** Evolutionary analysis of the first forms of intermediation and their functions, from an economic-historical perspective.	Presented at Technology Transfer for Society 2024, Brussels. Submitted to the Journal of Evolutionary Economics in October 2024 (1st Revise and Resubmit)	Co-authored with Julien Pénin[12]
3	***How Do U-I intermediaries Work Together: Insights from a Leading Health Sector Region in France*** Qualitative survey (33 interviews, 8 types of organisation) in the health sector in Hauts de France, aimed at testing and refining the conceptual model.	Presented at EURAM 2024, Dublin. Submitted in Technovation in October 2023 (3 rounds)	No
4	***One Step Beyond: An exploration of Skills and Background of U-I Intermediary Professionals?*** Quantitative survey of 214 employees in five types of intermediary organisations, to determine the specific generic and technical skills required.	Accepted to EURAM 2025, Florence (will be presented in June 2025)	No

Table 1: Overview of submission and contributions of chapters

[12] All chapter was written by me except for section 2. Julien Pénin also contribtued to the introduction.

INTRODUCTION GENERALE : Diversité des liens science-industrie, diversité des intermédiaires?

Que peuvent avoir en commun Stanford, Cambridge, la Katholieke Universiteit Leuven (KULeuven) et l'Université de Strasbourg ? Au-delà de leur excellence académique, ces établissements sont réputés pour leur remarquable capacité à transformer la recherche en innovations de pointe grâce à des collaborations entre la science et l'industrie. Aux États-Unis, Stanford se classe parmi les meilleures universités pour le transfert de technologie et la commercialisation (DeVol et al., 2017). En Europe, la KULeuven et Cambridge occupent respectivement la 1re et la 4e place parmi les 100 universités les plus innovantes du continent. L'Université de Strasbourg, bien que classée 60e au niveau européen, constitue un acteur notable du paysage français de l'innovation, avec une longue histoire de transfert de technologie (Olivier-Utard, 2003).

Bien sûr, de nombreux facteurs peuvent expliquer le succès du transfert de technologie. Une combinaison de culture entrepreneuriale pérenne, d'initiatives stratégiques et de synergies avec l'environnement local et régional peut fournir un terreau fertile à la réussite (Acworth, 2008 ; Lenoir, 2014 ; O'Shea et al., 2007). Parmi ces explications, un facteur joue cependant un rôle fondamental dans la facilitation de ce processus : l'action des organisations de soutien, souvent appelées « organisations intermédiaires » (Villani et al., 2017).

Si l'on prend l'exemple de Stanford, on constate rapidement que cette université, située au cœur de la Silicon Valley, s'appuie sur plus d'une dizaine d'organisations de soutien. Par exemple, l'Office of Technology Licensing (OTL) de Stanford gère la propriété intellectuelle de l'université et collabore étroitement avec des fonds de capital-risque régionaux. En complément des efforts de l'OTL, Stanford héberge plusieurs initiatives spécialisées telles que StartX, un accélérateur à but non lucratif qui accompagne les start-ups affiliées à l'université, et le Stanford Venture Studio, qui offre ressources et mentorat aux entrepreneurs étudiants. Au-delà de ses structures internes, l'université s'appuie sur des organisations externes de la Silicon Valley comme TiE Silicon Valley, qui contribue également à la promotion de l'entrepreneuriat.

L'engagement de Stanford en faveur de l'innovation s'étend à des secteurs spécifiques : de nombreux programmes de recherche partenariale, tels que SPARK pour la recherche biomédicale, ou le TomKat Center pour le transfert de technologies dans le domaine des énergies durables. Stanford encourage aussi la recherche collaborative avec l'industrie via des centres comme le SystemX Alliance, dédié à la recherche en technologies de l'information et en systèmes électroniques. Le Stanford Research Park, l'un des premiers parcs de recherche affiliés à une université, offre en outre une interface concrète pour la collaboration université-industrie.

Cette approche multifacette du transfert de technologie n'est pas propre à Stanford ; des dispositifs similaires existent dans les universités mentionnées et ailleurs dans le monde. L'observation reste la même : une myriade d'organisations œuvre à soutenir les interactions science-industrie.

1. Liens science-industrie : de l'impact aux enjeux

Les liens science-industrie[13] englobent une vaste gamme d'activités collaboratives et de mécanismes d'échange de connaissances entre institutions académiques et entreprises privées (Ankrah & Al-Tabbaa, 2015 ; Bodas Freitas et al., 2013 ; Perkmann & Walsh, 2007 ; Vick & Robertson, 2018). L'histoire de cette relation remonte au XIXe siècle, lorsque la recherche scientifique s'est institutionnalisée au sein des universités (Layton, 1971 ; Wengenroth, 2000).

Au fil du temps, de nombreux exemples illustrent le rôle fondamental de la science et la manière dont sa traduction a conduit à des avancées majeures : du laboratoire de Menlo Park de Thomas Edison à la fin du XIXe siècle, avec l'invention du phonographe et de l'ampoule électrique, au développement du nylon chez DuPont dans les années 1930, en passant par l'émergence de l'industrie biotechnologique dans les années 1970-1980, jusqu'à la réponse mondiale récente à la pandémie de COVID-19. Ces exemples rappellent concrètement combien la collaboration science-industrie s'est avérée à maintes reprises essentielle pour stimuler l'innovation, relever des défis sociétaux majeurs et transformer des secteurs variés tels que l'énergie, les matériaux, la santé et l'agriculture.

[13] Dans cette thèse, nous nous referrons également aux Interactions Universités-Industries (UII)

Cependant, la nature et la force de ces liens ont évolué au fil du temps, notamment depuis les années 1980, sous l'effet des changements de politiques et de contextes économiques. Le modèle linéaire de l'innovation, formalisé par le rapport Bush en 1945, envisageait un flux unidirectionnel des connaissances de la recherche fondamentale vers la recherche appliquée et la commercialisation, impliquant une séparation nette des rôles. Ce modèle a été remis en question, car il ne rendait pas compte de la nature itérative et complexe du processus d'innovation. Les études en innovation ont alors souligné l'importance des processus interactifs et collaboratifs entre acteurs pour renforcer la compétitivité des systèmes nationaux d'innovation (Freeman, 1995 ; Kline & Rosenberg, 1986 ; Lundvall, 1992).

Parallèlement, les universités ont vu leur mission s'élargir sous la pression de l'attente de contributions accrues au développement économique, au-delà de l'enseignement et de la recherche fondamentale, pour inclure le transfert de connaissances et de technologies (Etzkowitz, 1998). La réduction de l'intervention publique et le recul des financements publics ont amené les universités à se tourner davantage vers l'industrie (Geuna & Muscio, 2009). Pour les entreprises, collaborer avec les universités est devenu un moyen prometteur d'améliorer leurs capacités d'innovation et leur compétitivité (Wright et al., 2008), notamment dans un contexte d'innovation ouverte, où l'on puise dans l'expertise et les réseaux externes pour compléter les efforts internes de R&D (Chesbrough, 2006 ; Perkmann & Walsh, 2007).

Depuis, la collaboration entre milieux universitaires et industriels est reconnue comme un déterminant clé de la croissance économique et essentielle pour relever des enjeux sociétaux complexes (OCDE, 2023). Elle s'est fortement développée à travers le monde (Ankrah & Al-Tabbaa, 2015), comme en témoignent la hausse des demandes de brevets conjoints, des créations de start-ups académiques et de l'activité de licences. Ainsi, les brevets co-dépôt par les institutions académiques et l'industrie passaient de 24 % des brevets de l'OEB (Office des Brevets Européens) en 1992 à 43 % en 2014 (OCDE, 2019b). Les start-ups académiques représentaient 14–15 % de l'ensemble des créations d'entreprises dans les pays de l'OCDE[14] entre 2001 et 2016 (OCDE, 2019). De même, les licences octroyées par les universités

[14]Cette étude prend en compte 20 pays y compris les 16 pays de l'OCDE, plus du Brésil, la Chine, l'Inde et la Russie.

américaines sont passées d'environ 300 en 1980 à 2 000 en 1995[15], avec une hausse de 26,5 % entre 2015 et 2020 (AUTM, 2020).

Outre les projets de recherche conjoints, le transfert de technologie comprend également le conseil, la recherche sous contrat, la mobilité des personnels, la co-supervision d'étudiants, etc.[16], autant de voies qui rapprochent industrie et université.

Malgré ces bénéfices et tendances croissantes, la collaboration science-industrie se heurte à d'importants défis. Il serait simpliste de croire qu'il suffit de rapprocher les deux acteurs pour assurer le succès.

Des difficultés liées à l'impact de la recherche et à sa valorisation, souvent qualifiées de « vallée de la mort » (Branscomb & Auerswald, 2002), aux différences d'objectifs, d'horizons temporels et de cultures opérationnelles (Bruneel et al., 2010 ; Perkmann et al., 2013), les collaborations sont marquées par des paradoxes et des tensions. L'ouverture de la science académique peut entrer en conflit avec la nécessité des entreprises de protéger leurs technologies, tandis que la vision à long terme et la bureaucratie universitaire peuvent se heurter au rythme rapide de la R&D industrielle.

Réussir et pérenniser ces partenariats exige de surmonter des barrières organisationnelles, culturelles et institutionnelles (Albors-Garrigós et al., 2014 ; Gilsing et al., 2011 ; O'Dwyer et al., 2022 ; Rossoni et al., 2023), soulignant le besoin d'interventions, c'est-à-dire d'intermédiaires. Ces obstacles seront donc un axe central de cette recherche et seront développés plus en détail dans la thèse.

Alors que la recherche s'est beaucoup focalisée sur les acteurs académiques et industriels, tant au niveau institutionnel qu'individuel (Perkmann et al., 2021), cette thèse propose de déplacer le regard vers des acteurs moins visibles, mais tout aussi essentiels, qui œuvrent en coulisses pour soutenir ces interactions (Clayton et al., 2018).

[15] https://news.mit.edu/1998/nelsen-0926 (site visité en Octobre 2024)
[16] Voir chapitre 1 pour la revue complète.

2. Intermédiaires science-industrie : un bref aperçu

La notion d'intermédiation s'est développée dans de nombreuses disciplines, de l'économie de l'innovation à la géographie, en passant par les sciences de l'environnement. En économie et gestion, l'« intermédiation » désigne initialement le processus par lequel banques ou courtiers facilitent les échanges entre prêteurs et emprunteurs ou entre acheteurs et vendeurs. Le terme vient du latin « intermediārius », dérivé de « inter » (entre) et « medius » (milieu), évoquant l'idée d'un intermédiaire jouant le rôle de « tiers de confiance ».

Ces organisations, publiques ou privées, sont des entités neutres qui servent de « ponts institutionnels » (Mokyr, 2002) ou de « colle » qui maintient les différents acteurs ensemble (Iturrioz et al., 2015), œuvrant en coulisses (Clayton et al., 2018) pour faciliter divers aspects de l'innovation (Howells, 2006). Leur rôle est multifacette : diffusion d'informations, mise en relation et catalyse de collaborations qui n'auraient pas lieu autrement (Howells, 2006). Dans le contexte des interactions université-industrie (UII), les intermédiaires peuvent être définis comme « *des organisations qui facilitent l'échange (scientifique et technologique) de connaissances entre universités et industrie en créant des relations bidirectionnelles à valeur ajoutée* » (Santos et al., 2023, p. 1).

La croissance générale de la collaboration science-industrie à la fin du XX^{e} siècle s'est accompagnée de l'émergence d'organisations de soutien. Bien que les intermédiaires soient apparus de façon organique, la plupart des dispositifs que nous connaissons aujourd'hui ont été institutionnalisés par des politiques publiques.

Le rôle de la recherche dans la promotion de l'innovation est devenu une préoccupation majeure des décideurs (Commission européenne, 2024 ; Mazzucato et al., 2018). Des politiques telles que le Bayh-Dole Act (1980) aux États-Unis visaient à accélérer la traduction des recherches financées par des fonds publics en applications commerciales, en permettant aux universités de protéger la propriété intellectuelle et de concéder des licences à des entreprises privées. Cette loi a exigé la création de bureaux de transfert de technologie (BTT), marquant ainsi le début de l'histoire des organisations intermédiaires. Aux États-Unis, le nombre de BTT est passé de 25 en 1980 à plus de 200 en 1990 (Mowery et al., 2001). Cette tendance s'est rapidement étendue : l'Europe a adopté des politiques similaires dans les années 1990 et 2000, multipliant les BTT. En Royaume-Uni, la privatisation du British Technology Group en 1985 a favorisé la création de nombreuses structures. En Europe continentale, la croissance des BTT a été influencée par le décret flamand de 1998 sur les universités et par l'abolition du privilège du professeur en Allemagne en 1999. En France, les universités ont mis en place des structures internes appelées SAIC après la loi sur l'innovation de 1999, tandis que les SATT (Sociétés d'Accélération du Transfert de Technologie) n'ont été créées qu'en 2010, soit trente ans après les États-Unis.

Les incubateurs académiques, soutenant l'entrepreneuriat universitaire, sont apparus à la même époque, passant d'environ 40 incubateurs aux États-Unis dans les années 1980 à plus de 100 au milieu des années 1990, puis à plus de 1 000 en 2010 (Mian et al., 2016). Les années 1990 et 2000 ont vu une expansion mondiale de ce modèle d'incubateurs. En Europe, le réseau European Business and Innovation Centre (EBN), fondé en 1984, a soutenu le développement d'incubateurs, dont beaucoup étaient liés à des universités (Commission européenne, 2002).

Le concept de parc scientifique, initié par le Stanford Research Park en 1951 (Castells, 2014), a inspiré des initiatives similaires dans le monde entier. Au Royaume-Uni, le premier parc scientifique a été créé à l'Université Heriot-Watt d'Édimbourg en 1965, ouvrant ainsi la voie au mouvement des parcs scientifiques en Europe (Bakouros et al., 2002). Les parcs scientifiques avaient pour objectif de créer une relation symbiotique entre universités et entreprises de haute technologie, favorisant l'innovation et le transfert de technologies (Link & Scott, 2003). Aux États-Unis, leur nombre est passé de 12 en 1980 à 200 en 2012 (Mian et al., 2016), tandis qu'en Europe, on en dénombrait environ 400 en 2014 (Lecluyse et al., 2019).

3. Paysage actuel

Au fil du temps, de nombreux types d'organisations ont émergé pour faciliter les liens science-industrie (centres communs de recherche, organismes de recherche technologique, pôles de compétitivité, agences d'innovation, etc.) et continuent de se multiplier en nombre et en diversité (fab-labs, living labs, centres de preuve de concept, etc.).

Le paysage contemporain des organisations intermédiaires est devenu de plus en plus complexe, chaque type d'intermédiaire étant caractérisé par un focus, des méthodes et des atouts spécifiques. Bien qu'ils remplissent différentes fonctions et activités, on observe des recouvrements dans leurs rôles (Good et al., 2019), notamment en matière d'interactions université-industrie. Cette complexité peut poser des défis pour les parties prenantes (chercheurs, entreprises, investisseurs, entrepreneurs, décideurs) qui peinent à distinguer les responsabilités et spécificités de chaque intermédiaire.

Ce problème est particulièrement saillant dans le contexte français. Le foisonnement des structures de soutien à la recherche et à l'innovation en France, apparu dès les années 1990, est devenu un sujet de préoccupation politique depuis les années 2010. Plus de 20 rapports officiels ont pointé la complexité et l'imbrication des dispositifs comme un frein à l'innovation (Oumohand, 2020). Dans le rapport fondateur de l'IGAENR[17] de 2013, les auteurs relèvent un manque de cohérence stratégique entre les dispositifs de soutien, aggravé par une gestion fragmentée entre plusieurs administrations, et soulignent que les schémas politiques successifs depuis 2000 ont abouti à la création d'outils redondants plutôt qu'au remplacement des précédents. Ils estiment que ce millefeuille constitue une barrière importante à l'innovation, particulièrement pour les petites et moyennes entreprises (PME) qui manquent souvent de ressources pour naviguer dans un système si complexe (Thiard et al., 2013, p. 15-16). Cette redondance est également soulignée dans le rapport de la Cour des comptes publié la même année *: « Les dispositifs publics visant à soutenir la recherche et l'innovation ainsi que la valorisation et le transfert des résultats de recherche sont nombreux, parfois redondants, et appellent clairement un effort de simplification »* (Cour des comptes, 2013, p. 171).

Ces constats illustrent la complexité du *« millefeuille »,* terme employé pour décrire la superposition de niveaux et d'acteurs dans le système français de soutien à la recherche et à l'innovation, spécificité reconnue de notre pays (OCDE, 2014). Les rapports mentionnés, ainsi que d'autres[18], pointent régulièrement le manque de lisibilité du système et l'accumulation de dispositifs sans vision d'ensemble cohérente, et appellent à une approche plus rationalisée du soutien à l'innovation en France.

Si cette vision persiste aujourd'hui, les discours politiques les plus récents témoignent d'une approche plus nuancée. Par exemple, le rapport gouvernemental de 2018 sur les aides à l'innovation propose non pas une suppression massive de structures, mais une amélioration

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[17] L'IGAENR (Inspection générale de l'administration de l'éducation nationale et de la recherche) est un organisme gouvernemental français de haut niveau qui supervise et conseille l'éducation et la recherche. Elle évalue les institutions et les politiques, conseille les ministres, mène des études pour améliorer l'efficacité et recommande des réformes dans ces secteurs. Son rapport mérite une attention particulière dans le discours sur la politique d'innovation française, car il a été fréquemment cité comme l'une des premières analyses complètes. De plus, les rapports précédents n'incluent pas les bureaux de transfert de technologie (BTT) qui ont été créés en 2012 en France.

[18] Voir l'étude de Oumohand (2020) pour une description complete des rapports de 1998 à 2018

équilibrée du système existant : il recommande, certes, de fusionner ou de supprimer certains dispositifs, mais met surtout en garde contre des réformes précipitées susceptibles de menacer la stabilité du système. Les auteurs soulignent les risques d'une homogénéisation excessive, qui pourrait négliger les spécificités territoriales et la nature multifacette des processus d'innovation (Lewiner et al., 2018, p. 27). Ils préconisent plutôt d'améliorer la transparence et l'accessibilité du système. De même, le rapport le plus récent, publié en juin 2023 par le ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation, insiste sur le fait que la diversité actuelle peut être nécessaire pour répondre aux besoins spécifiques de chaque territoire, et recommande de clarifier les rôles et responsabilités des acteurs (y compris des intermédiaires eux-mêmes) et de renforcer la coordination, plutôt que de créer de nouvelles structures (Gillet, 2023, p. 65).

La littérature académique a également identifié les limites d'une prolifération sans fin de structures et appelle à des recherches complémentaires. Les travaux sur les intermédiaires de l'innovation, qui étendent l'analyse au-delà des seuls partenariats science-industrie, reconnaissent qu'ils sont devenus de plus en plus nombreux et diversifiés, rendant le concept difficile à cerner. Comme le notent Caloffi et al. (2023), l'expansion de la recherche sur ces intermédiaires a paradoxalement obscurci leur définition et leurs fonctions, en raison de la multitude de termes employés (courtiers, facilitateurs, « boundary spanners »…) et de la diversité hétérogène des organisations étudiées (services à forte intensité de connaissances, agences de transfert de technologie, parcs scientifiques, incubateurs, plateformes virtuelles…) (Kanda et al., 2018).

La littérature en entrepreneuriat a également commencé à alerter sur les effets pervers d'une abondance de structures de soutien au sein des écosystèmes entrepreneuriaux (incubateurs, accélérateurs, parcs scientifiques, makerspaces). Le manque de différenciation complique pour les porteurs de projet la recherche de l'organisation la plus adaptée à leurs besoins, donnant l'impression d'un « paysage encombré » (Hrůšková et al., 2022). Malgré cette prise de conscience, la plupart des études restent cloisonnées, examinant les dispositifs isolément plutôt que dans une perspective globale (Bergman & McMullen, 2022).

Les travaux sur le transfert de technologie et la valorisation de la science aboutissent à des conclusions similaires : si les intermédiaires sont nombreux (Santos et al., 2023), l'approche atomistique – chaque intermédiaire étudié comme une unité distincte – limite notre compréhension de leurs comparaisons et synergies (Clayton et al., 2018). Des recherches récentes appellent d'urgence à une approche holistique pour appréhender les interactions, recouvrements et complémentarités éventuels entre intermédiaires (Good et al., 2019). Clayton et al. (2018) recommandent de considérer le « tableau institutionnel complet » et la diversité institutionnelle d'un territoire donné, plutôt que de chercher à identifier un unique « meilleur » intermédiaire.

L'étude des intermédiaires dans les liens science-industrie comme catégorie est encore relativement récente (Villani et al., 2017 ; Santos et al., 2023), et l'absence de cadre global sur leurs rôles justifie pleinement cette recherche. Cette thèse vise à éclaircir la confusion, tant dans la pratique que dans la théorie, en examinant simultanément le rôle de plusieurs intermédiaires dans divers canaux d'interaction université-industrie. En optant pour une approche holistique — c'est-à-dire en considérant simultanément l'ensemble des intermédiaires, leurs fonctions et leurs synergies — nous soutenons l'idée que cette complexité et diversité peuvent être justifiées.

4. Problématique générale et approche de recherche

4.1 Problématique, objectifs de la recherche, questions de recherche spécifiques

Les éléments précédents et la littérature existante mènent à interroger cette multiplicité d'acteurs et à remettre en cause l'idée selon laquelle plus d'intermédiaires serait systématiquement bénéfique. Cette thèse se centre sur la question suivante :

Comment peut-on expliquer le phénomène de multiplicité des intermédiaires dans les relations science-industrie ?

La question de recherche générale invite à explorer plus en profondeur les liens entre science et industrie sous une perspective relationnelle, en s'intéressant aux intermédiaires, à leurs fonctions dans une approche organisationnelle et micro, à leur émergence et à leur évolution, mais aussi aux relations entre les deux et entre eux. Ce faisant, je me suis interrogée sur ce que les théories et les cas réels pouvaient nous apprendre sur ce phénomène, mais aussi sur ce que l'histoire et les données de niveau micro pouvaient apporter en complément à notre démarche de recherche. Cette recherche s'articule autour de trois axes complémentaires :

1. **Complémentarité et coordination :** Comment les intermédiaires se complètent-ils et collaborent-ils pour surmonter différents obstacles ? (Q1)
2. **Évolution historique :** Quand et comment les premiers intermédiaires sont-ils apparus, et quelles ont été leurs évolutions ? (Q2)
3. **Compétences individuelles :** Comment les compétences et les profils des professionnels des intermédiaires traduisent-ils leurs fonctions spécifiques ? (Q3)

Cette thèse s'appuie sur la littérature en économie, en gestion et en histoire dans le domaine de l'innovation et de l'entrepreneuriat. En raison de l'émergence des liens entre science et industrie ainsi que des intermédiaires université-industrie dans le monde occidental, et de leur particularité en France, cette thèse se concentre spécifiquement sur ces aspects.

4.2 Méthodologie générale de la recherche et principaux résultats

La force et l'originalité de cette recherche résident non seulement dans son analyse globale des organisations intermédiaires, mais aussi dans l'emploi de stratégies méthodologiques variées à travers ses chapitres.

Le choix de recourir à plusieurs méthodologies est motivé par plusieurs facteurs. Tout d'abord, compte tenu du caractère exploratoire de la question de recherche et de l'absence de jeux de données exhaustifs, cette thèse justifie l'utilisation d'outils méthodologiques divers pour étayer ses arguments. Toutes les données utilisées ont été collectées spécifiquement dans le cadre de ce travail. Le second motif provient de la littérature sur les intermédiaires université-industrie, qui, à ma connaissance, a peu adopté certaines des méthodologies développées ici. Enfin, le troisième motif tient à ma curiosité personnelle : issu d'un parcours en analyse statistique et économétrique dans les sciences sociales, je me suis toujours interrogé sur d'autres manières de conduire la recherche.

Cette thèse est structurée de manière à répondre systématiquement à nos questions de recherche et s'organise en quatre chapitres, chacun recourant à une approche méthodologique théorique et empirique distincte. En premier lieu, pour répondre à notre question principale, nous adoptons une approche théorique et conceptuelle. **Le chapitre 1** constitue la pierre angulaire de cette thèse, en fournissant un cadre théorique et conceptuel solide qui sous-tend l'ensemble de la recherche. Ce chapitre est fondamental car il éclaire le lien essentiel entre les relations science-industrie et les organisations intermédiaires. Au travers d'une analyse approfondie de la littérature sur les interactions université-industrie et les intermédiaires de l'innovation, il développe un modèle conceptuel global des rôles des intermédiaires dans la facilitation de ces interactions. La grille de lecture et les perspectives proposées servent de fil conducteur tout au long de la thèse, assurant cohérence et profondeur à l'analyse.

Fort du socle théorique posé, **le chapitre 2** adopte une perspective historique et propose une vision évolutive des intermédiaires science-industrie. Il se concentre sur l'évolution des organisations intermédiaires à travers trois grandes périodes, de la « préhistoire » de la science aux XIIe–XIIIe siècles jusqu'au début du XXe siècle. En identifiant les tendances et tournants historiques majeurs, ce chapitre fournit des preuves des premiers intermédiaires et de leur évolution au fil du temps. Cette perspective historique enrichit notre compréhension en révélant la dynamique et les transformations de long terme dans le champ de l'intermédiation science-industrie. Ensemble, les chapitres 1 et 2 offrent une compréhension approfondie du lien entre types de relations science-industrie et types d'intermédiaires.

Les deux derniers chapitres, chapitres 3 et 4, font basculer l'analyse des concepts vers l'investigation empirique. **Le chapitre 3,** fondé sur une étude qualitative, explore en profondeur des cas spécifiques et propose une démonstration empirique et une extension du modèle du chapitre 1 à travers 33 entretiens menés dans huit cas d'étude du secteur de la santé en Hauts-de-France. Les chapitres 1 et 3 se présentent ainsi comme des jumeaux, le chapitre 3 validant et affinant les propositions théoriques du chapitre 1.

Le chapitre 4 fournit des données plus larges et généralisables grâce à une enquête quantitative inédite menée auprès de 214 professionnels travaillant dans différentes organisations intermédiaires. Ce chapitre adopte une approche micro-niveaux, mettant en lumière les compétences des individus au sein de ces structures. Il apporte une dimension cruciale en se centrant sur le capital humain qui permet à ces organisations de fonctionner efficacement.

Ainsi, la structure de la thèse suit une progression logique : établir d'abord les fondations théoriques, apporter ensuite un contexte historique, puis mener des investigations empiriques à la fois organisationnelles et individuelles. Chaque chapitre s'appuie sur les enseignements du précédent, tissant la trame narrative de la recherche. Le cadre conceptuel du chapitre 1 informe l'analyse historique du chapitre 2 et éclaire l'étude empirique du chapitre 3. Les conclusions des études de cas nourrissent l'angle d'approche du chapitre 4, et les résultats empiriques des derniers chapitres peuvent rétroagir sur le cadre théorique initial pour l'affiner et l'élargir.

Les principaux résultats de cette thèse défendent l'existence d'intermédiaires multiples du fait de leurs complémentarités tant au niveau organisationnel qu'au niveau individuel (Chapitre 1, 3 et 4), de leurs efforts coordonnés (Chapitre 3) et de l'évolution dynamique de leurs fonctions en réponse aux changements des relations science-industrie et des contextes historiques (Chapitre 2). Cette thèse fournit des preuves conceptuelles et empiriques étayant un modèle multi-intermédiaires dans lequel plusieurs organisations intermédiaires coexistent au sein de l'écosystème science-industrie.

L'approche multiple adoptée dans cette thèse se reflète également dans la diversité des canaux de diffusion des résultats de recherche. Ceux-ci ont été valorisés par différents moyens : articles scientifiques soumis à des revues à comité de lecture, présentations et échanges lors de conférences, diffusion des résultats auprès des praticiens (universités, agences d'innovation, grand public) et animation d'ateliers universitaires. Tout au long de ce travail, j'ai accordé une attention particulière à la traduction de mes résultats en recommandations pratiques et à leur impact au-delà du milieu académique, en proposant notamment de restituer ces enseignements aux participants de l'étude. À cet égard, deux ateliers organisés par l'Université Catholique de Lille m'ont permis de partager ces résultats de manière interactive.

4.3 Structure de la thèse

Ce manuscrit de thèse est présenté sous la forme d'articles de recherche. Plus précisément, les chapitres 1, 2 et 3 sont structurés en articles initialement soumis à des conférences, puis à des revues à comité de lecture, ayant bénéficié de premières séries de révisions. Une synthèse détaillée est fournie dans l'introduction (**Tableau 1**), où nous contextualisons notre travail : comme nous l'avons vu, le concept de multiplicité d'intermédiaires a animé différents débats politiques.

L'organisation des chapitres de ce manuscrit, et leur manière de répondre à notre question principale ainsi qu'aux différentes sous-questions, est illustrée à la **Figure 1.** Enfin, une section de discussion vient clore la thèse, en mentionnant notamment les limites de l'étude, en explorant des pistes de recherche futures et en soulignant les contributions modestes de ce travail.

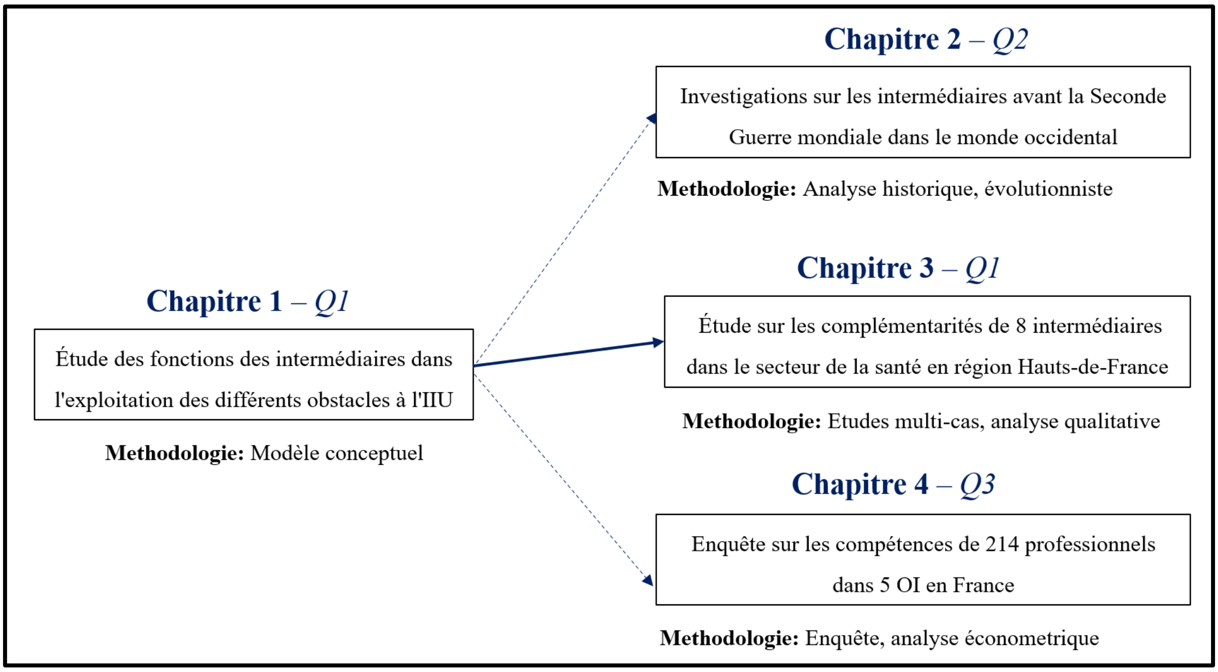

Figure 2: Liens entre les chapitres et les sous-questions de recherches

- ***Chapitre 1 – Pour un problème, une solution ? Comprendre la diversité et les fonctions des intermédiaires U*-I**

Chapitre 1 jette les bases théoriques et conceptuelles de la thèse, offrant un cadre structuré pour comprendre la multiplicité des organisations intermédiaires (IO) dans les interactions université-industrie (UII). À travers le développement d'un cadre conceptuel et d'un modèle, il justifie cette pluralité, s'appuyant sur la notion de barrières dans les relations science-industrie. Suite à une revue exhaustive de la littérature sur les interactions, les barrières et les intermédiaires, il identifie deux barrières majeures (« barrière de type Williamson » et « barrière de type Merton ») et introduit la nouvelle « barrière de type Polanyi ». Ce travail montre que certains intermédiaires sont plus efficaces pour lever certaines barrières selon les UII spécifiques. Il a donné lieu à une version article soumise en juillet 2023, révisée en juillet 2024 dans la revue Industry & Innovation.

- ***Chapitre 2 – Histoire des intermédiaires science-industrie jusqu'à la Seconde Guerre mondiale: une vision fonctionnaliste***

Le chapitre 2 explore l'émergence et l'évolution historiques des intermédiaires science-industrie dans le monde occidental. Remettant en cause l'idée que ces liens aient débuté après la Seconde Guerre mondiale, il retrace leurs origines plusieurs siècles en amont. Dans un cadre néo-Schumpétérien ou d'économie évolutive, il analyse l'adaptation des intermédiaires aux contextes historiques changeants et à l'institutionnalisation des relations science-industrie. Il identifie trois périodes distinctes de développement et démontre, via le cadre conceptuel du chapitre 1, que différentes formes d'intermédiation ont émergé pour répondre à des barrières spécifiques : avant le XIX^{e} siècle, la priorité était donnée à la réduction de la barrière de type Williamson, tandis que les périodes suivantes ont centré l'attention sur les barrières de type Polanyi et Merton. En examinant une dizaine de formes d'intermédiation à travers l'histoire, il offre une compréhension exhaustive des dynamiques de long terme de ces structures. Ce travail est adapté en article pour le Journal of Evolutionary Economics, soumis le 31 octobre 2024.

- ***Chapitre 3 – Comment travaillent ensemble les intermédiaires U-I ? Enseignements d'un région santé de premier plan en France***

Ce chapitre présente une enquête empirique sur le rôle des organisations intermédiaires (IO) dans la facilitation des UII. Structuré à partir d'un article soumis à Technovation en octobre 2023 (première révision incluse), il s'appuie sur 33 entretiens menés dans huit types d'IO du secteur de la santé en Hauts-de-France. L'objectif est d'explorer empiriquement le modèle conceptuel du chapitre 1 et de montrer comment ces intermédiaires collaborent pour faciliter les UII. Cette démonstration empirique met en lumière les rôles spécifiques de chaque IO et souligne les efforts coordonnés pour lever différentes barrières. Le chapitre identifie plusieurs modes de coordination, influencés par les canaux d'interaction et la nature des barrières, et introduit une nouvelle « barrière de type Arthur ». Il illustre les dynamiques de collaboration et d'action indépendante entre IO.

- ***Chapitre 4 – Un pas de plus : exploration des compétences et parcours des professionnels intermédiaires U-I***

Le chapitre 4 déplace l'analyse vers le niveau micro en examinant les caractéristiques individuelles des employés des organisations intermédiaires U-I. Complétant les volets théorique, historique et organisationnel, il comble une lacune en se focalisant sur les compétences et le profil des professionnels. Basé sur la première enquête quantitative menée auprès de 214 collaborateurs de cinq types d'IO (BTT, incubateurs académiques, pôles de compétitivité, OTR, fablabs), il offre des éclairages inédits sur l'équilibre entre compétences génériques et techniques spécifiques, et sur la variation de ces besoins selon les types d'intermédiaires et leurs activités.

Chapitres	Lien dans la structure de la thèse	Détails des soumissions	Co-auteur(s)
1	***Pour un problème, une solution ? Comprendre la diversité et les fonctions des intermédiaires U-I*** Développement d'un cadre conceptuel et d'un modèle expliquant la diversité des intermédiaires U-I .	Presenté at R&D Management 2023, Trento. Soumis dans Industry & Innovation en Juillet 2022 (2nd Revise and Resubmit)	Non
2	***Histoire des intermédiaires science industrie jusqu'à la Seconde Guerre mondiale: une vision fonctionnaliste*** Analyse évolutionniste des premières formes d'intermédiation et de leurs fonctions, selon une perspective économico historique.	Presenté à Technology Transfer for Society 2024, Brussels. Soumis dans Journal of Evolutionary Economics en octobre 2024 (1st Revise and Resubmit)	Co-écrit avec Julien Pénin[19]
3	***Comment travaillent ensemble les intermédiaires U I ? Enseignements d'un région santé de premier plan en France*** Enquête qualitative (33 entretiens, 8 types d'organisations) dans le secteur de la santé en Hauts de France, visant à tester et affiner le modèle conceptuel.	Presenté at EURAM 2024, Dublin. Soumis dans Technovation en octobre 2023 (3 rounds)	Non
4	***Un pas de plus : exploration des compétences et parcours des professionnels intermédiaires U-I*** Enquête quantitative auprès de 214 employés de cinq types d'organisations intermédiaires, pour déterminer les compétences génériques et techniques spécifiques requises.	Accepté à EURAM 2025, Florence (sera présenté en Juin 2025)	Non

Tableau 2: Récapitulatifs des soumissions aux conférences internationales et aux journaux

[19] Julien Pénin a écrit la section 2. Tout le reste du chapitre a été écrit par moi.

CHAPTER 1

FOR ONE PROBLEM, ONE SOLUTION: UNPACKING THE DIVERSITY AND ROLES OF U-I INTERMEDIARIES

Summary of Chapter 1:

University-industry interactions (UII) are crucial for innovation policy to promote a strong innovation landscape. Numerous and diverse intermediary organizations (IOs) have grown significantly in recent decades to support UII, creating a complex landscape. Existing research lacks a comprehensive global analysis to understand the multiplicity of IOs in facilitating UII. This research aims to propose for the first time a comprehensive and unified conceptual model that justifies the existence of ten types of IOs. To support our analysis, we rely on the concept of barriers and introduce a novel barrier known as the "Polanyi barrier." We show that different IOs address specific barriers in five different interaction modes. Our holistic model can provide a roadmap to assist universities, industries, policymakers, and IOs in overcoming collaboration barriers and effectively navigating the knowledge transfer ecosystem.

Keywords: U-I intermediaries, science-industry links, barriers, Williamson, Merton, Polanyi, conceptual

Table of contents for Chapter 1

Chapter 1: For One Problem, One Solution: Unpacking the Diversity and Roles of U-I intermediaries[20]

1. Introduction

It is widely recognized that collaboration between public research institutions and private organizations is crucial for national innovation ecosystems to develop innovation and address socio-economic challenges (OECD, 2019a). In knowledge-based economies, innovation is recognized to be highly interactive and collaborative, involving various actors. University-Industry Interactions (UII) have received increasing attention over the last couple of decades, and many studies have investigated the broad range of forms and activities UII takes (Nsanzumuhire et al., 2021). Therefore, the variety of channels through which universities and industries interact is considerable within this interactive framework (Schartinger et al., 2002). While technology and knowledge transfer, involving a unidirectional transfer from universities to industries, has been the predominant lens, UII has evolved to encompass a bilateral and co-creation dimension (Arza, 2010; De Silva & Rossi, 2018; Perkmann & Walsh, 2009). The results are that UII is a complex bi-directional transfer and exchange of ideas, resources, skills, and expertise (Vick & Robertson, 2018) that goes through various formal and informal channels (Perkmann & Walsh, 2007).

To support UII, multiple 'interface' organizations such as Technology Transfer Offices (TTOs), Collaborative Research Centres (CRCs), incubators, and Research and Technology Organizations (RTOs) have grown considerably over the past decades. Other actors, such as innovation agencies, science and technology parks, and clusters, have also been found to act as facilitators. These U-I intermediaries promote U-I links and assist universities and industries through their mediating skills and providing different value-added services. They can facilitate

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communication and relationships by acting as a go-between, providing advice or commercial services, promoting research, etc.

From a policy perspective, these actors constitute important entities as they can facilitate the transfer and exchange of knowledge among different organizations and respond to systematic failures within innovation systems (van Lente et al., 2003). These intermediary organizations can be considered 'knowledge and institutional bridges' that coordinate knowledge gaps between institutionally distanced actors.

The role of intermediaries in U-I contexts has gained particular attention in the last decade (Albats et al., 2022; T. Kodama, 2008; Villani et al., 2017; Wright et al., 2008; Yusuf, 2008). The literature has provided several contributions to the activities and functions of different IOs. However, some challenges remain. The literature has been considered fragmented (Klerkx & Leeuwis, 2009) and rather atomistic, looking at the role of IOs in isolation (Good et al., 2019a), which makes it difficult to understand what the 'big picture' is and how IOs complement each other in U-I context. Literature studying IOs has mainly focused on traditional intermediaries such as TTOs (see Santos et al., 2023) and technology transfer activities such as licensing and spin-off creation. Few studies investigate the role of multiple intermediaries in UII within a single framework (e.g, Alexandre et al., 2022; Fernández-Esquinas et al., 2016); Suvinen et al., 2010; Villani et al., 2017; Wright et al., 2008; Yusuf, 2008). These studies often account for a few types of intermediaries and focus on specific channels of interactions. This current stream might place too much emphasis on formal interactions (Hayter et al., 2020) and does not give justice to the richness and complexity of the knowledge transfer ecosystem. For example, with the open innovation paradigm, other emerging arrangements, such as open labs, have been identified to play a critical role but are almost absent in the literature. In this regard, *many* heterogenous intermediaries gravitate around universities and industries and aim to fulfill the same goal: facilitating interactions between university and industry. However, the literature has insufficiently provided a holistic conceptual mapping of intermediaries in U-I interactions (Chau et al., 2017; Good et al., 2019a).

This phenomenon is even more critical as many intermediaries make the present knowledge transfer landscape challenging to grasp. In some developed countries, the term 'layer-cake' has been used to emphasize this problem. Having too many diverse structures can render identifying and differentiating the roles of IOs tedious (Caloffi et al., 2023), which yields potential risks such as mismatches of actors and overlapping roles.

In light of these challenges, we aim to justify the existence of U-I intermediaries by answering the following question:

How can we explain the roles of multiple intermediaries in university-industry interactions?

This paper aims to propose for the first time a novel unified conceptual model to justify and explain the roles of multiple intermediaries across different U-I interactions.

To ensure rigor, we followed guidelines from conceptual research design papers (Jaakkola, 2020; Jabareen, 2009). We consider five types of interactions and review the roles and functions of ten intermediary organizations (IOs). To explain the roles of different intermediaries in supporting different interactions, we use the concept of barriers as a methodological tool (Jaakkola, 2020).

The use of barriers to comprehend the roles of IOs holds significance in the context of UII for at least three reasons. First, it has been widely acknowledged that academia and industry adhere to distinct institutional norms and rules (Sauermann & Stephan, 2013), which can lead to barriers with detrimental effects on knowledge transfer. These obstacles are typical in U-I alliances and require more attention than other inter-organizational collaboration forms (Galán-Muros & Plewa, 2016). Second, following a functionalist approach inspired by the work of Coase (1937) and Williamson (1979) to justify the existence of firms, we similarly advocate that intermediary organizations emerge and exist to internalize and mitigate the costs and barriers that universities and industries cannot effectively address on their own. Therefore, different costs indulged by barriers in different interaction channels explain the presence of different intermediaries. Third, while literature has focused on factors that can lower those barriers or 'facilitators' such as collaboration experience, inter-organizational trust (Bruneel et al., 2010; Tartari et al., 2012a), and communication (Plewa et al., 2013), there is a lack of overall understanding of why at what level IOs mitigate the identified barriers.

More specifically, we rely on the categorization of barriers by Bruneel et al. (2010) and Tartari et al. (2012). These studies are well-recognized and allow us to encompass many obstacles. Conflicts arising from differences in norms, values, and cultural orientations between the two actors are called 'Mertonian barriers.' Additionally, administrative complexities and transaction costs can create obstacles known as 'Williamson barriers '. We also introduce a novel barrier that we term the 'Polanyi barrier,' addressing the challenges in transferring tacit knowledge.

Tacit knowledge has been recognized to affect UI processes (A. T. Alexander & Childe, 2012; Santoro & Bierly, 2006; Steinmo, 2015), but it has not been categorized as a barrier per se. We advocate that this dimension is increasingly important as universities are more and more pushed to not only transfer knowledge to the socio-economic world but to engage and co-create knowledge with multi-stakeholders (Ankrah & AL-Tabbaa, 2015; Carayannis & Campbell, 2009; De Silva et al., 2023; Roux et al., 2006).

Our conceptual framework combines three concepts (interactions, intermediaries, and barriers) to explain the multiplicity of intermediaries. Interrelationships among these concepts are developed, and the results are mapped into a figure (model).

Our study contributes to the literature on university-industry interactions by providing a unified model that explores relationships between concepts that have been underdeveloped in order to better understand the phenomenon of multiple IOs in UII. Our study highlights the importance of considering the diversity of intermediaries and the richness of existing interactions to understand the complex dynamics of university-industry collaborations fully. Our conceptual model has predictive means as it depicts the type of intermediary that will be involved by the type of interaction and why.

The paper is structured as follows: the research approach is presented in the next section, followed by the elements of the three concepts in Section 3. Section 4 presents the derived conceptual model, illustrating how specific intermediaries respond to interaction barriers. We discuss the model and conclude the paper in Section 5.

2. Research approach

Conceptual research is adequate and relevant as the phenomenon studied is "observable but not adequately addressed in the existing research". The goal of a conceptual framework is to lay out key factors, constructs, and variables and presumes relationships among them (Miles & Huberman, 1994, p.440). Producing a conceptual framework is an inductive process and a multi-phase analysis where concepts are put together to explain a bigger map of possible relationships. According to Imenda (2014, p 189), a conceptual framework is "*the end result of bringing together a number of related concepts to explain or predict a given event, or give a broader understanding of the phenomenon of interest – or simply, of a research problem*".

To rigorously build our analysis, we follow guidelines and considerations provided in conceptual research design papers (Jaakkola, 2020; Jabareen, 2009). At the starting point, we observed and analyzed present information on the given topic of intermediaries of science-industry relations; our general focus concerns the institutional arrangements that bridge universities and industries. We identify three different concepts by deriving knowledge from different streams of literature (university-industry interactions, technology transfer, academic engagement, intermediaries of innovation and creative regions). Those are intertwined: interactions, barriers impeding collaboration, and intermediaries. We then explored and augmented connections between the three constructs using existing theories. During this process, we also extended current concepts to new ones to better understand the facilitation phenomenon. We delineated the elements by classifying them into different categories and levels to schematize our analysis. Finally, our arguments were summarized in figures. The different phases are shown in Figure 2.

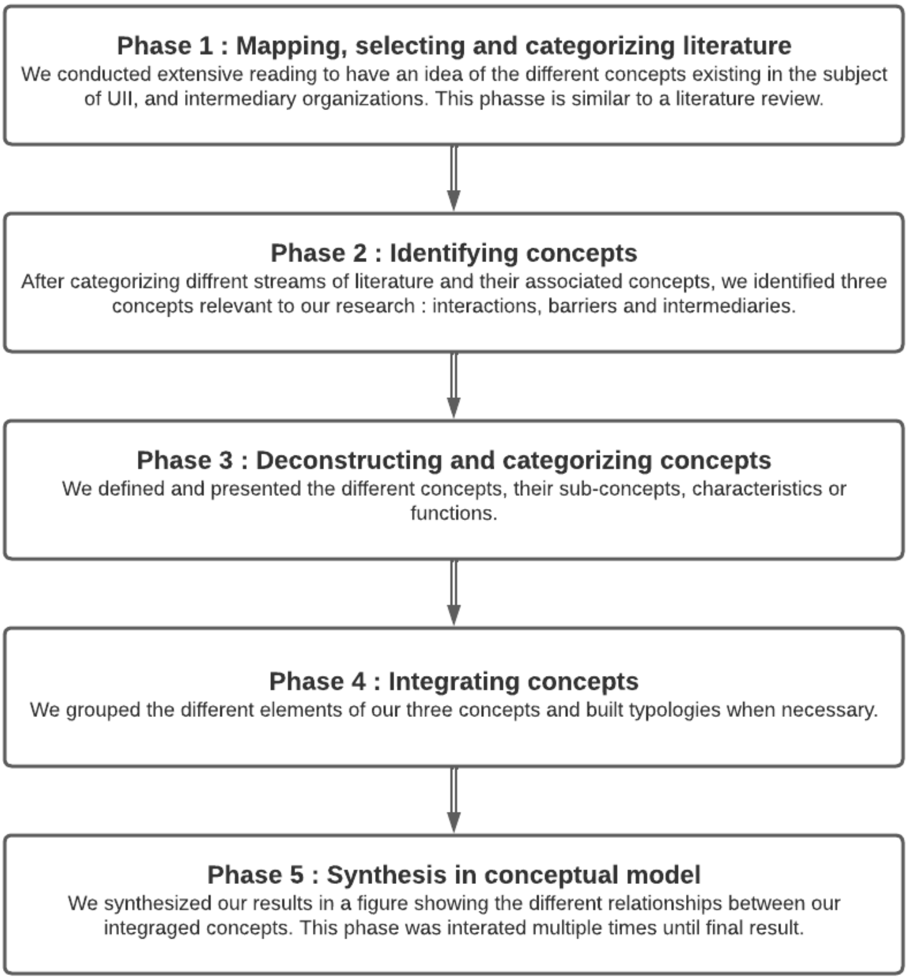

Figure 3: Phases for constructing our conceptual model.
***Source*: own elaboration, inspired from Jabareen (2009)**

The goal of our conceptual model is to explain how one type of interaction is characterized by a dominant barrier, therefore leading to the involvement of a particular type of intermediary organization. This helps us understand the role of intermediaries in the process of facilitation of knowledge exchange.

3. Conceptual Framework: unpacking the constructs

3.1 University-Industry Interactions (UII)

3.1.1. Interactions: some definitions and identification

Universities and Industries Interactions (UII) is not new as a phenomenon or as a research subject. An extensive number of studies have identified interactions and developed interesting typologies. This section highlights some key considerations before discussing the diverse activities that the UII refers to.

First, the definition of U-I interaction is not somewhat straightforward (Schaeffer et al., 2017). Interestingly, in the literature of UII, different terms have been used to define the variety of interactions held by universities and industries. The term "interaction," "collaboration," "linkages," "relationships," "cooperation," "alliances" and "partnerships" have been interchangeably used in the literature. However, studies often refer to only one term without justifying its use. For example, authors sometimes refer to the same activities when speaking about “collaboration” or “interaction,” whereas others specify this difference. The distinction between these terms is important to grasp the different approaches used to describe how universities and industries interact. Collaborative forms of interaction, such as collaborative research, contract research, and consulting, differ from intellectual property (IP) transfer (Perkmann & Walsh, 2009). Therefore, *University-Industry collaboration (UIC)* should refer to specific forms of interaction, whereas *University-Industry Interactions (UII)* or *University-Industry Linkages (UIL)* should account for a broader range of channels. Therefore, when using the term “interaction” or “linkages,” we will refer to this broader view of channels. Channels of interaction are used to describe the "mechanisms" or the "pathways" through which information, knowledge, or other resources are exchanged or co-produced between universities and industry (Perkmann & Walsh, 2007). Channels of interactions are the "media," through which information is exchanged.

Distinguishing between “collaboration” and interactions as channels is essential because it accounts for actors' different relational involvement in different channels. Collaborative forms of interaction imply a high relational involvement among actors. Collaboration is the most advanced form of interactive communication, where joint activities (co-creation) are based on a common strategy, shared identity, common responsibilities, and objectives (Russell & Smorodinskaya, 2018). On the contrary, some channels will require no relational involvement as researchers and industrialists will not need to interact. This occurs for transfer of university-generated IP. The industry only acts as a buyer of patents and licenses.

Another aspect to consider is that channels of interactions are at the core concepts of technology and knowledge transfer in a U-I context. Technology transfer is an intentional and a goal-oriented interaction that has been used to describe the movement of knowledge or technology as a unit from one well-defined economic unit to another (Amesse & Cohendet, 2001). Technology transfer has usually referred to the exploitation of academic results for commercial purposes where technology developed by universities is used by firms to be commercialized (Bozeman, 2000). The fact that commercial channels have been emphasized in the literature is not to go unnoticed. Indeed, research on UII has primarily focused on the transfer of intellectual property (IP), such as patenting, licensing, and academic entrepreneurship, causing other interactions to be neglected. This is because measuring and assessing outputs such as patents, licenses, or spinoffs are much more accessible than other forms of interaction.

Since their emergence, numerous studies have identified various channels through which universities and firms exchange knowledge. Nowadays, they represent a wide range of activities with numerous characteristics and properties. Authors have differentiated interactions regarding the duration and frequency of interactions, the type of partners involved, the level of acquaintance between them, the presence or absence of an external partner, and the degree of formality (Perkmann & Walsh, 2007; V. Schaeffer et al., 2020; Schartinger et al., 2002), the degree of personal ties (Arza & Carattoli, 2017); the level of interaction (very integrated or partial) (Baraldi et al., 2013) , and difference in motivations and expected benefits (Arza, 2010). Schartinger et al. (2002) identify 16 types of interactions and characterize interactions regarding the type of knowledge (tacit), the degree of formalization, and the personal face-to-face contact. Similarly, D'Este and Patel (2007) identified nine interactions grouped into five categories: meetings and conferences, consultancy and contact research, creation of physical facilities, and training. We identified the most common interactions mentioned in the literature (see Appendix 1 for the full review) and identified the following interactions[21]:

1. Conferences, forums, workshops
2. Informal interaction
3. Research services (consulting and contractual research)
4. Transfer of IP (through licensing)
5. Entrepreneurial activity (spin-off creation)
6. Joint research projects
7. Joint supervision of master or PhD
8. Hiring or internships of graduate students
9. Joint projects (involvement of students in industrial projects)
10. Teaching from researchers in firms
11. Employment or sabbatical of scientists in industry

It is likely that these interactions might have evolved over time. This is important to consider, as some interactions may not have been reviewed in the literature. Even if we try to represent as many interactions as possible, it is not entirely exhaustive, as creating a typology with all possible links between university and industry is an extremely difficult task (Blackman & Segal, 1991).

[21] We differentiate between interaction as a process and interaction as resources and mean. For example, we excluded "fundings from industry" as it can appear as a resource in several channels of interactions (contractual research or joint research projects, for example). The use of materials and facilities can also be considered as resources to joint research or other projects. Moreover, we distinguish between the interaction as a process and its outcome. For example, entrepreneurial activity (process) can lead to the creation of spinoffs (outcome). The same applies to joint research and co-publications, or conference as a media to share publications.

Currently the UII implies a broader range of activities and many partners. Different governance modes apply to them, namely transactional and relational (Alexander & Martin, 2013). We consider in the following sub-section the interactions mentioned in the literature.

3.1.2. University-industry Interactions (UII): a co-production lens

Although the previous typologies have enlightened on the variety of interactions, it is important to consider the actual context and put UII in perspective. Since the 90's, science-industry links have been viewed through a Mode 2 lens where knowledge production is driven by applied problems and collaboration is fostered in a Triple-Helix Model between universities, industries and the government. However, modalities and channels of interaction between these actors have evolved in the last decade. Increased competition, the rise of complex societal challenges and the evolving nature of the university's mission have pushed collaboration towards a stronger multi-stakeholder and co-creation perspective. Such as firms renewing their practices with in the open innovation paradigm. Moreover, the third mission of universities or 'entrepreneurial university' encouraged institutions to engage in community-based practices which contribute to society at large (Etzkowitz, 1998, 2003, 2004; Etzkowitz et al., 2008). In this regard, interactions include relationships between universities and non-academic stakeholders in a broader sense (Compagnucci & Spigarelli, 2020). The production of knowledge in this case is governed by quadruple-helix dynamics, which involve research institutions, practitioners, students, and sometimes citizens (Carayannis & Campbell, 2009). In a Mode 3 of producing knowledge, universities and industries are involved in new ways of collaborating that are more multidisciplinary and transdisciplinary, which is more oriented towards problem solving and includes other stakeholders. This can have different policy implications, as this suggest that benefits derived can impacts individuals outside the boundaries of academia and industry (Rossi et al., 2017).

Knowledge 'co-production' or 'co-creation' involves the joint creation and integration of up-to-date knowledge by academics and know-how by business, and sometimes even practitioners and end-users to overcome specific challenges and solve problems (De Silva et al., 2018). In this process, partners provide reciprocal inputs into research project design and outcomes. This process involves active collaboration and deep interactions between actors in which they work together to produce knowledge that is co-created and co-designed through mutual learning and dialogue, and is typically relevant and applied in both academic and industrial settings. This view contrasts with the knowledge transfer approach, in which the process of moving knowledge from one individual or organization to another is often a unidirectional transfer from academia to external actors and involves the dissemination of research findings with the goal of commercializing or applying the research in practical settings (De Silva et al., 2023). This criterion is relevant, as some interactions depict only unilateral flow of knowledge, and some imply actors to be involved and engaged in producing together knowledge that benefits both.

This is strongly linked to the typology of channels constructed by Perkmann and Walsh (2007) that is based on the relational involvement of actors. They concern "situations where individuals and teams from academic and industrial contexts work together on specific projects and produce common outputs' (Perkmann et Walsh, 2007, p. 263). We propose studying interactions regarding this typology to account for mutual learning and reciprocal inputs, not only unilateral relations. Moreover, we are inspired by the work of Arza (2010), who classifies interactions according to the direction of knowledge flow (unidirectional or bi-directional). When both actors derive intellectual motives, the knowledge flow is likely bi-directional. When academics aim for economic benefits, knowledge flow is likely unidirectional to industry. Hence, the potential benefits of knowledge affect how knowledge is exchanged between actors (Schartinger et al., 2002).

We combine these two views and claim that different interactions prioritize certain characteristics in terms of co-production and direction of knowledge flow, which will trigger the appearance of different barriers. Of course, interactions are not strictly confined to these characteristics, and we acknowledge that categorizing induces simplification. However, we claim that relative to the others, ceteris paribus, each channel is likely to depict a particular knowledge flow more predominantly due to the benefits derived.

This allows us to capture barriers in various interactions that might differ accordingly. The interactions studied are summarized in the following table and are further developed below:

Informal exchange	Human Resources Transfer	Commercial Transfer	Co-production
• Participation in events (conferences, forums, workshops) • Informal interactions	• Hiring of academics or students • Sabbatical periods of academics • Teaching from academics in firms	• Transfer of IP (licensing and patenting) • Research services (contractual research, consulting) • Academic entrepreneurship	**Structured** • Joint research projects **Unstructured** • Other joint projects (see Table 2)

Table 3: Typology of interaction.
***Source*: Own elaboration and inspired from Perkmann & Walsh (2007).**

Commercial transfer of technology or services is when academics transfer research results to commercial industries. This goes through the transfer of IP through licensing, research services, and academic entrepreneurship[22]. We grouped consulting and contractual research into the category of research service in line with the typology of Perkmann & Walsh (2007). Therefore, the transfer here is from university to industry and is unilateral: knowledge created from academics is transferred to industry for commercial means (Azra, 2010).

Human resources transfer refers to personal exchange for education and mobility. This includes hiring or internships of students (graduate or doctoral), the employment or sabbatical periods of academics in industry. This transfer is likely to be unilateral, here human capital is moved from the university to the industry.

Co-production is when university and industry jointly produce knowledge. The exchange of knowledge is likely to be both-ways. We differentiate between structured and unstructured co-production. Table 2 summarizes the main differences between the two types of interactions.

Structured co-production refers to joint research conducted in a structured way, meaning there is at least some control over the process and the outcomes. This type of channel is usually bound to some degree of contractual statements about the terms of the partnership (selection of partners, length of the project, contributions, prospective benefits, etc.), which reduce some of the uncertainty. Illustrative examples of structured co-production could include a joint research

[22] Academic entrepreneurship can be considered as commercial transfer in a sense that: a spin-off creation is when academics pursue entrepreneurial activity and create their own firm based on knowledge they have created. To be considered a spin-off, there must be a transfer of that knowledge from the academics to the industrial world in the goal to be commercialized (Arza, 2010)

project between a university and a pharmaceutical company to develop a new drug, a collaborative research program between a university engineering department and an automotive manufacturer to improve electric vehicle battery technology or a consortium focused on developing advanced materials for aerospace applications. These projects have well-defined parameters, including timelines, budgets, deliverables, and governance models outlined in contractual agreements. The roles and contributions of partners are clearly established from the outset, and projects often have formal structures, such as regular meetings and assigned team members.

Unstructured co-production refers to other types of joint projects that are highly exploratory. Due to this nature, uncertainty about the process and outcomes of the projects can be hard to control. The conditions are likely to evolve with the projects. Some contractual forms might still prevail; however, the process is highly unstructured and less predictable. For example, the selection of participants and their contributions are not settled as other participants (including citizens or students) can be involved at different steps of the process. An example of such a projects could be an open innovation challenge organized by a university to address a complex sustainability issue (Osorio et al., 2024). Other examples could be a living-lab initiative or a hackathon event to develop unique technological solutions to address societal problems. These projects are characterized by their open, iterative, and adaptive nature. They involve a diverse group of participants, such as students, civil society organizations (CSOs), local businesses, and city officials who can join or leave at various stages, and the projects evolve based on the ideas and contributions of these participants. The outcomes are often uncertain, and the process is highly flexible, with teams self-organizing and adjusting their approach as needed.

Unstructured co-production accounts for triple-helix and quadruple-helix dynamics, while structured co-production is more tailored for double-helix links.

	Structured co-production	Unstructured co-production
Outcomes	Unclear	Unclear
Partners	Selected multi-partners	Selected and/or open multi-partners
Direction of knowledge	Bilateral	Bilateral
Nature of research	Exploitative	Exploratory

Level of uncertainty	Usually high	Usually high
Degree of control	High (through terms and conditions defined ex-ante)	Low (no conditions pre-determined or defined during the process)
Examples	Joint research project, collaborative research, consortium	Open innovation challenge, living-lab initiative, hackathon
Structures dynamics	Double-helix	Triple-helix, quadruple-helix

Table 4 : Structured vs. Unstructured co-production.
***Source*: own elaboration inspired from De Silva et al. (2023)**

Informal exchange involves actors to meet, discuss and exchange contacts through scientific and non-scientific conferences, forums, workshops, or informal contact. Those interactions are likely to be a bilateral way of exchanging knowledge.

3.2 The diverse landscape of U-I intermediary organizations

3.2.1. On the origins of intermediaries

In the 20th century and the beginning of the 21st century, the roles and functions of those bridging entities and actors were studied more specifically in the agricultural and textile industries (Bessant & Rush, 1995; Hargadon & Sutton, 1997). Considered "knowledge brokers" (Hargadon & Sutton, 1997), intermediaries act as translators and disseminators of knowledge that can bring and link ideas from various industries, which help firms to find technological solutions and develop new products in those sectors mentioned above.

The open innovation paradigm has further understood the role of "innovation intermediaries." In an open innovation context, "firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology" (Chesbrough, 2003). In other words: firms cannot innovate alone; they should cross the boundaries to seek new knowledge. This paradigm highlights the importance of interacting at various stages of the innovation process. In this context, intermediary organizations are vital actors facilitating connections, exchanges, and collaborations between stakeholders (Chesbrough, 2006).

The concept of "innovation intermediaries" as a separate class of organizations was established by Jeremy Howells in 2006. According to Howells (2006, p.720), an innovation intermediary is: *"an organization or a body that act[s] as agent or broker in any aspect of the innovation process between two or more parties."* Furthermore, more specifically, intermediaries pursue very diverse activities such as *"helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting a mediator, or go-between, bodies or organization that are already collaborating; and helping find advice, funding and support for the innovation outcomes of such collaborations*". Howells (2006, p 720), summarize the activities in 10 key functions:

1. Foresight and diagnostics
2. Scanning and information processing
3. Knowledge processing and combination/recombination
4. Gatekeeping and brokering
5. Testing and validation
6. Accreditation
7. Validation and regulation
8. Protecting the results
9. Commercialization
10. Evaluation of outcomes

Since then, interesting typologies have been developed to understand their roles and functions. Agogué et al. (2013) categorized activities into two groups: brokering and networking. An agent or an organization as *a broker* will facilitate interactions between innovation actors by offering diverse contents (mediation, information adding, activities related to contracts and terms verification.). As *a networker*, it will bring actors from different entities to connect and meet. Moreover, a third group of activities can be added to complete the existing typology and marks a turning point in the mission and role of intermediaries in the innovation process. Intermediaries should act as active actors and participate in the knowledge co-creation process. In this case, intermediaries pursue "exploring" activities to trigger participants to develop knowledge they don't know. Intermediaries are considered " architects *of collective exploration*" (Agogué et al., 2013). We give some examples of intermediaries activities in

Table 3. Agogué et al. (2017) distinguish 4 core functions according to different missions of intermediaries. problem solving, technology transfer and innovation ecosystems.

Missions	Problem solving for companies	Technology Transfer	Innovation systems
Functions	Broker	Broker	Networker
(i) Connecting actors	Connect seeking companies with problem solvers	Establish connections between academic or industry science.	Create and maintain network for ongoing multilateral exchange.
(ii) Involving, committing and mobilizing actors	Enlist scientists that want to solve problems	Perform marketing activities, attract potential investors.	Mobilize resources : human and financial capital.
(iii) Solving, avoiding or mitigating potential conflicts of interests	Define the right problem; avoid conflicts between high expectations and limited solutions capacities	Balance conflicting interests (financial and non-financial).	Create common vision and agenda.
(iv) Actively stimulating innovation	Articulate, combine and re-engineer knowledge	Engage in the exploration of new technology and transfer of knowledge.	Support learning, stimulate experiments and adaptations.

Table 5: Functions of intermediaries.

***Source*: Aguogué et al. (2017)**

It is important to note that intermediaries can be considered organizations or individuals. For example, in the case of brokers for problem-solving, consultants can be considered brokers.

3.2.2. Overview of the intermediaries in the U-I context

In university-industry context, intermediaries of innovation are facilitators of knowledge exchange. Their crucial role is building relationships and facilitating industry communication and collaboration (Villani et al., 2017). All their activities aim to reduce the potential misalignment of goals and interests and misunderstandings (Debackere & Veugelers, 2005a;

Siegel, Waldman, Atwater, et al., 2003). Moreover, because knowledge transfer is complex by nature, it requires the existence of an external actor that mediates and bridges relations between actors (Alexander et al., 2020). We overview the IOs in a U-I context and provide some definitions. We summarize their definitions and main functions in **Table 5.**

Key established organizations have usually been mentioned in the literature that facilitate technology transfer. Those are TTOs and incubators. They can be internal or external organizations to the universities. **TTOs** – Technology Transfer Offices or TLOs – Technology Licensing Offices are organizations responsible for technology transfer and other research commercialization activities in universities: TTOs have initially existed to protect the university's IP and support the commercialization of inventions. **Incubators** are structures usually built within universities to support technology-based spinoff activities of academics or students. We call this category of organizations hybrids as they allow to foster and blend different institutional logics, specially the academic and the commercial. **CRCs** - Collaborative Research Centers – are organizations created to increase the R&D activities of local industries. Those are put in place to promote and facilitate collaborative projects between researchers, students, and industries. Those are usually external to the universities and non-lucrative private organizations. Similar to CRCs, academic centers also benefit from industrial funding. Those are called UICRC Industry-University Cooperative Research Centers. They usually have a multidisciplinary approach. **RTOs** – Research and Technology Organizations – are applied-oriented research organizations. According to the European Association of Research and Technology (EARTO)[23], RTOs provide research and development, technology, and also research services to enterprises, governments, and other clients. Recently, **ad-hoc organizations** such as hybrid centers have been created by universities to dodge the administrative rigidity but also because there is a lack of government support. Those are similar to CRCs and RTOs and facilitate cross-sector research collaboration or R&D for a specific purpose (Giachi & Fernández-Esquinas, 2021).

Historically, science and technology parks, clusters such as competitiveness poles have played a significant role in fostering interaction between established entities in a geographic area with at least one governing structure. **Science park's** primary goal is to attract and develop high-tech firms and manage the park's activities. According to the International Association of

[23] http://www.earto.org

Science Parks (IASP)[24]; a science park can be defined as: *"an organization managed by specialized professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions*". In the same streamline, **clusters of innovation** defined by Porter (1998) contribute to attract and group small, medium or large companies, organizations, and institutions concentrated within a geographical area and develop synergies in a particular technological field. In the French landscape, **competitiveness poles**[25] are French-specific clusters recognized by the government. They promote the development of collaborative projects in R&D. Other similar public entities such as **regional development agencies**, and innovation agencies also support innovation in a regional area by supporting projects. Those organizations are specialized in providing business support and financial aid and act as institutional bridges between all actors in the regional innovation system.

More recently, intermediation has also been found in spaces such as fab-lab, co-working spaces, and living labs and communities (Fabbri & Charue-Duboc, 2016; Hakkarainen & Hyysalo, 2016; Mérindol et al., 2018). Those constitute emerging forms of intermediaries that have usually been overlooked in the literature of U-I. **Open labs** are a place and an approach supported by various actors, intending to renew the methods of innovation and creation through the implementation of collaborative and iterative processes, open and giving rise to a physical or virtual materialization (Mérindol et al., 2016). There are four types of arrangements that can also be categorized in the family of open labs: Fab-labs, living labs, Hackerspace and makerspace and Tech shops. They substantially differ in their organizational modes and business models but all contribute to experimenting different innovation methods. For example, **living labs** allow real-life experimentation environments in which new products and services are shaped through the collaborative efforts of users and developers, research, public and private organizations in a process of learning and the creation of pre-commercial demand (Baltes & Gard, 2010; Hakkarainen & Hyysalo, 2016). Their unique characteristic is that they facilitate work, learning and interactions by providing a space to experiment. Finally, **co-working spaces** are physical workspaces adapted to service activities, which are joined with a

[24] https://www.iasp.ws/our-industry/definitions
[25] Other similar public entities exist in other countries. For example, in the UK, the concept exists under the term "Innovation Catapults".

desire to share with co-presenters (formal and informal interactions, knowledge exchanges), beyond the desire to develop one's project (Fabbri, 2016; Fabbri & Charue-Duboc, 2016).

Type	Definition	Main functions/activities	Authors
TTOs	Organizations that are responsible for transferring technology from universities to market, and other research commercialization activities in universities	• Identify high potential technologies • Develop licensing or commercialization strategy • Protect IP rights in order to generate returns • Support pre-commercialization of inventions • Support the creations of academic spinoffs • Provide services • External and internal networking activities • Simplify bureaucratic processes	Debackere & Veugelers (2005) ; Good et al. (2019) ; Rothaermel et al. (2007) ; Villani et al. (2017).
Incubators	Organizations that help the creation and development of startups – spinoffs - by providing a range of services. (including accelerators, proof of concepts centers)	• Attract and search for startups and spinoffs • Provide facilities, shared open-space and other services • Provide access to coaching • Internal networking with qualified staff (*Alumnis*, institutions, funding agencies)	Clarysse et al. (2005); Good et al. (2019); Villani et al. (2017).
CRCs	Formal organizations which perform research and has the explicit mission to promote directly or indirectly cross-sector collaboration, knowledge and technology transfer.	• Provide funding for long-term research projects • Provide environment for actors to meet and conduct research • Support professional development of young scientists • Promote cooperation across disciplines, fields, institutes and faculties • Brokering and networking activities	Boardman & Gray, (2010) ; Dolan et al. (2019) ; Gibson et al. (2016) ; Villani et al. (2017) ; Wright et al. (2008).

		• Enhancing research quality and addressing research impact	
RTOs	Applied-oriented organizations that provide research and development, technology and research services to firms, governments and other clients.	• Produce R&D • Supply technical knowledge to industry induced in collaborative projects • Provide services such as consulting, licensing, and spinoffs companies creation	Barlatier et al. (2016) ; EARTO[26] ; De Silva et al. (2018) ; Good et al. (2019)
Other ad-hoc R&D institutes	Organizations that are created by different arrangements for specific purposes of cross-sector research collaboration (strategic technology sector or basic science commercialization).	• Their functions are similar to the ones of CRC's or RTO's but they can also derive different properties. • Their rise is due to the lack of incentives of policies or administrative rigidity of universities. There are sometimes more numerous than CRC's or RTO's.	Giachi & Fernández-Esquinas (2021)
Science Parks	Organization linked to a university ran by an administrative entity which main goal is to attract and develop technology-based firms and provide services related to business development and technology transfer.	• Attract and screen various actors and potential residents • Networking activities (internal to the park but also external to local and international stakeholders) • Build links with the university	Good et al. (2019)
Regional clusters[27]	Initiatives to promote the grouping of small, medium or large companies, organizations, and institutions concentrated within a geographical area and develop synergies in a particular technological field. An entity usually an association coordinates the cluster or sometimes it is	• Networking • Support collaborative projects • Provide advices to firms • Organize events, fairs • Support new business creation • Facilitate inter-firms or UI links (if independent association)	Agogué et al., (2017) ; Kodama, (2008) ; Porter (1998).

[26] http://www.earto.org
[27]There is a difference between cluster initiative, clusters as grouping and as an organization. The nature and definitions of clusters is not always consensual, we do not intend to make a whole review on this concept as it has already been largely studied. We rather give a general definition.

	embedded in the science park governance.		
Innovation agencies	Organizations specialized in providing business support and financial aid and act as institutional bridges between all actors in the regional innovation system.	• Implementation of public policy initiatives to create innovative dynamics (high-tech firms, knowledge intensive business firms, affluence of highly human capital, financial support..) • Counselling activities such as subsidy advice, assistance • Seek for and provide funds • Provide training sources	Esquinas et al. (2016) ; Wright et al. (2008)
Open labs	A place and an approach supported by various actors, intending to renew the methods of innovation and creation through the implementation of collaborative and iterative processes, open and giving rise to a physical or virtual materialization	• Provide spaces for co-design and experimentation • Support networking activities • Mediation of informal relationships	Mérindol et al. (2016)
Coworking spaces	Physical workspaces adapted to service activities, which are joined with a desire to share with co-presenters (formal and informal interactions, knowledge exchanges), beyond the desire to develop one's project	• Enable and support connections between different types of actors in a physical space • Provide simple and direct communication tools • Provide specific organizational space design • Organize events and exchanges	Fabbri (2016); Fabbri & Charue-Duboc (2016)

Table 6 : The intermediaries in the U-I context.

***Source:* Own elaboration, inspired from Good et al. (2019).**

3.3 Barriers to interactions

3.3.1. A primer on barriers to UII

Barriers refer to “all obstacles that impede the full success of the cooperation” (Rossoni et al., 2023). There are two ways to understand why science and industry have difficulty interacting. First, the academic and industrial worlds are very distinct regimes that follow specific norms and cultures that can be conflicting. Second, the knowledge-transfer process is highly complex for universities and industries. As we have seen, many interaction channels involve relational and contractual mechanisms, making knowledge transfer activities exist at multiple levels (Alexander et al., 2020).

Barriers can impede interactions at various levels, with the most negative effect being the cessation of the activity initially pursued. Although barriers do not always lead to this extreme case, they can prevent actors from establishing and sustaining trust (He et al., 2021) which is fundamental to exchange knowledge, solve problems and understand each other needs (Bruneel et al., 2010).

As academics and industrialists hold different views, the barriers that they perceive during interactions are likely to differ. Studies have either focused on barriers perceived by academics (Muscio & Vallanti, 2014; Tartari et al., 2012a, 2012b) or industrialists (Bruneel et al., 2010). Recently, efforts have been made to consider the two perspectives (He et al., 2021).

Moreover, barriers may appear at different stages of the knowledge-transfer process. Barriers might prevent actors from collaborating in the first place, but they could also impede the collaboration process. This is in line with the study of D'Este et al. (2012) and Kleiner-Schaefer & Schaefer (2022) in which they differentiate between perceived versus deterring barriers by showing that barriers can only be perceived if they are experienced and hence if actors are already engaged in collaborative activities. From the initial stage, where cultural differences and misgivings can prevent actors from even wanting to interact in the first place, barriers can also be detrimental during the process. For example, academics and private actors working together in a project hold different views on the outcomes which can lead to transgressing one's values. Finally, barriers can persist over time if the negative experiences prevent actors from engaging in future interactions.

Literature on barriers to UII has been studied at different levels and types of interaction. Some authors relied on analyzing a wide range of interactions, while others decided to focus on one project level where actors collaborate more explicitly. More recently, O'Dwyer et al. (2022) studied barriers in an evolutionary context, allowing us to follow the evolution of the perceived barriers. Finally, studies on barriers have been both quantitative and qualitative in nature. Some examples of studies on barriers are provided in **Table 5.**

Authors	Research question	Methodology	Perception	Level	Findings
Bruneel et al. (2010)	The effect of factors that diminish different type of barriers	Quantitative – survey of 504 firms.	Industry	Project-level	Prior experience, trust and breadth of interaction reduce orientation-barriers but increase transaction barriers.
Tartari et al. (2012)	How professional and collaborative experiences of academics shape either perception of barriers to industry collaboration.	Quantitative – survey of 657 individuals in UK universities.	Academic	Project-level	Perceived orientation barriers to collaboration are lower for academics with industrial and collaborative experience and for those who have trust in them.
Muscio & Vallanti (2014)	Impact of main obstacles on U-I collaborations	Quantitative – survey of 197 directors of university departments in Italy.	Academic	12 interactions	3 out 4 obstacles negatively affect probability of engaging in collaboration with industry.
He & al. (2021)	Impact of orientation barrier on success of research collaboration	Mixed-method – 29 interview with academics and longitudinal survey data	Both	Project-level	Orientation asymmetry spurred cognitive and affective conflicts in team. Those with perception conflict asymmetry impacted programmatic and relational success of collaborations.

Table 7: Examples of studies on barriers and their main goals and characteristics. *Source:* Own elaboration.

3.3.2. Barriers to U-I interactions: an overarching framework

Various approaches have been used to address barriers that can impede knowledge transfer. The study of Van Dierdonck & Debackere (1988) offers a framework with three types of barriers: cultural, institutional, and operational, but they only focus on some types of UII: licensing arrangements and entrepreneurial ventures. The study by Nsanzumuhire & Groot (2020) offers a framework to compare barriers for developing countries.

We chose to build upon the categorization proposed by Bruneel et al. (2010), which offers a dualistic framework of orientation-related and transaction-related barriers that is well-recognized in the literature on barriers (Rossoni et al., 2023). Tartari et al. (2012) built upon Bruneel et al. (2010) and coined these Mertonian and Williamson barriers. We selected this categorization because it encompasses a broad range of well-identified obstacles that were investigated across various modes of interactions from the firm's (Bruneel et al., 2010) and university's (Tartari et al. 2012) perspectives.

While we build up on this categorization, our approach extends in two ways. While we use the exact definition for investigating the Merton barrier, we adopt a broader definition of Williamson-type barriers encompassing different transaction costs (search and information costs, negotiation and decision costs, and enforcement costs). Second, we introduce a novel barrier, the 'Polanyi' barrier, to address the challenges of transferring tacit knowledge. Many interaction channels involve relational mechanisms, making knowledge transfer activities and the need to transfer tacit knowledge exist at multiple levels (Alexander et al., 2020).

This expanded view allows us to capture a broader range of difficulties that arise in different UII modes and helps explain the roles of various intermediaries in mitigating these costs. These barriers are elaborated further below and summarized with examples in **Table 6.**

a) Merton barrier

Industries and universities function in very different and distinct institutional logics that follow their own norms, rules, and values. Scientists mostly behave under the academic logic while industries follow a commercial logic (Sauermann & Stephan, 2013). Those fundamental differences in norms and values can lead to misalignment of goals and expectations, raising tensions and conflicts between the two parties and impeding the collaboration process. We call those barriers "Merton barriers" in line with Tartari et al. (2012), referring to all barriers linked to orientation conflicts and tensions which lead to costs of knowledge exchange between science and industry.

R. K. Merton laid down the foundations to study science as a distinct social institution. The central idea is that the "Republic of Science" presents its own norms and values, namely called the "ethos of science" which governs the behaviors of academics. This ethos can be characterized by four principles abbreviated as the CUDOs norms (Merton, 1973,1942): Communalism, Universalism, Disinterestedness and Organized skepticism. *Communalism* refers to science as being similar to a public good; everyone should be able to access it and its use of it should not restrict others. Because scientific knowledge is collectively built as researchers base their findings on previous research, knowledge should be available to all. *Universalism* refers to science being independent of socio-political or personal attributes. This is accounted for example, in the double-blind review system of research articles. *Disinterestedness* means that scientists do not carry out their research for their own personal interest but rather for the intrinsic social value that scientific progress can bring to society. Finally, new scientific knowledge can never be taken as granted. The scientific community should always criticize and doubt new knowledge. This functions through the *organized skepticism* of the peer-review system and work presentation in conferences and workshops for example.

Although CUDOs remain general principles of ‘pure science’ and hence not always applicable, they give relatively good insights into how academics perform and perceive their research activities and how those might significantly differ from the market-oriented logic of firms. Collaborating with industry can transgress some of the CUDOs principles. *Communalism* and *Organized skepticism* can be challenged as the industry on the opposite of science, relies on the privatization of knowledge to gain a competitive advantage (Teece, 1986). Therefore, tensions might arise in the form of disclosure as firms will tend to withhold information and academics publish their scientific results. This is termed as *secrecy problem* between science and industry. Disinterestedness could be challenged as the industry seek rent and profit and is more applied-oriented. This could transgress the *Disinterestedness* or the *Originality* principles.

b) Williamson barrier

In the literature on barriers between universities and industries, transaction costs were only attributed to costs of dealing with intellectual properties or with administration. However, we would like to broaden this view and include other transaction costs between universities and industries. This is relevant because it considers the variety of interactions. Moreover, we distinguish costs that are strictly associated to the transaction and those that are more related to sustaining relationships.

The principle of transaction costs was introduced by Coase (1937) where he explains that firms exist because there are "costs of using the price mechanism," associated with the use of the market. When actors make a transaction (an exchange of a good or service), coordination costs will emerge because of asymmetry of information and possible opportunistic behaviour. Transaction costs theory (Williamson, 1979) suggests that due to those costs, economic agents will choose the structure of governance which can minimize those costs, which can lead to the creation of different organizational forms: markets, hierarchies or hybrid forms. Indeed, universities and industries can be considered actors of a market where they exchange knowledge or technology as a good or service and different types of transaction costs can appear. There are three types of costs that can be identified in a university-industry context (Dahlman, 1979): those related to search and information, negotiating and decision costs and finally, enforcement costs. Indeed, uncertainty requires individuals to search and acquire information about the process of collaboration but also about finding partners. For example, they might know the different legal procedures to follow in order to licence or when developing a start-up. Second, negotiating and decision costs, as in the case of IP, require time and effort from both actors when they need to negotiate and decide the contract terms. Finally, enforcement costs exist because free-riding behaviors need to be identified and overruled. This could be the case in joint research where one party does not fully or correctly involve themselves. It can take time and effort to ensure monitoring or make sure that that one party fulfil its contractual obligations.

Moreover, in line with the work of Weckowska (2015), we distinguish between *costs associated to treating interaction as a commercial exchange of tradeable products* (transaction costs) and *costs related to building and managing complex relations between stakeholders* (relation costs). This latter can be associated with the "connection barriers" identified in the literature, which refer to the challenges of establishing awareness and contacts necessary for initiating cooperation between universities and businesses (Galán-Muros & Plewa, 2016). In this case, actors don't necessarily want to protect themselves from opportunistic behaviour, but they might find it difficult and costly to identify partners, negotiate with them and coordinate their relations. Actors might know how to do initiate contact or where to find partners. It can be costly for them to prospect or gather information about potential partners. We may find therefore different Williamson costs within one interaction. Those related to the commercial aspect of the transaction, for example, knowing all the different procedures to successful sales and licences of IP, and those related to the relations, ensuring for example a two-way communication from the beginning to ensure the right match between the potential licensees and the academic.

c) Polanyi barrier

Transferring knowledge between science and industry is a complex and challenging task where knowledge does not simply 'spill over' from one sphere to another (Santoro & Bierly, 2006). One of the main barriers to knowledge exchange has been developed under the theory of the firm's Knowledge Based View (KBV). When a firm wants to absorb or create knowledge, it must consider that knowledge can present itself in explicit and tacit forms. Michael Polanyi had stretched out this difference when he explained that tacit or implicit knowledge, as opposed to explicit knowledge, cannot be fully codified or verbally communicated. In other words, as he stated: *"we can know more than we can tell"* (Polanyi, 1966, p.4). This difference has also been tackled by Nonaka (1994) to explain organizational learning. He explains that tacit knowledge is deeply rooted in one's personal experience and mental model, making it hard to express or extract from one person to another (examples include learning new languages or recognizing someone). The same applies at the organizational level. When tacit, knowledge is more valuable as it can bring a sustainable competitive advantage for firms because it is hard to imitate but can also bring difficulties as it will take more time and energy to transfer. This presents a significant challenge for firms wanting to benefit from the flow of knowledge from the university-industry collaboration.

In a science-industry context, this presents a significant barrier to knowledge exchange which we term *Polanyi barrier.* University-industry interactions require a combination of both explicit and tacit knowledge exchange. While explicit knowledge can be important for sharing data and facts (publications, books, patents), tacit knowledge is also crucial to exchange expertise and is more valuable for the success of collaborations. Tacit and explicit knowledge can be apprehended through a sort of continuum where the less explicit and codified is knowledge, the more difficult and time consuming it will be to exchange. Tacit knowledge is more difficult to transfer and to grasp because it cannot be easily communicated in verbal or written form compared to explicit knowledge. University intellectual properties can be expressed in codified knowledge because they can be translated into patents or publications. And this knowledge can be easily transferred: results of a research paper can be easily communicated at conferences; patents are a codified form of "know-what" where the necessary information about the technical invention can be easily found and understood. Tacit knowledge is gained through experience, intuition and observation and is usually embedded in individual's skills, expertise and routines. Hence, it can be difficult to articulate something that 'seems natural and obvious' and express it with the right words (Haldin-Herrgard, 2000). The differences in knowledge backgrounds can result in different languages, which diminishes the ease with which knowledge is exchanged (de Wit-de Vries et al., 2019). For example, a researcher may hold 'scientific cunning or know-how' (Howells, 1996) in a field gained through hands-on experimentation and observation which can be difficult to express when developing a joint project. Moreover, there could be cognitive difficulties for the industry to understand the stakes or the jargons of that research field or the underlying scientific and technical aspects of a technology developed. Similarly, 'practical know-how' of the industry can be crucial for academics who want to apply their knowledge.

Name	Type of costs or conflicts	Examples
Merton	• Conflicts related to differences in orientations, motivations and overall cultural differences that firms and universities have (Bruneel et al. 2010; Merton, 1973; Sauermann & Stephan, 2013; Tartari et al. 2012)	• Information disclosure (open vs. close) • Choice/orientation of topics (basic vs. applied) • Timing (short term vs. long term) • Mutual lack of understanding about expectations and working practices
Williamson	• Costs related to the interaction process: transaction or relation costs (Dahlman, 1979; Williamson, 1979) o Costs of search and information o Costs of negotiation and decision o Costs of enforcement	• Looking for partners or collaboration opportunities, seeking information on legal or business aspects of UII • Dealing with rules and regulations or university policies and distributional conflicts of IP rights (Bruneel et al. 2010; Tartari et al. 2012)

		• Reporting, ensuring follow-up and compliance
Polanyi	• Costs of transferring knowledge/technology due to its tacitness (Nonaka, 1994; Polanyi , 1966)	• Cognitive difficulties in understanding the technology or knowledge exchanged • Cognitive difficulties in expressing or communicating tacit knowledge

Table 8: Type of UII barriers and corresponding examples.

***Source:* Own elaboration.**

4. Towards a conceptual model

The previous part explained the concepts, their key factors, and variables. This third section presents the final steps of building our conceptual model: combining the related concepts to explain the phenomenon studied. This phase was iterative, and the final results were synthesized in a figure.

Our conceptual model examines two central relationships. Firstly, we investigate the types of barriers that arise in different interactions and their varying intensities. Secondly, we explore how different intermediary organizations (IOs) can leverage specific types of barriers through their activities and functions.

Barriers can be present across all interactions; however, our argument posits that each barrier possesses a certain intensity level contingent upon the characteristics of the specific interaction. The essence of this notion lies in the differentiation between interactions displaying co-production characteristics and those that do not. In other words, interactions have distinctive characteristics and do not exhibit the same types of barriers at the same level of intensity. For example, the relational involvement of actors entails the presence of Merton barriers. The intensity of a barrier can be characterized by its relative significance within a particular type of channel compared to other barriers. A high level of a specific barrier, such as the Williamson barrier, in the commercial transfer channel suggests that this barrier is most likely to be encountered in this particular channel compared to other barriers, posing more significant challenges to the process and, at times, impeding success.

Recognizing that barriers can entail significant costs for both academia and industry aids in understanding the existence of intermediaries. We contend that specific interactions may encompass barriers that are excessively costly for the academic or industry partner to bear, necessitating externalizing these costs to a third entity. In other words, barriers with high-intensity levels require the involvement of intermediaries. Specifically, we posit that IOs can address specific barriers in certain interactions under their unique functions.

Figure 3 provides a baseline model. It summarizes the related concepts into a decision tree, showing how one type of interaction is characterized by a dominant barrier that leads to the involvement of a particular type of IO.

The conceptual model depicted in **Figure 4** offers a more detailed picture of the phenomenon. The three-dimensional graph shows the different barriers in each type of interaction and the different intermediaries. Each axe shows one type of barrier: Williamson on the horizontal axis, Polanyi on the vertical axe, and Merton for the applicate. There are no numeric values attributed to the barriers. We aim to show different levels of conflict to compare each barrier's predominance.

On the graph, we can see that different barriers can appear for each type of interaction. It is crucial to notice that all barriers exist during all interactions; however, one is often dominant. Human resource transfer faces shallow Polanyi and low Williamson and Merton barriers on the bottom-left-hand side of the figure. Moving to informal exchange, we can see that all barriers are also low, but it has a slightly higher level of Williamson barrier. Commercial transfer faces high Williamson conflicts and some knowledge and orientation barriers. Structured co-production faces more Merton and Polanyi obstacles than the latter, as well as a medium Williamson barrier. Finally, the last interaction is faced with the highest Polanyi barrier, a medium Merton barrier, and a lower Williamson barrier.

In the subsequent two sub-sections, we delve into the barriers manifested in each interaction and then into the different IOs involved in leveraging the barriers. We derive a set of propositions to elucidate these relationships further.

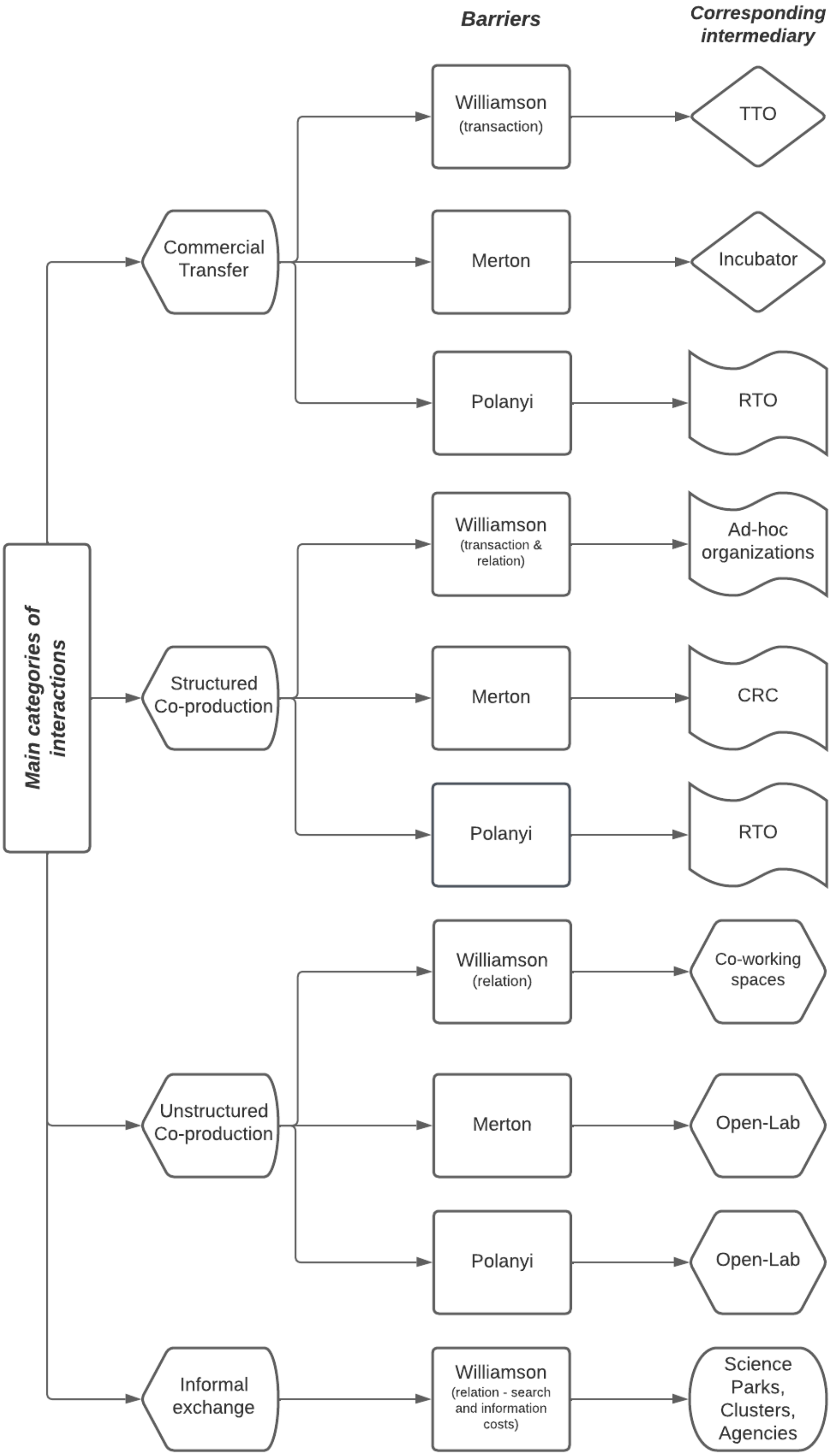

Figure 4: Decision tree.

***Source*: Own elaboration.**

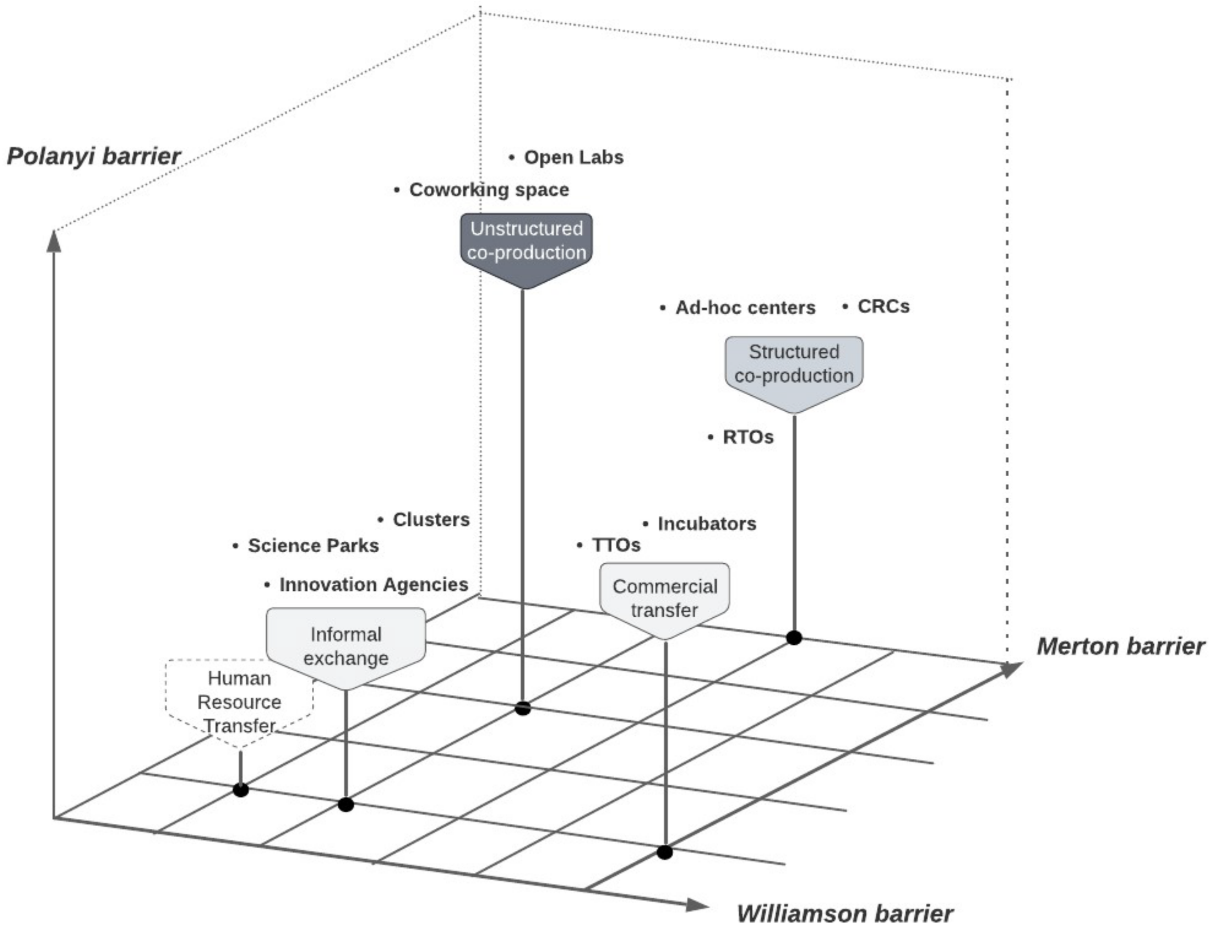

Figure 5: The Interaction-Barriers-IOs Conceptual Model.
***Source:* Own elaboration.**

4.1 Types of barriers for different types of interactions

This subpart shows that all barriers are likely to appear but with different intensities for each type of interaction. For each interaction, we analyze the three categories of barriers.

Human Resource Transfer, as the mobility of researchers into industry or industrialists into academia, is a bi-directional knowledge transfer. Since tacit knowledge is bound to an individual's experiences, the mobility through recruitment and sabbaticals of one individual to an organization allows the transfer and assimilation of tacit knowledge. Industry can assimilate scientific "know-how" by hiring academics because it allows in-depth interactions and face-to-face contact, enhancing socialization and transferring tacit knowledge (Nonaka, 1994). Human resource transfer as a channel is hence not characterized by barriers regarding the transfer of tacit knowledge.

When individuals move from academia to industry (or vice versa) through human resource transfer, they may encounter challenges adapting to the norms and values of their new organizational environment. However, these challenges primarily affect the individual's work performance and integration within the organization rather than causing direct conflicts between the academic and industrial partners. Barriers related to organizational culture may be less significant because human resource transfer, such as student mobility, often has established frameworks and is more straightforward in terms of objectives and outcomes. Hence, transferring personnel does not necessarily involve the active collaboration and negotiation of competing interests that can exacerbate Merton barriers in other forms of UII, such as co-production (Galán-Muros & Plewa, 2016).

Finally, the mobility of academics or students from universities to industries can be difficult again as they might not know the industry's needs. There might still be some transactional barriers, such as search and information costs, as labor and demand must be a good match. Those barriers are likely to be relatively significant; however, the costs arise from labor market failures and are likely to be supported by individuals and not by the university; hence, they do not apply directly to the university-industry context.

Informal exchange implies a low relational involvement of actors because actors do not need to engage actively in the design and output over time. In conferences, workshops, or networking events, academics and industry professionals engage in free-flowing discussions without the constraints of formal agreements or intellectual property concerns. While participants may hold different values and motivations, the informal setting allows for exchanging ideas without the pressure of aligning goals or navigating complex collaborative processes. As a result, the potential for Merton barriers to cause disruptive conflicts is reduced, even though the underlying differences in institutional logic persist.

Informal interactions can exist across all the other interactions and are essential to developing first contact and maintaining interactive relationships. Interpersonal relations develop outside of formal encounters at different events such as conferences, social gatherings, or networking occasions. During those encounters, the type of knowledge exchanged can be shared in codified forms (conference presentations). However, overall, they facilitate the process of socialization and social connectedness, facilitating the exchange of tacit knowledge. Hence, a low level of Polanyi barrier characterizes informal exchange.

The biggest challenge to successful informal exchange is that actors must know the different possibilities to interact informally. The opportunity to meet new collaborative partners in events and networks is challenged because actors might not know the opportunities to participate in such activities. They might also not be encouraged or enticed to do so. Therefore, informal exchange is characterized by Williamson costs associated with managing partner relations, such as search and information costs related to identifying partners.

Commercial transfer implies a low to medium relational involvement of actors. Research services require a relatively low relational involvement[28] as it is usually a one-shot or short-term provided service. Academic entrepreneurship yields a medium level of relational involvement. Medium if the spin-off is managed co-jointly with an industrial partner, low if the spin-off is managed independently from the academic. Indeed, academics do not need to build relationships and interact with the industry to conduct commercialization of IP and licensing activities. In other words, actors are not 'collaborating' in a strict sense, meaning that orientation conflicts are less likely to occur as research topics are already decided beforehand. Nevertheless, some orientation conflicts might still occur, especially for academics who pursue entrepreneurial activities: they may find it challenging to understand the market logic of the industry and the challenges that come with it.

[28] We interpret this differently than the typology of Perkmann & Walsh (2007).

Even if knowledge creation at the beginning holds both explicit and tacit dimensions, it is usually transferred through codified forms such as patents, formulas, prototypes, or reports in IP and licensing activities and academic entrepreneurship. Hence, Polanyi barrier is less likely to appear in this interaction. Besides research services, academics provide expertise for a specific applied problem: rapidly transferring knowledge to the industry might be challenging as knowledge might be intricate to translate into industrial jargon.

Commercial transfer is characterized by a unidirectional transfer of knowledge from academia to industry, meaning that the main challenge for those interactions is the right match-making between the ‘receiver’ and ‘producer’ of knowledge. Transactional barriers are likely to appear, namely search and information costs associated with knowing the different steps and procedures to follow and finding the right partner with the proper knowledge or innovation. Moreover, negotiation costs might also occur when dealing with the university’s IP rule and enforcement costs to ensure follow-up.

Co-production projects exhibit significant barriers, including Merton, Polanyi, and Williamson, because it involves relational commitment from partners, sharing and producing knowledge, and the need for coordination. However, structured and unstructured co-production projects differ in the importance of these barriers.

Structured co-production involves cooperative interactions between members of two communities (academia and industry). Those actors' distinct interests, expectations, and priorities can sometimes conflict (Verschuere et al., 2012). Scholars are motivated to share the results early on to enhance their scientific reputation, while companies tend to delay the disclosure of findings to maintain competitive advantage. Additionally, universities often emphasize fundamental research and academic curiosity, while industry partners may be focused on applied research and commercial viability. This misalignment in research goals and the project's desired outcomes can cause tensions. Moreover, universities often operate on longer-term academic timelines, whereas industries may have more immediate and time-sensitive goals. Conflicts may occur when aligning project timelines, milestones, and deliverables to accommodate both. Finally, differences in values, expectations, work practices, and management approaches can lead to conflicts, particularly related to decision-making, project management, or work methodologies. Hence, structured co-production projects tend to experience a high level of Merton barriers, given the high stakes associated with the outcomes of such projects.

Moreover, when new knowledge is created in research projects, tacit knowledge is valuable in bridging the gap between theoretical knowledge generated in academic settings and practical application in industry. In those projects, there is a combination of both explicit (publications, reports, patents) and tacit knowledge (know-how, skills, and insights) from both actors. The combination of knowledge enhances the relevance and applicability of research outcomes in addressing real-world challenges. Tacit knowledge in this context helps understand industry-specific contexts, refine research approaches, and translate findings into practical solutions. Transferring knowledge might be challenging due to differences in organizational cultures, languages, and practices. For example, both actors might have different terminologies, research methods, and approaches (Orr & Bennett, 2012) on the topic they are investigating. While the exchange of tacit knowledge and expertise remains vital in sharing expertise, actors typically possess subject-specific knowledge and understanding in this channel, reducing the reliance on sharing tacit knowledge.

Finally, Williamson barriers associated with transactions and relations are likely to appear. Negotiation and contracting costs might arise over drafting the contract or the distribution of financial benefits derived from IP. Ensuring everyone is filling the part of their work and not deviating from the milestones can increase enforcement costs. Finally, building and managing relationships is likely costly in this type of interaction.

Unstructured co-production involves collaboration between multiple stakeholders, academics and industries, users, and designers. In such projects, tacit knowledge is crucial in knowledge sharing, mutual learning, and integrating different perspectives and expertise. Actors involved in co-production have to bring diverse perspectives, insights, and competencies to solve problems or develop ideas/solutions in a specific context (Leonard & Sensiper, 1998). Hence, they bring their tacit knowledge rooted in their experiences, values, and local contexts. It contributes to a deeper understanding of the problem, helps co-create innovative solutions, and supports effective stakeholder collaboration. However, the distributed nature of unstructured co-production poses more obstacles to sharing and diffusing tacit knowledge than structured co-production, which usually involves only two organizations (Bonesso et al., 2014). Actors might struggle to build solid, continuous collaborative relationships and exchange ideas. First, failures to share information and communicate effectively can cause misunderstandings that impede the transfer of tacit knowledge. Furthermore, expressing and understanding tacit forms of knowledge (experiences, intuition..) takes time and requires repeated direct personal interaction and practical application (Lee, 2020). Hence, tacit knowledge becomes challenged if those underlying conditions are not fulfilled. Moreover, this channel is characterized by high uncertainty (about the goals and incentives), resulting in experimentation and exploration phases during the co-creation process. Those situations force individuals to confront unfamiliar contexts and knowledge, making assimilating tacit knowledge even more difficult (Seidler-de Alwis & Hartmann, 2008).

Merton barriers remain significant as conflicts due to differences in cultures and orientations are likely to occur as the number of actors from different institutions and disciplines increases. However, since actors are united in addressing the same problem, usually a complex societal challenge, they collaborate cohesively towards a shared vision. Those projects do not necessarily involve conflicts about the outcomes because actors usually do not formulate expectations about their benefit. Hence, Merton barriers tend to be less of a concern than in structured co-production. The goal is to have a shared meaning and vision to tackle a specific complex problem.

Finally, transactional costs might also exist, particularly concerning relationship management. The absence of predefined exchange protocols and the implication of diverse individuals lead to higher coordination and management costs. It becomes notably more challenging to coordinate multi-partners projects (Cummings & Kiesler, 2007). Identifying and connecting different actors at various stages and ensuring that knowledge is well-integrated pose some challenges. While no conditions are pre-determined, negotiation costs might be high as actors must align their goals to create a common one to solve a specific problem. Enforcement costs will likely occur to ensure that actors are motivated and participate throughout the process.

4.2 Type of intermediaries for different types of barriers

In this final subpart, we show the link between barriers and IOs. More specifically, we show how different IOs can tackle the barriers in each interaction. We derive some propositions.

Human Resource Transfer is a unique channel without any apparent IO. Even if all three types of barriers can be found, the identified barriers are not high enough for an intermediary to emerge. There might be search and information costs associated with the matching; we argue that some mechanisms which facilitate this process exist (such as online professional platforms such as Linkedin or Indeed), but those are outside the scope of the intermediary literature and more related to labor market considerations. Some intermediaries might help to connect students or academics to the industry, such as incubators, academic open-lab, or even science parks. However, those relations do not necessarily lead to hiring students or academics in the private sphere. For the university's entrepreneurship culture, it is important to have projects which include industries (Hackatons, for example) or the intervention of professionals from the industry. Hence, no identified intermediary carries out the mechanisms that ease the tensions.

Proposition 1: Human resource transfer exhibits a low level of barriers, with no dominant barriers and hence no apparent intermediaries

For *informal exchange*, Williamson barrier associated with the relations can be leveraged through the networking functions of intermediaries. We argue that all intermediaries provide activities and services that are meant to connect actors. However, it seems easier for some organizations to do so and operate it on a large scale because of geographical proximity. Shorter physical distance can lead to more accessible connections by establishing personal contact between academic and industry staff, access to specialized literature, and attending seminars and conferences (Vedovello, 1997). Many regionally embedded intermediaries, such as innovation agencies, clusters, and science parks, can use public resources to maintain open and flexible networks with diverse partners. Because they have extensive knowledge about regional competencies and the industry landscapes, they can quickly identify and connect SMEs with various organizations, including academia, for specific projects or needs (Rossi et al., 2021). For example, science parks plan networking events with residents and non-residents and build external networks with local and international stakeholders (Good et al., 2019b).

Proposition 2: Informal exchange exhibits a low level of barriers with a greater emphasis on Williamson barrier associated with relations compared to other barriers, which Clusters, Science Parks, and Innovation agencies are more likely to respond to compared to other IOs

When pursuing *commercial transfer* activities, academics and industrial partners will likely face transactional barriers (Williamson), especially in intellectual property activities. Both actors may not know the necessary information and procedures to follow. In this case, TTOs can reduce search and information costs by sharing information and proposing clear procedures and standard guidelines about commercial transfer activities. TTOs also connect researchers and industry partners. They prospect and assess potential research that has commercialization opportunities. TTOs reduce negotiation and enforcement costs because they assist in negotiating and drafting contracts between partners. Moreover, there can be asymmetric information between academics and industries on the value of innovation (Macho-Stadler et al., 2007). It is difficult for firms to assess the quality of the invention ex-ante. Meanwhile, it is also difficult for researchers to assess the commercial profitability of their inventions. TTOs can help with that by pooling innovations across research labs and raising the value and prices of innovations by putting projects on hold. Moreover, TTOs also reduce some Williamson barriers associated with the relations. They also pursue internal and external networking to connect different actors but only to support earlier stages of technology transfer (Good et al., 2019b).

As our model depicts, other IOs can come into play and leverage other barriers in commercial transfer. Although not as crucial in this channel, we identified some Merton barriers at the level of academic entrepreneurship. We argue that incubators can provide the necessary tools to overcome those obstacles by providing training and various programs for creating a start-up. We also identified some Polanyi barriers to the service channel; intermediaries close to industries such as RTOs can offset this difficulty because they specialize in applied research and quickly transform knowledge into a suitable format.

Proposition 3: Commercial transfer exhibits a high level of Williamson barrier related to the transaction compared to other barriers, which TTOs are more likely to respond compared to other IOs

For *structured co-production*, an institutional setting like collaborative research centers (CRCs) can provide several benefits. An essential function in the management and operation of CRCs is the coordination of actors with diverse institutional affiliations, disciplinary backgrounds, and goals. Hybrid spaces allow institutional logic to co-exist (Perkmann et al., 2019) and help actors align their goals to a specific project (Bodas Freitas & Verspagen, 2017). For example, having an established governance structure involving representatives from academia and industry ensures that interests from both sides are considered and integrated into the project's direction and outcome. Moreover, CRC is an institutional setting that can reduce Merton barriers by leveraging other barriers. This is in line with the direct and indirect effect of the intermediary's functions in the study of Villani et al. (2017). CRCs can be place-based and allow face-to-face interaction through frequent meetings and active participation in the research network. Opportunities for collaboration, networking (reduce Williamson barrier associated with relations), and incentives such as joint workshops, seminars, or forums contribute to facilitating knowledge sharing (reduce Polanyi barrier). Formal agreements and governance frameworks ensure the active involvement and dedication of all collaborating partners (reduce Williamson barrier associated with transactions). All those activities associated with the different barriers reduce the Merton barrier by building trust, solid relationships, and a common organizational identity over time (Davis et al., 2013).

Regarding the potential role of other IOs, other institutional organizations similar to CRCs, such as RTO or ad-hoc organizations, can leverage barriers. Increased administrative procedures have triggered the emergence of new forms of organizations in some countries. They pursue similar activities as CRCs and RTOs and allow to reduce some of the transaction costs actors face when no other structures than universities are available to support their projects.

Proposition 4: Structured co-production exhibits a high level of Merton barrier compared to other barriers, which CRCs are more likely to respond - by leveraging other barriers - compared to other IOs

Unstructured collaboration is characterized by a high Polanyi barrier. Open labs or fab labs provide a physical space to share tacit knowledge by allowing actors to meet informally (Mérindol et al., 2018). The exploration and experimentation processes require face-to-face interaction, particularly in shaping and developing ideas into prototypes. According to Koskinen et al. (2003), face-to-face interaction is the most effective communication medium for transferring tacit knowledge as it allows for immediate feedback and the interpretation of non-verbal cues such as body language and tone of voice. Prototypes that can take various forms (physical models, sketches, simulations, or even stories) provide a common interface for stakeholders to come together, explore, and contribute. Most specifically, they act as a device for sharing insights into problem dimensions and potential solutions, enabling collaborative exploration and engagement (Bessant, 2020). Compared to CRCs, open labs offer the opportunity to use knowledge in real-life situations (in practice), which helps individuals gain a better understanding (enactment) of that knowledge, which is crucial for generating new knowledge. Members of Fab-labs can learn by watching, imitating and practicing with their peers (Maravilhas & Martins, 2019). Hence, open lab can leverage barriers regarding the transfer of tacit knowledge by connecting the immaterial and cognitive aspects with the material space (Ollila & Yström, 2020).

Open labs contribute to some extent in reducing Merton barrier because they offer an inclusive and egalitarian environment that respects different viewpoints. In this space, hierarchical distinctions are set aside, emphasizing competence and mutual respect (Maravilhas & Martins, 2019). Moreover, by facilitating the exchange of tacit knowledge through occurrences of interaction and engagement in joint activities, open labs help with mutual understanding and the alignment of goals. The organization of the space as well as the presence of facilitators play a significant role in creating social spaces, influencing motivation, power dynamics, and goal orientation (Ollila & Yström, 2020).

Finally, open labs enable actors to connect in a physical space (co-working space), meaning that actors who might not know each other yet can have the opportunity to develop projects together or give each other advice (reducing). Moreover, the design of the interaction space and the specification of role models for stakeholders, the content management as well as the collaboration modes carried out by facilitators contribute in reducing Williamson barrier associated with relations.

Proposition 5: Unstructured co-production exhibit a high level of Polanyi barrier compared to other barriers which Open labs are more likely to respond to compared to other IOs

5. Discussion and conclusion

Knowledge and technology transfer is a highly complex process that requires different skills, capabilities, and resources that are not necessarily in the hands of universities and industries. This study offers a conceptual model using the concepts of barriers to understand the multiplicity of IOs in U-I interactions. Although the subject is inherently complex and multifaceted, we provide the first attempt to understand its intricacies.

5.1 Discussion and contributions

Our conceptual model shows that different channels depict different barriers at different intensity levels (propositions 1 to 5), leading to different intermediaries' involvement (propositions 6 to 10). Our model suggests that Science Parks, Clusters, and Innovation agencies are better at tackling Williamson barrier associated with relations in the informal exchange channel (Proposition 2), TTOs are better at tackling Williamson barrier associated with transactions in commercial transfer (Proposition 3), CRCs are better in tackling in Merton barrier in structured co-production (Proposition 4), Open labs are better in tackling Polanyi barrier in unstructured co-production (Proposition 5). Even though each IO is not bound to a specific barrier (for example, both incubator and CRCs can tackle Merton barrier), each IO is better at tackling one type of barrier compared to others, which means that IOs, even if they have overlapping functions in reducing barriers, still complement each other at some point.

Our conceptual model supports the argument that the more the interaction has a **knowledge transfer character,** the more likely it will depict Williamson barriers and the more likely traditional intermediaries such as TTOs will be involved. Whereas, the more the interaction has a knowledge co-production character, the more likely it will show Merton and Polanyi barriers and intermediaries such as CRCs or open labs can respond to these barriers. Most importantly, we can argue that the more we move to the right, towards interactions facing even more barriers, **the more complex** will be the IO. Co-production channels are faced with higher barriers and require the involvement of very heterogeneous and complex organizations. The outcome of our findings aligns with the argument put forth in recent work (Giachi & Fernández-Esquinas, 2021; Perkmann et al., 2019): intermediaries such as research centers exhibit complexity and tend to develop into multifunctional entities with a complex set of activities to respond to a wide range of outcomes.

Our analysis shows that different interactions can be facilitated through **the roles of many intermediaries**, not exclusively TTOs. Villani et al. (2017) explain that different IOs facilitate interactions. We integrate other IOs and link their roles to different interactions. Along with TTOs, incubators, and CRCS, the role of RTOs and similar ad-hoc organizations has been put forward. They are likely to respond to barriers that are not tackled by 'traditional' intermediaries. Moreover, the role of science parks, clusters, and innovation agencies is highlighted. These 'external intermediaries' (Wright et al., 2008) can offer complementary services to traditional intermediaries by improving the general connectedness between actors. Moreover, open labs should not be overlooked in UII. We advocate that these experimental place-based interfaces allow for the integration of knowledge between various actors. In line with the work of Good et al. (2019), we show that a more expansive knowledge transfer ecosystem view is essential to account for the diversity of intermediaries and the richness of existing interactions.

Our contribution to the literature on university-industry interactions lies in providing **a unified model** that incorporates the involvement of multiple intermediaries and examines the interconnectedness between interactions, intermediaries, and barriers. Previously, these research areas have been explored somewhat independently. While there are papers that try to link barriers to interactions (Galan-Muros & Plewa, 2016) and on the other side those that bridge barriers and intermediaries (Alexandre et al., 2022; Villani et al., 2017), there is no comprehensive framework that bridges the two. Our work bridges this gap.

Our work additionally refines the understanding of the underlying concepts, which builds up the previous streams of literature. The use of barriers to explain the multiplicity of IOs has not been advanced in the literature. Recent works by Good et al. (2019) and Caloffi et al. (2023) have provided reviews highlighting the phenomenon of multiple intermediary organizations. However, they do not use barriers or delve into the reasons underlying their increase. Our work is a direct response to this gap.

Compared to the previous literature studying types of interactions between university and industry, we propose to include the knowledge co-production channel. The concept of knowledge co-production is not new as a phenomenon, however, its rise in the literature on university-industry interactions has gained recent attention (De Silva et al., 2021, 2023; De Silva & Rossi, 2018). We choose to include it to have a more complete view of the different forms of collaboration today.

We also extended the work on barriers of interaction. We propose considering a broader view of the "Williamson barrier" to account for all transaction costs, not only those related to negotiation over intellectual property (IP).(Tartari & Breschi, 2012). Even though tacitness of knowledge has been considered one dimension of knowledge interactions (Alexander & Martin, 2013; Schartinger et al., 2002), it has not been considered an obstacle. This broader framework allows us to understand better the involvement of intermediaries.

5.2 Implications

This work directly impacts all stakeholders: policymakers, universities, industries, and the IOs. Our model can provide a practical guideline and act as a roadmap for actors to better understand the roles of IOs in their landscape. By doing so, we hope to enhance our comprehension of the knowledge-transfer ecosystem and navigate it more effectively. More practically speaking, actors can better identify the type of IO to reach regarding the type of interaction they want to promote. The decision is tree holds particular relevance in this case.

Moreover, our work also provides a benchmark for intermediaries who wish to evaluate their roles and activities and enhance the way they leverage barriers and somehow perform better. Moreover, our work can help managers of IOs understand better how they can relate to other actors. This can help avoid potential overlap and improve the "teamwork" of all the IOs in the ecosystem.

Our study highlights that an increased number of actors involved in university-industry knowledge transfer does not necessarily lead to reduced effectiveness. Instead, it emphasizes the importance of maintaining a rich and diverse landscape of intermediaries to support this ecosystem. While all the necessary elements are present, policy makers and IOs must focus on facilitating effective collaboration among the intermediaries or adapting their functions per the evolving dynamics of the university-industry interaction.

Finally, this can have significant implications for research policy and evaluation as some organizations may be overlooked. Hybrid and multifaceted organizations have been growing considerably. Although there are more agile in leveraging different barriers, they remain challenging to observe and hence require particular attention for their evaluation.

5.3 Considerations and research agenda

Our analysis presents, of course, some drawbacks and considerations. We are aware that our analysis provides a **general and simplified view of the role of the intermediaries.** First, it should be noted that their functions in real-life might differ in reducing the different types of barriers. For example, even though open labs are more likely to reduce "Polanyi barriers" for unstructured collaboration, we could find that they do not seem to reduce them as much. We could also find that they can reduce "Williamson barriers." Similarly, TTOs, beyond their leading role in reducing transaction costs, could also play a role in reducing the "Merton barrier." In real life, a continuum to depict the prominence of the role of each structure will always be helpful. Our analysis can still bring forward their core function in leveraging barriers and facilitating interaction between universities and industries.

Our study is conceptual, so we advance that empirical analysis should be investigated to see to what extent this model can be validated and enriched (this is investigated in Chapter 3 of this thesis. Furthermore, our work highlights the possibilities of bridging our understanding of the dynamics of the identified barriers. We do not consider when the barriers appear in the interaction process and which barriers should be leveraged first when they are interrelated. This implies that the involvement of an intermediary can differ throughout the interaction process. Adopting a longitudinal approach to understand those dynamics would better help understand this phenomenon.

Another consideration is that **other barriers exist, and IOs might not necessarily tackle them**. First, barriers inherent to the individual's ability cannot be influenced by intermediaries but relies on various factors of the associated institutions. Promoting entrepreneurialism, access to training, autonomy level, public funding system support, and political strategies..etc. significantly shape an individual's ability. Even if those barriers are leveraged, Williamson, Merton and Polanyi barriers are likely to remain a problem for university-industry interactions and are likely to involve IOs. Our aim was to identify barriers which will involve the presence of an IO and not those which will involve other actors or other mechanisms. For example, funding depends on the government (which will influence the ability of individuals to pursue collaborative research projects for example) but it will not influence how the project is carried out. Hence, funding as a barrier does not capture how the government plays a role as a broker or a connector in this type of project. Rather other IOs are likely to be involved during the project.

Moreover, it is essential to note that the facilitation process might be done through mechanisms that **do not necessarily involve IO as an organization per se.** There are also forms of intermediation operating at the individual level or through digital platforms and virtual communities (Albats et al., 2022), which might also complement the existing organizations studied. For example, intermediation might be done directly by the doctoral student or the doctoral school in joint thesis supervision (structured co-production). The literature on "boundary spanners" could be an attractive complementary approach to our organizational-level analysis.

Using barriers as a theoretical lens provides valuable insights into the emergence and role of intermediaries in UII. Our findings shed light on the fundamental reasons behind the existence of U-I intermediaries and their critical role in facilitating effective knowledge transfer and collaboration. While this study focuses on Mertonian, Williamson, and Polanyi barriers, it is likely, that other types of interactions and barriers give rise to different tailored intermediaries. As UII continues to evolve, different forms of interaction may emerge with obstacles of their own. Following our reasoning, it is expected that new forms of intermediaries emerge. These new barriers could also even include barriers associated with existing intermediary structures.

This has been stretched out with ad-hoc organizations like CRC and RTO proliferating in the landscape to respond to existing structures' administrative rigidity of TTOs. This highlights the dynamic nature of the U-I ecosystem and the need for intermediaries to adapt an evolve to meet the changing demands of academia and industry.

Conclusion of Chapter 1

Knowledge and technology transfer is a highly complex process, it requires different skills, capabilities and resources that are not necessarily in the hands of universities and industries. Different intermediary organizations (IOs) have been developed to facilitate this process. However, their growing number has led to a fuzzy landscape, creating confusion for stakeholders and even criticism. Although the subject at hand is inherently complex and multifaceted, we aim to gain a partial understanding of its intricacies. By doing so, we hope to enhance our comprehension of the knowledge-transfer ecosystem and navigate it more effectively. Our conceptual model gave a holistic view of how IOs can help facilitate this process by leveraging different barriers. More specifically, each IO has a specific role to play. Even though each IO is not bound to a specific barrier (for example: both incubator and CRCs can tackle Merton barrier), each IO is better at tackling one type of barrier compared to others, which means that IOs, even if they have overlapping functions in reducing barriers, still complement each other at some point. To sum up, a rich and diverse landscape of intermediaries remains essential to support the university-industry knowledge transfer ecosystem.

While Chapter 1 establishes the theoretical framework for understanding multiple intermediary organizations and their roles in addressing specific barriers (Williamson-type, Merton-type, and Polanyi barriers), a natural question arises: How did these different types of intermediaries come to exist? Chapter 2 addresses this question by taking us on a historical journey, revealing that the multiplicity of intermediaries we observe today has deep historical roots predating World War II.

CHAPTER 2

THE HISTORY OF SCIENCE–INDUSTRY INTERMEDIARIES UNTIL WWII, A FUNCTIONALIST VIEW

Summary of Chapter2:

This study examines the historical evolution of science-industry intermediaries in the West up to World War II. Using a neo-Schumpeterian evolutionary framework, the research highlights how intermediaries emerged and evolved to address three main categories of obstacles in science-industry relations: transaction costs, cultural differences, and tacit knowledge transfer. The study identifies three distinct periods of intermediary development: pre-19th century, 19th century, and the turn of the 20th century. It reveals that early intermediaries focused primarily on reducing transaction costs, while later periods saw a shift towards facilitating knowledge transfer and addressing cultural gaps as science and industry became more institutionalized. By analyzing various forms of intermediation, including guilds, patrons, and academic societies, this work provides insights into the changing nature of science-industry relations and the adaptive role of intermediaries in facilitating technological innovation and knowledge dissemination throughout history.

Keywords: science-industry intermediaries, technology transfer, evolutionary framework, first intermediaries

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Chapter 2: The history of science–industry intermediaries until WWII, a functionalist view[29]

1. Introduction

Innovation intermediaries, i.e. organizations that act as facilitators, brokers, matchmakers, etc., between actors of the innovation process are now commonplace, particularly in the context of open innovation (Agogué et al., 2013; Howells, 2006). Among all the existing intermediation structures, a significant number occur in the context of science-industry relations, with the aim of fostering interactions between science and industry. Notable intermediaries include technology transfer offices (TTOs), business and university incubators, Research and Technology Organizations (RTOs), Collaborative Research Centers (CRCs), innovative clusters, innovation agencies, FabLabs,etc.

In economics and management, the issue of university–industry interactions is often presented as having started after the Second World War, with the importance of the Bush Report (1945), and especially from the 1980s onwards, following reforms such as the Bay-Dole Act in the USA (Sampat, 2006). After that period, issues such as the valorization of academic research and technology transfer from science to industry took on central importance in political discourses and academic writings. As a result, the process of explicit and formal institutionalization of science-industry intermediaries emerged really in the last quarter of the 20th century (Mowery et al., 2001; Sampat, 2006) and the interest in the role of intermediaries took a historic turn starting this period. Very few studies have looked into how science-industry intermediaries took form before this period even though research into the history of science and technology has shown the existence of science-industry links long before this. Institutionalization (often implicit) of science-industry links started in the 19th century but first forms of interactions between the "natural" and the "practical" can be traced back to the premise of modern science in the Renaissance. It is likely that intermediation forms, admittedly

[29] This chapter was co-written with Julien Pénin, who wrote Section 2 and contributed to the introduction. All the other parts was written by me.

quite different from today's forms, appeared also during this time (Galvez-Behar, 2008, 2020; Mercelis et al., 2017).

Therefore, our research is motivated by these following questions:

When did science-industry intermediaries first emerge? And most of all, how have they evolved and why?

In particular, it analyzes the historical emergence and evolution of science-industry intermediaries in the West, from the premises of modern science up to the first World War. We identify the different forms of intermediation, distinguishing them according to their function. We also show how the functions performed by these intermediaries evolve with the historical context and, in particular, with the progressive institutionalization of academic and industrial research.

We're restricting ourselves to the Western case (Europe and North America), essentially because that's where modern science and industry were born. We should also point out that the science-industry relations we are studying must be understood in a much broader sense than they are today. Before the first World War there were no incubators, TTOs, RTOs and so on. Our study takes place in a pre-industrial or nascent-industrial context, where both science and industrial research did not exist in the way they are institutionalized today. For example, the invention of the industrial research laboratory dates from the end of the 19th century (Meyer-Thurow, 1982). It was also at this time that modern science was born, with its own rules and ethos. Talking about science-industry relations as we consider there relations today doesn't really make sense until the 20th century, so we need to look at other forms of interactions and other forms of intermediation than those we know today. Rather than examining science-industry relations in the restricted sense, in this work we take a more general interest in relations between (often isolated) inventors and society at large (industry, state and the general public). We examine the way in which different forms of intermediation have facilitated interaction between inventors and the socio-economic world, and ultimately facilitated access to new technologies and inventions. For example, we study the role of guilds, patrons, academic or industrial societies, exhibitions, intellectual property advisors, etc.

We adopt a neo-Schumpeterian or evolutionary framework (Nelson, 1985; Nelson et al., 2018). We consider that the evolution of organizations follows an evolutionary process in which new organizational forms emerge in relation to a given historical context (economic, technological, etc.), and survive according to their degree of adaptability to this context. Within this framework, it is essentially the historical context that determines the function and performance of organizations. Different modes of organizations emerge because they are better adapted and more effective in responding to the problems posed in a given historical context. In particular, the historical context and the institutions in place at a given time will affect the costs and benefits of certain organizational modes, and thus guide their evolution. In other words, we adopt a functionalist approach: organizations appear and evolve historically in response to problems that they are better able to solve than alternative forms of organizations.

In the historical context of relations between inventors and society, our theoretical framework implies that intermediaries emerge and evolve because they contribute to improving these relations, reduce friction and overcome possible obstacles and barriers to these interactions better than other organizational modalities. Our historical analysis thus enables us to identify the different types of intermediaries in history, their evolution and also their function, i.e. the barriers and obstacles that they manage to help overcome. This historical analysis, alongside the identification of different intermediaries, thus also highlights the functions of these intermediaries and helps us to understand the problems they address. Ultimately, it is the evolution of the technological and/or economic context that changes the nature of the problems and obstacles to science-industry relations and, consequently, modifies the nature and functions of intermediaries.

More specifically, in line with the conceptual framework developed in this thesis (Chapter 1), our historical analysis highlights three main categories of obstacles to science-industry relations, and therefore three main categories of functions for intermediaries: problems linked to the existence of transaction costs (Williamson-style barriers), problems linked to different cultures (Merton-style barriers) and problems linked to the difficulty of transferring tacit knowledge and know-how (Polanyi-style barriers). In relation to these obstacles, and depending on their importance in the different periods studied, we observe the emergence of intermediaries sometimes focused on reducing transaction costs, sometimes on transferring tacit knowledge, and sometimes, but to a lesser extent, on easing tensions linked to different cultures. We also highlight the evolution of the types and functions of intermediation structures as the importance of these obstacles changes over time. It should also be noted that these identified barriers are likely to be different from those of today, such as we know them, and may emphasize different aspects throughout history. For example, Williamson-type barriers which encompass different costs may be less about negotiating licenses and more about costs of search and information.

This exercise enables us to distinguish three periods for science-industry intermediaries which were marked by turning points in the history of science and industry links: **1)** Before the 19th century (the premise of modern science), although organizations not specifically dedicated to intermediation may play an intermediary role (e.g. guilds), there is no established, institutionalized intermediary structures. The emergence of the first organizations with a significant function of intermediation begins with the end of the Renaissance and is focused on reducing transaction costs, i.e. intermediaries emerge essentially to reduce costs of information exchange, reduce opportunism, etc. **2)** The 19th century sees the emergence of a first phase of institutionalization of science and the birth of industrial firms, which provokes a significant evolution of intermediary structures. The latter become more directly involved in intermediation. Their function remained primarily to reduce transaction costs, but the necessity to promote exchange of useful knowledge and interactions between "knowers" and "doers" (i.e. Polanyi like barriers) also contributed to shape intermediaries. **3)** Finally, the beginning of the 20th century witnessed a second phase of institutionalization of science and the birth of the industrial research laboratory. This double change triggered a further evolution of science-industry intermediaries, which now become to be entirely dedicated to intermediation and have to focus on transaction costs, on the dissemination of tacit technical know-how, but also on reducing the growing cultural gap between science and industry (i.e. Merton type barriers).

The remaining of this work is as follows: in the next section we study the premise of European science and the emergence of the first intermediaries (section 2). In section 3 we study the 19th century which witnesses a first period of institutionalization of science and industry linkages. In section 4, we study the late 19th century and early 20th century, which see a further evolution of science, industry and related intermediaries. Section 5 concludes.

2. The premise of modern science and the emergence of the first intermediaries

In modern times, intermediaries between science and industry often take the form of **places** that encourage meetings and exchanges between the two worlds (innovative clusters, fablabs, etc.). In the Western world, these places may have their origins in the Agora of ancient Greece, where philosophers could freely exchange ideas with the population From our point of view, however, these Agoras were primarily used for teaching and collective thinking. They are therefore far removed from intermediaries as we understand them in this study. In the ancient and medieval world, public reciters, troubadours, etc. were also essential transmitters of knowledge, helping to build the ancient and medieval epics we still know today (the Song of Roland, the Iliad, the Norse epics, the Old Testament, etc.). Researchers have shown that for decades, even centuries, these epics were transmitted and developed according to an evolutionary logic, following a formulaic oral tradition that facilitated memorization and collective construction, and encouraged a theoretically infinite collective exploitation of these texts, which evolved according to the authors who recited them (Frosio, 2018). This formulaic oral tradition enabled texts to evolve while preserving their internal coherence. In a way, this is one of the ancestors of "open source" mode of knowledge production (Pénin, 2011). However, once again, it seems to us that these public reciters, while they played an undeniable role in the creation of Western culture and while they were evident transmitters of knowledge, remain very different from the subjects that interest us in this study.

Perhaps more relevant at first glance are the first medieval universities and the relationships they maintained with their contemporaries. In the West, the first universities were founded in the 12th and 13th centuries in Italy, England, France and Spain. They taught mainly highly theoretical and metaphysical subjects (law, medicine, philosophy, theology). However, it is well known that these medieval universities were very reluctant to engage in practical applications (the tensions between academic physicians, who preached centuries-old remedies, and surgeons, who were in touch with the realities of the human body, were, for example, the subject of numerous satires). All in all, it is now accepted that medieval universities had a fairly marginal impact on technological progress, and that most of the real advances in science took place outside these universities (Fumaroli, 2015). It is therefore not necessarily relevant to look at the possible intermediaries between these universities and their contemporaries. Instead, the first forms of intermediation between inventors and the socio-economic world in the West to have been sufficiently structured, spread across all countries and long-lasting, were probably guilds and corporations.

2.1 Guilds and corporations

Throughout the period from the 12th century to the end of the 18th century, and even the middle of the 19th century in some countries, guilds and corporations played a central role in the regulation of economic activities in Europe. Their role is still debated today in economic history literature. It is undisputed that this system had harmful economic effects, promoting cartels, protectionism and conservatism of all kinds, and discriminating against minorities, particularly women. But, on the other hand, several authors have attempted to show a more complex reality and put forward a more positive role, explaining in particular that guilds may have favored economic and political stability, the circulation of knowledge and best practices, the training of apprentices, reduced uncertainty, etc. (Epstein and Prak, 2008). According to this view, the economic performance of guilds should not be judged against our contemporary economic system, but against the context of the time. And, in their particular historical context, guilds would have been highly appropriate institutions. For Epstein, in particular, guilds could have been an "ideal market structure for innovation" (Epstein, 1998, p. 704), in the particular historical context in which they existed (see also Merges, 2004).

Clearly, guilds are not an institution whose priority is the transfer of technology and knowledge. Their primary aim is to control economic activity (to the benefit of a small majority), and this involves regulating new inventions and technologies. They wanted to minimize the potentially harmful effects of new technologies for their influential members, and not necessarily promote the arrival of new inventions. That said, there are at least three aspects of the guild system that touch on technological intermediation, and which therefore interest us in this work: i) a role of spreading of tacit knowledge via both the training through apprenticeship and the proximity (social, geographical, cultural) encouraged by the guild system; ii) a role of certification of inventions and skills; iii) a role of organization of the economic activity that is conducive to the creation and dissemination of inventions.

First and foremost, guilds may have contributed to the dissemination of tacit knowledge, particularly among their members, via the apprenticeship system and the training of apprentices by masters, and via the mobility of apprentices and craftsmen that was encouraged between guilds in different towns (Epstein, 1998; 2005; Epstein and Prak, 2008). Still linked to the dissemination of inventions and tacit knowledge, guilds were also able to promote exchanges and interactions through the proximity they fostered and the frequent meetings and assemblies held within them. This role would thus be similar to that of innovative clusters in our contemporary economies.

Secondly, guilds may also have played a central role in reducing transaction costs between inventors and the socio-economic world, notably by offering a form of certification for new inventions and skills. A guild's endorsement of an invention can be a minimum guarantee of economic success, sending a signal to other players in the economy. Gustafsson (1987) considers this certification role to be essential in justifying the existence of guilds. Guilds may also have played a role in certifying skills, notably through the training and assessment of apprentices.

Thirdly and finally, several studies have argued that guilds as institutions may have played an important role to promote innovation, notably by providing a more suitable incentive structure for both the production and diffusion of inventions (Merges, 2004). In particular, guilds helped to reduce uncertainty, guarantee market power for the inventor and limit price competition (Epstein, 1998; Epstein and Prak, 2008).

However, for other researchers, these positive roles played by guilds in terms of inventive activity are, to say the least, greatly exaggerated. For Ogilvie (2019), for example, guilds were clearly not interested in providing certification services, training apprentices or promoting the production and dissemination of inventions. For example, when it came to certification, guilds had every interest in favoring their own members, certifying them even if they didn't meet the criteria, and not labeling others, even if they did. They also had every interest in taking advantage of their monopoly to sell certifications to the highest bidders. For Ogilvie (2019, p. 419): "*theoretically a guild might have been unusually effective at testing and certifying skills, but empirically it has strong incentives to use its control over skills assessment to extract rent for its members*". Furthermore, according to Ogilvie, guilds were not considered reliable certification bodies by their contemporaries. Public authorities (cities and states in particular) or merchants were considered far more reliable for certifying product quality (merchants, in particular, because in competition with each other, they had to attach particular importance to their reputation, which was not the case with guilds).

When it came to training, the guilds' track record would not be particularly satisfactory either. According to Ogilvie, the guilds were not effective in training apprentices. Once again, she suggests that the apprenticeship system was largely abused to the benefit of guild masters, notably to reduce competition and increase barriers to entry. Behind the rhetoric of apprenticeship and training, there is little of substance, other than an attempt to justify the system itself. Empirical data suggest, for example, that in most cases, apprenticeships were unnecessarily long and disproportionate to the difficulty of the trade. Nor does Ogilvie's data show any consistency between the difficulty of the learned job and the length of apprenticeship imposed by the guilds.

Finally, when it comes to encouraging the production and dissemination of inventions, the guilds' track record is also questionable. Instead of fostering innovation it is quite possible that, in the end, guilds were a powerful brake on them. Guilds were conservative institutions. In a way, they were the guardians of the temple. They often acted as a barrier to inventions, sometimes only letting inventions through that would undoubtedly benefit them.

Ultimately, Ogilvie's work shows that the guild system that ruled most European countries for almost 800 years is an example of an extractive institution, based on collusion between powerful merchants and political power, and operating to the detriment of the vast majority of the population, particularly those categories of individuals discriminated against by the guilds (ethnic and religious minorities and women in particular). According to Ogilvie's estimates, guilds devoted significantly more financial and human resources to their rent-seeking and lobbying activities than to their other activities (such as certification, training and encouraging innovation). In this system, the guilds' sole objective is the interests of their most influential members. There may sometimes be positive effects for the rest of the population, but only if this coincides with the guild's own interests. As a conclusion, according to Ogilvie, with a few exceptions, guilds have not played a significant role in intermediation between inventors and the socio-economic world.

2.2 Renaissance, scientific patronage and the emergence of a need for intermediation

The humanist movement and the European Renaissance of the 15th and 16th centuries marked a turning point in the history of science. As far as intermediaries are concerned, the changes dating from this period saw for the first time the emergence of organizations whose primary function was intermediation. The changes dating from this period that opened the door to modern science are manifold. We can identify at least four of them:

First and foremost, the humanist movement helped to legitimize the act of human creation by placing man at the center of thought, thus taking the place previously attributed to God. Man becomes aware that he is free and autonomous and that he can do things for himself and not only for the sake of God. In terms of creation, this brings about a major philosophical upheaval: man can now conceive of himself as a creator. Previously, for a man to claim to be a creator was tantamount to defying God. It was heretical thinking. Godin explains: "*For most of its history, the concept of innovation had nothing to do with economics or creativity. Rather, it* *was a concept linked to religion and politics [...] The concept of innovation is, in fact, the "secularized concept for heresy*" (Godin, 2020). From the Renaissance onwards, man became aware that it was tolerable to create new things, and this had multiple consequences in terms of invention. It was at this time, for example, that the notion of intellectual property was born, a notion that had previously been meaningless. Above all, this change led to the disinhibition of systematic thinking about nature and how to modify it.

At the same time, man realized that the world could be intelligible and that it could be modified, changed to be more useful and favorable to him. This idea can be traced back to Bacon's philosophy of "useful knowledge" (Mokyr, 2002; Kuhn, 1977). Understanding the world is not a sacred thing, the preserve of God. On the contrary, the world is comprehensible to mankind, and acquiring knowledge about nature, discovering its "secrets", can enable men to "command" it. The idea of progress is also linked to this movement. Before the Renaissance, the world was considered closed, static. From then on, people became aware of the infinite nature of the universe, associated with the notion of progress.

The scientific revolution of this period was also based on a completely new way (we can even write a completely new philosophy) of producing knowledge, based on mathematical formalization and experimentation. Today, this philosophy is embodied by the historical figures of Galileo and Newton. For Mokyr (2011), beyond the use of mathematics, what changes from this point onwards is the shift from a logic of empirical discovery, based essentially on serendipity, with no understanding of the underlying mechanisms and therefore no possibility of improving the discovery in a systematic way, to a logic of systematic and codified knowledge production. This is the emergence of a truly systematized intellectual approach to knowledge production, which has proved extremely fruitful in a logic of incremental and cumulative improvement of existing knowledge.

Last but not least, the Renaissance period is of course linked to the invention of the movable printing press, an invention that completely overturned the way ideas and knowledge spread, first in Europe, then worldwide (Dittmar, 2011; Eisenstein, 1980).

Mokyr (2017) sums up the changes brought about at this time: "the scientific revolution is based on two essential cultural elements: 1) it is tolerable to defy God and manipulate nature, and 2) nature is intelligible and full of regularities that the scientist must discover". The cultural shift is radical and conducive to innovation, exploration and change. In particular, it opens the door to Schumpeterian growth based on continuous innovation.

In terms of intermediation between inventors and the socio-economic world, these changes, which created a more favorable climate for invention, led to an increase in the number *of patrons and protectors* (princes, aristocrats, ecclesiastics, wealthy merchants, etc.) who supported discoverers and inventors**.** These patrons provided financial and material support. But they also played an essential role in legitimizing inventions and inventors, thereby promoting their dissemination. In our view, these patrons played a kind of intermediary role between the inventor and society. Indeed, despite the rise of the humanist movement, religious beliefs remained powerful in Renaissance Europe. It was always perilous for an inventor/discoverer to assert himself in the public sphere. The role of patrons and protectors (often important figures in the political and/or religious hierarchy) thus consisted in legitimizing new inventions and discoveries, and calming the societal tensions induced by novelty.

In certain respects, patronage thus constitutes a form of intermediation (via certification and legitimization functions) between science and society, but this intermediary role is neither central nor direct. The primary objective of patrons is not intermediation. They don't see themselves as intermediaries, but rather as protectors and friends of the arts and sciences. Leaving aside the possibility that some patrons may really have been science lovers whose objective was truly intellectual curiosity and the advancement of knowledge, patrons' motivation was essentially twofold: utilitarian and ornamental (Moran; 1991; Biagioli, 1993; David, 2004). They wanted to attract the best researchers in order to improve civil and military techniques and thus create advantageous positions for themselves in relation to their competitors. But they also wanted to enjoy the ornamental benefits derived from their support of renowned scientists. Whatever the reasons, in all cases, this system of patronage, often capricious and unstable for researchers, nonetheless constituted the bulk of their resources and income (Moran; 1991; Biagioli, 1993).

The existence of patrons and protectors does not date back to the Renaissance. They were already playing a role as financiers and protectors in the Middle Ages, albeit on a more modest scale. The Renaissance period did, however, bring about two important changes: first, the new philosophy towards novelty significantly increased the number of patrons, in a context of a race for patronage, since a central objective of patrons was to stand out in terms of prestige from their patron competitors. The increase in the number of patrons therefore only served to reinforce the competition between them and generate an inflation of patrons, each trying to outdo the others. Secondly, the growing role of mathematics and the increasing complexity of science made it increasingly difficult for patrons to select the scientists they wanted to protect (David, 1998; 2004; 2008). In other words, what changed with the Renaissance was the gradual change in inventors' status, the pace of discoveries associated with this change in status, and the way science was done, which became more professional and less accessible to patrons.

This complexity, essentially due to the growth in mathematical technicality, did increase the agency problem faced by patrons (David, 1998, 2004; 2008). In the process of selecting the most prestigious scientists, it becomes increasingly difficult for patrons to identify promising researchers to support. The mathematization of science heightened the asymmetric-information problems posed for the Renaissance system of court-patronage. In short, from the Renaissance onwards, patrons themselves needed intermediaries to enlighten them. The growing complexity of science now requires a validation mechanism that is understandable and acceptable to patrons. They need a process to legitimize, i.e. to signal, the scholars they wish to support. This is how the first elements of "open science" came into being, along with the first real intermediaries – organizations whose main function, or at least one of their main functions, is linked to intermediation, i.e. the certification and legitimization of researchers for outsiders.

Paul David (1998; 2004; 2008) thus offers a functionalist explanation of the emergence of open scientific institutions from the Renaissance:

« My central thesis here is that the formation of a distinctive research culture of open science was first made possible, and, indeed, was positively encouraged by the system of aristocratic patronage in an era when kings and nobles (both lay and ecclesiastical) were immediately concerned with the 'ornamental' benefits to be derived by their sponsorship of philosophers and savants of great renown […] I argue that the economic logic of the patronage system in post Renaissance Europe induced the emergence and promoted the institutionalization of reputation building proceedings, all of which turned upon the revelation of scientific knowledge and expertise among extended reference groups that included « peer experts ». The mechanism involved spanned a range of practices from participation in informal networks of correspondence, to public challenges and contests, open demonstrations and exhibitions, and the certification of individuals by cooptation and election to « learned societies » (David, 2004, p. 578)

David also draws an analogy with modern universities which similarly compete to recruit the best talents and which benefit from the standards of openness of science, and from the individual reputations created by them, in order to identify talents and allow them to recruit the best researchers.

Before modern science, the Patrons could either understand and identify by themselves the scientists they wished to support, or simply create the reputation and credibility of these scientists themselves. This is in fact an argument put forward by Bagioli (1993): rather than the quality of the research, it is the quality of the sponsor that makes the reputation of the scholar. The simple fact of supporting a scholar from a prestigious patron gives him legitimacy[30]. However, we can argue that this process of legitimization, quite credible before the advent of mathematized science and experimentation which allow the refutation of a scientific theory, is less and less true afterwards. From now on, patrons, if they make bad choices of scientists, can be judged more easily. They now need scientific legitimacy and this legitimacy can only come from the scientists themselves. Also: *« Given this situation, how were elite patrons to have been reasonably assured that they weren't taking into their service as client a putative mathematician who was an incompetent, or worse, a charlatan, and whose eventual exposure as such would only reflect badly upon his own repute among rival patrons of the arts and sciences? »* (David 2008, p. 52).

The answer is provided by the emergence of institutions which certify and legitimize scientists and helped disseminating knowledge, the publication and sharing of discoveries, validation by peers, academies and learned societies where peers co-opt each other, competitions and prizes awarded by these learned societies, etc. Beyond more formal assemblies such as academies, honorary professional societies and learned societies where members are formally elected, the simple act of developing correspondence between scholars can be considered a reputational signal in the late Renaissance patronage system. Having regular informal correspondence with a co-opted scholar, being admitted to exchanges in private salons is in fact a sign of admission into the community, within the invisible college. The emerging institutions of open science,

[30] "If it is a bit naive to consider scientific credibility as related only to peers' recognition, even in modern science, such a view is seriously misleading when used to interpret the construction of scientific credit and legitimation in early modern science. I think it would be useful to suspend for a moment the 'natural' belief that Galileo, Kepler, and Clavius earned their titles (e.g., in the case of Kepler, 'Mathematician to the Emperor') because of their credibility and the quality of their scientific work. As a thought experiment, we may think, instead, that they gained scientific credibility because of the titles and patrons they had." (Biagioli, 1993, p.59)

formal or informal, thus have a dual function: they form arenas which regulate a reciprocal exchange of knowledge between members; and they certify, legitimize and signal scientists to the socio-economic world and especially to patrons.

In other words, these institutions of evaluation and legitimization, which are today part of the internal functioning of open science, were initially intended, at least in part, to improve relations between science and patrons, i.e. were intended in the socio-economic world. They were used to signal the best scientists to patrons. They offered "theaters for disclosure where patronage seeking practitioners of the new natural philosophy might enhance their public repute" (David, 2004, p. 584). They therefore undeniably acted as intermediaries, perhaps the first organizations for which intermediation was one of the primary objectives.

One of the most important institutions in this regard were the *scientific or learned academies* that were established under royal patronage in several European countries. As stated by Dosi (2023, p. 75): « The various scientific societies of the day, including especially those in Manchester and Birmingham, but also the Royal society in London, were another forum for contact between scientists and inventors, although there were certainly periods when these links were minimal". The two preeminent examples were the Royal Society in London, founded in 1660, and the Académie Royale des Sciences in Paris, founded in 1666. These academies brought together leading natural philosophers and mathematicians and provided them with a forum to present and discuss their work. For example, the Académie Royale des Sciences acted as a "tribunal of science" to which authors could submit their work for evaluation and approval. If approved, the work could be published in the Academy's *Mémoires or Mémoires des Savants étrangers* series (Belhoste, 2016). This stamp of approval from the leading scientific body in France carried immense prestige. Another key means of disseminating scientific knowledge was through printed books and periodicals that were published by learned societies like the *Journal des Savants* and *the Philosophical Transactions* containing scientific papers, reviews and news. These publications grew significantly in the beginning of the 18th century with, for instance, the proportion of scientific books accounted for 20% of all books published in the 1720s (Belhoste, 2016).

In addition to the national academies, a large number of provincial academies and scientific societies sprung up across Europe in the 18th century, especially in France, Germany and Italy. For example, academies in France were established in Bordeaux (1712), Montpellier (1706), Lyon (1724), and Dijon (1740). These provincial academies were often modeled on the Parisian

Académie des Sciences and were centers of intellectual activity in their regions. They held similar functions and held public contests on scientific topics, awarded prizes, maintained libraries and botanical gardens, and in some cases published memoirs.

3. The Industrial Revolution, the birth of modern science and their consequences on science-industry intermediaries

The industrial revolution and the role of 'science' has been widely studied and recognized in economic history. It is recognized that the two phenomena of the scientific revolution in the 17th century and the Enlightenment era in the 18th century paved the way for the Industrial Revolution in Britain and later in France and other countries. It instilled a scientific mentality and culture which influenced technological development.

Simultaneously, during the 19th century, science underwent a process of institutionalization, becoming more formalized and integrated into the fabric of society. This transformative period spanning roughly from the 1760s to 1880s, marked a significant shift in economic growth driven by technological innovation, particularly in Britain and parts of Europe.[31] We distinguish during this time span two major periods: the first Industrial Revolution which occurred roughly between 1760 and 1830 marked the 'Invention Age' (Sullivan, 1989) and a second period spanning from 1830 to 1880 which is marked by the growing institutionalization of science and its growing economic role, especially in chemistry and electricity.

Indeed, a first major trend of this period concerns the invention of modern science and modern industry and, especially from the 1830s onwards. These periods which we will deal with to present the intermediaries, laid groundwork for the sustained innovation and the growing institutionalization of science (Galvez-Behar (2020). This institutionalization materialized in the creation of specialized journals, learned societies, universities, an increase in the number of university professorships, and the definition of the first rules of attribution and priority. This period also saw the first discourses on the autonomy of science, the separation and preservation of pure science from industry. However, this autonomy remained largely at the stage of rhetoric. In practice, it remained impossible for obvious reasons of funding necessity. As Galvez-Behar (2020) points out: "*Institutionalization does not, however, define a clear-cut*

[31] This spread later in the US as modern science diffused expanded from Western Europe to the rest of the world. We will focus principally on Europe for the first sub-section.

boundary between science and industry. Contrary to what is established in the order of discourse, science in action can be industrial or commercial, depending on the opportunities and temptations faced by those who want to turn science into a profession, and who are in search of greater economic and social recognition"

Nevertheless, these trends mark a first step towards an institutionalized science, separate from industry. The main consequence is an increase in transaction costs between science and industry (growing asymmetry between inventors and society, multiplicity of inventors, etc.). Issues such as the dissemination of technical information and the certification of inventions are emerging, which triggers the rise of intermediaries whose main role, as in the previous period but even more so, is to reduce transaction costs. For example, exhibitions and scientific and industrial associations play an essential role in certifying and signaling inventions in order, for example to attract investors and partners. These issues are addressed in section 3.1.

Parallel to this trend, the period (especially the period of the first industrial revolution from 1760 to 1830 approximately) is also characterized by an increasing emphasis on the importance of sharing and circulating knowledge among various groups in society, particularly between those who possessed knowledge ('knowers') and those who could apply it in practical ways ('doers') (Mokyr, 2002). We advocate that the emergence and nature of intermediaries during this time also take essence in this growing recognition of the value of knowledge exchange between individuals who 'knew things', which is broader than scientific knowledge and those who 'made them'. The need to bridge these knowledge gaps across different domains and different actors was already emphasized during the Enlightenment era[32] but it came widely into applications during the following period. While learned societies of the end of the Renaissance still remained important to reduce these transaction costs, other institutions therefore emerged and proliferated in the 18th to 19th century to fulfill this intermediary function. Different intermediaries helped disseminating knowledge between different groups of individuals between 'inventors', pure scientists and society. This intermediary role is examined in section 3.2.

[32] Particularly in Bacon's work.

3.1 The birth of institutionalized science and its impact on intermediaries: exhibitions, patent agents and inventors' societies

The 19th century marked a pivotal period in the relationship between science and industry, characterized by the professionalization and institutionalization of both sectors. While the exchange of knowledge remained important, the increasing complexity of technology and the growing cultural gap between scientists and inventors led to the emergence of new models of interaction and institutional arrangements.

During this period, Europe and the United States underwent a radical shift from agrarian economies to industrialized, mechanized production (Wengenroth, 2000). The Industrial Revolution, driven by technological innovations such as the steam engine, mechanized textile production, and advancements in metallurgy, revolutionized manufacturing processes and gave rise to the factory system[33]. This transformation not only created a demand for new technologies and specific scientific skills to support industrial progress but also had a profound impact on the development of modern science. The prospect of applying scientific knowledge to solve industrial challenges stimulated public support for science. A key milestone was the founding of the École Polytechnique in Paris in 1794, the first major scientific school of the modern world, established to apply science in service of France. Meanwhile, the 19th century saw the emergence of 'modern science' as a distinct and systematic discipline. The establishment of scientific methodologies, laboratories, and the professionalization of scientists led to the creation of specialized academic disciplines and the formalization of research institutions (Knight, 2009). Until the 19th century, religion held a prominent place in university curricula, but its influence in research universities diminished throughout that century. The Wilhelm von Humboldt's university reform (1810) in Germany which integrated fundamental research into higher education, transformed the roles of universities into vectors of scientific progress[34]. By the mid-19th century, the idea of 'science' had become firmly embedded in public discourse and governments started to see the value of scientific research for economic and military purposes, leading to vast movement of reforms concerning higher education and

[33] Shift of production from artisans and craftsmen in workshops and small shops to mass production carried by a large number of workers within a single place

[34] In the US, the Morrill Act of 1862 established state-run land grant universities which emphasized both practical applications and theoretical research in agriculture and mechanics. By the mid-19th century, some American colleges, such as Harvard, Yale, Pennsylvania, Princeton, and Columbia, began to adopt the German model and incorporate research into their academic programs. This marked the emergence of the American research university.

research. In the United States, Johns Hopkins University was the first to implement the German research university model, leading the way for its widespread adoption by other American universities.

As science and industry became more institutionalized, the landscape of invention and innovation grew increasingly complex. Individual inventors, who were becoming more specialized and educated in engineering and technical fields, began to see the advantages of assigning ownership of their patents to firms (Lamoreaux & Sokoloff, 1996)[35]. Meanwhile, scientists responded to industrialists' questions by providing the necessary knowledge and technical solutions, sometimes becoming employees of industrial companies or putting themselves at their service.

This dual-speed model of interaction, with links between inventors and industry on one hand and links between science and industry on the other, laid the groundwork for the 20th-century model of invention carried out by large firms instead of individual inventors. The 19th century thus represents a crucial period in the evolution of science-industry relations, setting the stage for the more complex interactions and institutional arrangements that would emerge in the following century.

3.1.1. The birth of institutionalized science: a growing separation between science and industry

Although a clear distinction between science and industry had not yet been fully established, the seeds of this separation were being sown. In 19th century, the concept of "pure science" emerged as a powerful argument for the autonomy of scientific research, even as science became increasingly entangled with industrial interests (Carnino, 2015). Interestingly, the discourse on “pure science” was already happening long before the Bush Report (1945). Particularly in France where it gained prominence starting in the 1850s’ with the naturalist Armand de Quatrefages, who asserted in 1848 that *“it was from ‘pure science’ that the most beneficial applications arose”*. By the 1860s and 1870s, the concept of ‘pure science’ had spread across various disciplines, from the natural sciences to law, agronomy, and even economics. Importantly, the purity attributed to science at this time did not necessarily imply a contradiction with its growing ties to industry. On the contrary, the idea ‘pure science’ of the

[35] This phenomenon happened first in the US and then later in Europe due to better and less costly patenting system.

1860-1880 period was widely associated with the potential for industrial applications and economic progress. The construction of an image of science that aligned with industrial capitalism was carried out by scientists themselves. Scientists[36] and their supporters argued that by pursuing research free from the constraints of immediate financial gain, they would ultimately generate the most valuable and transformative innovations.

This argument for scientific autonomy was, in essence, a paradoxical one: by claiming to be disinterested in the practical outcomes of their work, scientists could secure the interest and support of industry, government, and the broader society. The purity of science, defined as the freedom from the direct pursuit of personal financial gain, was presented as the essential condition for realizing the full potential of scientific research to drive human progress. The growing links between science and industry in 19th century thus served as a powerful justification for the autonomy of scientific research. Scientists leveraged the promise of industrial applications to secure resources, infrastructure, and support from both the government and private sector. Influential figures like Louis Pasteur played a key role in promoting this vision, famously declaring that "*if pure science makes the glory of the nation, their applications make its richness*." (Carnino, 2015, p.122). Throughout his career, Pasteur worked closely with the government to advance both national industry and his scientific endeavors. Pasteur’s work is a prime example of how science became an integral part of industrial progress in the latter half of the 19th century. Other notable figures who exemplified this approach include Justus von Liebig, a German chemist who made significant contributions to agricultural and biological chemistry while also developing commercial products, and William Thomson (Lord Kelvin), a British physicist who made fundamental contributions to thermodynamics while also working on practical applications.

Ultimately, the success of science in the late 19th century was deeply intertwined with its ability to align with industrial aspirations. As industrial processes became more complex, industries required the input of scientific labs which drove them to seek out scientific expertise to validate

[36]The term “scientist” was coined by William Whewell, professor of philosophy and mineralogy at Cambridge, replacing the earlier term “natural philosopher” in 1833. This linguistic shift marked a significant step towards professionalization.

and improve their processes. Notable scientists of the time, such as Louis Pasteur, were actively engaging with industries, often acting as consultants[37] (Carnino, 2015).

The relationship between science and industry during this time was characterized by a complex process of negotiation between the autonomy of scientific work and its integration into the capitalist industrial system (Galvez-Behar, 2020). The growing autonomy of science during this period didn't isolate it from industry. Instead, it surprisingly led to many interactions between the two fields. Scientists, seeking better social and economic status, collaborated with businesses while trying to balance the ownership of scientific knowledge with its commercial uses. This was especially common in chemistry and electricity research. By strategically navigating the complex relationships with government, industry, and public opinion, the scientific community sought to carve out a space for autonomous research while simultaneously demonstrating its value to society. At the same time, scientists had to navigate the institutional and professional norms of their own field, balancing the demands of scientific autonomy with the commercial pressures of industrial collaboration.

While professional scientists played a crucial role in the 19th century scientific landscape, they were not the sole contributors to scientific progress. Self-taught amateurs, often members of economic societies, also conducted valuable scientific work. This period saw the rise of individuals with dual careers, straddling both scientific and industrial realms. The 19th century also witnessed the professionalization of research and development (R&D) and engineering. This evolution necessitated the emergence of individuals who could effectively translate knowledge between practical engineering and theoretical science. These "translators," as described by Layton (1971), typically possessed expertise in both scientific theory and practical engineering. They were often referred to as "engineer-scientists" or "scientist-engineers," depending on their primary affiliation[38]. These translators often occupied positions that bridged academia and industry. They might teach science to engineering students, manage government scientific agencies, or consult for industry while maintaining academic positions. The need for

[37] This form of science-industry link can be assimilated as consultancy driven by conviction rather than economical.

[38] Oliver Heaviside's work provides a notable example of this translation function. Heaviside transformed James Clerk Maxwell's complex electromagnetic equations into a form more readily applicable by engineers. Similarly, some British engineers adapted Maxwell's work on indeterminate structures into practical methodologies for their peers. In another instance, Henry Rowland and Francis Hopkinson independently discovered the same principle but expressed it in scientific and engineering terms respectively, highlighting the growing divergence in language and priorities between these fields.

such intermediaries underscores the increasing specialization and complexity of both scientific and technological domains in the 19th century, which made direct communication between the two spheres necessary. In many ways, these 19th-century translators can be seen as precursors to today's "boundary spanners" - professionals who facilitate communication and collaboration across different disciplines or sectors. In addition to these boundary spanners, the period also witnessed the emergence and reinforcement of intermediary institutions.

3.1.2. Exhibitions, patent agents and inventors' societies

In the 19th century, thanks to the growing institutionalization of science, intermediaries continued to play crucial roles in making knowledge more accessible and in verifying its credibility. However, two significant developments intensified the need for these functions, particularly in the area of certification: first, the growing complexity of scientific knowledge. As scientific disciplines became more specialized and advanced, it became increasingly difficult for non-experts to understand and evaluate new discoveries and theories. Second, the boom in inventive activity: the Industrial Revolution spurred a dramatic increase in the number of new inventions and innovations, creating a need for reliable assessment and validation of these novel ideas. These factors led to the emergence of new types of intermediaries focused on certifying knowledge and inventions but also facilitating its diffusion and its economic valorization. These intermediaries played a vital role in translating complex scientific concepts into forms that could be understood and utilized by industrialists, inventors, and the general public. In particular, we identify the emergence of three new types of intermediaries: public exhibitions, patent agents and industrial societies.

Industrial exhibitions or world's fairs were an essential feature of the period. They helped popularize science and inventors. They highlighted the marvellous nature of technology and inventions, and, in line with the romanticism of the period, emphasized the almost supernatural character of inventors (Galvez-Behar, 2020). But more importantly, they played a central role in the certification and dissemination of inventions.

Exhibitions were significant cultural events which were organized by these economic societies, municipalities and private organizers in the 19th century. Inventions wanting to be exposed had to go through the examination of a jury composed of scientists or specialists of a specialized industry. They would testify and report on the novelty, contribution to progress in the country. This signal was highly appreciated by inventors to showcase their inventions and gain recognition. Exhibitions also organized contests and awarded prices which increased this signal. Exhibitions benefited other inventors as the showcase would provide much more information than simple advertisement or patent.

The first universal exhibition took place in London in 1851 at the Crystal Palace which was followed by the 'Exposition Universelle' in Paris (1855; 1889) and by the Centennial Exposition in Philadelphia (1876). The number of exhibitions increased from the 1830s onwards, but especially from the 1880s onwards. They attracted millions of visitors, making them significant cultural events that shaped public perception of progress and modernity.

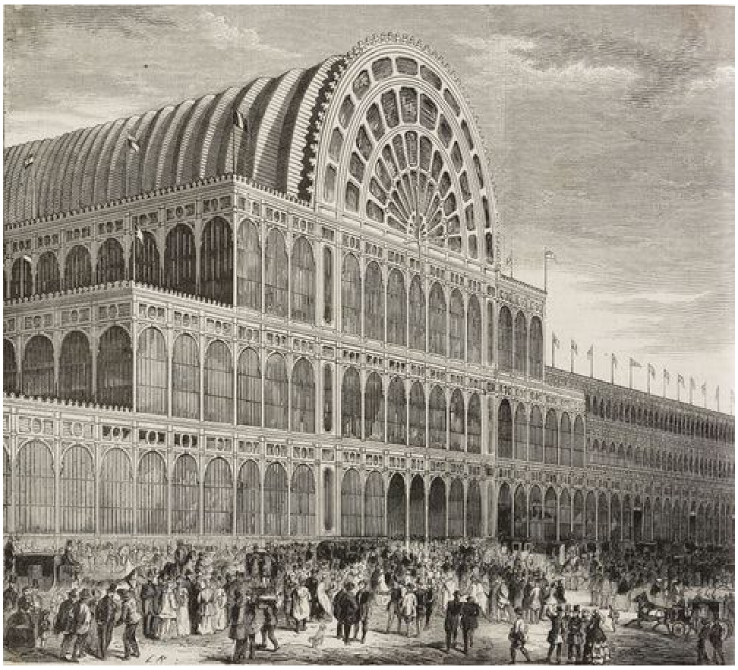

Image 1: Universal Exhibition London, Crystal Palace (1851)

Exhibitions served as showcases by demonstrating the practical applications of science through industry to a broad public audience, which reduce the cultural gap between science and the socio-economic world, mostly public sphere. These exhibitions, were not only grand displays of technological and artistic achievements but also platforms where the emerging connection between science and industry was showcased and validated. For instance, the 1855 exhibition in France highlighted how scientific advancements were integral to industrial progress, with machines attracting more visitors than the fine arts, thus underscoring the public's growing interest in technological innovation. Through these exhibitions, the public was educated on how scientific principles could be harnessed for industrial applications, thereby reinforcing the narrative that science and industry were inseparable in their mission to serve societal progress. The exhibitions also played a vital role in popularizing scientific knowledge and spurred the creation of scientific journals, further solidifying their role as a bridge between the scientific community and the general public.

In addition to this information diffusion function, exhibitions also performed a clear signaling and certification function by selecting and rewarding (by the attribution of prizes and medals) the most promising inventions and inventors. This function is clearly emphasized by the debate at the end of the 19th century about the too many number of fairs and prizes. A specific phenomenon which deserves some attention is the proliferation of doubtful intermediaries. As the volume of technical information grew during this period, intermediaries also played an important role in organizing and validating this knowledge. However, as historian Gabriel Galvez-Behar (2008) has noted, the proliferation of intermediaries at the end of the 19th century could sometimes have a negative impact on information quality, as competing organizations vied for attention and influence. By the end of the period, virtually every city was organizing fairs and awarding prizes. Galvez-Behar (2008) quotes a comment from the period: "*Exhibitions, instead of being international competitions for masterpieces, will soon be nothing more than gigantic bazaars*". The immediate consequence of this proliferation is to dilute the signal, which, to borrow an expression from game theory, becomes "non-separating". As the intermediary institutions for evaluating inventors and inventions grew, so did the uncertainties surrounding their value and credibility. Some exhibitions granted unverified awards to participants, undermining the trust and standards of these forums. This led to concerns about patent nullification, espionage, and usurpation of recognition, as premature publicity could lead to the loss of patent rights. These institutions exposed weaknesses in the intellectual property system. The need for a more formalized and trusted intermediaries to manage the validation and protection of new technologies became more apparent. The institutionalization of patent offices and intellectual property intermediaries such as patenting consulting companies during this time became important in the process of securing legal protection for inventions (Galvez-Behar, 2008). We argue that these became less of an intermediary between science-industry links and were more supporting of inventors in firms. As far as we're concerned, these debates clearly demonstrate the certifying and signaling role played by exibitions during this time.

The second half of the Enlightenment saw a shift in the perception of invention and entrepreneurship. Profits were now associated with intellectual property, and patenting activities began to grow in the 1820s. The roles of *patents agents* played a significant role in reducing transaction costs and facilitating exchange of technological information across geographic areas. Indeed, while the role of patents in industrial development is still strongly debated today (North and Khan, for example, emphasize it, but Moser questions it very strongly), what is less discussed is the emergence of patent agents, who have probably facilitated the rise of independent inventors by facilitating the transfer and valorization of their inventions. This point is underlined by the work of Lamoreaux and Sokoloff (2002), who write:

"But trade was also facilitated by the emergence of intermediaries who economized on the information costs associated with assessing the value of inventions and helped to match sellers and buyers of patent rights. Patent agents and lawyers were particularly well placed to provide these kinds of services, because they were linked to similar attorneys in other parts of the country and because, in the course of their regular business activities, they accumulated information about participants on both sides of the market for technology."

Patent agents are recognized to be key technology intermediary who began to proliferate in the 19th century. Patents offices appeared much later in Britain than in other parts of the Western world[39]. While in the US, they started to proliferate in the 1840s, Britain saw its first Institute of Patents Agents appear in 1882. Initially, these came into being because the invention of the patent was first and foremost a legal issue that the inventor didn't necessarily have sufficient knowledge about (Galvez-Behar, 2008). Patents agents had both legal and technical background and helped inventors navigate the patent application process and defend patents in legal proceedings. One of the main challenges during this period was to facilitate the connection between inventors and large enterprises. Overtime, their roles expanded to helping to buy and sell patents by connecting inventors to capitalists (Lamoreaux & Sokoloff, 2002). They would actively match inventors with firms or individuals interested in acquiring their rights and often maintained networks of contacts in various industries to identify potential buyers for new technologies. They would also publish technical periodicals about technological developments and lists of patents issued as a lone inventor could not guarantee the dissemination of technical information about their patent. These publications helped to disseminate information about new technologies more widely and rapidly to keep players

[39] This is likely due to the differences in the emergence and evolution of patent systems in different countries (MacLeod, 1991). The French and US systems underwent more frequent reforms compared to the British system which kept an old system and depicted higher costs for obtaining patents. France saw their first offices in 1836 (Galvez-Behar, 2008)

informed of the state of the art but also acted as publicity and made easier for potential buying firms to learn about new inventions.

Finally, academic societies continued to play an important intermediary role as some of them became more focused on applications and applied science. For example, Jean-Baptiste Dumas as a key member of the French Society for the Development of National Industry (1801), played a crucial role in introducing scientific knowledge to industries. Dumas's efforts were instrumental in establishing the validity of scientific methods in industry. These societies often used scientific experts to certify the validity of the inventions. This helped to reduce the costs of search of information as there was a massive number of technical inventions that were arising at this time. Similarly, many associations of the 19th centuries emerged with the professionalization of engineering, a key example was the British Association for the Advancement of Science, established in 1831 which was dedicated to mechanical science, serving as a bridge between theoretical sciences and practical engineering.

However, in addition to these academic societies, the period also saw the emergence of *Inventors' associations* such as the 'Association des inventeurs et artistes industriels' (AIAI) created in 1849 in France or the 'Verein Patentshutz' (1896) in Germany, which were also essential in these intermediary roles. Such unions offered a range of services common to economic or industrial societies: offering documentation, organized exhibitions and competitions but were now solely focused on supporting inventors. These unions were supporting inventors by advertising and funding their exhibitions. However, they distinguished themselves by setting up emergency funds and providing information on industrial property matters and providing material assistance to inventors through a bank or by making tools or workshops available (Galvez-Behar, 2008). Overall, these societies played an clear role in order to reduce transaction costs: they contributed to diffuse inventions, they helped to ensure their protection, they helped to find financers and partners, etc.

3.2 Interactions between the "natural" and "practical": and the need for informal networks and societies as intermediaries to sustain the continuous exchange of tacit knowledge

It is important to understand that most of the inventions during the first Industrial Revolution were driven by practical knowledge and engineering more than formal science. In fact, first science-industry links did not emerge until the mid or late 19th century and began to be formalized when the 20th century started. This poses obvious challenges in estimating the nature of the interactions between science and industry during this time. We argue, however that we can consider a broader view, considering ‘science’ not as an institution but as ‘scientific knowledge’ acquired by individuals and their interactions with the socio-economic world, consisting of individuals from industries but also the government and the public sphere. Most of the inventions came from skilled craftsmen, engineers, or practical inventors who used hands-on experience and trial-and-error to develop new technologies.

3.2.1. “Knowers”, “doers” and their interactions

A second central trend of the Industrial revolution and the birth of modern science is the growing development of “useful knowledge”. Most of the inventions during the first Industrial Revolution were driven by practical knowledge and engineering more than formal science. By generating a pool of available ‘useful and general knowledge’ to be mapped and applied science largely influenced technology and industry (Jacob, 2014; Mokyr, 2005). This useful knowledge that underpinned the Industrial Revolution was a complex amalgamation of scientific, artisanal, and practical knowledge. Again, before the late 19th century, discussing this period in terms of a simple dichotomy between science and technology or the ‘applied world’ doesn’t make sense as ‘science’ and ‘industry’ did not yet exist as separate institutions. The boundaries between science and technology were not as clear-cut as it is today. It doesn’t mean that inventions were not driven by science, it means that it was driven by diverse sources of knowledge (including ‘science’) rather than a straightforward application of scientific knowledge to industry. Advances in science and technology often intersected and reinforced each other making the separation irrelevant in this context, while scientific discoveries and principles laid foundation for new technologies and industrial processes. Techniques, instruments and technological inventions, played a vital role in advancing scientific understanding (Jacob, 2014; Mokyr, 2002).

To understand the complex knowledge interaction between science and industry during this time, we use the conceptualization of knowledge of Mokyr (2002) who distinguishes between 'propositional' and 'prescriptive’ knowledge. *Propositional knowledge,* which Mokyr terms "knowledge what" or Ω-knowledge, refers to beliefs and understanding about natural phenomena and regularities that provide the underlying principles and theories of how things work. In contrast, *prescriptive knowledge*, or "knowledge how" (λ-knowledge), is the instructional or practical knowledge of techniques and processes - the actual application of propositional knowledge to create technology and drive innovation. According to Mokyr, it is the relationship between propositional and prescriptive knowledge that was key during this period, more than the interactions between ‘science’ and industry. Propositional knowledge was broader than just formal 'scientific knowledge'. It also included practical know-how, informal knowledge about nature, materials, mechanics that were often developed through hands-on experience, trial-and-error and folk wisdom and artisanal traditions passed down through experience (Hilaire-Pérez, 2007; Mokyr, 2005). Propositional knowledge, which increased and spread consequently during the second half of the 18th century, provided the epistemic base for the development of techniques (prescriptive knowledge). Hence a wider epistemic base increased the chance of having knowledge to develop inventions or improving techniques which were fundamental for the Industrial Revolution.

Naturally, because knowledge is first and foremost rooted in the human mind, it appears to question who were the individuals holding propositional and prescriptive knowledge and how they were exchanging it. It could be assumed that different groups of individuals held these different types of knowledge. However, again, if it was the case, the careers of individuals would reflect different ‘scientific’ and industry institutions, but they did not exist (or started to appear). The word “scientist” did not exist until the 1830s. In reality, the ‘main actors’ who drove technological progress during this time came from diverse backgrounds and many of them were simultaneously engaging in scientific inquiry and invention activity.

Scientists, engineers, mechanics, chemists, physicians, natural philosophers and sometimes entrepreneurs were individuals eager to both create, learn and apply knowledge. Artisans were not only skilled workers but also held ‘some knowledge’ that was complex and hybrid which allowed them to innovate (Hilaire-Pérez, 2007). What characterized these individuals is the "hybrid careers" or "dual careers" they most often held, combining their scientific knowledge with practical applications (Kranakis, 1992, as cited in Mokyr, 2002). For examples, in Britain, Peter Barlow (1776-1862) was a mathematician and physicist who wrote scientific books but also became an authority on railroad and locomotive construction, contributed to telegraph development, and helped correct ship compass deviations. Claude Berthollet (1748-1822), one of the most prominent French chemists contributed both to the understanding of chemical reactions and invented the chlorine bleaching process. Benjamin Franklin (1706-1790), an American natural philosopher who studied Newtonian mechanics, conducted experiments on electricity during the 1740s-1750s and invented practical items like the lightning rod, bifocal spectacles, the Franklin stove[40].

Moreover, and most importantly, these individuals were constantly exchanging and formed creative communities and networks where access to knowledge was the primary objective (Mokyr, 2002). Collective knowledge sharing was common during this time (Bessen & Nuvolari, 2016). For example, John Smeaton was an influential 18th century English engineer, most famous for designing and building the Eddystone Lighthouse. Though primarily known as a practical mechanic and engineer, Smeaton cultivated an extensive intellectual network centered around the Royal Society, collaborating with a diverse group of hybrid knowers who combined theoretical knowledge with practical expertise (Morris, 2021). He regularly consulted and exchanged knowledge with figures like Benjamin Franklin, Henry Cavendish, and John Michell on topics ranging from geology and meteorology to electricity, leveraging their varied expertise to inform his engineering projects and research into areas like hydraulic limes. Another example is Josiah Wedgwood. Though primarily a manufacturer, he was an experimenter who corresponded with many scientists, including Lavoisier, Priestley, and James Keir. Individuals such as engineers and entrepreneurs, even though coming from different background could easily combined their efforts and expertise because they 'share technical vocabulary' (Jacob, 2014).

These individuals were curiosity driven but also sought to derive profits from their applications (Jacob, 2014). These examples show again how technology was shaping science as much as it was supported by it. Moreover, what appears clearly is that the 'scientific and collective culture' was becoming inherent to the inventing activity during this time as emphasized by Mokyr (2002, p.74): *"It seems, however, that the crucial elements [that brought the Industrial Revolution] were neither brilliant individuals nor the impersonal forces governing the masses, but a small group of at most a few thousand people who formed a creative community based on the exchange of knowledge."* These individuals didn't come from universities or industries. Moreover, most of them had no formal education (Allen, 2009; Jacob, 2014), this emphasize again that the role of universities was limited in contributing to inventions during this time. In Europe, except for the Prussian empire, until the late 19th and beginning of 20th centuries,

[40] Lightning rod (a metal pole that protects buildings from lightning strikes), Bifocal spectacles (glasses that allow you to see both near and far), Franklin stove (an improved fireplace that produced more heat with less smoke).

universities were places of purely theoretical knowledge that had little connections with the practical realms.

3.2.2. Social places and spaces as “knowledge gap bridges”

At that period, the increase in knowledge was thus fundamental, but it is rather the interaction and continuous feedback between propositional and prescriptive knowledge that was key for technological advancements. Of course, many other institutional factors including technologies contributed to the increased access to knowledge. Improvements in printing technology, transportation, telecommunications with invention such as the telegraph increased the speed of the circulation of knowledge, let it be in forms of news articles, journals, books. The codification of knowledge also played a major role in facilitating access: through Encyclopedias and technical compilations, the standardization of language, terminologies as well as building common weights and measures and the improvements in technical illustration and representation through advanced mechanical drawing techniques or descriptive geometry (see Mokyr (2002)). While these factors were crucial for disseminating codified knowledge, most often, this information in the form of books, published in Encyclopedias could not be understood alone. The social aspect of knowledge exchange was therefore crucial to share its tacit form (Hilaire-Pérez, 2007). The role of intermediaries to ensure knowledge circulation and interactions between knowers and doers became consequently absolutely critical.

We focus especially on the roles of economic societies, and other informal networks, which played an intermediary role. These institutional forms provided a dynamic, interactive, and socially-embedded means of knowledge exchange that went beyond mere information transfer. The role of informal networks and exchanges during this time was decisive in the process of technological innovation and were more useful in forging links between scientific knowledge and industry than learned societies (Gráda, 2016). For example, a recent study gives empirical insights into how countries with high number of networks in the form of freemasonry, friendly societies, libraries, and booksellers were more prominent in developing innovation as measured by new patents and exhibits at the 1851 Crystal Palace World’s Fair (Galofré-Vilà, 2023). Along with helping circulation of knowledge, these personal and informal contacts which took place in associations, clubs, salons, Masonic lodges or coffeehouses were fundamental in *“smoothing the path of knowledge between scientists and engineers on the one side and those who carried out the instructions and used the techniques on the other side”* (Mokyr, 2002, p. 74). A plethora of societies, associations, clubs and salons proliferated in the late

Enlightenment era until the middle of the 19th century. These offered public spaces and practices of sociability and intellectual exchange and debate in the 18th century:

- Salons

Salons were private gatherings held in the homes of aristocratic or bourgeois hosts and hostesses. They brought together a curated group of intellectuals, artists, and socially prominent figures for polite conversation, literary readings, and philosophical and scientific discussion. The tone was refined and the emphasis was on wit, elegance and "politesse" (Belhoste, 2016).

- Coffeehouses

They originated in England as public establishments They opened to a broader clientele of professionals, merchants, and gentlemen who had a more bourgeois, even popular character. They served as nodes of news, gossip, business, and informal associational life, where patrons read newspapers, exchanged information and ideas, and debated about the issues of the day. They also played a particularly important role in the spread of science. In London especially, coffeehouses hosted lectures and demonstrations on natural philosophy, contributing to the spread of Newtonian science. The Marine Coffee House near the London Stock Exchange hosted public lessons in mathematics, astronomy and navigation (Belhoste, 2016).

- Private clubs and societies

More formal and organized than the coffeehouses were *private clubs and societies*. In England, these ranged from the gentlemanly and aristocratic to the more bourgeois and even working-class organizations, and many had a scientific bent (Belhoste, 2016). One of the notable examples was the Lunar Society of Birmingham (c. 1765-1813), an informal club that met monthly on the Monday nearest the full moon. Its members were a mix of scientists, doctors, industrialists and entrepreneurs, including Matthew Boulton, Erasmus Darwin, Josiah Wedgwood and James Watt. The Derby Philosophical Society (founded 1783), focused on scientific subjects and maintained a library and museum. The Chapter Coffee House, a club for freethinkers and republicans also attracted fellows of the Royal Society. It was frequented by Benjamin Franklin during his time in London.

- Freemasonry

With its secretive lodges and esoteric rituals, freemasonry embraced the Enlightenment ideals of rational inquiry, progress, and the dissemination of knowledge in the late 18th century. For example, the *Bavarian Illuminati*, a radical group that sought to spread Enlightenment philosophy and science through a network of Masonic lodges (Belhoste, 2016).

- Economic societies

Along these informal places, the roles of *economic societies* were perhaps one of the most significant ones during this time. While these institutions held similar functions as the learned societies of the Enlightenment Era, they stood out in their explicit purpose to improve society as a whole and focused on applying practical, useful knowledge to benefit society at large. Indeed, while the aforementioned learned societies, salons and masonic lodges were important in disseminating knowledge, these institutions were often very exclusive and only allowed elite members and focused on benefiting their own members. Moreover, some groups were more interested in expanding intellectual and theoretical pursuits and not necessarily in its practical or applied applications (Koschnick et al., 2022). The Royal Society (1666) in England for example gradually lost interest in 'useful arts' as they found that translating natural philosophy into practical improvements was much more difficult than they initially thought.

Economic societies emerged in the 18th century and developed throughout the 19th century in Europe with the earliest ones appearing in Great Britain and Ireland. Earliest examples include the Society of Improvers in Edinburgh (1723), Dublin Society (1731), the Society for the Encouragement of Arts, Manufactures and Commerce in London (1754) (Stapelbroek & Marjanen, 2012). The movement subsequently spread across continental Europe, reaching as far as North America with American Agricultural Societies (1785). The count varies between 233 and 562 societies in Europe, the US and Russia during the 18th century (Engelhardt, 2007; Stapelbroek & Marjanen, 2012) and it continued to increase in the 19th century.[41] These societies, varied in their specific focuses and organizational structures and operated within different local economies adapted to the specific human, technical and economic characteristics of their region. Some societies were created to respond to specific local economic constraints of their region and to promote industry (Galvez-Behar, 2008).

[41] For example in Britain: "there were 1,020 associations for technical and scientific knowledge by the middle of the nineteenth century, with a membership of roughly 200,000" (Inkster, 1991, pp. 73, 78-79 in Mokyr, 2005). In France, over 20 societies emerged in the second half of the 19th century in different regions (Saint-Etienne, Lyon, Marseille, Mulhouse, etc.) (Galvez-Behar, 2008).

Their activities were similar to those of the learned societies. They held regular meetings with debates and public lectures, but the open and egalitarian aspects of these societies allowed a wider range of people to join, rather than being restricted to elites. They also brought together members from different social classes, allowing nobles and non-nobles to interact on an equal footing. Typical present actors included: representatives of the State, intellectual and financial elites and industry practitioners, and members with scientific expertise (scientists, professors, doctors, pharmacists, engineers, etc.) (Galvez-Behar, 2008).

Many societies hosted demonstrations of new techniques and experiments, providing hands-on understanding as well as collaborative problem-solving which helped disseminating knowledge in its tacit form. These "places of scientific, technical and industrial sociability" were places where inventors could share their ideas and collaborate with others in the field and hence keep themselves acculturated to a scientific culture. By fostering a community of practice, societies helped in rapid dissemination of new ideas because quick discoveries or inventions would be shared before they were formally published. Societies also organized prize competitions to solve specific problems (Stapelbroek & Marjanen, 2012). Beyond the symbolism, the prizes helped to distinguish between the ‘good’ and the ‘bad’ information and were more focused on certifying the quality of inventions rather than scientific works and hence help to reduce Williamson-type barriers.

Finally, economic societies also published journals with articles on recent advances, and maintained libraries with scientific books and collections of instruments/machines (Stapelbroek & Marjanen, 2012). For example, the Society of Encouragement for National Industry in France (1801) held a hotel for regular meetings, a library, a Museum and a Bulletin. They centralized, described and compared technical objects which constituted an ‘information center’ for technical information (Galvez-Behar, 2008) which overall reduced access costs of information.

To summarize, informal networks were most important at the end of the 18th century. The learned societies in the late 18th century were different from the ones of the Renaissance or the 17th century. They focused on facilitating access to knowledge but also increased propositional knowledge. They became specialized in ‘science’ while other societies emerged to be closer to applications and open to everyone. Although not in their core function, these intermediaries (economic and industrial societies) helped in disseminating tacit knowledge and know-how of inventors. These continued to play a role in the 19th century, along other forms of intermediation which emerged during this time.

4. One step further: the institutionalization of science and the creation of industrial research lab

As we have seen earlier, inventions in the early 19th century were often ad hoc and driven by individual inventors. By the second half of the 19th century, with the birth of industry and big corporations (Chandler, 1977), there was a shift toward inventors being more closely tied to companies, rather than operating fully independently (Lamoreaux and Sokoloff, 2001). During the late 19th and early 20th century, the role of large firms in driving innovations became even more important. Meanwhile, scientific advancements began to intersect more directly with industrial needs and innovations became increasingly grounded in scientific knowledge. This era, encompassing the Second Industrial Revolution (1870-1914), witnessed two pivotal and interrelated developments: the rise of industry-based research and a second phase of the institutionalization of science which ultimately led to the reorganization of the inventing activity in the 20th century.

The institutionalization of invention through corporate R&D was driven by several economic and institutional factors (Mowery, 1990). As industries like chemicals, electricity, and telecommunications grew more technologically complex, companies recognized the need to invest in systematic research and development to drive innovation and stay competitive. The pressures of industrial capitalism and global competition necessitated continuous improvements in products and processes, which could no longer be achieved through traditional trial-and-error methods or reliance on independent inventors[42]. This shift towards industry-based research was facilitated by changes in patent legislation, which became better adapted to industrialization. The expansion of patent systems with strengthened protection of intellectual property increased the utility of holding patent portfolios, incentivizing companies to invest in systematic research efforts. This allowed firms to secure exclusive rights to new inventions and monetize their innovations, further driving the internalization of inventive activity within industrial settings.

[42] Even if large firms started to conduct industrial research for inventions, they continued to acquire patents from outside inventors with many patents assigned to large firms coming from outside inventors (Lamoreaux et al., 2009).

By the beginning of the 20th century, large companies, particularly in the United States and Germany, began establishing their own research laboratories. These labs combined scientific and practical approaches to R&D with the aim of generating new products and processes that could give companies a competitive edge. The chemical industry, especially in Germany, was at the forefront of this trend, with the development of synthetic dyes serving as a prime example of industry-driven scientific innovation. Bayer established its first main scientific laboratory in 1891 and developed extensive research infrastructure, including multiple specialized labs, libraries, patent departments, etc.

Parallel to the rise of industry-based research, science continued to transform from amateur pursuit into a formal, structured profession with specialized training, standards, and institutions. Especially with the universities taking on the dual roles of knowledge production and technical education. However, the university models varied across countries (e.g., U.S. focused on universities while France relied on engineering schools and later public research institutions). Universities became key sites for scientific training and research, particularly in Germany, in the UK and the US. Throughout the 19th and 20th centuries, the establishment of numerous technical schools promoted the widespread dissemination of scientific knowledge and fostered further scientific progress.

What was specific during this period was the growing support from governments. Many countries began to recognize the strategic importance of scientific research for economic, military, and technological development, leading governments to establish and fund national research institutions (e.g., In Germany, the Physikalisch-Technische Reichsanstalt (1887) and the Kaiser Wilhelm Society (1911) were founded to foster advanced research in fields like physics, chemistry, and biology. In France, the Pasteur Institute (1887) became a global leader in microbiology and public health research). Governments increasingly supported science through financial grants, the creation of research institutes, and the recognition of leading scientists with honors and public appointments. The legitimization of science as a profession and a source of authoritative knowledge had far-reaching implications. It contributed to increased public trust in scientific expertise, as trained professionals were seen as objective and capable of solving complex social and industrial problems. This growing legitimacy of science also led to an increased role for scientific advisors in public policy, especially in areas like public health, military technology, and infrastructure development.

4.1 Science-industry links in the late 19th and early 20th century: the growing recognition of two distinct worlds and the first evidence of technology transfer

This period saw the emergence of more institutionalized links between these sectors, primarily due to the increasing separation of both science and industry as two distinct spheres. This era witnessed the first recognizable forms of what we now call "commercialization of science" or "academic engagement." With science finding its place within universities, it becomes more meaningful to discuss science-industry links.

Recent studies advance that academic commercialization were already quite common among certain scientists, especially in fields like chemistry, engineering, and applied physics[43], well before the late 20th century rise of the "entrepreneurial university" (Mercelis et al., 2017). In fact, much of what we know today of university-industry collaboration were also found at this time: industrial research fellowships, contract research, along cooperative courses, funding of materials, …etc. and most of them were conducted by scientists themselves without the university being involved or regarding towards such activities.

The most widespread commercial activity among professors in the late 19th and early 20th centuries was academic consulting especially in the field of chemistry and engineering (Guagnini, 2017; Mackie & Roberts, 2020; Mercelis et al., 2017). The spectrum of consulting roles was diverse and were closely related to professors' research interests and teaching areas. Many academic scientists were consultants for private companies especially in emerging technological fields and provided their expertise such as solving technical problems, advising on product development and improvements and giving endorsements by testing products (Guagnini, 2017). The reason why academic consulting was so common can be explained by the fact that many scientists were first and foremost practical individuals before becoming professors and joining academia, which made them well-suited for the job. Scientists' expertise and laboratory skills were also valuable for emerging science-based industries. For instance, the German dyestuffs manufacturer Hoechst established consulting arrangements with university laboratory directors, providing them with funding and materials for research that had commercial potential for the company (Meyer-Thurow, 1982). Interestingly, complementary

[43] These were also found in photographic science, and in molecular biology.

to their industrial advisory positions, academic scientists also provided their expertise to local governmental agencies and in legal proceedings (Guagnini, 2017). They would provide expert opinions in patent litigation cases or legal disputes related to industrial accidents or product failures. They would also participate in government-sponsored research initiatives (e.g., analyzing the safety and quality of air and water, giving advice on large-scale public engineering projects). The motivations behind engaging consulting derived from both financial considerations and the desire to stay current with industrial developments, viewing consulting as complementary to their teaching and research activities. As Guagnini (2017) notes in her study of British engineering professors, consulting was a convenient way to supplement academic salaries, which were often not adequate[44].

As we have seen in the previous section, patenting was common for scientists as it provided recognition and protection of their findings. This practice continued to be increasingly prevalent among academics during this period, although patenting activities varied greatly in terms of number and success (Guagnini, 2017; Katzir, 2017). Some professors took their commercial activities a step further by engaging in full-blown entrepreneurship, although evidence show that this practice was rarer (Guagnini, 2017; Katzir, 2017). Most of engaging professors pursued all three activities throughout their career (see examples in text box) and moved from one sphere to the other. Moreover, science-industry link in the form of contract research can be foundduring this period where companies directly funded academic laboratories, and industrial fellowships that supported students and researchers (Mercelis et al., 2017).

[44] Typical academic salaries were around £600-£800 at this time and consulting work could lead to earnings of £1,500-£2,000 (Guagnini, 2017).

William Thomson and Oliver Lodge as emblematic entrepreneurial scientists

William Thomson or Lord Kelvin (1824 – 1907) was a professor of natural philosophy at the University of Glasgow, Kelvin was not only a renowned physicist but also a prolific inventor and entrepreneur. From 1854 and 1907, his portfolio accounted for 63 patents primarily in marine navigation and electrical instruments with 49 of them filed during his professorship. Kelvin's commercial activities extended beyond patenting to include consulting and manufacturing. He co-founded a telegraphy consultancy firm and later became the majority partner in a scientific instrument manufacturing company. These ventures proved highly lucrative, with Kelvin earning substantial fees from telegraph companies and amassing considerable wealth. Notably, Kelvin reinvested some of his commercial earnings into academic pursuits, funding laboratory improvements at the University of Glasgow.

While holding prestigious positions at University College Liverpool and later as Principal of Birmingham University, **Oliver Lodge (1851-1940)** actively engaged in various commercial ventures. His activities ranged from consulting for major electric battery companies to prolific patenting, with 27 patents to his name, particularly in wireless telegraphy. In 1901, he co-founded the Lodge Muirhead Wireless and General Telegraphy Syndicate Ltd., successfully competing with Marconi's enterprise. Lodge's entrepreneurial spirit extended to other ventures, including the Lodge Fume Deposit Company for industrial smoke abatement and involvement in Lodge Brothers, which manufactured electrical ignition devices. He also served as a scientific advisor to the Eastern Telegraph Company.

Both profiles show that some individuals had the ability to translate scientific knowledge into practical, profitable applications while maintaining a distinguished academic career, demonstrating the potential for synergy between scholarly and commercial pursuits in science and engineering.

Source: Based on Katzir (2017), Guagnini (2017) & Trainer (2004)

Box 1: Examples of entrepreneurial scientists in the end of the 19th and early 20th century.

Large firms started to recruit scientists from universities, shifting away from hiring from rival firms. Therefore this phenomena marks the first type of mobility of scientists in industry. Meyer-Thurow (1982) emphasizes that companies in Germany transitioned from relying on consulting scientists to hiring salaried industrial researchers. In the field of chemistry, chemist-entrepreneurs and external consultants were applying academic knowledge to industrial problems on a project basis. However, as firms like Bayer grew, they required a more continuous and systematic source of innovation. Consultants were often limited to specific projects and production process was still controlled by practical foremen who guarded manufacturing secrets. In fact, scientific control over production was weak and unorganized. By establishing dedicated research laboratories and hiring university-trained Ph.D. chemists, companies integrated scientific expertise directly into their operations, creating permanent research roles within the corporate structure. In France for example, engineers from Polytechnique and Centrale were recruited to organize and manage laboratories (Caron, 2010).

The connections between academic science and industry grew significantly, manifesting in a variety of forms which reflected both the increasing applicability of scientific knowledge to industrial problems. In parallel to the intensification of interaction between science-industry, the growing institutional divide between academia and industry started to let emerge the first "Merton-type" barriers.

While universities were largely tolerant of scientists' involvement in commercial activities in the beginning, skepticism grew among the academic community and the institution (MacLeod, 2012; Mercelis et al., 2017; Weiner, 1987). Consulting and patenting activities, in particular, became focal points in this evolving relationship. Although patenting was generally more acceptable than other commercial ventures, it started nonetheless to raise ethical concerns among scientists. Many scientists feared that patenting would commercialize the academic environment, corrupt the traditional nature of universities. The paper of Weiner (1987) highlights several controversies and unresolved issues in patenting practices of academic scientists in the early 20th century and shows that there was widespread concern that patents would alter the allegiances and aims of scientists, skew research priorities and hinder the open exchange of information among colleagues that is crucial for scientific progress. This marked a critical shift, as universities sought to maintain the integrity of academic pursuits while acknowledging the growing commercial potential of scientific findings and many introduced regulations to balance academic responsibilities with external engagements. Scientists had to navigate this landscape by carefully patenting inventions they deemed separate from their core research. For example, the paper of Katzir (2017) which traces historical examples of commercialization in this period, mentions the case of Leo Szilard, a Hungarian physicist who was advised against patenting his scientific discoveries. Szilard had to patent his work based on inventions and instruments rather than based on scientific discoveries and experimental designs. The contrast was essential; while inventions and instruments were seen as practical applications of science, discoveries were viewed as fundamental knowledge that should remain accessible

This unease was far from uniform across the scientific world, and some faced professional consequences for engaging in such activities. There are many examples in the study of Mercelis (2017) which shows that there was apprehension among academics and their institutions about profit-driven endeavors which could undermine the ideal of impartial, disinterested research. Academic scientists had to sometimes give up their positions in academia to pursue their entrepreneurial activities: Bruno Meyer, a professor of art, interested in photography development, resigned from his position at the Technische Hochschule Karlsruhe due to scrutiny over his commercial activities. Similarly, Ernst Abbe, despite his business success with the Zeiss company, took measures to preserve his scientific reputation by remaining a silent partner (Mercelis et al., 2017).

Of course, these institutional and cultural tensions were not universally felt and varied significantly among academic institutions due to differences in their founding missions and institutional cultures and policies. While some institutions, such as land-grant universities and those with strong engineering programs, embraced a more practical orientation from their inception, others prioritized basic research and were initially skeptical of commercial activities. For example, the historical study of the University of John Hopkins by Feldman & Desrochers (2003) shows that the university’s founding mission (1876) and long-standing institutional culture, focused on basic research, created barriers to technology transfer compared to MIT (1861) or Stanford (1885). As mentioned in their study, regarding consulting: MIT allowed professors to spend 20% of their time on outside consulting and Stanford had a culture so entrenched to commercialization that “if an engineering faculty member wasn't consulting with industry, he wasn't sure if he should be on the faculty” (Feldman & Desrochers, 2003, p. 17). Overall, the US had greater emphasis on "useful knowledge," linking academic research more closely with industrial applications than many European institutions (Mowery & Sampat, 2001), except for Germany which led the way in institutionalizing close ties between universities and industry, particularly in the fields of chemistry and physics.

Such tensions could also be found in industry. Bayer often restricted scientists’ autonomy by having strict policies on intellectual property and publications which credited the company, rather than the individual. These limited researchers’ freedom to contribute to broader scientific debates (Meyer-Thurow, 1982). These pressures frequently led to dissatisfaction and even a "brain drain" as some scientists left industry for academic positions that offered greater independence (Meyer-Thurow, 1982).

4.2 Intermediaries: collective labs and first technology transfer organizations

The intermediaries that emerged during this time reflect the multiplicity of actors necessary to tackle different obstacles to science-industry links. Intermediaries of the previous period prevailed in their function of certifying information and facilitating its exchange. But as knowledge becomes more complex moving into different scientific disciplines, the number of inventions increased and the number of actors involved as well, these functions took even more importance and at larger scale.

- Collective labs

In the early 19th century, the archetype of the lone inventor in a workshop prevailed, reflecting a more artisanal approach to invention. By the late 19th and early 20th centuries, laboratories transitioned from small, personal spaces to large, institutionalized centers. Early inventors like Thomas Edison pioneered the concept of the industrial research lab, exemplified by his Menlo Park Laboratory, where teams of specialists could experiment and prototype under one roof, accelerating invention and product development. As universities embraced scientific research, academic laboratories emerged as key sites for both fundamental discoveries and practical applications, contributing significantly to areas like chemistry, physics, and electrical engineering. Meanwhile, corporate research labs like General Electric and Bell Labs institutionalized R&D, integrating scientific principles directly into industrial production and commercial technology.

As industrial and academic scientists began to operate under different paradigms, the informal channels that had previously facilitated this knowledge exchange became less effective. Perhaps one of the main challenges that arose during this time was the growing divide in how science was conducted from the two institutional settings. As Stokes (1997) explains "*the establishment of universities as the home for pure science, and the concurrent institutionalization of applied research within industry, only heightened the perceived separation between these two spheres*".

What characterizes this period is the rise of intermediaries which facilitate knowledge transfer. These labs could be considered as the ancestors or twins of the industrial labs but what characterized these places was there was a need to transfer tacit knowledge from both science and the applied field in order to develop new products.

We see emerging *'test laboratories' or proto-laboratories* (Galvez-Behar, 2008) which reflected the blending of scientific and industrial spheres. These early testing labs emerged as crucial sites for quality control in the production and sale of goods. By testing products, these labs provided manufacturers with vital data, ensuring that quality standards were met. Beyond quality control, these laboratories also became centers of research, largely due to the availability of equipment and trained personnel. The data collected during product testing was often used for further scientific study, effectively making these labs precursors to modern research and development (R&D) departments. They functioned as spaces for proto-research, where new scientific inquiries could be explored in an industrial context.

In the same vein, *collective testing laboratories* (Galvez-Behar, 2008) began appearing in the 1890s and provided shared facilities for both scientists and industrialists. These institutions not only facilitated scientific experiments but also offered a shared space for both scientists and industrialists to interact, share knowledge, and conduct collaborative research. They were particularly crucial in industries such as electricity and chemicals, where precision and access to cutting-edge tools were essential for innovation. An important example is the 'Laboratoire Central d'Électricité de Paris' (1888) - Paris Central Electricity Laboratory - which allowed engineers and scientists to carry out personal research, repeat significant experiments, and benefit from a centralized facility equipped with the latest scientific instruments. This laboratory helped democratize access to advanced technology, enabling smaller firms and independent inventors to use the same resources as larger companies. In 1898, the Paris Chamber of Commerce and the National Office of Commercial Trade established a similar institution, providing a public laboratory that offered industrialists and engineers access to high-level scientific techniques. In the United States, the creation of the National Bureau of Standards (NBS) (1901) helped set technical standards for industries, ensuring that new technologies, especially in electrical engineering, met rigorous scientific criteria. These institutions were the precursors to modern FabLabs and collaborative innovation spaces, where shared equipment and expertise were leveraged to accelerate technological development. Their collaborative nature helped break down some of the cultural barriers between academia and industry, as scientists and industrialists worked alongside each other.

- First technology transfer organizations

The question of which intermediaries could manage patents of inventors in academia remains therefore open. We argue until the beginning of the 20th century, there was no formalized structure and scientific inventors pursued their patenting activity in isolation and had to carefully navigate these sometimes-conflicting activities as stated earlier. Even though science was done at universities, these institutions were little involved in managing any aspect of commercial activities in the early 20th century due to reluctance (Mowery, 2001b). This phenomenon extended for a longer period in Europe roughly till the end of the 20th century and beginning of the 21st century due to the professor's privilege which enabled academic researchers to retain ownership of their inventions[45]. Therefore, we see first structured intermediaries for academic inventions appearing in the 20th century, especially in the US. Notably, the first to date was the *Research Corporation* which was founded in 1912 by Frederick Gardner Cottrell, a scientist and inventor. The Research Corporation's primary mission was to act as a **technology transfer organization.** It took responsibility for managing patents from scientists in academia and licensing them to industry from the 1930s through the 1970s. This generated income that could then be reinvested into scientific research, primarily through grants to universities and research institutions. The Research Corporation negotiated "Invention Administration Agreements" with hundreds of US universities, starting with MIT in 1937. Under these agreements, universities would disclose inventions to the Research Corporation, which would evaluate them and handle patenting and licensing (Mowery, 2001a).

Interestingly, there was cases of university patenting which happened outside of the Research Corporation. One of the earliest examples was the role played by the Wisconsin Alumni Research Foundation (WARF) in 1925 which managed the patent rights to a process for synthesizing vitamin D, developed by Harry Steenbock. As the University of Wisconsin didn't want to manage his patents, Steenbock convinced the WARF to do so, as it was an affiliated but legally separate foundation. Throughout the 20th century and until the Bay-Dol-Act,

[45] There were disparities by countries with UK, Spain and Switzerland being early adopters of university's ownership systems, see Geuna & Rossi (2011) and (Martínez & Sterzi, 2021) for more details.

universities started to manage technology transfer with their own staff, especially public universities which established patent management foundations (Mowery, 2001a).

5. Discussion and conclusion

This study has demonstrated that intermediaries have always played a critical role in the complex relationship between science and industry, long before they appeared in the economic literature in the last quarter of the 20th century. Although the literature on intermediaries often neglects their historical depth, this research shows that their presence is deeply rooted in the history of science and innovation. These intermediaries responded to a range of problems and their functions evolved according to the specific needs of their time.

Historically, the distinction between science and industry was always present, but it became more pronounced with the institutionalization of these fields, particularly in the 19th century and the 20th century. Prior to this, science was primarily understood as a methodology, but by the 19th century, it had grown into a broader cultural force, shaping public understanding and becoming institutionalized in various forms. The rise of professionalized institutions such as universities, industrial laboratories, and learned societies further solidified this separation (Popp Berman, 2008). However, even before this divide became institutionalized, the interactions between science, markets, and governments were multidirectional and complex. The evolution of these interactions demonstrates that innovation has never been a simple linear progression from science to industry.

The role of intermediaries during this period underscores the collective dimension of invention and innovation. Throughout history, innovation has rarely been the work of isolated individuals; rather, it has been a collaborative process, shaped by networks of individuals, informal exchanges, and, eventually, organized institutions (Powell & Giannella, 2010). The literature often overlooks the organizational structures, both formal and informal, that supported the exchange of ideas and practices. This study brings to light the importance of these structures in facilitating the flow of knowledge and highlights the collective nature of innovation long before the 20th century.

We have also shown that the landscape of intermediaries was complex even before the modern era. From patrons and learned societies to patent agents and economic associations, intermediaries played a key role in reducing Williamsonian barriers by lowering transaction costs, certifying inventions, and protecting intellectual property. These intermediaries facilitated knowledge transfer, albeit in different forms, long before the rise of industrial laboratories and institutionalized science. However, the Polanyi barriers—which involve the challenge of transferring tacit knowledge—were less relevant during this period, as inventors often managed their own inventions without needing to transfer knowledge to third parties. As such, while informal structures such as guilds, learned societies, economic societies and associations existed, their role in knowledge transfer was secondary to their primary function of reducing transaction costs. It was only with the institutionalization of science and industry in the late 19th and early 20th centuries that new challenges, including Mertonian barriers, began to arise. The norms of science, which emphasized open knowledge sharing, began to clash both with the commercial appeal of scientists and industry needs, leading to the increase institutionalization of the research profession. These barriers, which did not hold relevance in earlier periods, became significant as the cultural divide between academic science and industrial research deepened. The emergence of industrial research laboratories and other collective research laboratories, beginning in the early 20th century, represents a key turning point in this process (Galvez-Behar, 2017).

In conclusion, the role of intermediaries in the innovation process has always been vital, though their functions have evolved. Interestingly, we find similar functions to the current intermediaries and some forms of intermediaries can be considered as ancestors of what we already know today. The functions of intermediaries can be resumed chronologically in the following table:

Period	Identified Intermediaries	Intermediary functions	Corresponding barrier	Ancestors of
Premise of modern science				
15th – 16th century	Patrons	• Provide resources and protection • Support dissemination of knowledge	Williamson	Philanthropic foundations, government grants
16th – 17th century	Learned societies	• Reduce access costs of knowledge • Certify knowledge	Williamson	Scientific institutions
Preindustrial revolution				

End 18th and 19th century	Informal network in social places and spaces	• Facilitate exchange of knowledge	Williamson and to lesser extent Polanyi	Third spaces
	Economic societies	• Reduce access costs to knowledge • Certify knowledge • Facilitate exchange of knowledge	Williamson and to lesser extent Polanyi	Innovation agencies
First institutionalization of science and birth of industry				
19th century	Patent agents	• Reduce access costs to knowledge • Reduce transaction costs (uncertainty in markets, connecting actors, legal aspects)	Williamson	Patent institutions
	Inventor associations	• Reduce access costs to knowledge • Certify knowledge • Facilitate exchange of knowledge • Giving advices on legal aspects	Williamson and to lesser extent Polanyi	Clusters
	Exhibitions	• Certify knowledge • Facilitate exchange of knowledge • Increase adhesion to 'science'	Williamson and to a lesser extent Merton	Show rooms
Second institutionalization of science and birth of industrial research				
End 19th – early 20th	Proto-labs	• Facilitate exchange of tacit knowledge	Polanyi	Fab-Labs
	Collective testing laboratories	• Facilitate exchange and co-creation of knowledge • Reduce orientation conflicts	Polanyi and to lesser extent Merton	Collaborative Research Centers
	Research Corporation (US)	• Reduce transaction costs	Williamson	TTOs

Table 9: Science-Industry Intermediaries before WW2

This study also highlights the importance of individuals in shaping the science-industry nexus throughout history. In the early stages, individuals straddled both worlds, with scientists, inventors, and industrialists often operating within the same social and professional networks. As professions became more specialized in the 19th century, institutions such as universities and firms imposed their own regulations, which began to formalize the separation between science and industry (Guagnini, 2017). Despite this, informal exchanges and personal networks remained crucial, even as the complexity of knowledge and technology grew. Today, we see the legacy of this historical development in the specialized intermediaries that continue to facilitate innovation across the boundaries of science, industry, and government.

While this study has explored the origins and evolution of intermediaries, it has not been exhaustive in covering all intermediary forms across different periods. The selected periods are flexible, and future research could examine the evolution of intermediaries in a specific period or a specific country for enriching this analysis. We have focused our historical study until the early 20th, while it is highly possible to find other forms of intermediaries in the 20th century (pre 1980), we argue that they are likely to be the intensification of the dynamics already existing in the late 19th and early 20th century (for examples, clusters became more associated to scientific institutions leading to science parks in the mid-20th century, patent systems became even more institutionalize, etc.). The continued evolution of intermediaries will undoubtedly remain central to understanding the dynamics of science-industry interactions in the future.

Further research should investigate the evolving relationship between institutional goals and individual activities. Understanding how institutions such as universities and firms shaped the behavior of scientists and inventors, and how this, in turn, necessitated new forms of intermediation, is critical to gaining a comprehensive understanding of the historical development of innovation. Future work could also explore the role of individual inventors versus institutional actors in shaping technological advancements.

Conclusion of Chapter 2

The historical analysis presented in this chapter challenges the conventional narrative that university-industry intermediation emerged primarily after World War II. By tracing the evolution of intermediary organizations through three distinct periods, we reveal a rich history of intermediation that adapted to changing contexts and needs. This evolutionary perspective demonstrates how different forms of intermediaries emerged to address specific barriers: from early focus on Williamson-type barriers to later emphasis on Polanyi and Merton-type barriers. The identification of approximately ten distinct forms of intermediation throughout history not only validates the theoretical framework developed in Chapter 1 but also enriches our understanding of how intermediary functions have evolved over time. This historical perspective provides crucial context for understanding contemporary intermediary organizations and suggests that future evolution will continue to respond to emerging barriers and changing institutional contexts.

Having established both the theoretical framework for understanding intermediary organizations and their historical evolution, we turn to a contemporary empirical investigation to see how these concepts manifest in practice. Chapter 3 brings our theoretical and historical understanding into the present day through a detailed case study of the health sector in France's Hauts-de-France region, examining how different intermediaries collaborate to overcome the barriers identified in Chapter 1. This Chapter therefore can be considered as a twin chapter with Chapter 1.

CHAPTER 3

HOW DO U-I INTERMEDIARIES WORK TOGETHER: INSIGHTS FROM A LEADING HEALTH SECTOR REGION IN FRANCE

Summary of Chapter 3:

Intermediary organizations (IOs) are essential tools to promote University-Industry-Interactions (UII) and innovation. Their increased number has raised some concerns about their roles both from theoretical and practical points of view. However, research falls short in investigating if these intermediaries jointly facilitate university-industry interactions. Based on a qualitative case study of 8 types of IOs in the region of Hauts-de-France (France), this study aims to examine the roles of these intermediary organizations in a holistic approach to grasp the degree of their uniqueness and complementarities. Our results reveal that IOs interact with each other on three levels of coordination patterns when facilitating UII: 'multiple', 'single', and 'agile'. These were dependent on two elements: the type of channel of interaction and the type of barriers (Williamson, Merton, Polanyi, and Arthur).

Keywords: U-I intermediaries, complementarities, qualitative case studies, health sector

Table of contents for Chapter 3

Chapter 3: How do U-I Intermediaries Work Together: Insights from a Leading Health Sector Region in France[46]

1. Introduction

The interaction between universities and the economy is crucial, as it enables the transfer of knowledge and technology, fostering innovation and economic growth, and addressing societal challenges. Collaboration between universities and industries is unavoidable for developing ground-breaking innovations and outcomes based on research. However, the involvement of actors from these different organizational fields is also what makes it highly challenging as coordination problems and conflicts are highly likely to arise and make collaborations fail.

“Intermediary organizations” or ‘Hybrid’ or ‘interface’ organizations have been recognized to play a significant role in addressing these challenges (Albats et al., 2022; A. T. Alexander & Martin, 2013; T. Kodama, 2008; Noack & Jacobsen, 2021; Santos et al., 2023; Villani et al., 2017; Wright et al., 2008; Yusuf, 2008). Various 'intermediary organizations' come into play in facilitating relationships between universities and industries, serving as 'institutional and knowledge bridges' to alleviate innovation system failures. For example, Technology Transfer Offices (TTOs) have been recognized to be an important player in supporting the commercialization of research since the 1980s. But other actors have been developed since then, Collaborative Research Centers (CRCs), Incubators, Science and Technology Parks, and Industrial Associations, to name a few, have also been recognized to play crucial roles. University-industry Intermediaries (UIC) have highly increased in number and diversity over the years.

However, while the body of literature on these organizations has largely expanded, our understanding of what they do remains under investigation for at least two reasons.

[46] Chapter written alone. This chapter is based on an article version submitted on October 2023 and currently under revision (second round) in Technovation.

First, the recent scholarly discourse has raised pressing concerns about the lack of a 'holistic approach' to studying these organizations (Good, et al. 2019). The literature on intermediaries has been too atomistic, studying their functions, activities, and other organizational components separately. Although intermediary organizations in the context of university-industry interactions follow distinct purposes and activities they serve the same goal of supporting universities and industry interactions and contribute to some extent to the regional economic development. While we understand the individual roles they play, there's a significant gap in our understanding of how these roles intersect and complement each other. The consequence is that most studies overlook how those organizations collaborate and coordinate to facilitate technology and knowledge transfer.

Second, the multiplicity of actors has generated conceptual ambiguities and theoretical fuzziness, leading to confusion and questioning from both policy and operational perspectives (Caloffi et al., 2023; Mignon & Kanda, 2018; Santos et al., 2023). This perception of a 'cluttered landscape' (Hruskova et al., 2022) makes it challenging to understand to what extant these organizations overlap and complement each other when facilitating interactions. The consequences are that it makes it confusing for actors involved to navigate the landscape of knowledge transfer and also poses critical questions about the legitimacy and rationality of having multiple intermediaries from the perspective of policy makers, as many of them derive from public funding (Feser, 2022).

Faced with these challenges, this calls for clarification and exploration of the roles of U-I intermediary organizations. Recent studies in the innovation intermediaries literature have shed light on clarifying their roles by employing systematic reviews and providing typologies or taxonomies (Caloffi et al., 2023; Kivimaa et al., 2019; Mignon & Kanda, 2018) also in the U-I context (Santos et al., 2023). Others have empirically investigated their roles altogether and showed that different intermediaries can address diverse needs (Alexandre et al., 2022; Villani et al., 2017). Specifically, these studies show that each intermediary can leverage different organizational, cultural, cognitive, and relational barriers. The work of Good et al. (2019a) additionally offers an organizational framework encompassing different intermediaries, to help refine comparisons in future research.

Despite these recent investigations, most of the main existing literature on the roles of U-I intermediaries remains atomistic, focusing on a few specific types of intermediaries and studying them separately. The consequences are that these lack a holistic view of the knowledge transfer ecosystem and its components (Chau et al., 2017; Good et al., 2019a), which overall makes it difficult to understand the role and impact of each type of intermediary, how they overlap or complement each other to facilitate UII.

We respond to the recent calls which address the need to further investigate the roles of other intermediaries (Villani et al. 2017) as well as their interaction (Good et al., 2019). Therefore, our study seeks to address the following research question:

How intermediary organizations work together to facilitate UII?

Our research aligns with the idea that having many intermediaries might not be intrinsically problematic. Instead, they might rather be indicative of a 'rich and robust' ecosystem.

We echo the thoughts of Hruskova et al. (2022) and Tung (2023, forthcoming), arguing that the diversity and number of intermediaries can be rationalized by their distinctive roles in overcoming various barriers and leveraging different aspects of university-industry interactions. The study of Hruskova et al. (2022) examined this phenomenon within the 84 organizations in the entrepreneurial ecosystem of Glasgow, Scotland. Through an organizational thickness lens, they argued against the prevailing notion of a 'cluttered landscape' and proposed that the seeming problem could likely be resolved through more precise segmentation rather than a reduction in the number of organizations. The latest research by Tung (2023) provides a comprehensive framework that encompasses a multitude of interactions as well as ten types of intermediaries, offering a pioneering overview. This first framework aids in understanding the antecedents that shape the various facets of intermediaries which in turn provide supporting arguments in favor of their diversity.

This paper seeks to delve deeper into the empirical aspects of this phenomenon through a case study conducted in the health sector of the Hauts-de-France region (France). The region of Hauts-de-France emerges as a suitable ground for this exploration, given its substantial endeavors to bolster innovation and public-private partnerships, particularly in the health sector. This region is home to a diverse array of intermediary organizations and features a network of loosely coupled actors, each representing various spheres of the healthcare industry.

Our results show that IOs have overlapping functions that enable them to leverage the same barriers in the same channel of interaction. In each channel, several IOs pursued the same activities. However, those overlaps are not intrinsically bad as we show that IOs complement each other by collaborating and coordinating on specific aspects. This proves that each has a specific role to play in the ecosystem.

This study contributes to the existing literature on university-industry intermediaries by providing the first empirical holistic analysis of their roles and they complement each other. This extends our theoretical understanding of why intermediaries exist in numerous forms. We investigate the roles of other intermediaries' accounting and how they also contribute to different aspects of UII. In this vein, we generate a general framework that allows us to identify different coordination patterns that appear at different stages in different channels. We also contribute to the literature on barriers by identifying another barrier associated with network effects, which we term the 'Arthur' barrier. This allows us to understand further the complementary roles of additional intermediaries.

The paper is structured as follows: we first give a state-of-the-art overview of the functions of intermediaries in the science-industry context. Section 3 details the methodology of our qualitative approach. Next, we describe and use our empirical results in Section 4. We discuss our results to propose a refined framework and conclude in section 5.

2. State-of-the-art

2.1 University-Industry Interactions (UII)

Literature acknowledges that there are many ways through which universities and industries interact and exchange knowledge and technology. University-industry interactions (UII) or 'channels' of interactions between the two actors encompass a wide range of activities that necessitate different kinds of support. These channels are used to describe the "mechanisms" or the "pathways" through which information, knowledge, or other resources are exchanged or co-produced between universities and industry (Perkmann & Walsh, 2007). Channels of interaction refer to the following activities: transfer of IP through patenting and licensing, entrepreneurial activity, consulting, and contractual research, joint research projects, joint supervision of students, hiring, training, sabbatical periods of scientists and industrialists, participation in various events, informal interaction… (Arza, 2010; Schartinger et al., 2002; D'Este et al., 2013; Rossoni et al., 2023). Recent work also emphasizes the existence of channels that refer to projects more applied-oriented which are opened to other partners besides universities and industries such as practitioners from various institutions, citizens, students, and end-users (Compagnucci & Spigarelli, 2020; De Silva et al., 2018; Rossi et al., 2017).

2.2 U-I Intermediary organizations

Innovation intermediaries have been recognized to play an important role as agents of innovation. The earliest work of the characterization of intermediaries by Howells (2006) defines an innovation intermediary as '*an organization or a body that acts as an agent or broker in any aspect of the innovation process between two or more parties'* (Howells, 2006, p. 720). Intermediaries are recognized to perform a variety of functions which have been investigated extensively since the mid-2000s. The literature on innovation intermediaries has grown considerably over the years as their number, variety, and scope of actions have also increased. Different typologies and taxonomies co-exist and have been proposed to systematize their roles and functions (Agogué et al., 2017; Howells, 2006; Lopez-Vega & Vanhaverbeke, 2009; Mignon & Kanda, 2018; Santos et al., 2023). Innovation intermediaries

Intermediation between two or more actors usually that these actors are quite different, coming from distinct institutions for example. Therefore, intermediaries can act as 'middlemen', boundary spanners, knowledge brokers, and translators which help access knowledge as well as other resources. They can improve innovation capabilities by providing different support and technological services to their client firms and are also recognized for stimulating collaboration through their connecting activities, by creating connections and coordinating collaborative processes between various actors. Overall, the role of innovation intermediaries is to help firms, universities, research centers, and government agencies overcome barriers to innovation, such as lack of information, resources, or collaboration opportunities which in turn avoid systematic failures in regional innovation systems (Howells, 2006).

The body of literature focused on intermediaries has prominently highlighted the roles they play within the framework of university-industry connections (Albats et al., 2022). Intermediaries play a crucial role in facilitating exchange and collaboration between universities and industry by providing value-added services (Wright et al., 2008). Intermediaries have been found to take many different forms, they include actors such as science parks, incubators, accelerators, technology transfer offices, innovation networks, consultants...etc. They can also operate at different levels, at the individual and organizational level, and in different sectors or technological domains.

The study of Santo et al. (2023) and Good et al. (2019) provide an extensive overview of the main types of U-I intermediaries. We briefly explain their purpose and activities below[47].

a)TTOs

Technology Transfer Offices (TTOs) are independent departments or units within universities or research institutions. Their primary goal is to maximize the societal and economic impact of research by fostering partnerships with industry, facilitating the commercialization of intellectual property (IP), and supporting entrepreneurship. TTOs could also refer to technology licensing offices (TLOs) and industrial licensing offices (ILOs). These conduct similar activities but in limited scope. Some activities of TTOs include: identifying potential industry partners, negotiating contracts, and protecting the university's intellectual property (Siegel, Waldman, Atwater, et al., 2003).

b) CRCs

Collaborative Research Centers (CRCs) are interdisciplinary research initiatives established by universities, government agencies, or industry partners to address complex or specific scientific or technological challenges. These centers are usually largely publicly funded. They bring together researchers from different organizations to work collaboratively on a common research agenda. CRCs are very heterogeneous and vary highly by country (Gibson et al., 2019). The literature is fragmented, for example, some authors consider public research organizations to be CRCs. Others are more restricted to university-industry centers. Overall, CRCs promote collaborative projects and can help in technology transfer activities (Gibson et al., 2019; Villani et al., 2017).

c) RTOs

Research and Technology Organizations (RTOs) are organizations similar to public research organizations except that they are more focused on conducting applied research and are close to industries (Giannopoulou et al., 2019). Their activities can consist of providing technical services and consultancy to their client firms. RTOs are usually publicly funded and receive funding from firms. RTOs are also heterogeneous and are considered to be recent in the

[47] In order to introduce the empirical cases, this part briefly resumes the type of intermediaries (a resuming table in Chapter 1 can be useful here).

literature of intermediaries. Examples of RTOs include the Fraunhofer in Germany, the TNO in the Netherlands, and the CEA in France.[48]

d) Science and technology Parks

Science and technology parks are regional or territorial organizations that provide co-location to technology-based companies and offer a wide range of services and facilities to their tenants such as pieces of advice related to legal and business aspects and networking opportunities (Good et al., 2019a) to support their development. The essence of Science Park lies in its proximity to public research institutions or universities. These are usually implemented in the park.

e) University Incubators

University Incubators and accelerators are structures that support the commercialization of research through academic entrepreneurship and university-industry collaborations. University incubators are different from other incubators as they host entrepreneurs who have more research-oriented profiles. Their activities consist of providing a range of services such as advice on marketing and business, funding, accounting, and other administrative services related to the creation of a company. They can also help in facilitating connections between actors (Good et al., 2019a; Villani et al., 2017).

f) Industrial associations

Those entities are close to companies and are key actors in regional innovation systems. They are concentrated geographically and are very knowledgeable about their industry and specific technological fields. Their activities include technology forecasting, responding to industries' needs through different services, and connecting collaborative partners including universities. One typical form of industrial association is regional clusters.

g) Open-labs

Open-labs (fab-labs, living-lab, tech-shops, proof-of-concepts) act as place-based platforms that experiment with innovation practices (Hakkarainen & Hyysalo, 2016). These are relatively

[48] https://www.earto.eu/about-earto/members/

new organizations that are very heterogeneous in the way they are organized and managed. These intermediaries target different actors that have different needs. Their goal can range from simple locations for experimentation to developing and facilitating collaboration between heterogeneous actors (including users, clients, or citizens) to develop innovations. In the university-industry context, they can provide spaces for experimentation, especially at the early-stage of invention such as prototyping, and offer networking opportunities with actors of the business sectors. Some of them have been recognized to provide funding.

h) Public institutional intermediaries

These agencies aim to support innovation and economic regional development. They are publicly funded are close to regional instances and implement policy initiatives to support innovation. They promote innovation initiatives and support university-industry collaboration and entrepreneurship. Their activities consist of providing services such as subsidy pieces of advice, innovation consultancies, administrative support, funding opportunities, and training.

Other forms of intermediaries exist, specifically that act at the individual level such as entrepreneurs, doctoral students, patent agents, technology scouts, and technology brokers that were also mentioned in the literature (see Santos et al., 2023) but we chose to focus our attention on intermediary as organizations. Moreover, we do not focus on financial intermediaries because they are not in direct contact with universities and industries. One recent study (Howells, 2024) has also mentioned digital platforms as intermediaries but we will not focus on these either.

2.3 Complementarities of U-I Intermediary organizations

The fact that intermediaries are widely considered in the science-industry context is unsurprising, given that one of the principal functions of intermediaries is to forge links between entities from disparate institutions that are characterized by distinct norms, values, and incentives (Klerkx & Leeuwis, 2009; Nooteboom, 2000). Establishing such relationships often proves to be more complex than in other areas as these entities often operate under potentially conflicting systems, presenting considerable challenges to overcome and may require more effort and different expertise that are not in the hands of one sole intermediary.

Several studies explore the function of diverse intermediaries in leveraging different barriers to facilitate technology or knowledge transfer. For example, the study of Villani et al. (2017)

shows in their Italian case study that different intermediary organizations (TTOs, CRCs, and incubators) can reduce both geographical and non-spatial barriers, such as social, organizational, and cognitive barriers. The study of Fernández-Esquinas et al. (2016) also provides evidence of the different roles played by different intermediary organizations in the region of Andalusia in Spain. They show that different interface organizations (TTOs, science parks, and regional innovation agencies) may be more effective in supporting different types of channels of interaction. Recent work proposed by Alexandre et al. (2022) finds intermediaries help overcome relational barriers and are better suited to help small firms than large ones. All these empirical investigations highlight the fact that there seems to be a link between the type of channels, barriers, and the involvement of intermediaries.

However, while these studies offer the necessary standpoint to differentiate their roles, they fall short in examining when these roles are involved in the UII processes and how they altogether contribute to facilitating it.

We use most frequent framework developed in Chapter. The model proposes that distinct barriers emerge at varying degrees for each channel of interaction. These barriers subsequently prompt the engagement of specific IOs, as each possesses varying aptitudes in addressing certain obstacles more effectively. Most specifically, these barriers have been categorized into three distinct classes: namely Williamson for costs of transaction (search, negotiation, and enforcement), Merton for orientation and cultural conflicts; and Polanyi barriers to refer to the costs of transferring knowledge and or technology due to its tacitness.

The framework is relevant for various reasons. First, it encompasses a wide array of interactions including collaborative projects that are open to other partners. This is relevant as science-industry relations have evolved into new forms of collaboration which include other partners (Albats et al., 2022; Mérindol et al., 2018). Second, this framework accounts for the roles and functions of ten types of intermediary organizations. This is relevant as new forms of organizations have populated the landscape and should not be overlooked when reviewing their diverse contributions to knowledge transfer activities. Third, this study acknowledges that several UIIOs can leverage similar barriers of interactions, inducing that they do overlap in their functions.

The fact that intermediaries have overlapping functions is of interest to us as it may indicate that there are some inefficiencies in the technology transfer ecosystem. Where do those overlaps appear and why? Much literature has focused on how intermediaries can foster collaboration between firms or between universities and firms, or how they interact with academics (Y.-C. Kim et al., 2019; O'Kane, 2018) we know little to almost nothing about the dynamics between intermediaries. There has been literature about teamwork within types of intermediaries such as TTOs (Kaiji et al., 2022) but not on how different intermediaries can work together to facilitate UII. In the case of sustainable innovation intermediaries, Kant & Kanda (2019) conducted a qualitative case study of four intermediaries and mentioned in one of their results that to increase their internal value creation, intermediaries get involved in complementing activities with other intermediaries. Similarly, intermediary organizations may complement each other in different channels of university-industry interactions.

We use this framework to guide our subsequent qualitative study. We explain how the framework helped us in enriching our understanding of the common or separate roles of intermediaries.

3. Methodology

3.1 A qualitative approach

The case study aims to gain deeper insights into the roles of intermediary organizations to better understand their roles and complementarities. To study this phenomenon and hence answer our exploratory research question, we choose to conduct a multi-case study of 8 types of IOs in the health sector in the region of Hauts-de-France. Each IO represents one case, and all cases are studied within the same regional context. The unit of analysis was either managers from the IO or academics and industrialists collaborating with the IO.

We follow a flexible pattern-matching approach (Bouncken et al., 2021; Sinkovics, 2018). We use the former conceptual framework of Tung (2023) to guide our investigation and use it as a methodological tool. This also enabled us to capture some of its applicability, which gives a first overview of the phenomenon. We confront the conceptual framework to field data to validate its relevant parts and enrich some aspects but not generalize results (Miles & Huberman, 1994; Tavory & Timmermans, 2014).

3.2 Regional context and case studies

3.2.1. Innovation context in France and in the region of Hauts-de-France

To avoid regional context bias and understand the dynamics between different actors, we decided to focus on IOs within one regional context in France. One particularity in France is its unique organization of public research which is marked by the coexistence of numerous and diverse research organizations (universities, research institutions, engineering schools, to name a few). These entities exhibit missions, statutes, supervisory bodies, and practices that reflect varying realities. This characteristic deserves attention as it may also mirror the multiple technology transfer organizations representing them. Since the 2000s, there has been a significant effort from French policymakers to enhance investments and infrastructure aimed at promoting public-private collaborations, and hence innovation. The first milestone was the enactment of the Law on Innovation and Research "Allègre" in 1999, which induced measures to foster ties between universities and businesses, facilitate the establishment of innovative start-up companies for academics, and file patents. A wide number of organizations close to universities were established to fulfill these goals. This legislation induced the creation of university incubators. Moreover, in 2005, the formation of Competitiveness Clusters (Pôles de compétitivité) was initiated to strengthen R&D projects between industries, universities, and research centers. In line with these initiatives, the Investments for the Future Programs programs (PIA - Programmes d'investissements d'Avenir) launched in 2010, allocated substantial funding towards strategic priorities. Key components of these initiatives were the creation of two major organizations: Technology Research Institutes (IRT) launched in 2010 and Technology Transfer Acceleration Companies (SATT) in 2012. These are the French counterparts of Collaborative Research Centers (CRCs) for the former and TTOs for the latter. These organizations were implemented across the thirteen regions in France and their governance, business models and sectorial coverage may vary from one region to the other.

The region of Hauts-de-France was created in 2014 and is the unification of two former regions located in the north of France: "Picardie" and "Nord-Pas-de-Calais". Historically, the region of Nord-Pas-de-Calais specialized in industrial sectors such as textile, metallurgy, and coal, whereas Picardie mainly specialized in the agriculture and food industries. The region has been negatively impacted by its industry decline since the end of the "Glorious Thirty" in the 1980s and was also heavily affected by the 2008 crisis. The region has been considered economically and socially lagging compared to other regions in France, recording high unemployment, poverty, and low levels of growth. To counter this phenomenon and to increase its attractiveness, the region of Hauts-de-France has been implementing many strategic policies to develop its regional economic development since the 2000s. Indeed, excellences poles and clusters have been developed in strategic sectors such as biology/health and transport. Nowadays, the region has eight excellence sites, all specialized in different sectors, with the one in the health sector representing the most important one because of its early development in the 90s. It tackles issues regarding nutrition, health, and longevity. This makes today the Hauts-de-France region one of the top three leading regions in France in the field of healthcare[49].

3.2.2. Case selection

We focus our cases on IOs operating in the health sector because of their growing regional success and their peculiarity in the innovation landscape. Innovation in the health sector can take various aspects, include many different actors, and operate through different collaboration modes (Kodama, 2015). It encompasses a broad range of innovation processes, products, services, and technologies that improve the health and lives of individuals. Health innovation can range from a new drug or treatment to a new connected device that can help monitor information of patients more efficiently, to even a new organizational process such as a new hospital room. Moreover, open innovation in the health sector has also emphasized the role of patients and their interactions with scientists. Today, there are more possibilities for patients to participate in science, a phenomenon emphasized through Mode 3 (Carayannis & Campbell, 2009). In this context, IOs play a key role in facilitating collaboration at different innovation stages and seem more diverse in the health sector (Cooke, 2002).

We identified 8 IOs and tried to select those specialized in the health sector whenever it was possible. We resume their main characteristics in **Table 8.**

[49] https://www.nordfranceinvest.com/business-sectors/health/

Type	***Name***	***Formal unit***	***Affiliation***	***Year of establishment***	***Founding origins***	***# of employees***	***Sectors***	***Fundings***	***Innovation metrics***	***Purpose and activities***
TTO	*SATT du Nord*	Yes	Independent	2012	Government	34	Transversal	Public	# of patents: 250 # of licences: 66 # start-ups: 24 # projects: 179	The TTO's mission is to facilitate, simplify and accelerate the transfer of technology and knowledge from public research to businesses of all sizes. Their **activities** consist of: facilitating contacts between academic and industry, innovation and market detection, patenting, licensing.
Incubator	*Bio-Incubator*	Yes	Development agency[50]	2000	Development agency	22	Health	Public-Private	# of start-ups created: 270	The incubator's mission is to encourage the creation of innovative companies based on the results of public research or in conjunction with public research in the health sector. Their activities consist of: providing workshops and training, coaching and individualized support, networking, community access..
CRC	*Alpha*[51]	No	University, Industry	2017	Research lab and industry	4	Health	Public-Private	#projects: 2	The mission of this collaborative research agreement is to pursue new advances in research and to develop new resources.
RTO	*CIC-IT*	Yes	University Hospital	2008	University Hospital	20	Health	Public	# of start-up created: 9	The RTO's mission is to encourage all initiatives to better meet the

[51] The name of the lab was kept private as wished by the industry.

									# patents: 18	expectations of research, industry and healthcare organizations.
Open-Lab	*Concept Room*	No	Cluster	2012	Cluster	3	Health	Public-Private	# projects: 5	The open-lab's mission is to prototype future health products, biotechnologies or other services through collaborative projects bringing have companies, hospitals and researchers.
Cluster	*Cluster-NSL*	Yes	Development Agency	1995	Development Agency	14	Health	Public-Private	# of labeled projects: 280	The cluster's mission is to foster innovation projects between private and public players, with the aim of stimulating and promoting the nutrition-health sector.
Science Park	*Eurasanté*	Yes	Development Agency	1990	Hospital and Urban association	9	Health	Public-Private	-	The innovation park's mission is to contribute to the region's economic development by creating jobs and wealth, while improving prevention and care.
Innovation Agency	*HDFID*	Yes	Independent	2008	Regional council	37	Transversal	Public-Private	# collaborative projects: 348	The innovation agency's mission is to support startups and companies in their innovation and industrial performance projects while developing entrepreneurship and supporting the economic development policies of the region.

Table 10: Summary characteristics of IO's. *Source*: From intermediary websites and reports.

First, we include the Innovation Park 'Eurasanté' which is centered around the University Regional Hospital Center of Lille (CHU) and is a leading European Center of Excellence dedicated to research in biotechnology, health, and nutrition. The CHU constitutes the largest hospital-university campus in Europe, hosting more than 200 companies in the park, 10 hospitals, 4 faculties, and 50 laboratories.

The Park also hosts a Competitiveness Cluster-NSL which brings together actors from the agri-food industry and biotechnology sector on projects at the intersection of Nutrition and Health. The Cluster has a network of 300 members and has labeled 250 R&D projects since 2006.

In 2012, the Cluster launched the initiative of open-lab "Saga Concept Room", they function as living-lab and bring together researchers, medical professionals, entrepreneurs, designers, and end-users in collaborative projects. Five collaborative projects have been developed since. For example, the first project consisted of creating a full-scale prototype for an imagined futuristic hospital room.

We also include the Bio-incubator which is an academic incubator that provides support, development, and acceleration for academic startups and businesses.

The governance of Eurasanté and these organizations is ensured by an Economic Interest Group (GIE), similar to a Development Agency[52], whose ambition is to bring together actors from the world of higher education, medical research, and specialized companies in the health domain.

On the site, we also consider a special type of RTO called the center of clinical investigation (CIC-IT). Localized in hospital universities, they constitute a shared space, open to research labs, industries, and clinicians. They provide methodologies and technical platforms dedicated to innovation and the evaluation of technologies in the health sector. This organization also holds a small Living-Lab and collaborates with ergonomists and designers.

[52] Created on the initiative of local authorities, economic development agencies are associations under the French law of 1901 whose role is to develop companies and the economy of their territory. This one is specialized in the health sector.

The CRC[53] we study is a consortium between a research unit from the University of Lille, specializing in materials, and a leading company in implants.

We study the SATT du Nord, the regional TTO[54] of the region. It has a unit of 7 employees focusing on the health sector and promotes proximities between universities and industries for the implementation of innovative solutions that meet the needs of patients and healthcare.

Finally, we include in our study the innovation agency of the region HDFID, whose mission is to develop entrepreneurship and support startups and companies in their innovation and industrial performance projects. The agency also supports the region's economic development policies.

This selection of IO's within one context in one sector allowed us to account for a broad range of IOs and also allowed us to study how they interacted with each other.

[53] There was no Technology Research Institutes (IRT) in the health sector in the region. So, we selected a particular type of CRC that were launched by the National Research Agency (ANR) in 2011: the LabComs "Laboratoires Communs" initiative. These are consortiums with long-term fundings and agreements.

[54] Please not that there are two other technology transfer units in the region that are commissioned to defend the interest of two specific public research organizations INSERM and CNRS. For simplification, we decided to include only the TTO because it represents the University of Lille and its related Schools.

Type	***Name***	***Formal unit***	***Affiliation***	***Year of establishment***	***Founding origins***	***# of employees***	***Sectors***	***Fundings***	***Innovation metrics***	***Purpose and activities***
TTO	*SATT du Nord*	Yes	Independent	2012	Government	34	Transversal	Public	# of patents: 250 # of licences: 66 # start-ups: 24 # projects: 179	The TTO's mission is to facilitate, simplify and accelerate the transfer of technology and knowledge from public research to businesses of all sizes. Their **activities** consist of: facilitating contacts between academic and industry, innovation and market detection, patenting, licensing.
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										networking, community access..
CRC	*Alpha*[56]	No	University, Industry	2017	Research lab and industry	4	Health	Public-Private	#projects: 2	The mission of this collaborative research agreement is to pursue new advances in research and to develop new resources.
RTO	*CIC-IT*	Yes	University Hospital	2008	University Hospital	20	Health	Public	# of start-up created: 9 # patents: 18	The RTO's mission is to encourage all initiatives to better meet the expectations of research, industry and healthcare organizations.
Open-Lab	*Concept Room*	No	Cluster	2012	Cluster	3	Health	Public-Private	# projects: 5	The open-lab's mission is to prototype future health products, biotechnologies or other services through collaborative projects bringing have companies, hospitals and researchers.
Cluster	*Cluster-NSL*	Yes	Development Agency	1995	Development Agency	14	Health	Public-Private	# of labeled projects: 280	The cluster's mission is to foster innovation projects between private and public players, with the aim of stimulating and

[56] The name of the lab was kept private as wished by the industry.

										promoting the nutrition-health sector.
Science Park	*Eurasanté*	Yes	Development Agency	1990	Hospital and Urban association	9	Health	Public-Private	-	The innovation park's mission is to contribute to the region's economic development by creating jobs and wealth, while improving prevention and care.
Innovation Agency	*HDFID*	Yes	Independent	2008	Regional council	37	Transversal	Public-Private	# collaborative projects: 348	The innovation agency's mission is to support startups and companies in their innovation and industrial performance projects while developing entrepreneurship and supporting the economic development policies of the region.

Table 11: Summary characteristics of IO's. *Source*: From intermediary websites and reports.

3.3 Data collection

The selection of respondents was made through an identification phase and was accompanied by snowball sampling. We first identified managers in intermediary organizations and then asked informants to suggest other personnel from academia and industry that could provide relevant information. To counter some of the snowball sampling bias, we used available information on the IO's website as well as reports to identify potential academic and industrial respondents. We contacted top-level individuals as they are the most knowledgeable about the activities of the IO but also managers operating at project levels that could better perceive obstacles. We interviewed scholars who had experience with industry and vice-versa or were responsible for exchanging with the intermediaries. In some cases, we considered it unnecessary to have the perspective of academics and industrialists, mainly because the situation did not lend itself to it. For example, in the case of the RTO, the coordinator was himself an academic leading a research team.

The period of conducting interviews lasted around 6 months, starting end of June 2022 to the end of November 2022. A few additional interviews were conducted in September 2023 as well as in April 2024. Out of the 45 individuals we contacted, we received 36 positive responses. We conducted preliminary interviews to test and refine our interview from June to July 2022. In line with the work of Villani et al. (2017), we developed distinct interview protocols: one for IOs and one for academics and industrialists. The interview protocols were structured in four parts with about 10 questions. One part was dedicated to the functions and missions of the respondent's organization; the second was about their collaboration experience with the industry; the third consisted of questions about their perceived obstacles during the collaboration mentioned; and the last was about the roles and functions of IOs (see **Appendix 2**)

During the interview phase, we also used secondary sources that were either collected online or sent by the respondents to gather diverse information on the characteristics of the IOs. These consist of annual reports, internal strategic reports and presentations, information on websites, online public interviews or videos, and press and media articles. This step helped identify potential respondents but most importantly these documents were fundamental to enrich, validate, and triangulate insights gained during the interviews (Jick, 1979). We were able to gain a better understanding of the different university-industry projects specific to the health sector in the region. During the triangulation, we asked informants by mail to share any internal or external additional documents. We also exchanged informally with five people knowledgeable in technology transfer to learn about the context of technology transfer in the region of Hauts-de-France. Finally, we also conducted some follow-up interviews to gain deeper insights into specific aspects. The documents, along with the exchanges and interviews helped us improve our understanding and avoid potential inconsistencies.

We relied on the fundamental structure of the interview to kickstart and guide the interviews and we chose to be flexible in following the interview protocol. As a result, we didn't strictly follow the order of the questions in the protocol and extended or adapted the interview protocol to include additional context-specific questions based on secondary data. This allowed us to increase our understanding of the intermediary activities and capture new themes.

We conducted 36 interviews with 20 employees of IOs, 10 academic researchers or executives, and 6 industrial partners. We also collected insights from managers responsible for the innovation department at the Hospital as it is a leading partner in the health ecosystem of the region.

We conducted additional interviews for the open-lab and the CRC that were in different yet similar entities. The open-lab and the CRC we identified in the health sector were very specific forms of intermediaries. They do not have formal units nor have the human resources or a dedicated team as intermediary managers. In fact, to improve our understanding of these entities and the positioning of our cases, we decided to conduct several additional interviews in similar entities to control for any specificities. Therefore, we conducted: two interviews from Managers of other open-labs and two interviews from another similar CRC[57].

All interviews lasted from 30 to 100 minutes and took place mainly online via Teams. All interviews were done in French and were all recorded and transcribed. All transcripts were kept in French for data analysis, relevant quotes were translated into English after analysis. **Table 10** gives an overview of our data as well as the secondary data sources per case.

Given the sensitive nature of studying barriers, the qualitative case study was conducted anonymously to ensure that respondents felt comfortable sharing their experiences and

[57] one Living-Lab associated to the Lille Catholic University (team size: 6; date of creation: 2013) and one from one Fab-Lab at the University of Strasbourg (team size: 3; date of creation 2018); two interviews with one CEO and Academic of CRC in the University of Lille (date of creation: 2008)

perspectives. Additionally, participants were asked to sign a consent form to inform them about the purpose and implications of the research, ensuring their understanding and voluntary participation. For these reasons, we assigned a code for each interview consisting of their position regarding the intermediary and a number.

Respondents sometimes gave insights into other intermediary organizations (IOs). It allowed us also to verify some of the IO's discourses, check for inconsistencies, and gain different perspectives. Moreover, respondents in different intermediaries gave the same information, which allowed us to saturate our data. We made notes after each interview to have an overall impression and used secondary data to get more background knowledge on the cases. These were essential to learn about the different partners and who they were interacting with.

Intermediary	# Interviews	Status	Position	Interview number code	Interview duration (min)	Additional data
TTO	5 (5 h and 6 minutes)	2 Intermediary Managers	1. Head of Institutional Relations 2. Manager of the national TTO's Network	TT-1 TT-2	78 71	Intermediary website, reports from the national network of TTO, blog posts & online articles, brochures
		2 Academic researchers/executives	3. Scientific Director in Engineering School 4. Professor at the University Hospital Center	TT-A1 TT-A2	66 49	
		1 Managers at firm	5. Head of Portfolio	TT-I1	42	
Hospital	2 (1 h and 5 minutes)	2 Intermediary Managers	1. Technology Transfer Officer 2. Health Economist	TH-1 TH-2	65 (joint)	University Hospital report
Incubator	6 (6 h and 49 minutes)	3 Intermediary Managers	1. Technology Transfer Officer 2. Business Manager 3. Director of incubator network	IB-1 IB-2 IB-3	28+47 60 60	Intermediary website, annual activity report (2022, 2023), annual report of the BPI[58], Ministry of research's website and reports
		1 Academic Researcher	4. Professor at the Lille University	IB-A1	62	
		2 Entrepreneurs	5. Entrepreneur with PhD 6. CEO of spin-off with PhD	IB-I1 IB-I2	85 68	
CRC 1,2	7 (4 h and 57 minutes)	2 Intermediary Managers	1. Technology Transfer Officer 2. Innovation Partnership Officer	CR-1 CR-2	60 81	University and laboratory website, newsletters online posts
		3 Academic Researchers	3. University Professor (CRC 1) 4. University Professor (CRC 2) 5. University Professor (CRC 2)	CR-A1 CR-A2 CR-A3	27 50 (joint)	

[58] BPI is the Public Bank of Investment who is tasked with supporting small and medium-sized enterprises, mid-sized businesses and innovative companies in support of government and regional public policies.

		2 Managers at firms	6. CEO of company (CRC 1) 7. R&D Engineer (CRC 2)	CR-I1 CR-I2	32 48	
RTO	3 (1 h and 58 minutes)	2 Intermediary Managers	1. Managing Director and Professor at Hospital University 2. Managing Director, Coordinator of the Living-Lab	RT-1 RT-2	64 54	Intermediary website, report from the national network of CIC-IT, online articles.
		1 Manager at firm	3. CEO of start-up incubated at RTO	RT-I1	37	
Open-Lab	3 (2 h and 57 minutes)	2 Intermediary Managers	1. Coordinator of FabLab 2. Coordinator of LivingLab	OP-1 OP-3	59 59	Websites, newspaper articles.
		1 Academic Researcher/executive	3. Associate Professor, Head of Research in Engineering School and Participant	OP-A1	59	
Cluster	2 (2 h and 43 minutes)	2 Intermediary Manager	1. Collaborative Projects Manager 2. Coordinator of Open-Lab and Director of Strategy and Communications	CL-1 CL-2	69+31 41+23	Intermediary website, annual activity report (2022, 2023), government's website.
Science Park	5 (4 h and 53 minutes)	3 Intermediary Managers	1. Associate Director 2. Innovation Project Manager 3. Business Development Manager	IP-1 IP-2 IP-3	52 28 48	Intermediary website, annual activity report, internal documents provided by the managers.
		2 Academic Researchers/executives	1. Professor at Business and Bio sciences school 2. University Professor, Head of Research and Innovation	IP-A1 IP-A2	65 100	
Innovation Agency	3 (4 h and 4 minutes)	2 Intermediary Managers	1. Head of Data Department 2. Head of Research and Innovation	IA-1 IA-2	65+74 60	Intermediary website, reports about the innovation strategy of the region retrieved on the regional council website.
		1 Academic executive	3. Head of Partnerships with Enterprises, University of Lille	IA-A1	45	

Total	N= 36 (35 h and 23 minutes)	Intermediary:20, Academic: 10, Industry: 6.	-	-	-	-

Table 12: Case and data overviews.

3.4 Data analysis

We followed a flexible pattern-matching approach as our analysis is guided by an initial conceptual model (Bouncken et al., 2021; Sinkovics, 2018). This approach combines both deductive and inductive analysis. Deductive because we have an existing framework with analytic categories (Patton, 2003) stipulated in the conceptual model of Tung (2023). Inductive because we coded our data in ways to allow other concepts to emerge with a grounded theory approach (Strauss & Corbin, 1990).

We conducted both within-case and cross-case analysis and the coding process was done using Nvivo 10 software. Throughout this process, we used different forms of visualization such as tables, diagrams, or figures to help detect patterns (Miles & Huberman, 1994).

First, for the coding process, we used an initial "start-list" of concepts that guided our analysis (Sinkovics, 2018). We had several central nodes and sub-codes common to all cases – 'interactions' and 'barriers'– and then sub-codes such as – 'commercial transfer', 'Williamson', or 'reducing functions' for example (see **Appendix 3**). We considered a barrier to be irrelevant in instances where respondents made statements such as, "This problem isn't perceived in our field…" or "We are not good in this…". We used versus-coding to compare situations where no barriers were found in the type of interaction mentioned. For example, we coded 'No-Merton' in the node of barriers for TTO. This first step allowed us to gain better insights into the conceptual model: which intermediaries leveraged which type of barriers and most importantly ***how.***

In the second step, while we were focusing on aspects described in the conceptual framework, we also paid attention to emerging themes, we used in-vivo, descriptive, and process coding for data that didn't match the conceptual framework. For example, we had codes such as 'importance of communicating' or more generic codes such as 'historical context. When a new barrier was identified, we coded it as well. The whole coding process resulted in 316 codes.

While the first step helped us gain better insights into the conceptual model, the analysis through the second step showed another finding related to the interactions between intermediaries. We detected an additional role of intermediaries which are associated with their ability to work together in the mean of facilitating UII in the ecosystem. This was not expected from the initial model. Therefore, in the third step of the analysis, we focused only on the links between the intermediaries.

The next section is structured similarly to our data analysis. First, we give some insights on the initial conceptual framework. Then, we choose to depict results by channel of interaction, rather by type of organization to avoid falling into an atomistic analysis that doesn't capture they dynamics.

4. Findings

We were able to find how IOs had overlapping functions in leveraging barriers in conformity with the initial conceptual framework. We then dived deeper in the emerging results in which we choose to display the results by interaction type. For each interaction, we will show when and how different intermediaries are coordinating to support the process.

4.1 Commercial Transfer

4.1.1. The multiple intermediaries' phase

We find that multiple IOs are involved in the research valorization or commercialization process. We find that the TTO, the incubator, the RTO and the innovation agency were all involved in this channel. Their involvement depended on the type of valorization path and step of the process. Specifically, we find that in the first phase of commercialization, multiple intermediaries were involved in leveraging **Williamson barriers associated to the relations.** This barrier derived from is related to the costs of search and information associated to finding the right partners (Chapter 1).

The commercialization process begins with the identification of promising academic research. During this step, we found that **the TTO and the incubator** collaborated and used their respective network to prospect and identify potential marketable research projects related to the health sector across the region. They then followed up on projects to discuss about possible ways of valorizing research as emphasized these two employees in the incubator:

> *"Some projects follow each other on both sides. There is a meeting every three months to discuss the projects and see how they are progressing on both sides and what feedback they have on the project and what we have, just to have common files and to know on both sides on which aspects the*

project holders are progressing and what we can do to better support them, which is different from what the TTO already does and vice versa."(IB-2).

"We often exchange ideas with our TTO counterparts. For example, we have a meeting about every 2 months where we review the projects we have in common, or could have in common, because that's what they do too: they do their own sourcing work, and we do ours." (IB-1).

Moreover, we find that the **innovation agency** acted as a front door for academics or SMEs who wished to collaborate in the health sector. They coordinated themselves to let the incubator prospect on the health sector. Whenever a project seemed to be marketable in the health sector, the innovation agency redirected them towards the corresponding TTO and the incubator as mentioned by the Manager of the innovation agency

"Things are normally done so that everyone can work well together. We tend to work with first-time innovators […] and our colleagues at the incubator of Eurasanté, for example, they are very linked to health experts. So, we are not health experts at all." (IA-1).

"And then it can go the other way too, because we're going to have pretty strong expertise in everything to do with healthcare. So, at some point, they may call us to tell us that they have an interesting project, but that it's not their field of expertise. We'll discuss it that way too." (IB-1)

Several support options are possible and depended on the researcher's affiliations and the outcome of the valorization that could take the form of a patent or a spin-off. We specify the roles for each sub-channel.

4.1.2. TTO as a single intermediary for transfer of IP

If valorization takes form of a patent, then the **TTO alone** took the lead without other intermediaries. As shown in the initial conceptual model, transfer of IP was characterized by high costs **Williamson barriers associated to the transaction.** This barrier in the case U-I context of is associated to the costs of information, negotiation and enforcement associated to pursuing an IP-related transaction (Tung, 2023). Academics and industries follow different rules from their respective institutions and might not be aware of the different procedures when collaborating with industry as emphasized by one Manager from a SME:

"Academic researchers aren't always aware of all the contractual, financial and other aspects. So, if there's someone to defend their interests, it's all the better for them. I think that the work of raising awareness and providing information on the various stages can be stepped up, precisely to avoid the frustration." (TT-I1).

As suggested by the initial conceptual framework, we found that the TTOs was the only one able to cope with these barriers. Because they represent the universities and school's administration regarding technology transfer, they are therefore very knowledgeable about the administrative and legal procedures. The TTO used tools to provide information quickly and in a synthesized way for academics and industries as emphasized by this quote:

"On our site, there is what we call a researcher's guide, with sheets that are really dedicated to this. A researcher's guide where we explain that, what is the valorization, what is the intellectual property, in which conditions you can valorize your results, and so on. It is quite well done. Under what conditions can you create a start-up? […] We also have small brochures that we give out at trade shows." (TT-2)

TTO also reduce costs of negotiating as they facilitate the contracting phase for companies and puts restricting rules to academics to ensure that actors stick to the agreed objectives in turn reducing costs of enforcement: *"Our goal is to adapt and streamline the contracting process, making it easier for companies."* (TT-2); *"Every year, a meeting is scheduled to see if they are doing everything possible to exploit the product"* (TT-1).

4.1.3. The incubator as an 'agile' intermediary for academic entrepreneurship

When valorization took form of a start-up, the incubator took the lead. As predicted in the conceptual framework, this channel depicted important **Merton barriers**. Tensions may arise as actors may not be aware of academic or market logic, as one interviewee mentioned: "*He/She completely neglects all the business and market aspects: it is somewhat complicated for them (academists) to consider aspects other than the technical and scientific ones."* (IB-2). We observed that the incubator used two main activities to reduce this barrier. First, they offered tailored training both for the academics and industries to bridge their knowledge gap as emphasized by these quotes:

“It’s a 9 months training courses [….]. The goal is to give pure scientists, for example, an awareness of the business model, all the techniques for developing an innovative project, finance and so on, to give them the basics to be able to get into entrepreneurship, and conversely, for pure businesswomen or businessmen, to give them knowledge about the market and regulatory constraints for launching new medical device or things like that.” (IB-A1).

“We often show them examples of startups, how they got from point A to point B, and why this is important. We also offer in-house training, not just in the start-up program. Training courses are offered throughout the year on a number of themes: on the market, on financing, and also with experts.” (IB-2)

“Following the trainings has really taken me out of my role as a scientist and put me in a different position. Instead of pushing our technology to the market, I focused on defining our product based on the needs of future users. That, was big change for me.” (IB-I1)

Second, the incubator also relied on organizing targeted events such as networking events for entrepreneurs to facilitate sharing information and entrepreneurial experiences. In fact, sometimes, meeting other people who had more experiences and were more advanced in the creation of their start-up helped them getting valuable insights and feedbacks for their own journey. They also organized events to facilitate the matching process between academic project holders and CEOs who will take over the project to bring it to the market.

“We also do networking events and it's an opportunity to meet other people and see what they've really done. Sometimes they can say that they are right. We are only a business manager on a theme and we don't necessarily know everything about it. So, it's good to meet other people or even to meet experts who are specialized in the field during meetings.” (IB-2)

“There is an event called the CEO Academy in which business developers present the project and state that they are looking for a CEO or a CTO and if the profiles are interested, they come to the business developer who then connects them with the project leaders." (IB-2)

However, as not stipulated in the initial conceptual framework, we observed interestingly that the incubator maintained closed relationships with other intermediaries to support the process of start-up creation. It relied on other intermediaries to further enhance the process on specific aspects.

The TTO was still involved in the start-up creation process. This follow-up stem from the actors' desire to see the projects succeed*: "We want things to go well, so we're working in partnership with Eurasanté, in particular the incubator"*. (TT-1). The TTO was an active member of the jury committee when projects are selected for start-up creation. The incubator relied on the TTO's expertise on the scientific and technological aspects while the incubator gave more insights to the business aspects. These can reduce potential misalignment of views between partners, and therefore contribute in reducing **Merton barriers.**

> *"Often, they know in advance that a project they've already seen is going to be presented to the commitment committee, and I've already had a discussion with the committee members where the TTO colleague was going to clarify the purely technological aspect. And vice versa. Because we're always very transparent with the other members of the committee." (IB-1)*

The incubator was also in touch with the innovation agency and redirected entrepreneurs to trainings and events offered by the innovation agency that can also help them on other aspects for building their startups. The innovation agency offered complementary knowledge that the incubator doesn't offer such as trainings on broader subjects. These trainings were not related to the business aspects of creating a start-up but on more general topics and fundings schemes. Hence, the incubator relied on the innovation agency to reduce some of the **Williamson barrier associated to search and information**. As two managers of the innovation agency and incubator stated:

> *"As part of the incubation process, they are supported by people whose job it is to support startups. And we come in to organize more global, more general training courses." (IA-1)*

> *"The incubator will inform incubatees about the training courses offered by HDFID, either in terms of training or the FRI scheme (regional subsidy*

for innovative company founders). Because when it comes to business plans, we provide in-house support. But there are very specific things that we don't necessarily have. I remember, one year they did a crypto training course. We don't do crypto, it's too specific for us to spend resources on training for that." (IB-1)

Finally, the incubator collaborated with the RTO to help leverage **Polanyi barriers.** This happened when the start-up required scientific expertise from the RTO (specialized in e-health and biosensors) or that the technology came from this lab. The incubator and the RTO developed agreement in which the start-up could be incubated within the RTO while continuing to benefit from the services provided by the incubator. Being in the same facilities as the academics where they conduct experiments in their technical spaces facilitated understanding of practical know-how of the technology. Academics could easily offer consulting on specific aspects. And being in the same place facilitated face-to-face interactions, informal communication and serendipitous learning which help absorb tacit knowledge associated to the technology. Being incubated in the research lab is also what enabled the industries to inform the academics on the commercial advancement on the start-up, leveraging **Merton barriers.**

"When we created the company, the goal was to benefit (from being with them). They are the ones who developed techno, so at the time they knew better than me or anyone else. And the idea was to stay close to all these thinking heads in case of a problem. And we did well, because at the very beginning we had a lot of problems to solve: technical or algorithmic, or clinical for that matter. And the fact of being in the same corridor as the research laboratory, well that allowed us to push a door and then to have the answer of a professional and a specialist of the subject immediately in fact." (RT-I1)

"And so I took the time to explain it to them, to re-explain it to them, and draw very simple diagrams to explain to them that without it [fund raising], we're dead, there's nothing left and so their baby is dead. Because it's their baby too." (RT-I1)

To resume, we can see that for commercial transfer, we have two models of coordination, either a single intermediary for leveraging Williamson barriers in transfer of IP and a multiple-intermediary model for leveraging Williamson, Merton and Polanyi barriers for academic entrepreneurship.

4.2 Co-production channel

4.2.1. The multiple intermediaries' phase

Co-production represent different types collaborative projects such as joint research projects, or projects such as open-innovation projects or projects involving students. Similar as in commercial transfer, these projects may induce different intermediaries and coordination.

In structured co-production, we found that **the incubator, the innovation agency the cluster** were involved in the first phase of setting-up collaborative projects to leverage Williamson barriers. They collaborated on tracking and monitoring calls of projects at different regional levels: regional, national and European and informing potentially interested academists and industrialists.

The cluster and incubator had different expertise regarding the type of projects, while the incubator was more specialized in setting up regional projects, the cluster was more specialized in national and European projects as mentioned by the Technology Transfer Manager of the Incubator:

> *"They (the cluster) are more trained in setting up projects, whether European or national. So, they'll be more involved in setting up hard-core projects, structuring, articulating and designing work packages. Choosing the right indicators and where to place them. Quite often we work in pairs, and it's the same with my colleagues in the Cluster. We work in pairs, and that enables us to have complementary expertise and work in synergy."*
>
> *(IB-1)*

4.2.2. CRC as a single intermediary for joint research projects

One of these calls of projects could lead to the development of a CRC agreement. Such agreements allowed actors who had previously collaborated to pursue and formalize the collaboration in a longer time-frame.

As predicted in the initial model, **Merton barriers** were prominent in these collaborations: tensions regarding information disclosure or having different temporalities and different interest in the orientation of topics were recognized to be a barrier in both as emphasized by these following quotes:

> *"Although we share the goal of developing a product to meet a clinical need, we don't have the same constraints, our approaches are different. Communication of results is nearly impossible or very limited in industrial projects where confidentiality is crucial." (CR-A2).*

> *"A company aims to achieve a return on investment as quickly as possible. Thus, companies are always keen to try out solutions, with "go-no-go" decision points occurring very swiftly, and it can be quite frustrating to abandon explored avenues when the industrial partner demands results to determine whether the avenue is applicable or not." (CR-A1).*

As predicted by the initial model, we found that the CRC contributed to reduce Mertonian barriers trough a bounding contract and agreement. This framework was jointly built by both academic and industry. In this document, actors defined the research areas and topics to investigate, the milestones to achieve, the financial resource and recruitment needed, as well as the management of the IP. This framework is jointly produced which necessitate communication and exchanges. This document offered a standpoint to avoid potential conflicts about orientation of the projects and disclosure policies.

> *"It is important to plan the project from the beginning and be aligned with the milestones to be achieved, as well as ensuring that the scientific project is in line with the company's strategy". (CR-I1).*

> *"We organize meetings where we gather everyone around the table so that everyone can speak. And these moments are very important to prevent any risk of distorting the message. That means that if there's a desire expressed by the top management of the firm, it's communicated directly to them. They hear directly what the top management wants or thinks for this collaboration, and it allows us to react immediately together and agree around the table. This allowed us to fine-tune things a bit, to build the project for which all stakeholders truly feel a total commitment."*

During the first step of setting up the project, we found that the coordination team of the CRC relied on the expertise of the legal department of the universities but not the TTO to enact it. This shows that the CRC still relied on the expertise of an external

“So, in fact, when we drew up this contract, we called on the support of the university's legal department, which assists the research teams we work with. We don't necessarily have this expertise in-house, so they helped us draw up the contract.” (CR-I2)

Moreover, the CRC allowed the pooling of human and material resources, this facilitated meetings and interactions which can contribute in leveraging to some extent the **Polanyi barrier.**

“The fact that people can meet each other because there are collaborators on site, it's always better to meet and exchange. There allows for the systematic application of one or the other in research programs when we want to initiate something new or to continue a program. And there, the research strategy is defined on both sides.” (CR-I2)

These meetings are very important as they allow avoid risk or misrepresentation of words and meanings” (CR-I1)

4.2.3. The cluster as an ‘agile’ intermediary for other innovation projects

These projects are co-innovative projects including multiple partners such as staff from the hospital. The goals of such projects is to produce prototypes related to healthcare.

The Cluster relied on its network to bring together actors to collaborate on these projects, especially firms-members. This allowed to reduce the Williamson costs associated to search for partners. Moreover, the Cluster also relied on the Science Park’s network to attract further members in the projects such as the staff from the university hospital, representative associations of patients or doctors, as well as start-ups to further diminish these costs.

“But we're a network, we're here to set up collaborative projects of this type, to bring companies together or put them in touch with the hospital, typically. So we were also able to draw on the Park’s expertise and knowledge of the network.” (OP-2)

Moreover, during the projects, it happened that the expertise of an external actor was necessary, the team relied on the Park for their expertise or for identifying the right partner. For example, one of the participants mentioned that that RTO got involved to bring solutions to some of the technological problems they encountered.

> *"So, for example, if a member is looking for staff, we refer them to the eurasanté HR team. If they need to raise funds, we pass it on to the eurasanté finance team and vice versa. We'll orient and guide members according to their needs and the services they can offer in the health sector." (OP-2)*

As predicted in the initial model, these projects were characterized with **Polanyi barriers and Merton barriers.** In order to reduce these problems, the Cluster relied on the expertise of the **Open-Lab team.**

Problems of language can be strong in these projects because they involve individuals coming from different sectors and environments. One of the coordinators explained that specialists coming from legal and technological environments had different terminologies and connotations about common words. This disparity also increases with users, for whom many of the language used was too technical or needed more clarification.

As predicted with the initial model, the IO facilitated the knowledge co-creation process through different actions which leveraged Polanyi barriers. They split the participants into different small working groups, this can facilitate the exchange of knowledge and experience. They gave them a framework and deadlines to follow and they made sure that everyone was participating. They also animated and coordinated groups. *"We had identified within the working groups, a kind of referent who naturally had knowledge on such or such subject and thus was our privileged interlocutor. This served us well because we did not have a scientific or technical profile in the team"* (CL-2).

They also facilitate the learning process by making information more accessible, using place-based for experiential learning. The open-lab in our case organized the prototyping phase with all stakeholders through workshops and visits at the place of expertise:

> *"Prototyping was done at their place because they had workshops directly in live, so they welcomed the groups to make the tour and made several*

protos in a row to show us little by little and then coordinate […]. There was an interest in having it done in a company that had specialized expertise. For example, if we had done this in a fablab, it would not have been very interesting for this type of project. […]. You don't make a hospital bed with a 3D printer, it didn't make much sense." (OL-A1)

These projects were also characterized by **Merton barriers** as emphasized by this manager: "In fact, the first problem we encounter with these partnership projects is one of timing. The second problem is one of language. The third problem is the convergence, or rather articulation, of the interests of each family of stakeholders." (OP-3).

To open-lab team contributed in leveraging Merton barriers by acting as a neutral actor that could mediate the relationships among stakeholders and coordinate the discussions working towards a common goal.

"The fact that we were a neutral actor, a non-profit association that was there to coordinate all the groups and set the pace of work, it helped a lot. Later on, when we stepped back to let the companies work together, that's when it became more tense, precisely because they were no neutral actors to arbitrate." (CL-2).

"This is the common goal for everyone, and each person must play their role at the right time, just like in a grand philharmonic orchestra. Therefore, it is necessary to formalize this common goal; it must be co-created. And this falls under the skills of the project manager, following co-design methods." (OP-3).

To sum up, co-production also requires different expertise at different steps of the projects.

4.3 Informal and network exchanges: leveraging *Arthur* barrier

Being part of networks for academics or industries is essential as they will have opportunities to collaborate and learn about other topics. We propose a novel barrier to understanding how IOs can facilitate UII through informal and network exchanges. Networks rely on active participation and exchange among members. However, joining the right networks and coordinating them can be challenging, reinforcing barriers to the relations. For intermediaries, having under-used networks can be inefficient. We term this type of barrier “Arthur” barrier. As first coined by W. Brian Arthur (Arthur, 1989, 1990, 1996).

This barrier is slightly different than Williamson barrier because it goes beyond the matching and scouting process of finding the right partner to address or collaborate with.

One of the underlying mechanisms that can differentiate the two is that Arthur barrier create network effects. Network effects happen when a product or a service is more valuable to its users as more people use it. (Katz & Shapiro, 1985). The value of the IOs is linked directly to the number of people using their services. For example, Cluster through label collaborative projects sends an excellent signal to the actors. However, without people wanting to collaborate in the first place, labeling collaborative projects becomes useless. Clusters depend highly on people wanting to collaborate but also on the number of collaborations. Therefore, clusters are prone to attract people to join and stay in their network; this is done through cluster membership. Furthermore, they also make participants interact with each other to increase the value of the network through events.

Although we found that the incubator used their networking function, we find that that some actors go further and seem to have the capacity to scale their networking function to a large number of actors. The **cluster and the science park** were able to foster interactions between academics and industries by creating and animating a myriad of events open to all participants or tailored to some only. For example, creating diverse and frequent events and meetings as emphasized by the Coordinator of Innovation Agency and Innovation Park: *“We create a lot of animation in fact, we create a spirit of promotion, we create animations, very regular meetings. We organize about 350 workshops a year, which is a lot […]. It is really about creating R&D collaborations and relationships, about bringing the academic and industrial worlds together. Maybe transfer, licensing.”* These can be events include after-work events, speed-dating, workshops on a specific subject, bigger events such as business conventions. These events provide opportunities for first contact between academics and industries which can further lead to university-industry collaborations as emphasized by the Manager of the Cluster:

> *"There is a lot of word of mouth, particularly regarding our labeling service. Many academics actively seek our label for their projects. And one thing leading to another, by discovering us through this labeling process,*

they realize that we are a network that allows them to exchange with industrialists, and so on, and this strengthens the links."

"We often act as the spark that ignites collaboration, such as when an industrialist expresses interest in an academic's project and initiates discussions for future collaboration. If the interaction progresses positively, they may return to us for funding." (CL-1).

Moreover, these events were also a way to connect students from universities with industries. The **science park and the incubator** organized events such as Hackatons and frequently organized visits in schools and universities to communicate about their innovating in the health sector and their missions

"HIBSTER or DIPSTER, enable companies in the health, nutrition or Deep tech sectors to be supported for 48 hours or for a given period of time on the principle of a hackathon, in fact, and to benefit from an outside viewpoint in relation to our problem. In fact, students come and work on their problems for 48 hours or 2 months. The advantage of this event is that the company gets a really different, fresh look at its project." (IP-2)

"Throughout the year, my role is to go into the schools to promote the health sector, to raise awareness of the health sector among students, simply to demystify it and show them that the health sector doesn't just recruit scientists, but that we need all kinds of skills to bring a project to fruition, whether in the digital, commercial, design, engineering or other fields."(IP-2)

Overall, these events were fundamental in initiating contact for first collaboration but in enabling already collaborating actors to enter and benefit from their network: connecting with other actors that can help scale up their projects such as SME or bigger companies, other entrepreneurial support organizations like business angels or venture capitalists which provide fundings or simply other intermediaries.

4.4 Improving connectedness and efficiency among intermediaries

What we also found interesting was the role of the innovation agency as an overall animator or 'orchestrator' of the intermediaries in the ecosystem. The innovation agency can act as a first main front door for many actors who want to start an innovation journey, especially for first-timers. The innovation agency can act as a "marshalling yard" or a "museum guide" and redirect them to the appropriate intermediary according to their sector or project. This step is crucial as it enables a first acculturation to the technology transfer ecosystem. They also provided digital support services to improve visibility of the activities of the intermediaries. They provided digital tools such as databases with varying information on the start-up creation process of all start-ups in the region. These facilitated the follow-up process and avoid potential unnecessary overlaps as actors could easily access information on where the start-up was incubated, by who and when. In the same line, they give much attention in tracking events of all intermediaries in real time and informed the actors of potential overlaps. Their communication service centralized all the events of all intermediaries on their website.

Moreover, the innovation agency was involved in making consistent the different roles of the intermediaries. This was done in several ways. First, as an organization that acts close to the regional Council, the agency is responsible for coordinating regular meetings with the directors of intermediary organizations to develop a common innovation strategy. Moreover, they provided trainings open to the managers of the intermediary organizations to improve their knowledge and management skills. These trainings allowed managers to acquire and update the necessary skills for their supporting start-up or setting-up projects.

> *"The new business models, for example, the challenges of artificial intelligence, how to present a project to finance a fundraising, how to set up a European project. How to help a company set up a European project and succeed? These are super important topics. So, it's a bit about all these things that allow us to improve skills in terms of advising and supporting businesses. We are indeed trying to raise the level of support." (IA-1).*

It was also mentioned how important it was for actors to have the ability to identify to rely on during the process:

> *"At each stage of the project, the person accompanying the project, it's their skill to identify the right levers to activate for the company to grow. There are indeed connections with financial organizations that come into play at a certain point in the life of the company. Or at the legal level or at the at the technological level, there might be a technical center or a lab to*

commission because there's an issue, etc. So, it's a very, very important responsibility of the person accompanying the project." (AI-1).

And third, they animated different networks in which intermediaries such as the TTO, various Clusters and Innovation Parks as well as the universities are members. These meetings were crucial to centralize information and share experience which in turn facilitated how they can better work together as emphasized by this quote:

"Because the more people know each other, the better they work together. And what does that mean? It means they address each other informally, they're able to pick up the phone and call each other right away. Oh, you've been in the company, I see, on your profile, I see that you've been in the company. What did you see that I didn't? Do you think if I go there I'll learn more than you did? So we are a facilitator in this." (AI-1).

Finally, we found that communication was key in facilitating collaboration and follow-up processes between intermediaries. This was enhanced because intermediaries in the region knew each other really well and got along as supported by the technology transfer manager of the Innovation Agency: *"The fact of knowing each other simplifies exchanges a lot as well. Even if we share the same objectives, we don't have exactly the same expertise, so it's really about trying to work in good harmony, hand in hand, you know."* (IA-2). We also found that academics and industries were well involved with the activities of IO. For example, several academics or industrialists of our sample were part of board members of either the Cluster, the incubator or the innovation Park. We believe these institutional links also reveal already close relationships and involvement of U-I collaborations in the health sector.

5. Discussion

Our study contributes to enhancing our understanding of how multiple intermediaries can jointly facilitate U-I interactions by leveraging different barriers. Combining the conceptual model of Chapter 1 and the inductive findings, we were able to slightly open the black box of when and how IOs complement each other. We summarize our results in **Figure 5.** Because we studied IOs in the same regional context, we gained insights on how intermediaries can all be involved throughout the collaboration process and work together. The actors take turns in different activities throughout the whole innovation process and seemed to be aware of each of their particular roles.

During the initial stages of University-Industry Interaction (UII), various Intermediary Organizations (IOs) typically collaborate, a phase we term the "***multiple intermediary phase.***" In this phase, the Williamson barrier often holds significant importance, more specifically intermediaries need to work hand in hand to reduce costs of search and information. As the collaboration between the university and industry progresses and demands more specialized expertise, a shift occurs where one intermediary assumes a leading role. This leading intermediary may operate independently, typically because it possesses unique expertise, a model referred to as the "***single intermediary model."*** This was the case for patenting where the TTO is the only one that can assume leveraging Williamson costs associated to the transaction. Alternatively, a single intermediary may also collaborate with other partners to complement its expertise in specific areas of the UII, leading to what we term the "***agile intermediary model."*** This is in line with recent study of Hernández-Chea et al. (2021) which shows that incubators source other partners to rely on their skills and resources, or the study of Abi Saad et al. (2024) which show similar results for a living-lab specialized in diffusing digital technologies in healthcare. The fact that intermediaries work together to leverage different barriers bolster the idea that knowledge and technology transfer between university and industry is a complex and long process which requires pooling resources and specialized skills. Creating an academic spin-off is a long road strewn with obstacles, which require the help of different supporting actors, which in turn may inevitably require their coordination to ensure its success.

Moreover, in line with the initial conceptual framework, we do find that intermediaries have overlapping functions and face the same barriers as illustrated in **Table 11**. However, we argue that these are not necessarily bad. Intermediaries can jointly reduce a common barrier in the same channel by joining their forces and different expertise on the same activities. This indicates that IOs possess inherent capabilities for effectively addressing specific types of barriers, which are recognized and valued by other stakeholders and are actively employed throughout the University-Industry Interaction (UII) process. The incubator relied on the RTO because it is good in leveraging Polanyi barrier. The cluster relied on the open-lab to leverage Polanyi barrier. However, the efficacy of this collaborative dynamic is likely to depend on the ability of the main intermediary to activate these complementary skills and on how well the entities are well connected. We show that this is possible through leveraging what we term Arthur barrier which increase overall connections among all stakeholders, but also though the coordinating role of an entity, in our case the innovation agency, acting as a meta-intermediary coordinating and facilitating interactions between IOs.

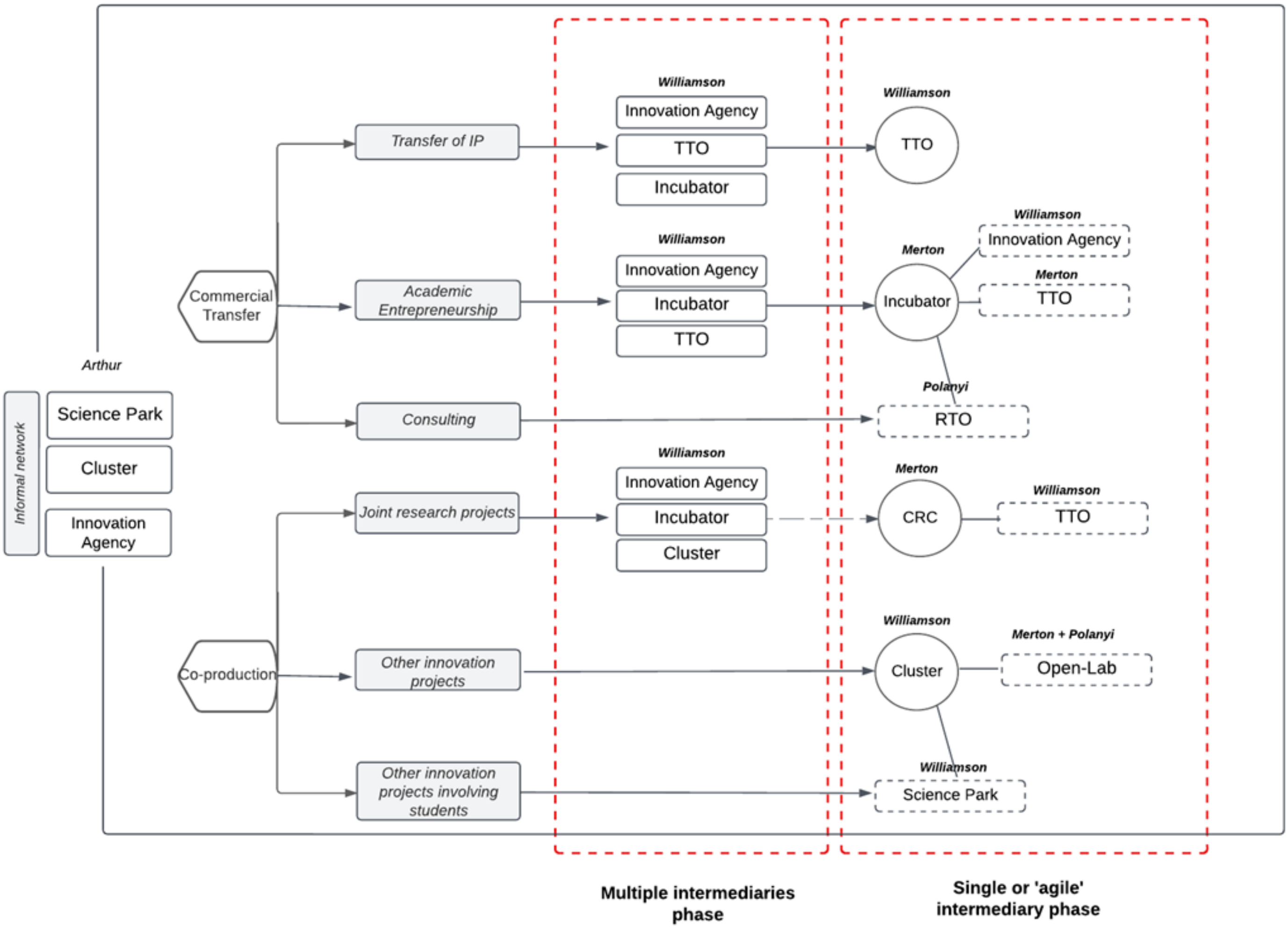

Figure 6: General framework of results.

***Source:* Own elaboration.**

	Interactions	Williamson (relations)	Williamson (transaction)	Merton	Polanyi	Arthur
TTO	Transfer of IP	Scouting and matching	Explain procedures, negotiate contracts ensure follow-up and deadlines	-	-	-
Incubator	Academic entrepreneurship Joint research projects	Scouting and connecting the right actors	Explain steps and procedures of start-up creation, Helping setting up projects	Provide trainings, Create networking events	-	-
CRC	Joint research projects	-	-	Enacting bounding contract for defining objectives	Offering pooling of human resources	-
RTO	Academic entrepreneurship, Consulting	-	Enacting contract for IP shares	Offering incubation space	Offering incubation space, consulting expertise	-
Open-lab	Other innovation projects	Connecting the right actors	-	Acting as neutral actor, Coordinating the working groups towards common goal	Relying on different expertise, Offering place-based experimentation	Create networking activities
Cluster	Joint research project, informal	Scouting, connecting the right actors	Helping setting up projects	-	-	Create events, animation for members
Science Park	Informal, other innovation projects	Connecting the right actors	-	-	-	Create events and animation
Innovation agency	Academic entrepreneurship, informal	Scouting, connecting the right actors	Helping setting up projects	-	-	Improving connections between intermediaries

Table 13: Functions of IOs and their degree of involvement
***Source:* Own elaboration[59].**

We contribute to the literature on university-industry intermediaries for several reasons. First, we contribute to the on-going debate of having too many "multi-layered structures" doing the same thing in the context of science and industry. In line with the study of Villani et al. (2017), we find that different intermediary organizations (IOs) have varying abilities to address specific barriers in university-industry interactions. We go further not only include a wide array of intermediaries but also investigate on they may interact and coordinate during this process. We generate a framework to better understand their level of coordination.

We also account for barriers that are perceived by both academics and industries (D'Este, Iammarino, et al., 2012), not only from the company's side (Alexandre et al., 2022). We also account for another barrier, Arthur barrier, which allowed us to capture the specific roles of Science Park, Cluster, Innovation Agency, Open-lab, and how they compare to TTO, Incubators and CRCs.

This study also offers a first standpoint for understanding the interactions of multiple diverse intermediaries. Although applied in the science-industry context, we believe that it can provide avenues in other contexts and other sectors, such as firm-to-firm relationships or Triple-Helix relationships, where innovation intermediaries come at play.

6. Implications

Our results in **Figure 5** show that IOs complement each other *between* type of interactions but also *within* type of interactions.

This research brings several implications for policies but also for all the actors involved. Our analysis shows that each IO has a specific role and that their combined efforts can make technology and knowledge transfer easier. In fact, accounting for these differences is of major importance as policy makers might wrongly assess their roles by looking at outcomes variables

[59] This table was created based on the coverage and number of quotes coded according to barrier and intermediary type. Darker blue indicates that among the four identified barriers for one IO, the occurrence of quotes associated with this barrier was higher than in the others. Blank space indicates either explicit mention that the problem didn't occur or the absence of functions associated with overcoming this barrier.

such as the number of patents or number of spin-offs. Such measures do not adequately capture how they differ in achieving these goals.

Hence, we advocate that while reducing the number of intermediaries might not necessary be the right solution, we advocate that our study could help in signaling better the different roles of these organizations to the ecosystem's stakeholder. Our study could help in building maps by region of the diverse existing intermediary and of their roles. For universities and industries, this can also help foster new channels by acknowledging that diverse organizations can support them, not only TTOs. Overall, our work could help managers of intermediaries position themselves better and also communicate better how they differ from one another and hence improve how they work together.

Moreover, as we attempt to grasp the 'connectedness' of the ecosystem through the animation role of the innovation agency, this poses the question of which entity 'orchestrates' the coordination of intermediaries and how it can be explained. We believe that our approach in a regional context helped studying connections between universities and industries but as well between supporting actors and gives more ground for developing ecosystem-level approach to UII.

Our analysis acknowledges certain limitations and considerations. First, we concentrated our study on the health sector within one specific region, allowing for a selection of various intermediaries. This region has been investing substantial effort in building Innovation Poles in diverse sectors. The health sector was one of the first to be developed and stemmed from historical collaborations between public and private which took place in the 90's. This explains why we find that actors are well connected in this sector. We understand that this scenario might not be reflective of regions with other historical contexts. Nonetheless, we believe that for this reason, the Hauts-de-France region can yield significant insights in how they are achieving knowledge transfer.

Another limitation pertains to the selection of intermediary organizations (IOs). The choice of IOs is based on predetermined types outlined in the conceptual framework, potentially introducing selection bias and disregarding other IO types that may have distinct roles or experiences in reducing barriers. In order to detect any similarities, there should be investigation in sectors other than in the health sector as barriers and intermediaries might slightly differ. For example, the way universities and industry interact in the digital sector is likely to be different: actors might be more prompt to open collaborative projects which is likely to involve other intermediaries such as open source consortia (Perkmann, 2015). Moreover, in line with De Silva et al. (2018), we argue that there is no single 'ideal type' of innovation intermediary, and that each must be tailored to its innovation environment. In our case, academics in the research labs in the health sector seemed to 'culturally' close to the industries as they already worked closely with clinicians and responding to the needs of the hospital. Although our work echoes the work of Vilanni et al. (2017) in the Italian settings, this calls for investigation in other European contexts, and in regions where proximities between actors may be less strong.

In the same aspect, it is crucial to emphasize that not all organizations categorized as TTO or incubator or CRC (or others) operate uniformly or yield equivalent outcomes. There may be considerable variability in their functions. For example, some regions with higher competition might have multiple incubators operating in the health sector, which increase the risks for potential overlaps. We propose that the degree of heterogeneity of organizations of the same category could be better understood trough this lens of studying barriers and how they manifest in various forms.

Finally, our study adopts a qualitative and exploratory approach through a case study methodology. The study aimed at gaining insights rather than generalizing the results to a broader population. Our work could be complemented by empirical quantitative analysis. Taking an ecosystem view calls for the constitution of extensive databases, which includes different IOs. We suggest researchers get closer to IOs as many actors have developed collaborative tools for members to share and mutualize information.

Conclusion of Chapter 3

Through our empirical investigation of the health sector in Hauts-de-France, this chapter provides concrete evidence for the theoretical propositions established in Chapter 1 while revealing new insights about intermediary collaboration. The identification of the "Arthur-type barrier" adds a new dimension to our understanding of the challenges in university-industry interactions and allow us to refine our model. The analysis of 36 interviews across eight types of intermediary organizations demonstrates that these entities don't operate in isolation but rather form complex collaborative networks to address multiple barriers simultaneously. The patterns of coordination identified vary based on both interaction channels and barrier types, suggesting a dynamic and adaptive intermediation ecosystem. These findings not only validate our theoretical framework but also extend it by highlighting the importance of inter-intermediary relationships in facilitating effective university-industry interactions.

While Chapters 1-3 examine intermediary organizations at the macro and meso levels—through theoretical frameworks, historical evolution, and organizational interactions—a crucial dimension remains unexplored: the human element. Chapter 4 zooms in to the micro level, examining the individuals who actually perform intermediation work. This investigation into the skills and backgrounds of intermediary professionals helps us understand how the theoretical functions and collaborative patterns identified in previous chapters are implemented on the ground.

CHAPTER 4

ONE STEP BEYOND: AN EXPLORATION OF SKILLS OF U-I INTERMEDIARY PROFESSIONALS

Summary of Chapter 4:

This study investigates the skills and backgrounds of employees working in university-industry (U-I) intermediary organizations in France. Using survey data from 214 professionals across five types of intermediaries - Technology Transfer Offices (TTOs), Academic Incubators, Clusters, Research and Technology Organizations (RTOs), and FabLabs - we examine how skills along with educational level and experience vary across different intermediary types and activities. Our findings reveal that while generic skills like management and networking are universally necessary, the balance between generic and specific technical skills varies by activity type and intermediary organization. Specific skills drive specialized activities like licensing and R&D projects, while generic skills are crucial for networking and informal exchanges. Each intermediary type shows distinct preferences in skills and educational backgrounds that align with their core functions.

Keywords: technology transfer professionals, skills, background, U-I intermediaries

Table of contents for Chapter 4

Chapter 4: One Step Beyond: An exploration of Skills of U-I Intermediary Professionals[60]

1. Introduction

As shown in previous chapters, facilitating knowledge and technology transfer requires a myriad of actors intervening and acting at different levels. While the literature has focused extensively on the organizational aspects of these organizations, such as their functions, activities, and missions (Agogué et al., 2017; Albats et al., 2022; Caloffi et al., 2023; Howells, 2006; Santos et al., 2023; Villani et al., 2017), our understanding of the individuals operating within these organizations remains limited. This seems paradoxical, as individual-level characteristics are recognized to play an essential role in the university-industry interaction (UII) literature (Perkmann et al., 2021). For example, literature has investigated profiles of scientists (D'Este, Mahdi, et al., 2012), and their motivations to engage in UII (D'Este & Perkmann, 2011; Lam, 2011). However, little is known about the individual characteristics of employees of intermediary organizations (IOs). As shown in previous chapters, these organizations have different functions to facilitate UII. Therefore, we can imagine that organizations with different functions also reflect disparities in the skills of their employees.

Investigating the skills of IO employees is relevant for several reasons. First, appropriate skills enable employees to perform their jobs better and achieve their objectives, enhancing organizational performance. Second, well-developed and adapted skills can provide better support in facilitating UII. Therefore, exploring the skills required for these professions is pertinent for training and employment.

It is recognized that different skills are required for different aspects of knowledge transfer (Cunningham & O'Reilly, 2018). Research acknowledges that effective technology transfer requires intermediaries to master both "hard skills"—such as technical knowledge and IPR expertise—and "soft skills", such as commercial awareness and networking abilities. Nevertheless, our understanding of these skill requirements remains incomplete.

[60] Chapter written alone. This Chapter was submitted to present at EURAM Conference 2025 in June, Florence.

Three key limitations emerge from the current research. First, studies predominantly focus on Technology Transfer Offices (TTOs), neglecting other types of IOs. Second, research beyond TTOs is fragmented, lacking the systematic approach needed for meaningful comparisons. Third, findings about required skill sets and their diversity across intermediary organizations remain scarce and scattered.

Therefore, the skills of U-I intermediaries remain an understudied topic. Both comprehensive theoretical frameworks and empirical investigations are lacking, leaving a significant gap in our understanding of how different skills vary across various organizational contexts.

Therefore, this study aims to address the following research questions:

What are the educational and professional backgrounds of individuals working in U-I intermediary organizations?

How do their skills vary across activities and from one organization to another, and why?

To address these gaps, we conducted a novel survey of employees working in five types of intermediary organizations at the national level in France: TTOs, academic incubators, regional clusters, RTOs, and FabLabs.

This study makes several contributions. First, we investigate the skills of professionals working across various intermediaries, not only TTOs. Literature has emphasized that TTOs are by no means the only intermediary that facilitates UII (Villani et al., 2017, Santos et al., 2023). We identify the different range of skills through the literature, underscoring their varying use in different U-I activities and intermediaries. Specifically, we investigate the balance of managerial, business, and relation-building skills (soft skills) versus technical and innovation driven skills (hard skills) and highlight which are more important for each activity. Second, we identify how they differ across different intermediaries. To further these analyses, we link the activities in which they are more specialized with the set of skills necessary per type of intermediary, reflecting their specific functions and roles in facilitating university-industry interaction (UII).

Third, this study provides novel empirical insights into the characteristics of innovation intermediary professionals in France's national innovation system. While most research on technology transfer professionals has concentrated on mature innovation ecosystems, particularly the United States and Canada through AUTM[61] surveys (Mom et al., 2012), the French context offers unique research opportunities. France's innovation landscape developed approximately two decades after the United States, and its current ecosystem has drawn attention from policymakers who note the complexity and potential redundancy of research and innovation structures. Through a comprehensive survey, our research examines the roles, skills, and activities of professionals across different intermediary organizations. This analysis helps identify both overlapping functions and distinct specializations among intermediaries, contributing to ongoing policy discussions about optimizing France's innovation support system.

The paper is structured as follows: Section 2 reviews and elaborates on the skills necessary for facilitating UII and highlights what the literature has said about the skills of different intermediaries, although not necessarily associated with the UII literature. Section 3 describes the methodology thoroughly emphasizing survey development and data collection. Section 4 presents the analyses and explains the findings. The last section concludes with a discussion of the results, provides implications, and highlights avenues for future research.

2. Review of the relevant literature[62]

Skills or *Competencies* encompass a combination of learned abilities, knowledge, attitudes, and behaviors that an individual displays in certain job functions or situations (Le Deist & Winterton, 2005; Mulder, 2007)[63]. These can be innate or developed over time. Examples include Critical thinking, leadership, and effective communication. The terms "competencies" and "skills" are often used interchangeably and vary across organizational contexts and domains (Le Deist & Winterton, 2005). While relevant bodies of literature could provide valuable insights, such as human resources management and educational sciences, the focus here will be primarily on the skills and competencies discussed in the context of technology transfer, science-industry relations, and innovation intermediaries.

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[61] Associations of University Technology Managers https://autm.net/

[62] We purposely omit to review the literature on intermediary organizations and U-I channels to avoid redundancy as it has been already developed in Chapter 1 and 3.

[63] The literature on human resources has emphasized that skills and competencies are different. While skill is like knowing how to use a specific tool effectively (example: programming), competency is knowing when and why to use that tool in a given context or situation. Competencies can be better suited in our context but we will not differentiate them for this study.

Technology and knowledge transfer are critical for translating academic research into industrial applications and societal benefits. However, as shown in previous chapters, these are challenging processes that require external organizations' facilitation. Intermediary organizations (IOs) pursue different functions to leverage different barriers (see Chapter 1). The literature strongly affirms that organizational success depends on human capital (Pasban & Nojedeh, 2016). This finding has particular relevance for innovation intermediary organizations (IOs), where individuals must possess specialized skills to facilitate complex intermediation processes. Our research examines these critical skill sets in detail.

2.1 Skills of TTOs

Most of the literature offering insights on the skills of employees in IOs focuses principally on Technology Transfer Offices (TTOs) and the link between human capital and the performance of these organizations. This stream of literature stems from concerns about the efficiency of TTOs and the criticism they have received since their creation (Chapple et al., 2005). Both monetary and non-monetary factors have been recognized as crucial determinants of TTO performance (Faccin et al., 2022). While several studies emphasize the importance of the size of the TTO, measured by the number of full-time equivalent staff (Chapple et al., 2005; Micozzi et al., 2021; O'Shea et al., 2005; Siegel et al., 2007), there is also evidence on the influence of the "quality" of these staff.

Research has shown that TTO performance, often measured through inventions, patents, and spin-offs, is significantly dependent on the expertise and educational background of TTO employees. TTOs are crucial in bridging the gap between academic research and commercial application. Research suggests that successful technology transfer professionals should possess technical expertise, business acumen, and interpersonal skills. Investing in full-time staff with specialized knowledge in law, engineering, and communication (measured as educational field and level) has enhanced the likelihood of generating revenue from patents (Leite et al., 2022). However, as TTOs expanded their activities to include the creation of start-ups, the required skill set has broadened to encompass a broader range of commercialization competencies, including opportunity recognition and business development (A. T. Alexander & Martin, 2013; Lockett & Wright, 2005; Siegel et al., 2007; Siegel, Waldman, & Link, 2003). Studies emphasized that TTOs often prioritize hiring individuals with expertise in patent law, licensing, or technical fields rather than actively recruiting those with marketing skills and entrepreneurial experience (Markman et al., 2005; Phan & Siegel, 2006). Deficiencies in marketing, technical, and negotiation skills (Siegel, Waldman, & Link, 2003) and business skills (Chapple et al., 2005) have been identified as potential barriers to TTO performance.

Recent studies have empirically investigated the importance of the diversity of these skills. The study of Kim & Kim (2022) and Soares & Torkomian (2021) found that along with research-oriented abilities to evaluate scientific inventions and legal expertise for managing IP and contracts, skills in marketing for identifying opportunities and commercializing technologies, typically possessed by staff with MBAs are also determinant. Similarly, Goble et al. (2017) found that directors with an MBA are more successful at obtaining invention disclosures than those with a doctoral degree, while directors with either a PhD or an MBA have greater success in promoting licensing agreements than those with a law degree.

In addition to the abovementioned skills, TTO employees require various soft skills to facilitate technology transfer effectively. These include communication, negotiation, networking, relationship-building, and commercial awareness (Mom et al., 2012; Sapir, 2021). Furthermore, Olaya-Escobar et al. (2020) highlight the importance of staff experience, sensitivity, and empathy as relevant dimensions in the success of technology transfer activities.

These results highlight that domain-specific skills are insufficient for these employees and that a diversity of skills and backgrounds are needed for TTOs, including business-related and soft skills.

2.2 Towards identifying the variety of skills across U-I intermediaries

As mentioned during this thesis, other types of IOs exist to facilitate UII; these include academic incubators that support early-stage start-ups, Collaborative Research Centers that foster joint R&D projects, consortia that bring together multiple stakeholders around a common research agenda, Science Parks that co-locate academic and industry partners, Clusters that promote innovation within a specific region or sector, and FabLabs that provide access to advanced manufacturing technologies..etc. Unlike the focused literature on the performance of TTOs, several papers identified that integrate skills focus on broader aspects. We will focus on the other intermediaries in our study besides TTOs: university incubators, RTOs, clusters, and FabLab[64].

[64] The selection of these intermediaries in our study is developed in the Methodology Section (Section 3.2).

For incubators supporting technology-based start-ups, we find several papers highlighting how managers' skills and experience influence the success of university business incubators. A key finding across studies is that managers' business and entrepreneurial experience significantly impacts incubator effectiveness. Fukugawa (2013), through survey data on Japanese incubators, shows that the technological skills of incubation managers are particularly beneficial for incubatees in science-based sectors. However, broader business skills are needed for other sectors. Redondo & Camarero (2017) also use surveys on Spanish and Dutch universities and emphasize that managers with business experience or "commercial logic" are more effective than those with purely academic backgrounds in providing comprehensive support, including business assistance, personal coaching, and networking opportunities.

Research Technology Organizations (RTOs) also rely heavily on their human capital to fulfill their mission in technology transfer and R&D collaboration with SMEs. The study of Albors-Garrigós et al. (2014) highlights the critical role of organizational structure and personnel policies in Spanish RTO performance. The authors use a field study approach of 14 RTOs in Valencia, Spain, and emphasize that successful RTO managers need strategy formulation, client monitoring and management, pricing and marketing, and human resource management capabilities. They also highlight that the ability of RTO employees to build relationships with clients, particularly SMEs, and to network with other research organizations is also crucial for the RTO's effectiveness. Zaichenko's (2017) study of 741 Russian RTOs emphasizes that managers must balance multiple objectives, such as maintaining scientific excellence while ensuring practical technology transfer and commercial viability. The study also highlights that successful technology transfer relies on specific expertise most effectively sourced from individuals with academic backgrounds.

The literature on the skills of managers in clusters is relatively scarce, and we found one study by Coletti, (2010). This paper examines the differences between science and technology (S&T) and industrial and service (I&S) clusters in terms of management requirements by analyzing survey data at the European level (n=107). Coletti finds that while both types of clusters share core requirements like sector knowledge and interpersonal skills (communication, leadership), the study reveals distinct patterns: S&T cluster managers prioritize international networking, English language proficiency, and R&D facilitation, whereas I&S cluster managers need a broader skill set encompassing various management tools (innovation, knowledge, quality), policies (regional, innovation), and project management capabilities. These differences reflect the varying nature of innovation and collaboration in each context - S&T clusters focus primarily on R&D activities. In contrast, I&S clusters involve a more comprehensive range of market-oriented activities across the value chain.

Literature regarding the skills of managers of Open-Labs initiatives was also scarce. The recent work by Osorio et al. (2024) proposes a comprehensive framework of the competencies required for innovation lab managers, incorporating hard and soft skills. Their model categorizes key competencies into four primary roles: facilitator (soft skills like mediation and intercultural understanding), maker (hard skills like interdisciplinary research methods and technology proficiency), visionary (soft skills like networking and entrepreneurial thinking), and manager (mix of research, collaboration and prototyping skills).

To conclude, while scholars recognize that innovation intermediaries require diverse skill sets—from technical knowledge to commercial expertise—the literature's narrow focus on TTOs and its fragmented approach prevents us from understanding how these skills compare across different intermediaries.

The existing research reveals some common threads - technical skills appear to be fundamental across intermediaries, and we also observe specialization patterns: the literature on TTOs mentions legal expertise, which is not identified for the other IOs; both TTOs and incubators emphasize technical and business experience; and clusters highlight policy understanding and communication skills. However, our ability to make systematic comparisons is limited. There are significant knowledge gaps regarding skill variations. While skills like networking and negotiation are documented for TTOs, their importance for other intermediaries remains an open question. Similarly, our understanding of educational background and professional experience varies considerably across intermediary types, with notable gaps for newer forms like Clusters and FabLabs.

The primary reason for these limitations is methodological: most studies focus on single types of intermediaries rather than comparative analyses, and no study focuses on variation across organizational contexts. The study of Mom et al. (2012) even found that organizational settings (university, company, or public research organizations) do not influence the importance of skills within TTOs. This TTO-centric approach again fails to capture potential variations across different types of IOs and their distinct functions.

We conduct an empirical investigation to address these gaps. Our study aims to provide this missing comparative perspective through a novel survey conducted at the national level in France, examining the five types of intermediaries. Using PCA and econometric methods, we will analyze and compare the background and skills of intermediary professionals across organization types and activities. The following section explains the survey development and collection in detail.

3. Data and methodology

This study employs a quantitative research design to investigate the skills of science-industry intermediaries in France. We developed and distributed a comprehensive questionnaire to employees of five types of intermediary organizations: Technology Transfer Offices (TTOs), Academic Incubators, Clusters, Research and Technology Organizations (RTOs), and a specific type of Open-labs. The following sections detail the survey development process, the sampling strategy, the data collection methods, and the analytical approach. We followed guidelines for developing the survey (Rea, 2014; Stantcheva, 2013).

3.1 Survey development

The development of the survey instrument was grounded in the review of the extant literature, which had been developed previously. The survey instrument was iteratively developed, incorporating the following key components:

Educational Background: Items designed to capture respondents' formal educational qualifications and disciplines.

Professional Experience: Questions aimed at elucidating the nature and extent of respondents' professional backgrounds.

Activity Types: Drawing on Mom et al. (2012), and our typology of the previous chapters, activities capture the type of university-industry interaction.

Skill Sets: As informed by our literature review, these skills should represent as many skills used by different intermediary organizations. More specifically, the identification and categorization of relevant skills were based on the work of Mom et al. (2012), which identified ten skills for technology transfer employees. We then supplemented this baseline with other relevant literature mentioned in Section 2.3 to capture the skills of incubators, clusters, RTOs, and FabLabs[65]. The final skillset included a total of eighteen skills.

In developing our survey instrument, I paid meticulous attention to several key aspects of questionnaire design to ensure the quality of data collection and the respondent experience to maximize the response rate. The approach encompassed the following considerations: the wording of questions, type of questions, length of questionnaire, choice of administration, and refinement (Rea, 2014; Stantcheva, 2013).

For the wording of questions, I crafted each question and asked for external reading to maximize clarity and minimize ambiguity. For the type of activities and skills, I defined what activities and skills referred to, and each option was defined. The definitions were inspired by the work of Osorio et al. (2024) and Mom et al. (2012). Especially for the type of skills, I inspire myself by the self-assessment approach used by Osorio et al. (2024). This approach uses anchoring phases to help participants rate their competence levels accurately to ensure understanding and avoid positive response bias. For example, item 1 was defined as *"I understand what the competence is and its importance, but **I don't use it at all** in my activities,"* and item 5 was defined as *"I understand what the competence is and its importance, and **I use it very often** in my activities."* (See **Appendix 14** to see the excerpt of the survey for activities and skills)

The survey also employed a variety of question formats to capture different data types. Each format was chosen: single and multiple-choice questions, Likert scales, numerical input, and open-ended questions. Most questions were fixed-answer to facilitate quantitative analysis and reduce respondent fatigue. For open-ended questions, information on how to structure the response was given. Some questions combined fixed answers with an "Other" option, allowing unanticipated responses.

The survey resulted in 27 questions estimated to take 5-10 minutes to complete. The survey is organized into 8 sections reflecting key components mentioned before. The following Table summarizes the structure of the questionnaire:

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[65]For example, we cross-checked for each of the paper found, the skills identified and added a new item when it was not identified in the study of Mom et al. (2012).

Sections	**Number of questions**	**Topics covered**	**Format**	**Number of options**
Demographic information	5 (Q1-Q5)	Year of birth	Open-ended numerical input	NA
		Gender	Single-choice selection	4
		Nationality	Multiple-choice with "Other" option	2
		Marital Status	Single-choice selection	6
		Salary Range	Single-choice selection	11
Educational Qualifications	5 (Q6 – Q10)	Initial education level	Single-choice selection	23
		Field of study	Single-choice selection	24
		Year of completion	Open-ended numerical input	NA
		Additional training	Single-choice with open-ended follow up	2
		Job specific training	Single-choice with open-ended follow up	2
Professional experiences	2 (Q11 – Q12)	Year started working	Open-ended numerical input	NA
		Previous job positions	Open-ended text input	NA
Current Position	9 (Q13 – Q21)	Current organization	Single-choice selection	6
		Organizational details	Multiple-choice with "Other" option	5
		Number of employees	Open-ended numerical input	NA
		Year organization started	Open-ended numerical input	NA
		Full-time employment	Binary choice	2

		Current job title	Open-ended text input	NA
		Team size	Single-choice selection	8
		Supported industrial sectors	Multiple-choice with "Other" option	18
		R&D domains	Multiple-choice with "Other" option	22
Activities	1 (Q23)	Frequency of involvement in various professional activities	Matrix question	11 items, 5-point likert scale
Skills	1 (Q24)	Frequency of using various professional skills	Matrix question	17 items, 5-point Likert scale
Additional Information	2 (Q25-Q26)	LinkedIn usage and profile sharing	Single-choice with open-ended follow-up	NA
Your comments	1 (Q27)	Open-ended feedback on the questionnaire	Open-ended text input	NA

Table 14: Structure of Questionnaire.

The survey was administered online through the University of Strasbourg's official online platform, LimeSurvey, offering a user-friendly experience. Progress indicators were implemented to show respondents their advancements through the questionnaire. Moving through the different sections was also possible to ensure flexibility in responding. Using LimeSurvey instead of other online survey tools was to reinsure participants about data security and management[66]. The survey can be accessed through this link: https://sondagesv3.unistra.fr/index.php/851683?lang=fr.

3.2 Population, sampling, and collection

This study focuses on employees amidst administrative staff working in intermediary organizations in France. The rationale for selecting these specific intermediaries was based on

[66] The University of Strasbourg is compliant with the General Data Protection Regulation (GDPR).

their established presence and the accessibility of information. The study did not include other types of intermediaries due to several factors. Many intermediary types are not well-cataloged, making it difficult to identify them and retrieve contact information and other necessary data for systematic analysis at the national level. For example, some intermediary types, such as Collaborative Research Centers (CRCs), like the "LabCom" initiatives, are relatively new to the innovation landscape. The absence of a centralized platform cataloging these organizations presented a significant barrier to their inclusion. Regional innovation agencies also lack a comprehensive directory, further complicating the identification process. In the case of Open Labs, as explained earlier in the thesis, different types exist. However, few are cataloged except for Living Labs, which are labeled through the European Network of Living Labs (ENoLL) but are not associated with the academic world for most of them. Hence, we decided to include five types of U-I intermediaries, namely: "*SATT*" (TTOs), "*Incubateurs Allègre"* (academic incubators), "*Pôle de compétitivité"* (clusters), "*IRT"* (RTO), and *Fab-Lab* affiliated to universities. I give some background information on these organizations in France:

Established in 2010 as part of the "Investments for the Future" program, *Société d'Accélaration du Transfert de Technologie,* SATTs valorize research results and facilitate technology transfer from public research institutions to the private sector. In 2019, SATT invested over €332 million in technology maturation and generated over 2,500 patents since its creation[67]. There are currently 13 SATTs covering different regions of France.

Academic Incubators, or *"Incubateurs Allègre,"* are tied to higher education and research institutions and were initiated in 1999 after the *Loi Allège* (Allègre law)[68]. These organizations support the creation and early development of innovative start-ups emerging from or linked to public research. Since their creation, they have supported the creation of over 3,000 innovative companies. There are 18 Allègre incubators in France.

In the French context, 'regional clusters' are known as "*Pôles de Compétitivité*." Launched in 2004 as part of France's new industrial policy, these clusters bring together companies, research

[67] https://www.enseignementsup-recherche.gouv.fr/fr/les-societes-d-acceleration-du-transfert-de-technologies-satt-47688

[68] Named after Claude Allègre, the then Minister of National Education, Research and Technology. The "Loi Allègre," officially known as the "Loi sur l'innovation et la recherche" (Law on Innovation and Research), was enacted on July 12, 1999 and was instrumental in reshaping the French Innovation landscape regarding research commercialization.

laboratories, and educational institutions in a specific region to foster innovation and competitiveness in key industrial sectors. There are 54 competitiveness clusters in France.

Research and Technology Organizations (RTOs): In France, these can be represented by the "*Instituts de Recherche Technologique*" (IRT). Created in 2010 and as part of the "Investments for the Future" program, IRTs are thematic interdisciplinary institutes that foster collaborative research between academia and industry in specific technological domains. There are 8 IRTs in France, each focusing on a specific technological domain such as manufacturing technologies (Jules Verne), materials and metallurgy (M2P), nanoelectronics (Nanoelec), railway systems (Railenium), aeronautics and space (Antoine de Saint Exupéry), digital systems engineering (SystemX), digital technologies (b-com), and infectious diseases and microbiology (Bioaster).

For OpenLabs, we specifically targeted *Fab Labs (Fabrication Laboratories)* associated with higher education institutions. The Fab Lab concept, originated at MIT, has been widely adopted in France. France has over 150 Fab Labs, with approximately 30 associated with higher education institutions. These spaces provide access to tools and knowledge for prototyping and digital fabrication, fostering innovation and creativity.

In order to identify the employees of these intermediary organizations, I first identified all the organizations within each type of intermediary. To do so, I used an official information website and verified if they were still active. This resulted in 118 organizations (see following Table):

Type	Label in France	Number	Sources	Websites
TTO	SATT	13	TTO's Network,	https://www.satt.fr/societe-acceleration-transfert-technologies/
Academic incubator	Incubateur Allègre	17[69]	Ministry of Higher Education, Research and Innovation	https://www.enseignementsup-recherche.gouv.fr/fr/les-incubateurs-d-entreprises-innovantes-lies-la-recherche-publique-46262

[69] There was a total of 18 identified incubators but one of them was found not active anymore.

Cluster	Pôle de compétitivité	53 [70]	Ministry of Higher Education, Research and Innovation	https://www.entreprises.gouv.fr/fr/innovation/poles-de-competitivite/presentation-des-poles-de-competitivite
RTO	IRT	8	French Institutes of Technology	https://www.french-institutes-technology.fr/les-irt-ite/
Open-lab	FabLab	27 [71]	Fabfoundation	https://www.fablabs.io/labs
Total	-	118	-	-

Table 15: Identification sources for IOs

Given the population's relatively small and heterogeneous nature, I employed a census approach rather than probability sampling (Nirel & Glickman, 2009). This decision was predicated on maximizing response potential and capturing the full spectrum of experiences within these diverse organizations.

The target population for this study includes all employees working within intermediary organizations. However, due to the unavailability of contact information for the entire population, the sample is limited to those employees for whom contact e-mail addresses are accessible. Moreover, the administrative personnel primarily serving in support roles were excluded from the sample. This included financial management staff, secretaries, etc., who are here to support the organization's overall management but are not directly involved in facilitating relationships between academics and industrialists.

The data collection process involved different approaches for identifying and contacting potential respondents.

For gathering contact information, I employed a hierarchical approach to obtain e-mail addresses. I used each intermediary organization's website to find employee's information and targeted employees with e-mail contact information. In cases where organizational websites provided insufficient information, such as displaying the name of employees but not their e-mail addresses. I employed several strategies:

[70] A total of 54 pôles were initially identified, however, due to the lack of available information (no website) for one of these poles, it was excluded from the analysis.
[71] We used the mapping function of the website and sorted Fab Labs by country and by their ‘active’ status. This resulted in 122 FabLabs. We then verified for each, those who were associated to a higher education establishment and were still active.

(1) Construction of e-mail addresses based on observed organizational e-mail formats with partial listings was provided.
(2) Identification of the organization director's e-mail address or LinkedIn.
(3) Telephonic contact with the organization as a last resort to request e-mail addresses and survey distribution permission.

The survey was distributed via e-mail with invitations tailored to each type of intermediary organization. For each organization, two variants of invitation e-mails were prepared 1) a direct invitation for individual employees 2) a request to organizational directors to disseminate the survey among their colleagues. The invitation (**Appendix 5** for an example) contained different parts strategically chosen to optimize the response rate. The following Table shows the details of the invitation and the strategy behind it:

Invitation Component	Content	Strategy to Maximize Response
Introduction	Study conducted by BETA-CNRS Laboratory, University of Strasbourg	Establishes credibility and academic legitimacy
Study Purpose	Examining professional trajectories and competencies in research-industry collaboration	Clearly communicates relevance to recipients' work
Importance Statement	Role of intermediary organizations in research and innovation	Emphasizes the value of participants' contributions
Researcher Information	Doctoral thesis context	Personalizes the research and adds relatability
Anonymity and Confidentiality	Assurances of data protection	Encourages honest responses and builds trust
Time Commitment	Estimated 5-10 minutes to complete	Sets clear expectations and demonstrates respect for participants' time
Request to Forward	Encouragement to share with team and colleagues	Implements a snowball sampling technique to increase reach
Survey Link and Deadline	Direct link and participation deadline	Provides easy access and creates a sense of urgency
Contact Information	Researcher's contact details for inquiries	Offers support and demonstrates openness to communication
Tailored Content	Adaptations for each type of intermediary organization	Ensures relevance and shows attention to specific contexts
Multiple Reminders	Follow-up e-mails sent periodically	Increases visibility and provides multiple opportunities to participate

Extended Survey Window	Two-month survey period (May to July 2024)	Accommodates varying schedules and workloads

Table 16: Invitation Structure

The invitation phase lasted from May to July 2024 and two follow-up reminders were conducted at two-week intervals.

To ensure a comprehensive survey evaluation, I sent the invitations to colleagues to spot any problems and receive feedback. Moreover, at the end of the survey, I included a section for feedbacks where we specifically asked respondents to comment on how the questionnaire was constructed. There were positive comments, except for some respondents who reported that the questionnaire took more than 10 minutes. To make up for this, I simplified the home page of the online survey to streamline the information, as the page initially contained much content.

Several challenges were encountered during the data collection process. First, I acknowledge that information asymmetry across organizations may have significantly impacted the final sample: the availability and comprehensiveness of employee information varied significantly across types of IOs, with FabLabs being the most challenging. No information on the employees was available for most of the FabLabs identified. We had to rely on contact forms, potentially significantly decreasing the response rate. We had difficulty identifying contact information for RTOs as well. Moreover, the reliance on organizational directors for survey distribution in some instances may have been unsuccessful or introduced selection bias, potentially affecting the sample's representativeness.

The response rate was calculated based on the sum of targeted mails for employees and directors[72].

Type	Label in France	#IO	Targeted employees by mails	Director's contacted	Nb. responses	Response rate
TTO	SATT	13	229	5	57	24.36%
Academic incubator	Incubateur Allègre	17	80	6	20	23.25%
Cluster	Pôle de compétitivité	53	570	7	121	20.97%

[72] Please consider that the responses rate may likely be lower due to the impossibility of knowing the number of responses triggered by sending the mail through the directors. This is particularly true for FabLabs.

RTO	IRT	8	41	5	31	67.39%
Open-lab	FabLab	27	-	27	14	51.85%
Total	**-**	**118**	**920**	**50**	**243**	**-**

Table 17: Response Rate across IOs

3.3 Data analysis

After cleaning and dropping partial or incoherent responses, the final sample was **214 employees**. To support our analysis, we relied on the survey's selection and use of both primary and secondary variables. While some variables were taken as they were, others were transformed or created based on the open-ended responses to the questionnaire[73].

3.3.1. Analytical strategy

We structured our analysis in two steps to explore the background and skills of employees working in intermediary organizations. First, we conduct an exploratory data analysis to gather information on employees' backgrounds for their educational and professional experiences. This part helps to respond to our first research question on the background of employees working in intermediary organizations. We give some critical insights into diverse patterns regarding education and professional experience. Second, to understand how skills differ from type of activities and type intermediary, that is our second research question, we conduct a Principal Component Analysis (PCA)on skills followed by two regression analyses to explore how skills influence involvement in activities (regression 1) and intermediaries (regression 2). Our variables of interest for both analyses consist of the 18 skills variables ranked by their frequency of use (1 to 5). All analyses were conducted using R Studio.

a) PCA

In this study, we used Principal Component Analysis (PCA) to analyze the skillsets of managers based on Likert scale data. The ordinal nature of our skills variables makes PCA an appropriate choice[74], as it preserves the order of the data while treating it as continuous, allowing us to capture the underlying variance across different skills. PCA is beneficial for

[73] This process resulted in a database with 124 variables.

[74] Other techniques such Multiple Correspondence Analysis (MCA) exist for categorical data, however is less suitable for our purposes because it disregards the ordinal structure inherent in Likert scales. MCA treats categories as unordered, which would obscure meaningful relationships between skill levels.

reducing the dimensionality of the dataset, identifying key components that explain the most variation in the skill ratings, and uncovering latent patterns, such as the clustering of related skills. The PCA was performed to reduce the dimensionality of the 18 skill variables by grouping them based on their similarities. Moreover, our sample size was sufficient to perform reliable PCA. A common rule of thumb is that the sample size should be at least 5-10 times the number of variables (Hatcher & O'Rourke, 2013). For 18 skills, the minimum sample size should yield 90-180 observations. PCA allowed us to create two components, meaning two distinct groups of skills, which will be described in detail in the Analysis and Results Section (Section 4). These two skill groups formed the basis for our two regression models, which we develop below.

b) First regression

To investigate the relationship between the type of skills and the type of activities individuals engage in, we conduct an ordered logistic regression for each of the 10 activities. The dependent variable, involvement in an activity, is measured on an ordinal scale ranging from 0 to 4, where higher values indicate greater involvement. Additionally, we included control variables that were selected based on our literature review.

The regression model is specified as follows:

$$\text{logit}(\text{P}(\text{Activity}_i \leq j)) = \alpha_j - (\beta_0 + \beta_1\text{PC1}_i + \beta_2\text{PC2}_i + \sum_{k=1}^{K} \beta_k\text{Control}_{ki}) + \varepsilon_i$$

where:

<u>Dependent Variable:</u>

$\mathbf{Activity_i}$ is our dependent variable, an ordinal variable representing the level of involvement in the ten activities, each scaled from 0 to 4. The ordinal scale allows us to understand the intensity of individual engagement[75].

<u>Independent Variables:</u>

[75] See **Appendix 14** on the excerpt of the survey for full definitions of these activities.

$\mathbf{PC1}_i$ ***and*** $\mathbf{PC2}_i$ are the skill dimension scores for individual i, derived from our PCA analysis. They represent the core competencies identified as crucial for innovation intermediation. These are also ordinal but treated as continuous.

<u>Control Variables:</u>

Control_{ki} are the k control variables for the individual i.

The literature consistently highlights the role of formal education in these professions. Therefore, $\mathbf{Educ\_level\_category_i}$ captures the education level of the respondent. It is a categorical variable with 5 categories (Bac+2, Bac+3, Bac+5, Bac+6, to Bac+8). The reference category is Bac+2.

Nb_positions is the number of positions held by the respondent before joining the intermediary which is a count variable. We chose this measure over traditional metrics like years of experience because it better captures the diversity of professional exposure unique to innovation intermediary careers. This approach aligns with Siegel et al.'s (2007) findings about high turnover rates in Technology Transfer Offices (TTOs), suggesting that career mobility is common in this field. Therefore, each position potentially represents unique learning opportunities and skill acquisitions. Moreover, innovation intermediation is a relatively new profession that lacks standardized educational pathways. As a result, professionals may develop their expertise through varied work experiences rather than formal education alone.

Innovation intermediaries often bridge the gap between the public and private sectors. Therefore, we include $\mathbf{Public\_private\_interaction_i}$, a binary variable indicating whether the respondent has had experience in both public and private sectors.[76]

The ordered logistic regression model is appropriate for this analysis, as it accounts for the ordinal nature of the dependent variable. The model estimates the cumulative probabilities of an individual being in each involvement category, given their educational and professional background.

c) Second regression

[76] Public experience refers to professional activities in the public sector, including both research and non-research roles within universities, public research institutes or public institutions.

For the second regression analysis, we investigate the relationship between the type of skills and involvement in different intermediaries using a multinomial logistic regression. The dependent variable is the type of intermediary an individual is involved with, which is a categorical variable with five levels (TTO, Incubator, Cluster, RTO, FabLab). The independent variables include the skill dimensions (PC1 and PC2) derived from the principal component analysis and the same control variables used in the previous analysis. The multinomial logistic regression model is appropriate for this analysis because it allows for predicting a categorical dependent variable with more than two levels. The model estimates the log odds of an individual being involved in a particular intermediary type compared to a reference category, given their skill dimensions and control variables. In this analysis, we use Cluster as the reference category, which we consider as the intermediary with the broadest skillset. By comparing the other intermediary types to Cluster, we can examine the potential effects of specific skills on the likelihood of being involved in different intermediaries.

The model specification is as follows:

$$\ln\left(\frac{P(\text{Intermediary}_i = j)}{P(\text{Intermediary}_i = \text{Cluster})}\right) = \beta_{0j} + \beta_{1j}\text{PC1}_i + \beta_{2j}\text{PC2}_i + \sum_{k=1}^{K}\beta_{kj}\text{Control}_{ki}$$

where:

$\mathrm{P}(\mathrm{Intermediary_i} = \mathrm{j})$ is the probability of individual i being involved in intermediary type j with $j \in \{TTO, Incubator, RTO, FabLab\}$.

Independent variables (skills) and controls are kept the same.

4. Analyses and results

4.1 Exploratory Data Analysis

This section aims at gaining basic statistics about the educational background and professional experience of employees working in these intermediary organizations.

The following table gives some basic statistics about our sample. About half of the respondents work in a "Pôles de Compétitivité". Our sample is made up almost equally of men and women, with slightly more men. The average age of respondents is about 39 years, and 95% are of French nationality.

Variable	Nb. Obs.	Modalities	Count	Frequency (%)
Type of intermediary	214	TTO	47	21.96%
		Incubator	16	7.48%
		Cluster	115	53.74%
		RTO	28	13.08%
		FabLab	8	3.74%
Gender	214	Female	101	47.20%
		Male	113	52.80%
Age	214	[20-30[	35	16.36%
		[30-40[	93	43.46%
		[40-50[	54	25.23%
		[50-60[	24	11.21%
		[60-67]	8	3.74%
Nationality	214	French	204	95.33%
		Other	10	2.14%
Marital status	214	Single	80	23.36%
		In a relationship[77]	80	37.38%
		Married	75	35.05%
		Divorced or separated	8	3.74%
		Other	1	0.47%
Income range €/month	214	<1500	4	1.87%
		[1500-2000[	60	28.04%
		[2000-2500[	65	30.37%
		[2500- 3000[	28	13.08%
		[3000-3500[	16	7.48%
		[3500-4000[	10	4.67%
		[4000-4500[	3	1.40%
		>4500	7	3.27%
		Prefer not to answer	10	4.67%

Table 18: Key Summary Statistics

4.1.1. Educational background of professionals in U-I intermediaries

The distribution of education levels shows that most respondents hold advanced degrees (**Table 17**) The most common category is the Master's degree (Bac +5), with 59.35% of the respondents representing the largest significant portion of the sample. This is followed by individuals with a PhD degree (Bac +8), representing 26.64%, followed by those with a Bachelor's degree (Bac+3) degree (6.07%), and those with a Specialized Master (Bac +6). The

[77] PACS, cohabiting, etc.

fewest respondents have an Undergraduate degree (Bac +2). This suggests that most managers in this dataset have pursued higher levels of education. Within the Master's level (Bac+5), a considerable amount comes from Engineering schools ("Diplôme d'ingénieur"), representing 23.36% of the total respondents.

Educational level [78]	**Count**	**(%)**
Bac +2	10	4.68%
Bac+2 : BTS (Brevet de Technicien Supérieur)	9	4.21%
Bac+2 : DUT ou anciennement DEUG, DEUST	1	0.47%
Bac +3	13	6.07%
Bac+3 : Licence, Licence professionnelle	13	6.07%
Bac +5	127	59.35%
Bac+5 : Diplôme d'ingénieur	50	23.36%
Bac+5 : Diplôme des Ecoles de Commerce	12	5.61%
Bac+5 : Diplôme des Grandes Ecoles (Autres)	3	1.40%
Bac+5 : Diplôme des Grandes Ecoles (IEP)	4	1.87%
Bac+5 : Master ou anciennement DEA, DESS	57	26.64%
Bac+5 : MBA, MPA	1	0.47%
Bac + 6	7	3.27%
Bac+6 : Master spécialisé MS	7	3.27%
Bac +8	57	26.64%
Bac +8 : Doctorat, HDR	57	26.64%
Total	214	100.00%

Table 19: Distribution of Educational Level

[78] Bac +2: BTS is an Advanced Technician's Certificate
Bac +2: DUT is a University Diploma of Technology, DEUG is General University Studies Diploma and DEUS is a Scientific and Technical University Studies Diploma.
Bac +3: Licence corresponds to a three-year bachelor's Degree, and licence profesionnelle to a professional Bachelor's Degree
Bac +5: Diplôle d'ingénieur corresponds to an Engineering Degree
Bac +5: Diplôme des Ecoles de commerce is a Business School Degree
Bac+5 : Diplôme d'autres Grandes Ecoles is other degree from les "Grandes Ecoles"
Bac+5: Diplôme des Grandes Ecoles Institut D'Etudes Politique (IEP) is the Institute of Political Studies Grandes Écoles Degree
Bac+5: Master's Degree or formerly DEA (Advanced Studies Diploma), DESS (Advanced Professional Studies Diploma)
Bac+5: MBA (Master of Business Administration), MPA (Master of Public Administration)
Bac+6: MBA (Master of Business Administration), MPA (Master of Public Administration)
Bac +8: Doctorate, authorization to supervise research (Habilitation à Diriger des Recherches)

This higher share of the engineering field is also represented in the fields of study. The following chart shows that Engineering sciences dominate the distribution, making up the most significant proportion at 20.09%. This reflects the technical background of many respondents in this sample. Biology follows with 14.95%, representing a significant portion of the respondents, suggesting that life sciences also have a strong presence. Management, Business, Finance, and Commerce constitute 13.55%, indicating that a notable number of respondents have backgrounds in business-related fields. Agriculture – Agri-food and Chemistry contribute 8.88% and 8.41%, respectively, showing strong representation in applied and natural sciences.

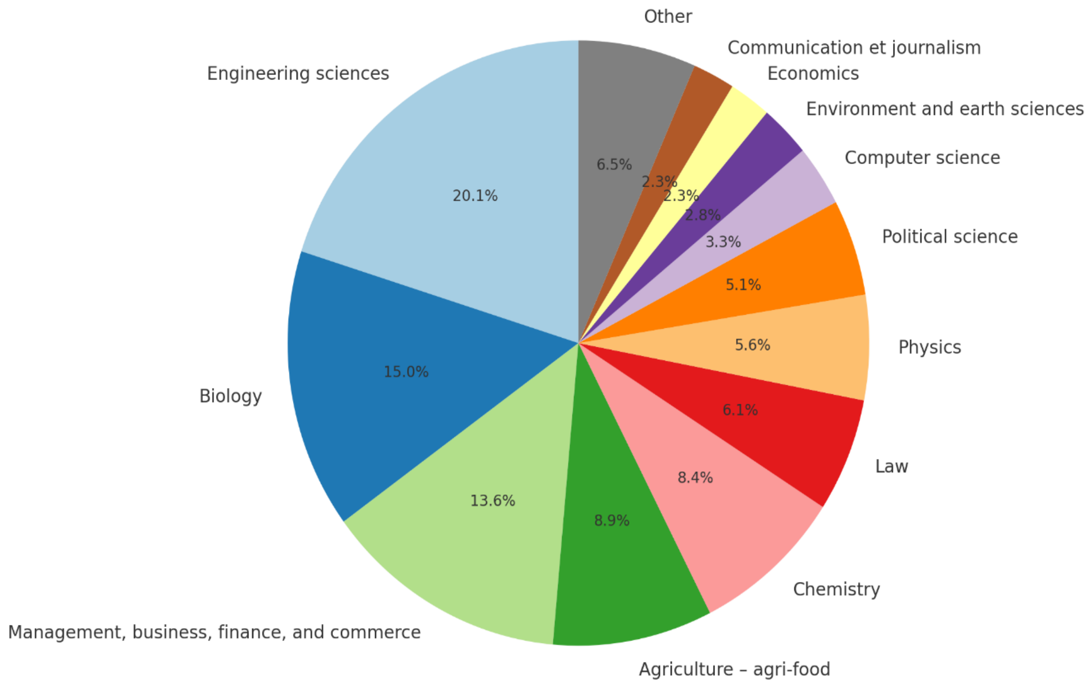

Figure 7: Distribution of fields of study

The remaining fields, such as Law (6.07%) and Physics (5.61%), also substantially contribute to the dataset. Other fields, such as Political Science (5.14%) and Computer Science (3.27%), have a moderate representation. Fields such as Communication and Journalism, Economics and Environment, and Earth Science make up about 2% each. The "Other" category, which groups fields contributing less than 1%, comprises a total of 6.5%, showing a variety of less represented fields, including architecture, arts, social sciences, and sports sciences.[79] This distribution suggests that the respondents come from diverse educational backgrounds, with a

[79] The category "Others" included the following fields: Humanities and social sciences (n=4); Medicine/Dentistry/Pharmacy (n=2); Mathematics (n=2); Health and social professions (n=1); Education sciences (n=1); Art, culture, design, and fashion (n=1); Sports sciences (n=1); Architecture, urban planning, and territorial development (n=1); Languages and literature (n=1).

strong presence in technical, business, and life sciences. We also included distribution by type of IO (see **Appendix** 9 and **Appendix 10**).

Interestingly, based on the question "*Did you pursue additional training to your main studies? If yes, please specify*" (Q9), about 27% of the respondents pursued an addition to their primary education, another degree. About 20% of these respondents pursued a degree in business and management. Biology, Physics, Engineering, and Chemistry Respondents were the most concerned.

Field of study	Count	(%)
Agriculture, agri-food	4	1.87%
Architecture, urban planning, and territorial development	1	0.47%
Biology	13	6.07%
Chemistry	4	1.87%
Law	1	0.47%
Computer science	2	0.93%
Management, business, finance, and commerce	3	1.40%
Medicine/Dentistry/Pharmacy	2	0.93%
Physics	6	2.80%
Engineering Sciences	6	2.80%
Economics	1	0.47%
Total	43	20.09%

Table 20: Distribution of Additional Degree in Business and Management

4.1.2. Professional experience of employees working in U-I intermediaries

Table 19 provide summary statistics of key variables about the professional experience of the employees. Respondents tend to have significant experience (10 years on average) with most having more experience in the private sector (mean: 5.78 years) compared to the public sector (mean: 2.07 years). A notable portion of respondents lacks experience in intermediary organizations (IOs), with the median for "Years in Other IO" and "Years of Evolution in IO" being zero, indicating that 75% are relatively new to these areas. In contrast, respondents have held their current positions for an average of 3.68 years, suggesting moderate job stability. The number of positions held varies, with an average of 2 to 3 roles during their careers. This suggests a moderate level of career mobility. This variable could indicate different career strategies or paths, with some respondents building deep expertise in fewer roles while others gain various experiences across multiple positions.

Based on the two variables, Years in Private and Years in Public Sector, we could compute the share of respondents with experience in both the private and public sectors, accounting for 24.77% of the sample, highlighting a significant group with a diverse background. Moreover, 10.28% of respondents had no experience representing newcomers to these professions. In **Appendix 11** we include the distribution of the type of experience (public, private, both or none) across IOs.

Variables	Mean	Sd	Min	Q1	Median	Q3	Max
Years of Experience	10.35	8.51	0	3	9	15	39
Years in Private	5.78	6.85	0	0	4	9	33
Years in Public	2.07	4.15	0	0	2	3	38
Years in other IO	0.62	2.01	0	0	0	0	14
Years of evolution IO	0.65	2.28	0	0	0	0	17
Years Current	3.68	3.89	0	1	3	5	26
Number of Positions	2.482	1.87	0	1	2	4	10

Table 21: Summary Statistics of Key Variables for Professional Experience

Based on the question (Q10), *"Have you pursued complementary training to develop skills for your current job?"* it appeared that nearly 40% (83) of the sample has participated, in addition to their educational degree, in formal job-specific training in areas such as Management (11.68%), Intellectual Property management (10.28%), Innovation (9.81%), soft-skills development (7.94%), domain-specific (4.67%). Examples of training included: "Certification of Project Management". Most respondents followed training by the National Institute of Industrial Property (INPI) in France for training in IP. This suggests that for many employees, their initial educational experience alone may not fully equip them with all the necessary skills for their current roles.

The additional training is reflected by the diversity of employees' job roles. The responses to the question "*what is your current position in the organization*" (Q13) reveal diverse professional functions within intermediary organizations that span strategic, scientific, technical, and operational expertise. A prominent group showed roles such as "Manager," "Director," and "Consultant," which underscore leadership and decision-making aspects. This managerial focus is complemented by more specialized positions, such as "Engineer" and "Technician," which emphasize the technical and scientific expertise that is also necessary. The prevalence of roles like "Project Manager," "Analyst," and "Coordinator" reflects a need for operational and logistical skills. Moreover, the presence of business-centric titles such as

"Business Developer," "Product Manager," and "Innovation Specialist" illustrates a focus on market orientation, commercialization, and strategic innovation.

4.2 PCA and Econometric results

This part aims to identify how skills vary by type of activities and type of intermediaries. First, we look at the distribution of skills.

Type of skills	Mean	Std	Min	25%	Median	75%	Max
Management	4.18	1.04	1	4	5	5	5
Listening	4.08	0.98	1	4	4	5	5
Information	4.02	1.04	1	3	4	5	5
Networking	3.99	1.20	1	3	4	5	5
Domain_specifc	3.88	1.04	1	3	4	5	5
Communication	3.82	1.11	1	3	4	5	5
Facilitation	3.78	1.10	1	3	4	5	5
Techn_watch	3.6	1.25	1	3	4	5	5
Commercial	3.45	1.34	1	2	4	5	5
Leadership	3.38	1.39	1	2	4	5	5
Systematic	3.37	1.33	1	2	4	4	5
public_relation	3.27	1.36	1	2	3	4	5
Mediation	3.13	1.14	1	2	3	4	5
Fundings	3.12	1.51	1	2	3	5	5
Negotiation	2.93	1.30	1	2	3	4	5
IP	2.90	1.37	1	2	3	4	5
Entpreneurship	2.68	1.37	1	1	3	4	5
Prototyping	2.29	1.23	1	1	2	3	5

Table 22: Summary statistics of skills variables ordered by decreasing mean value

The most common skills are **management, listening, and information handling. They** exhibit consistently high median scores, with all three having low standard deviation, indicating that most respondents rate themselves similarly in these skills, often at the high end of the scale. This is also displayed by the 75th percentile value of 5, indicating that at least 25% of respondents rate these skills at the highest level possible. This suggests that these skills are considered well-developed among most employees in the sample, which may indicate their importance in intermediary roles. In contrast, skills like **negotiation, IP management, entrepreneurship, and prototyping** tend to have lower median scores and a broader spread of responses, reflecting their more specialized nature. These skills may be less universally required across the various types of intermediary organizations or represent areas where certain employees possess more expertise than others. **Fundings, leadership, commercial,**

systematic, and public relations show a medium level of involvement and depict more significant variations, suggesting that they are perceived differently across respondents.

Many of these skills are highly positively correlated, as shown in the correlation matrix (see **Appendix 6**). Some skills tend to cluster together. For instance, leadership, negotiation, and networking are all somewhat correlated. Similarly, facilitation, mediation, and communication show positive correlations. These correlations suggest that certain skill sets co-occur, indicating potential underlying dimensions that could explain these patterns. Given these clusters of skills, using Principal Component Analysis (PCA) is an appropriate technique to reduce dimensionality and identify latent factors that may be driving these correlations.

The selection of principal components was based on the scree plot (**Appendix 7**) which displays the eigenvalues associated with each principal component. The "elbow point" in the scree plot indicates the optimal number of dimensions to retain, as additional dimensions beyond this point contribute minimally to the explained variance (Jolliffe, 2002). This analysis selected the first two principal components (PC1 and PC2), as the elbow point was observed at the second principal component. These two components collectively account for the largest proportion of the variance in the skill variables, collectively explaining 42.4% of the total variance in the data. Dim1 accounts for 30.7% of the variance, while Dim2 explains 11.7%.

The following biplot visualizes the relationships between different skills and their contributions[80] to the first two principal components (Dim1 and Dim2). The length and

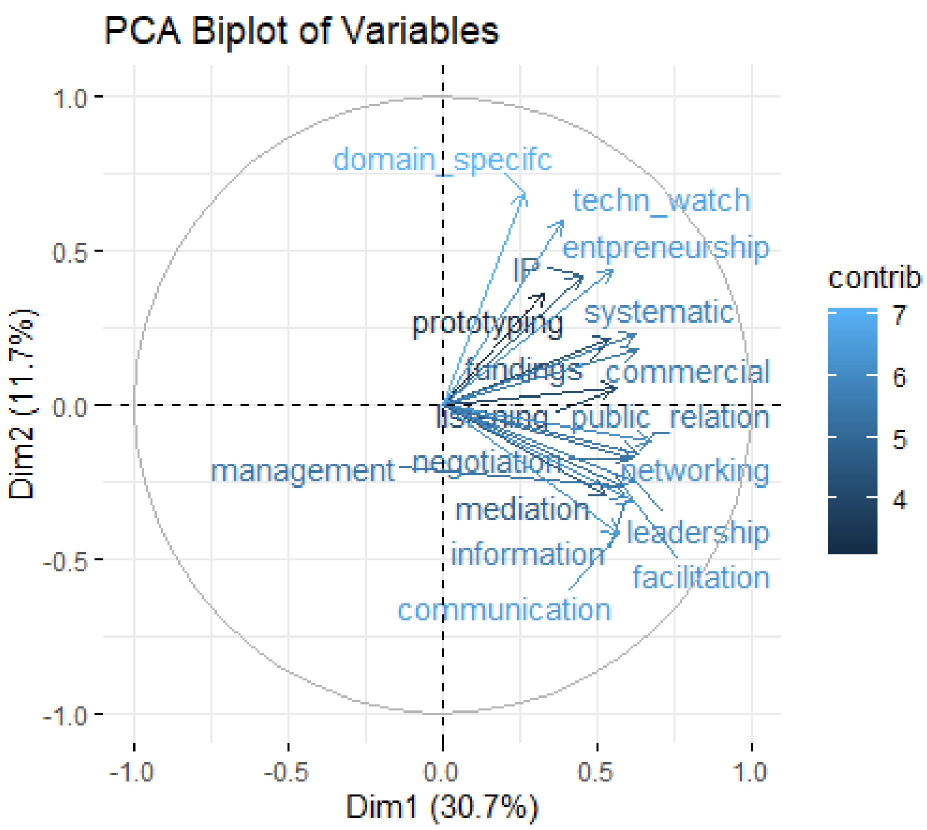

Figure 8: Biplot of skills

direction of the arrows representing each skill variable provide insights into their contribution to the respective dimensions. The biplot also reveals clusters of closely related skills. For example, "public_relation," "commercial," and "fundings" form a cluster, suggesting a strong correlation between these variables. Conversely, variables positioned orthogonally to each other, such as "communication" and "prototyping," exhibit little to no linear relationship. The color intensity of the arrows indicates the overall contribution of each skill variable to the two dimensions combined. Variables with darker shades, such as "leadership" and "domain_specific," significantly impact the variance explained by Dim1 and Dim2.

Variables strongly associated with Dim1 include Management, Networking, Negotiation, Commercial awareness, Leadership, and Public relations. This dimension could be considered *generic skills* representing managerial, business, and relation-building competencies. These

[80] For the details of the contributions of each skill, please see **Appendix 8**.

competencies are essential for managing partnership projects and the ability to manage teams. This could also reflect some dimensions of soft skills. On the other hand, variables, including domain-specific knowledge, prototyping, technology watch, entrepreneurship, and legal competencies, are more closely associated with Dim2. This axis could represent *specific* skills associated with technical and innovation-driven work critical in specialized fields such as research, development, and business incubation. Dim2 could also reflect some "hard skill» dimension. To sum up, these dimensions seem to capture the dual responsibility of U-I intermediary employees: fostering collaborative relationships and ensuring the successful commercialization of research innovations.

To further investigate the relationship between skills and intermediaries, a scatter plot **Figure 8** is presented, displaying the distribution of individuals across the two PCA dimensions. The points are color-coded according to the intermediary category to which they belong. Although the points are dispersed, some clusters of points with the same color tend to congregate in specific regions of the plot, suggesting that certain groups may have similar skill profiles along these two dimensions. While some groups exhibit distinct profiles, there is an overlap in their skills, as evidenced by the proximity of their centroids. The Cluster group appears to have a wide range of skills, with a higher concentration of points in the center of the plot compared to other groups.

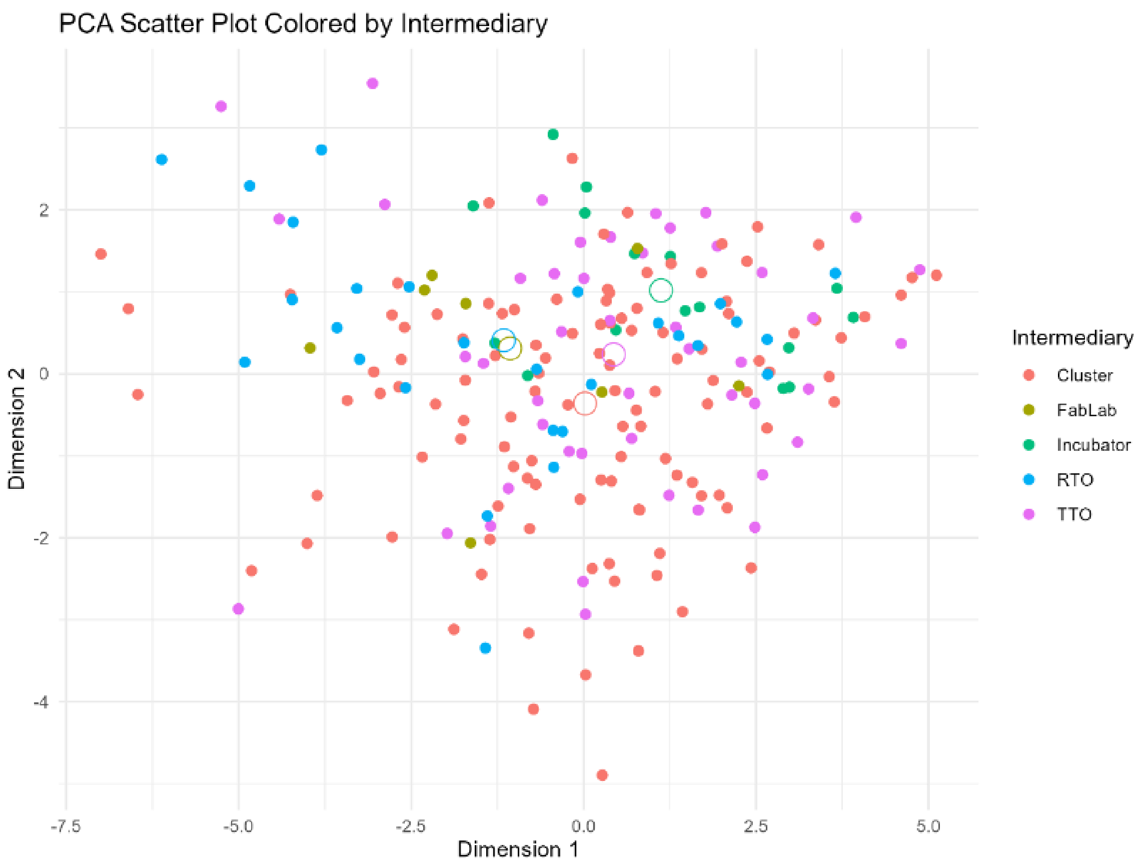

Figure 9: PCA Scatter Plot by intermediary

In this analysis's final step, we will explore whether these two skill dimensions can predict an individual's involvement in different types of activities and specific intermediaries.

4.2.1. Investigating skills and activities

Table 21 shows the results for the ordered regression. The generic skills dimension (PC1) and the specific skills dimension (PC2) emerge as significant predictors of involvement, with PC1 exhibiting a more consistent and significant impact across all activity types. PC1 has a significant positive effect across all activities ($p < 0.001$ for all models), although their effect varies by type of activity. Generic skills increase the chance of being highly involved in spin-offs development (56.7% increase in odds), informal exchange (54.1%), network development (49.8%), new business development (45.9%), contract research (36.3%), innovation projects (36.1%), Licensing and IP protection (33%), academic consulting (27.1%) and R&D projects (22.4%). The strongest effects of PC1 are observed in spin-offs development, informal exchange, and network development. This pattern indicates that generic skills are particularly crucial for activities requiring interpersonal interaction, relationship building, and entrepreneurial thinking. The relatively lower, though still significant, impact on activities like licensing, academic consulting and R&D projects suggests that while generic skills are universally beneficial, their relative importance may be moderated in more technically-oriented tasks.

Specific skills (PC2) has a more varied impact across activities compared to PC1 but is consistent with its results. PC2 demonstrate both significant positive and negative effects and is not significant for students' projects and contract research. A one-unit increase in specific skills increases the odds of involvement in these following activities (sorted by decreasing order of odds ratios): licensing and protection of intellectual property (75.1% increase in odds) development of spin-offs (58.6%) development of new companies (53%), academic consulting (35.1%), collaborative R&D projects (28%). This pattern suggests that specialized knowledge is particularly valuable in activities involving complex legal considerations or requiring deep technical understanding. Conversely, PC2 decrease the chance of being highly involved on informal exchange (-16.9%) and network development (-19.7%), indicating that an overemphasis on specific skills might hinder performance in more socially-oriented activities.

The contrasting effects of PC1 and PC2 across different activities provide insights into the optimal skill balance that combines both technical expertise and interpersonal capabilities for various roles. The most pronounced disparities between PC1 and PC2 are observed in Licensing and protection of IP, favoring hard skills (PC2 significantly outweighing PC1), suggesting that this area demands a higher degree of specialized expertise. Conversely, the opposite trend in informal exchange and network development highlights the primacy of generic skills in these domains. Activities such as new companies' development, innovation projects and academic consulting benefit comparably from both skill sets, with a slight advantage for hard skills except for innovation projects which favor soft skills. Collaborative R&D and spin-offs development, demonstrate a relatively more balanced use for both skill types but with again a slight advantage for hard skills. Overall, while there is a need for a balance set of skills for each activity with generic skills being important for all activities, hard skills seem to be slightly more used, except for informal exchange, network development and innovation projects.

Ordered Logistic Regression for Each Activity Type (Odds Ratios and p-values)

	Dependent variable:									
	activity_type									
	Spin-offs	Business Dev	Licensing	R&D	Exchange	Network Dev	Student Projects	Innovation	Contract Research	Consulting
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PC1	1.567^{***} (0.072)	1.459^{***} (0.064)	1.330^{***} (0.062)	1.224^{***} (0.059)	1.541^{***} (0.066)	1.498^{***} (0.068)	1.266^{***} (0.060)	1.361^{***} (0.061)	1.363^{***} (0.062)	1.271^{***} (0.062)
PC2	1.586^{***} (0.115)	1.530^{***} (0.099)	1.751^{***} (0.103)	1.280^{*} (0.096)	0.831^{*} (0.091)	0.803^{*} (0.098)	1.134 (0.092)	1.268^{*} (0.094)	1.108 (0.094)	1.351^{**} (0.096)
educ_level_categorical2. Bac+3	1.793 (1.044)	1.496 (0.897)	2.258 (0.833)	2.177 (0.796)	0.958 (0.770)	0.340 (0.743)	1.335 (0.737)	1.725 (0.750)	1.935 (0.813)	0.877 (0.807)
educ_level_categorical3. Bac+5	1.527 (0.888)	2.267 (0.707)	1.424 (0.691)	3.409 (0.648)	1.574 (0.596)	0.622 (0.616)	0.567 (0.599)	1.446 (0.594)	0.846 (0.654)	0.639 (0.653)
educ_level_categorical4. Bac+6	3.589 (1.100)	2.723 (0.954)	1.258 (1.005)	2.726 (0.890)	1.580 (0.875)	0.996 (0.948)	1.730 (0.869)	1.528 (0.857)	1.497 (0.959)	1.667 (0.958)
educ_level_categorical5. Bac+8	1.747 (0.913)	1.225 (0.745)	1.690 (0.727)	3.641 (0.696)	1.124 (0.647)	0.412 (0.677)	0.717 (0.641)	2.450 (0.646)	1.815 (0.694)	0.928 (0.696)
Nb_positions	1.055 (0.083)	1.082 (0.076)	1.206^{*} (0.080)	0.815^{**} (0.078)	0.962 (0.082)	0.845 (0.087)	0.975 (0.079)	0.948 (0.077)	0.974 (0.078)	0.998 (0.077)
private_public_interaction	1.499 (0.350)	1.340 (0.335)	0.680 (0.345)	1.020 (0.342)	1.670 (0.341)	1.998 (0.395)	0.896 (0.334)	0.979 (0.347)	0.612 (0.348)	0.929 (0.357)
Observations	214	214	214	214	214	214	214	214	214	214
Note:										$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table 23: Results of regression analyses for involvement in activities.

None of the education level variables have an impact on the involvement on activities. This suggests that skills are more important than the level of education or professional experience when performing these activities. The number of positions and experience both in public and private does not show significant results. This also suggests that breath of experience may not be as universally beneficial for these professions as skills. However, the notable exceptions in Licensing and R&D projects provide intriguing insights. The positive relationship between the number of previous positions and involvement in licensing activities (20.6% increase in odds) suggests that more diverse experience may enhance competence in this area, possibly due to broader exposure to various intellectual property scenarios and enhanced negotiation skills. Conversely, the negative relationship with R&D projects (-18.5 % odds) indicates that specialization and depth of experience may be more valuable in this domain than breadth. Frequent job changes might limit opportunities to engage in long-term R&D projects or develop deep expertise in a specific area.

4.2.2. Investigating skills and type of intermediary

Table 22 shows results for the coefficients of the regression results on the likelihood of belonging to different intermediary types compared to the reference category (Cluster). We detail the results by type of intermediary.

FabLabs demonstrate a strong emphasis on formal education across all levels (Bac+3 to Bac+8), with particularly high coefficients for Bac+3 (16.238, $p<0.001$) and Bac+5 (15.166, $p<0.001$). Interestingly, FabLabs shows no significant association between soft and hard skills or specific professional experiences.

Incubators exhibit a consistent and strong positive association with hard skills (PC2) across all models (coefficients ranging from 0.947 to 1.093, $p<0.001$). They also show positive associations with all education levels, particularly Bac+3 (15.595, $p<0.001$) and Bac+5 (13.542, $p<0.001$).

Generic skills (PC1) have a consistent negative effect on *RTO* affiliation across models (coefficients ranging from -0.194 to -0.260, $p<0.05$), suggesting that individuals with higher levels of soft skills are less likely to be affiliated with RTOs compared to Clusters. Hence, RTOs may prioritize technical expertise over general skills. Initially, RTOs show a positive association with hard skills, but this becomes non-significant after controlling for education. In terms of education, RTOs show a preference for Bac+8 individuals for the last model but also for Bac+3 level education across all models. RTOs are the only intermediary type to show significant associations with career-related variables, displaying negative associations with both the number of positions held (-0.487, $p<0.05$) and private-public sector experience (-2.542, $p<0.05$).

Finally, *TTOs* demonstrate a strong preference for higher levels of education, with significant positive associations for Bac+5 (16.803, $p<0.001$), Bac+6 (17.440, $p<0.001$), and Bac+8 (17.214, $p<0.001$) education levels. They correlate negatively with Bac+3 level education (-4.015, $p<0.001$). TTOs do not exhibit significant associations with either skill dimension or professional experience variables.

Comparing across intermediary types reveals exciting patterns. Both incubators and RTOs value skills in all models. Incubators emerge as technically focused entities, valuing hard skills and various educational backgrounds, likely reflecting their role in supporting knowledge-intensive start-ups. RTOs appear as specialized organizations that prefer technical over soft skills and more focused career trajectories. They prefer Bac+3 or Bac+8 individuals, emphasizing technical expertise over generalist or cross-sector experience. FabLabs and TTOs do not show significant preferences for either skill dimension; instead, they emphasize educational qualifications. TTOs show a strong academic orientation, prioritizing advanced degrees, although specific skills (PC2) are positively significant for TTOs before controlling for education level, suggesting that they also seem to be valued. Finally, FabLabs demonstrates the most flexible profile, with a broad appreciation for education at all levels.

Sequential Multinomial Regressions Adding Predictors One by One (reference=Cluster)

	Dependent variable:															
	FabLab	Incubator	RTO	TTO	FabLab	Incubator	RTO	TTO	FabLab	Incubator	RTO	TTO	FabLab	Incubator	RTO	TTO
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dim.1	-0.184	0.235	-0.194*	0.076	-0.265	0.249	-0.238*	0.034	-0.286	0.219	-0.220*	0.008	-0.296	0.257	-0.260*	0.001
	(0.149)	(0.125)	(0.090)	(0.079)	(0.167)	(0.132)	(0.104)	(0.085)	(0.167)	(0.136)	(0.110)	(0.087)	(0.168)	(0.145)	(0.113)	(0.088)
Dim.2	0.312	0.947***	0.360*	0.309*	0.364	1.011***	0.285	0.270	0.396	1.021***	0.208	0.257	0.375	1.093***	0.179	0.244
	(0.267)	(0.279)	(0.160)	(0.133)	(0.288)	(0.291)	(0.187)	(0.140)	(0.294)	(0.294)	(0.188)	(0.142)	(0.294)	(0.309)	(0.189)	(0.142)
educ_level_categorical2. Bac+3					16.072***	16.114***	2.873*	-5.312***	15.471***	15.736***	2.752*	-4.328***	16.238***	15.595***	3.140*	-4.015***
					(0.888)	(0.788)	(1.312)	(0.000)	(0.910)	(0.797)	(1.384)	(0.000)	(0.903)	(0.822)	(1.401)	(0.000)
educ_level_categorical3. Bac+5					15.152***	14.440***	0.912	15.385***	14.496***	13.928***	0.627	16.461***	15.166***	13.542***	0.982	16.803***
					(0.489)	(0.461)	(1.195)	(0.326)	(0.512)	(0.483)	(1.259)	(0.338)	(0.548)	(0.489)	(1.245)	(0.341)
educ_level_categorical4. Bac+6					-7.147***	15.070***	1.951	15.942***	-4.429***	14.616***	1.604	17.138***	-5.561***	14.369***	1.880	17.440***
					(0.000)	(1.075)	(1.555)	(0.780)	(0.000)	(1.078)	(1.605)	(0.780)	(0.000)	(1.093)	(1.593)	(0.785)
educ_level_categorical5. Bac+8					15.170***	13.870***	2.074	15.643***	14.453***	13.392***	2.153	16.723***	15.398***	12.773***	2.885*	17.214***
					(0.653)	(0.616)	(1.226)	(0.359)	(0.681)	(0.620)	(1.305)	(0.368)	(0.717)	(0.702)	(1.326)	(0.390)
Nb_positions									0.194	0.128	-0.487*	0.157	0.258	0.070	-0.212	0.200
									(0.194)	(0.144)	(0.192)	(0.096)	(0.214)	(0.167)	(0.204)	(0.108)
private_public_interaction													-0.714	0.708	-2.542*	-0.434
													(1.050)	(0.798)	(1.153)	(0.480)
Constant	-2.743***	-2.530***	-1.519***	-0.898***	-17.869***	-16.997***	-3.004**	-16.242***	-17.730***	-16.831***	-1.950	-17.734***	-18.453***	-16.562***	-2.607*	-18.106***
	(0.399)	(0.415)	(0.233)	(0.179)	(0.382)	(0.416)	(1.163)	(0.276)	(0.579)	(0.505)	(1.278)	(0.328)	(0.572)	(0.523)	(1.303)	(0.328)
Akaike Inf. Crit.	524.155	524.155	524.155	524.155	526.108	526.108	526.108	526.108	520.145	520.145	520.145	520.145	518.932	518.932	518.932	518.932
Note:																*p<0.05; **p<0.01; ***p<0.001

Table 24: Results of regression analyses for involvement in IOs.

5. Discussion and concluding remarks

Our research contributes to the literature on university-industry (U-I) intermediaries by providing insights into the individual-level characteristics of various intermediaries and highlighting their different preferences for skills and backgrounds. These findings underscore the diverse roles that different intermediaries play in the technology transfer ecosystem, with each type attracting and valuing different skill profiles, likely reflecting their specific functions.

5.1 Linking skills, activities, and intermediary types

Our results show that activities display a balance of soft and hard skills, which varies by activity type. Our findings align with and diverge from those of Mom et al. (2012) in several key aspects.

For skills and activities, we corroborate the critical importance of soft skills in professions facilitating university-industry interaction (UII). Their study on TTO's activities shows mixed effects on the relationship between activities and soft skills. Our results indicate its consistent importance across all activities, regardless of the type of intermediary. We also demonstrate the significance of hard skills, including domain expertise, for certain activities, a factor found not significant in their study.

Our analysis offers a more nuanced perspective on the context-dependency of skill importance. It shows that the type of organization matters in determining the balance of soft and hard skills. We also compare the use of skills across different intermediary organizations for the first time. Although we do not investigate the influence of activities on the type of intermediary, our exploratory analysis reveals that each intermediary type specializes in a distinct set of activities, aligning with their core missions and roles. The distribution of involvement in activity across intermediaries in the **Appendix 12** can visualize this. We find a close alignment between each intermediary's skill preferences and the core competencies required for their specialized activities.

More specifically, hard skills drive licensing, business development, spin-offs, R&D projects, and consulting, which are highly specialized activities by technology transfer offices (TTOs), academic incubators, and RTOs. Incubators' focus on hard skills and broad education level aligns with their role in nurturing tech-based start-ups. The technical focus of incubators enables them to provide the necessary expertise and resources to nurture early-stage, knowledge-intensive start-ups. A diverse level of education is likely to reflect the different breadth of knowledge and experiences that incubators can draw to help entrepreneurs. RTOs' prioritization of hard skills, specific educational level (Bac+3 or Bac+8), and focused career paths directly support their specialization in conducting R&D and providing contract research services. The combination of technical expertise acquired through Bac+3 and specialized knowledge in Bac+8 emphasize their mission of conducting research close to technical problems. Moreover, their emphasis on focused career paths also reflects their preference for expertise in specific domains, allowing them to establish solid reputations and competitive advantages in their chosen research fields. As mentioned in the Methodology section, each RTO in France is highly specialized in a single field.

TTOs have a robust academic orientation preference for advanced degrees (Bac+5, Bac+6, and Bac+8), which align closely with their primary licensing and IP protection activities. TTOs' focus on attracting personnel with doctorates ensures that they have the necessary understanding of scientific knowledge to identify and evaluate potential research outputs. Moreover, the fact that TTOs value Bac+6 individuals might reflect their preference for individuals pursuing additional training necessary for their jobs. FabLabs values diverse educational backgrounds (except for Bac+6, where they would instead retain Bac+2). This is interesting because it shows that FabLab prefers knowledge-specific competencies through doctorates. Finally, for Clusters, the comparison to other organizations shows that they value hard skills and higher education. Therefore, Clusters will likely value soft skills and Bac +2 educational level. Clusters' preference for soft skills aligns with their role in fostering networks by facilitating and coordinating connections between various actors. At the same time, their valuation of Bac +2 educational level suggests a focus on practical, industry-relevant knowledge, which aligns with their mission to support industries in the region. We resume our main findings in the following:

Intermediary	Specialized activities	Skill and educational preference
Incubators	New business development and spin-offs	Technically-focused, favoring hard skills and diverse educational backgrounds.
RTOs	R&D projects, contract research, academic consulting	Valuing hard skills, technical expertise (Bac+3 or Bac+8) and focused career paths (no previous positions or mixed experience).

TTOs	Licensing and IP protection, spin-offs development	Prioritizing advanced degrees and academic orientation.
Fab-Labs	Student projects	Valuing varying educational level.
Clusters	Innovation projects, Network development, Informal exchange	Values soft skills and lower educational background (Bac+2).

Table 25: Preferences of profiles across intermediaries

Our regression analysis reveals that French TTOs prioritize advanced educational qualifications over soft skills like commercial acumen and negotiation abilities. This emphasis is paradoxical, as these soft skills are crucial for their activities, including licensing, new business development, and spin-offs (Mom et al. 2012). The undervaluation of these competencies may explain French TTOs' lower performance than international counterparts. This finding aligns with Chapple et al.'s (2005) study on UK TTOs, which identified a need to enhance business acumen among TTO professionals due to low-efficiency levels. Our results suggest French TTOs face similar challenges, indicating a potential area for improvement in the French technology transfer ecosystem. Our findings also complement broader literature on TTOs in the US and UK, highlighting a trend towards the need for balanced skill sets in technology transfer professionals. Olaya-Escobar et al.'s (2020) study on factors contributing to patenting activity supports this. It shows that while staff quality (including experience and interpersonal skills) is relevant, its importance varies depending on other factors, such as researcher experience.

5.2 Implications for practitioners

Intermediary professional positions constitute a new profession that deserves further attention. Our research has implications for employees and human resource professionals within U-I intermediaries. By identifying the specific skill sets required for different intermediary types and activities, our findings enable these organizations to effectively carry out their core functions by ensuring they have the right mix of human capital to support their primary activities. We suggest that U-I intermediaries focus on developing soft and hard skills in their workforce. While technical expertise is crucial for certain activities, the universal importance of soft skills indicates that these should be a core component of training and development programs.

Moreover, different types of intermediaries may need to tailor their hiring and training strategies based on their specific skill requirements. For instance, technology transfer offices

(TTOs) and, research and technology organizations (RTOs), and academic incubators might prioritize candidates with strong technical backgrounds. At the same time, clusters may place greater emphasis on soft skills. Identifying these specific skill sets can help optimize the allocation of resources and talent.

The results also have implications for organizational design across all intermediary types. Managers should structure their organizations to reflect the specific balance of activities and skills identified in our study. For instance, managers should design targeted training programs that address the specific skill requirements of each intermediary type. This is particularly crucial for TTOs in France, where our findings suggest a need to enhance soft skills. Moreover, managers should enhance skills sharing within their organization to leverage skill gaps or enhance skill diversity. In this vein, managers should create complementary teams that combine different skill sets based on the organization's core activities. For example, TTOs might pair technically skilled individuals with commercially experienced managers.

Of course, these propositions also require attention from policymakers as the government supports intermediaries. Governments should, therefore, pay attention to any skill gaps across regions and design funding schemes to ensure skills development throughout careers.

5.3 Limitations and future research

While our study provides valuable insights into the skills necessary for facilitating University-Industry Interaction (UII), it is essential to acknowledge its limitations and identify areas for future research.

Our study focuses on the skills, but other individual characteristics are also important to consider. Future studies could investigate what motivates employees to work in U-I intermediaries, following the work of Pohle et al. (2022), Villani & Grimaldi (2024), Cucino et al. (2021). For example, future research could focus on the motivations for Ph.D. graduates to work in these organizations. Given these individuals' lack of traditional academic positions, intermediaries may represent a new job market worth investigating. Exploring the reasons for leaving these organizations would also be an interesting avenue for future research, as evidence shows high turnover within these organizations (Siegel et al., 2007). This is particularly important as high turnover can be a potential barrier to facilitating UII. This also calls for investigating career progression patterns within but also across different types of intermediaries. This would help to see to what extent are the skills transferable from one organization to the other.

Additionally, as knowledge and technology transfer positions are relatively new professions, it would be valuable to understand the sources through which these professionals acquire and develop their skills. As we have seen, a significant share of individuals pursues additional training, but more research is necessary at this level as very few formal educational programs exist. Therefore, the question of where and how they acquire their skills on the go is deemed necessary. Moreover,

Further research should continue to explore how skill composition influences innovation intermediaries' performance. It would be interesting to investigate further the influence of soft skills on the performance of these organizations. For example, studying how soft skills affect their network building. Team compositions also value skills. As Good et al. (2019, p. 46) pointed out, *"beyond simply recruiting individuals, managers must be able to build well-functioning teams."* This emphasizes the urgency of understanding the diversity of backgrounds and competencies of individuals and how they work together.

Finally, there is a lack of theoretical and empirical studies on the skills required to facilitate UII. We call for further research to start considering this as a distinct theme to develop a professional identity for this field. More data on other intermediaries besides TTOs is needed to validate and extend our findings further, particularly regarding the breadth and depth of the sample across different intermediary types and geographical contexts. Given the highly contextual nature of innovation and local networks, we suggest that future research should address this.

Conclusion of Chapter 4

This micro-level analysis of intermediary professionals reveals the need go one step further to understanding the roles of U-I intermediary organizations. Facilitating UII depend not only on institutional positioning of intermediaries but also on the specific skills and backgrounds of their employees. The survey results demonstrate distinct skill profiles across different types of intermediaries, reflecting their specialized functions in addressing particular barriers. The balance between generic and technical skills varies systematically across intermediary types, suggesting that successful intermediation requires carefully matched professional capabilities. These findings complement the organizational-level analyses of previous chapters by highlighting the human capital requirements for effective intermediation. Through this chapter, we tried to reflect that in order to leverage the different barriers inherent to different U-I channels, intermediaries need to rely on different skills.

GENERAL CONCLUSION

The diversity of intermediaries in the current landscape and the potential for overlap in their UII-related functions underscore the need to examine this specific class of organizations comprehensively. The main goal of this thesis was to explain the role of multiple intermediaries in the context of science and industry. We show that this complexity can be justified by the inherent roles of each organization in leveraging different science-industry barriers, their complementary functions and coordinated efforts, and their dynamic evolution in response to changing science-industry relationships. We do this by adopting multiple methodologies and providing theoretical, historical, qualitative, and quantitative methodologies.

More specifically, this thesis establishes a novel unified framework (**Chapter 1**), which serves as a unified point of reference for comparing how multiple intermediary organizations facilitate UII. This framework introduces the concept of barriers as a valuable construct to understand how different IOs address specific barriers in five different UII modes: human resource transfer, informal exchange, commercial transfer, structured co-production, and unstructured co-production. The paper identifies three main types of barriers: (1) Merton barriers, which arise from differences in institutional norms, values, and cultural orientations between academia and industry; (2) Williamson barriers, which encompass various transaction costs and relational costs associated with UII; and (3) Polanyi barriers, a novel concept introduced, which addresses the challenges in transferring tacit knowledge between universities and industry. The key results show that each interaction mode is characterized by a dominant barrier that leads to the involvement of a particular type of IO. Science parks, clusters, and innovation agencies are better at tackling relational barriers in informal exchanges; TTOs are better at addressing transactional barriers in commercial transfers; CRCs are more effective in mitigating orientation-related barriers in structured co-production; and open labs are better suited to overcome knowledge-related barriers in unstructured co-production. Our model suggests that as interactions move towards more complex forms of co-production, they face higher barriers, requiring the involvement of more heterogeneous and complex intermediary organizations. This Chapter contributes to understanding how different intermediary organizations serve distinct but complementary roles in facilitating university-industry collaboration. It provides a theoretical foundation for maintaining diverse intermediary ecosystems rather than viewing them as redundant.

The second contribution of this thesis lies in the evolutionary approach taken for studying multiple intermediaries (**Chapter 2**). Through a historical analysis, we show how different forms of intermediaries appeared throughout history to address specific barriers (transaction costs, cultural differences, and tacit knowledge transfer), revealing the long-term dynamics of intermediary functions. This Chapter examines the historical evolution of science-industry intermediaries in the West from the premise of modern science up to World War II. The study identifies three periods of intermediary development: the pre-19th century, the 19th century, and the turn of the 20th century. 1) Before the 19th century, we show that early intermediaries, such as patrons and learned societies, primarily focused on reducing transaction costs by providing resources, protection and facilitating the dissemination of knowledge. 2) In the 19th century, the growing institutionalization of science and the birth of industry led to the emergence of new intermediaries, such as exhibitions, patent agents, and industrial societies. These intermediaries facilitated knowledge transfer, reduced transaction costs, and certified knowledge. We also highlight the importance of informal networks and social spaces, such as salons, coffeehouses, and economic societies, in facilitating knowledge exchange and bridging the gap between "knowers" and "doers." 3) The early 20th century saw a second step in institutionalizing science and the birth of industrial research, which led to industrial research laboratories and collective testing laboratories. These intermediaries aimed to address the growing cultural gap between science and industry while continuing to facilitate knowledge transfer. We also see that the first forms of technology transfer units appear to reduce the increasing transaction costs further. This Chapter shows that the intermediaries' landscape has always been complex and that their functions have evolved according to the specific needs of their time.

Through a qualitative study of eight IOs (36 interviews) in the health sector in Hauts-de-France (**Chapter 3**), we use the framework developed in Chapter 1 to highlight the specific roles of each intermediary and also demonstrate their collaborative efforts in overcoming different barriers in different UII. We find that IOs interact with each other in three coordination patterns when facilitating university-industry interactions (UII): A multiple intermediary phase in the initial stages where various IOs collaborate to leverage Williamson barriers related to search and information costs. A single intermediary model where one IO takes the lead, operating independently due to its unique expertise, such as TTOs in patenting activities due to their unique expertise in handling Williamson barriers related to transaction costs. An agile intermediary model where a lead IO collaborates with other IOs to complement its expertise in specific areas of the UII. For instance, incubators work with RTOs to leverage Polanyi barriers related to the transfer of tacit knowledge. We also identify a new type of barrier, the 'Arthur' barrier, which refers to the costs of joining and coordinating the right networks. Some IOs, such as clusters and science parks, effectively leverage this barrier by creating and animating events and networks. We also highlight that the effectiveness of this collaborative dynamic depends on the connectedness of the entities within the regions. This Chapter highlights that the complementary expertise of IOs allows them to jointly facilitate the complex and lengthy UII process by leveraging different barriers at various stages.

Finally, the last Chapter investigates the skills and backgrounds of employees working in France's university-industry (U-I) intermediary organizations (**Chapter 4**). Using survey data from 214 professionals across five types of intermediaries - Technology Transfer Offices (TTOs), Academic Incubators, Clusters, Research and Technology Organizations (RTOs), and FabLabs - this Chapter examines how skills, educational levels, and experience vary across different intermediary types and activities. While generic skills like management and networking are universally critical, the balance between generic and specific technical skills varies by activity type and intermediary organization. Specific skills drive specialized activities like licensing and R&D projects, while generic skills are crucial for networking and informal exchanges. Each intermediary type shows distinct preferences in skills and educational backgrounds that align with their core functions: Incubators and RTOs prioritize specific technical skills, Clusters value generic skills and diverse educational backgrounds, TTOs show a strong preference for advanced academic degrees, and FabLabs appreciate education at all levels. This Chapter reveals that U-I intermediary organizations share certain core skills while maintaining distinct specializations. While their overlapping skills may allow them to perform overlapping functions, their unique expertise creates complementary roles in facilitating UII.

To sum up, the two main value-added contributions of this thesis stem from two main aspects: the study of multiple intermediaries and the plurality of methodologies. Unlike much of the existing literature that focuses on single types of intermediaries, this research takes a holistic view, simultaneously examining various forms of intermediary organizations. This thesis provides a multi-dimensional view of the research problem by employing four distinct methodological approaches. This approach allows for a more comprehensive understanding of the technology and knowledge transfer ecosystem and the interplay between intermediaries.

The findings of this thesis have practical implications for policymakers, intermediary managers, university administrators, and industry leaders.

1. Managerial and Policy Implications

1.1 Towards Better Evaluation Methods

Our research findings should give stakeholders a clearer understanding of different intermediary types' unique value propositions and complementarities. By mapping the intermediary ecosystem and identifying each intermediary's key characteristics and strengths, stakeholders can make more informed decisions when engaging with intermediaries to support their specific UII objectives. This, in turn, can lead to more effective and efficient collaborations between academia and industry, ultimately fostering innovation and driving economic growth.

Our model, therefore, can serve as a benchmark for public policies concerned with the multiplicity of actors. The implication is not to systematically justify the creation of intermediaries but rather to question when an intermediary will be useful. The barrier framework helps us understand this: if a barrier exists, third-party intervention becomes necessary. For each intervening intermediary, the barrier framework allows us to examine why they intervene in specific projects. Evaluating intermediaries through the lens of barriers primarily helps clarify the landscape. Simply mapping intermediaries' functions and operations may be insufficient to capture overlaps and complementarities. Moreover, we know that different intermediaries yield different performance metrics. While theoretical, the identified barriers can be transposed into frameworks of key practical difficulties encountered. We need to develop ways to group practical criteria that determine different barriers, and various indicators could be developed in this direction for better common evaluation.

1.2 Improving Coordination and Signaling

Our findings suggest that the solution lies not in simplifying the landscape but in better signaling to involved actors. We need to develop better-centralized information initiatives and improve communication methods. In France, the recent development of PUIs ("Pôles

Universitaires d'Innovation") moves in this direction, providing a single entry point and centralized actor focused on the university.

We encourage regions to share lessons more extensively and call on the government to initiate regional-level studies and disseminate their findings. Today, various organizations and networks conduct their studies independently but typically focus on a single type of actor, such as 'France Cluster', the 'FabLab network', or 'SATT network'. We need to develop more studies that consider interactions between intermediaries. Innovation agencies, as does the government, have a role to play at this level in guiding actors across different regions.

A common digital platform would enable the navigation of regional contexts and facilitate the sharing of best practices. This requires developing a sharing culture to avoid siloed behaviors and retained information. Of course, this necessitates transparency regarding each actor's role to avoid overlap. A unified platform would simplify navigation for researchers and businesses. While similar initiatives exist within universities and intermediaries, the research organization in France remains opaque for researchers affiliated with different structures. A government-level platform indicating regional contacts is necessary.

The level of coordination must be adapted to the regional ecosystem. An ecosystem with few links requires different initiatives than one with present but insufficiently strengthened connections. We have seen that overlaps are not necessarily harmful but can indicate pooled efforts. Furthermore, as the number of actors increases, coordination and clarification efforts become more necessary.

It is necessary to develop within intermediaries functions that enable monitoring of all organizations present in the region. Each of these assigned individuals must be in contact with one another. These people would be, among other things, "intermediaries of intermediaries," but in charge of mediating between organizations. For example, each person must monitor the actions undertaken by different organisms to avoid stepping on each other's toes and ensure that actions are not duplicated. Better coordination also requires simplification, not of structures but of administrative processes. The complexity also stems from administrative rules and measures that need streamlining.

1.3 Enhanced Training and Skills Development

The strengthening of science-industry collaborations requires a systematic approach to training and skills development. Our findings highlight the critical need for establishing comprehensive professional development frameworks in this domain. While multiple training programs exist in facilitation, collective intelligence, mediation..etc. there is currently no standardized approach to preparing intermediary professionals. This gap necessitates the development of specialized curricula and certification programs that address core competencies and legitimize these emerging professional roles.

A significant knowledge gap exists regarding how intermediary professionals acquires their skills. To address this, we recommend implementing government-led annual surveys to systematically track skills development.

Furthermore, training initiatives must address the cultural divide between academic and industrial sectors. Effective intermediaries need not only technical skills but also the ability to navigate and bridge institutional differences. However, individuals might not have both public and private experience when they graduate. This cultural integration aspect of training is crucial for developing professionals who can effectively facilitate collaboration between these distinct worlds.

2. Limitations and Future Research

Our thesis has highlighted the positive aspect of multiple intermediaries in science-industry relations. However, we acknowledge certain limitations and considerations in this research work that should be emphasized.

First, as discussed in Chapters 1 and 2, while we attempted to be comprehensive in our analysis, certain intermediaries were not included in our study. Notable omissions include digital platforms, crowdsourcing initiatives, venture capital firms, business angels, and technology scouts. While these intermediaries likely help reduce the barriers identified in this thesis, they may also exist in response to other barriers. Following our reasoning, it is plausible that emerging digital intermediaries are developing in response to new barriers arising from the evolution of science-industry collaborations in the digital age.

Second, it is crucial to acknowledge that intermediaries are neither universally necessary nor capable of resolving all challenges. Some interactions and collaborations can proceed effectively without intermediary intervention. For instance, when researchers meet at conferences and decide to collaborate on research projects and publications, intermediary involvement may be superfluous. The barrier framework remains helpful in understanding intermediary involvement - some collaborations face no significant barriers and thus require no intervention. Conversely, not all intermediary-supported collaborations succeed. The Mertonian barrier, which concerns fundamental values, proves particularly resistant to quick solutions. Future research could productively examine cases where intermediary-supported projects fail and analyze the underlying cause.

This also calls for exploring other factors which can facilitate UII alongside intermediaries. This thesis did not fully explore other important facilitative mechanisms such as CIFRE doctoral programs, research tax credits, funding schemes, project calls..etc. These mechanisms likely contribute to reducing specific barriers identified in this thesis or address other obstacles. Future research should examine how these mechanisms interact with and complement intermediaries' work or potentially replace them in certain interactions. For example, while entrepreneurship and licensing typically require intermediaries, other interactions may be better facilitated by alternative incentive mechanisms. In France, the CIFRE program facilitates mobility-related interactions, while "LabCom" project calls for support of collaborative research.

We acknowledge that addressing these questions may require process-oriented, longitudinal analyses focused on specific interaction types and giving up some complexity. We attempted to capture this in Chapter 3. However, we recommend that future research focus on one collaboration type and examine the entire value chain and the involvement and interplay of intermediaries and other mechanisms. This would allow us to capture more of the regularities within one type of collaboration—specifically interaction with high barriers such as transfer of IP, academic entrepreneurship, and multi-partner projects.

Third, studying these mechanisms raises questions about the role of government and research/innovation policies. As briefly noted in the introduction, many intermediaries and their institutionalization emerged from policy initiatives (particularly TTOs). This prompts several considerations regarding the emergence and institutionalization of intermediaries through policy actions. Chapter 2 demonstrated that historically, intermediaries often emerged through bottom-up initiatives, with innovation policies gradually incorporating these structures due to their crucial role. Further research could examine the institutionalization process of intermediaries and their evolution into subjects of national or regional innovation policy.

The role of innovation policies also raises questions about the articulation between their decisions and the influence on intermediary's functions and coordination. The missions of different actors are sometimes decided and formulated in advance at the regional level, as mentioned in Chapter 3. It would be interesting to study more deeply if the functions and coordination matches policy informed-decisions or how they change and why. It would be interesting in this vein to investigate the potential conflicts of interest at this level.

Fourth, each region has its unique context and specificity, challenging the notion of a "one-size-fits-all" model. This raises questions about the generalizability of our case study results. Cooperation modalities differ across regional contexts, leading to variations in intermediary forms. For example, "IRTs" are not uniformly present across all regions and sectors. Additionally, sectoral variations warrant consideration - the healthcare sector, for instance, presents unique challenges due to the presence of additional institutions such as hospitals. We need more studies and systematic comparative analyses that consider the multiplicity of intermediaries in different regional contexts and sectors.

Finally, this research points to several future research directions for understanding intermediary skills facilitating UII. First, further investigation is needed to understand how intermediaries deploy different skills across various stages of the innovation process, as their roles and capabilities may evolve throughout the collaboration lifecycle. Second, skills are likely to very by sectors and the complexity of technology. We call more research to investigate the variability of these skills. Third, there is a need to study the link between skill sets of different intermediary and their performance, as developed by the literature on TTOs, we need more studies investigating the performance of other intermediaries.

3. Critical Perspectives and Future Considerations

We have observed that multiple debates have animated science-industry relations since their emergence. Examining the role of intermediaries necessarily leads us to question these relationships more broadly. The facilitation of UII for innovation cannot be discussed without considering recent debates shaping science-industry links. Not all scientific innovations have been universally beneficial - the Manhattan Project is a controversial example that raises profound ethical questions. These considerations prompt us to examine potential drawbacks in science-industry relations and question the role intermediaries should play in this context.

The study of intermediaries essentially examines the evolution of relationships between science, industry, and society at large. As we have observed, these relationships are continuously evolving. Today, scientific development is increasingly intertwined with society, leading to the emergence of new intermediary actors such as FabLabs and Living Labs. These new forms of intermediaries reflect a broader shift toward more participatory and socially embedded scientific practice.

In current challenges such as climate change, new relationships are developing between various stakeholders: citizens engaging in citizen science initiatives, farmers participating in agricultural innovation, and other societal actors previously distant from traditional science-industry partnerships. These emerging relationships represent a significant evolution in how science and industry interact with society, moving beyond traditional bilateral partnerships toward more complex, multi-stakeholder collaborations. The evolution of science-industry links is accompanied by new types of intermediaries facilitating these novel interactions. This relation raises several important questions such as: What role should intermediaries play in addressing potential negative consequences of science-industry partnerships? How can new forms of intermediaries help balance economic objectives with societal needs?

4. Concluding Remarks

This thesis aims, among other objectives, to provide greater visibility to these increasingly crucial actors in our societies. At first, glance, it might seem paradoxical that facilitating UII required the emergence of external organizations - essentially a new organizational species rather than traditional government initiatives and funding programs alone. However, this apparent paradox reveals fundamental truths about the nature of innovation and collaboration.

The proliferation of intermediaries demonstrates that innovation requires interaction between diverse actors and that we need multiple bridges between them, each serving distinct purposes within the technology transfer ecosystem. As Berger (2016) astutely observed in her MIT report: "*Reform efforts have essentially focused on creating technology transfer institutions. Many organizations have been created. Few have been eliminated. However, what matters is the breadth, depth, and continuity of interactions at all levels between companies and* *university researchers from different disciplines. It is the sustainable exchange through a broad interface that generates economic impact*."

Our analysis reveals two crucial insights. First, successful innovation requires fertile ground—a rich ecosystem of diverse interactions. As Dosi (2023) noted, "*more is different*" - the quantity and diversity of intermediaries create qualitatively different possibilities of interactions important for innovation. This perspective explains why focusing on singular initiatives in isolation often proves insufficient. Second, innovation has never been about isolated individuals or institutions; innovation demands organizational diversity, as no single organizational form can address all challenges. Supporting UII requires a diverse ecosystem of complementary organizations working in concert. The African proverb "*It takes a whole village to raise a child*" finds therefore a fitting parallel.

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Appendices

Appendix 1 : Main interactions reviewed.

Interactions \ Authors	Bonaccorsi & Piccaluga (1994)	Meyer-Krahmer & Schmoch (1998)	Santoro (2000)	Schartinger & al. (2002)	D'Este & Patel (2007)	Perkmann & Walsh (2007)	Bekkers & Bodas Freitas (2008)	Arza (2010)	De Fuentes & Dutrénit (2012)	Ankrah & Al-Tabaa (2015)	Apa & al. (2020)
1. Conferences, forums, workshops	√	√		√	√	√	√	√	√	√	√
2. Informal interactions		√	√	√		√	√		√		√
3. Consulting	√	√	√	√	√	√	√	√	√	√	√
4. Contractual research	√	√	√	√	√	√	√		√	√	√
5. Licensing and patenting			√	√		√	√	√	√	√	√
6. Spin-offs creation	√		√	√	√	√	√	√		√	√
7. Publications (scientific or others)		√		√		√	√	√	√	√	√
8. Joint research projects	√	√	√	√	√	√	√	√	√	√	√
9. Joint publications	√		√	√		√			√	√	√
10. Joint supervision of masters or PhDs		√		√	√	√				√	√
11. Hiring or internships of graduate students	√		√		√	√	√	√	√	√	√
12. Involvement of students in industrial projects											√
13. Teaching from researchers in firms		√		√	√	√			√		
14. Sabbatical periods in firms	√			√		√	√			√	√
15. Employment of scientists by industry							√			√	√
16. Use of materials and facilities in industries/universities								√		√	√
17. Fundings from industry			√							√	√

Appendix 2: Interview Guide, example for intermediary manager.

Interview Guide: Intermediary

Introduction

- Presentation of the research and context.
- Explanation of the interview process.

Part 1: Characteristics of the Respondent, the Intermediary

1. Personal Introduction: Could you please briefly introduce yourself and explain your role within your organization or program?
2. Main Mission: What is the main mission of your organization or program?
3. Main Activities: Could you elaborate on the main activities carried out by your organization or program?

Part 2: Interactions

4. Stakeholders: Who are the stakeholders of your organization or program?
5. Stakeholders' Interests: What are the respective interests of the stakeholders in collaborating with your organization or program?
6. Actors' Projects: Could you provide examples of projects or activities in which these actors participate within your organization or program, such as projects involving intellectual property, consulting, service provision, collaborations?
7. Informal Exchanges: To what extent does your organization or program promote informal exchanges among actors, for example, during events, forums, or conferences?
8. Human Resource Transfer: To what extent does your organization or program facilitate the transfer of human resources, such as recruiting students, academics, or industry professionals?

Part 3: Barriers

9. Academic-Industrial Relations: How would you describe the relations between actors from the academic and industrial worlds within your organization or program?
10. Tensions and Disagreements: Are there any tensions or points of disagreement among these actors? If yes, what do you believe are the main causes of these tensions?
11. Understanding Difficulties: To what extent do actors sometimes struggle to understand each other due to different approaches, methodologies, or terminologies? What are the reasons for this, in your opinion?
12. Lack of Information during Interactions: To what extent might actors feel lost during their interactions or collaborations due to a lack of information about steps and procedures?

13. Difficulty in Finding Partners: To what extent do actors struggle to find partners, coordinate, and maintain relationships within your organization or program?

Part 4: Intermediaries

14. Conflict Management: How does your organization handle conflicts or issues that may arise among actors?

a) Actions to Foster Collaboration: What actions does your organization take to facilitate collaboration among actors and align their interests?

b) What actions does your organization take to facilitate understanding of each other and of the innovation developed?

c) Information: What actions does your organization take to facilitate the transmission of information related to different stages and processes of interaction and collaboration with industry?

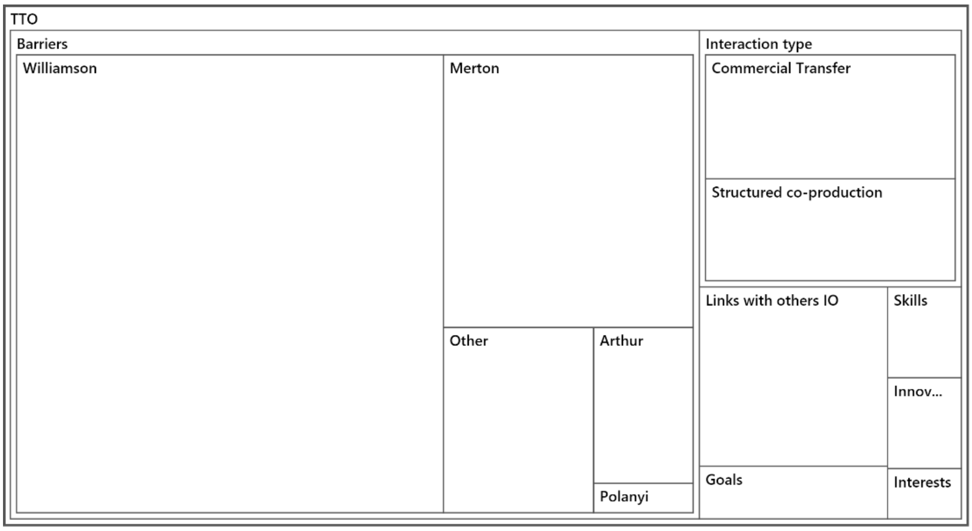
d) Facilitation of Interactions: How does your organization facilitate the frequency of interactions among actors, for example, by organizing events?

15. Skill Requirements: Are there certain skills or specific experiences required to join your organization? What are the profiles that your organization generally recruits?

Relations with Other Actors:

16. What are your connections with other organizations, such as: [choose from SATT, incubators, joint laboratories, competitiveness clusters, innovation parks, innovation agencies], or other actors not mentioned here?
17. Specifically, how do you work together and on which projects?
18. What do you bring that these structures do not? And vice versa?

Appendix 3: Extracted hierarchical diagram of codes for TTO.



N.B: The codes are shown for the firs-order codes. We have sub-levels for each code. For example, within Williamson, we will find the different types of costs. For Merton, we also coded "No-Merton" when IOs emphasized that they didn't encounter those types of problems.

Appendix 4: Online Survey.

Enquête compétences

Bonjour,

Vous avez été invité(e) à répondre à ce questionnaire en ligne portant sur le parcours et les compétences des employés travaillant dans diverses organisations intermédiaires. Vos réponses sont précieuses et contribueront à orienter les plans d'action pour développer et soutenir les compétences nécessaires à ces nouveaux métiers.

Nous vous remercions pour votre temps.

Informations importantes:

- Le questionnaire comprend 23 questions et prend en moyenne 5 à 10 minutes pour être
- complété. Vous pouvez répondre aux questions dans l'ordre que vous souhaitez en cliquant sur l'onglet de navigation "***index des questions***".

- Si vous souhaitez reprendre le questionnaire plus tard, enregistrez vos réponses via l'onglet "***enregistrer mes réponses au questionnaire***" et suivez les indications.

- Il est essentiel de répondre à toutes les questions jusqu'à la fin, sinon vos réponses seront perdues et ne pourront être exploitées.

- Le questionnaire sera ouvert jusqu'au 15 juillet.
-

En cas de problème durant le questionnaire, veuillez nous contacter au 06 85 37 10 72 ou par mail à stung@unistra.fr.

Il y a 27 questions dans ce questionnaire.

Appendix 5: Invitation letter for online survey.

Appendix 6: Correlation Matrix

Faculté de Sciences
Economiqes & de Gestion
61 Avenue de la Forêt Noire
FR-67085 Strasbourg Cedex

Skills

A l'attention des employés des incubateurs académiques : il reste encore quelques jours pour participer à l'enquête compétences ! Si vous avez déjà répondu, veuillez ne pas tenir compte de ce mail.

Madame, Monsieur,

Dans le cadre d'une enquête nationale comparative, le Laboratoire d'Economie BETA-CNRS de l'Université de Strasbourg mène actuellement une recherche visant à étudier les parcours professionnels et les compétences des employés (hors corps administratif) travaillant dans diverses organisations soutenant la collaboration entre la recherche, l'industrie et le monde socio-économique. Ce projet est porté par Mme Sarah Tung, dans le cadre de sa thèse de doctorat en économie.

Les SATT, les incubateurs académiques, les IRT, les laboratoires communs, les pôles de compétitivité, laboratoires ouverts (Open-Lab, Fab-Lab, Living-Lab) …etc. jouent un rôle indispensable pour la recherche et l'innovation. Comprendre les différentes trajectoires et compétences des individus ayant choisi d'y travailler est primordial afin de renforcer les dispositifs de soutien à ces nouveaux métiers.

Nous vous serions très reconnaissants si vous acceptiez de collaborer en répondant avec la plus grande précision possible à notre questionnaire en ligne. La durée pour y répondre est estimée à **5-10 minutes** et les réponses seront traitées de manière strictement anonyme et confidentielle.

Pour répondre au questionnaire, cliquez ici !

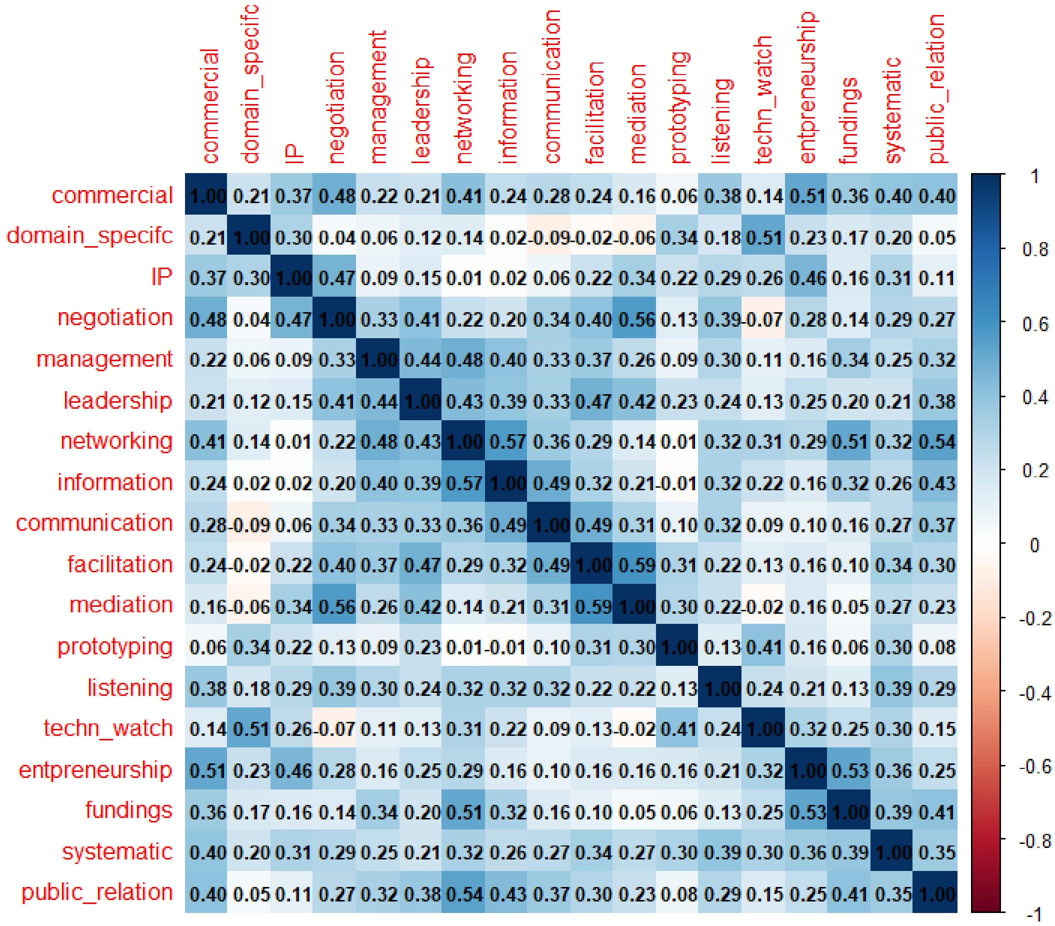
La date de fin de l'enquête a été étendue jusqu'au **15 Juillet.** Afin de générer un nombre de réponses qui assure la représentativité des résultats, nous vous serions reconnaissants de bien **vouloir transférer ce mail auprès de votre vos collèges et réseaux.**

Nous sommes à votre disposition si vous avez des questions ou besoin de plus amples renseignements sur cette recherche. Votre contribution est essentielle pour enrichir notre compréhension du rôle des structures d'innovation en France. Il sera disponible d'accéder aux résultats de l'enquête début 2025. N'hésitez pas à nous contacter en attendant.

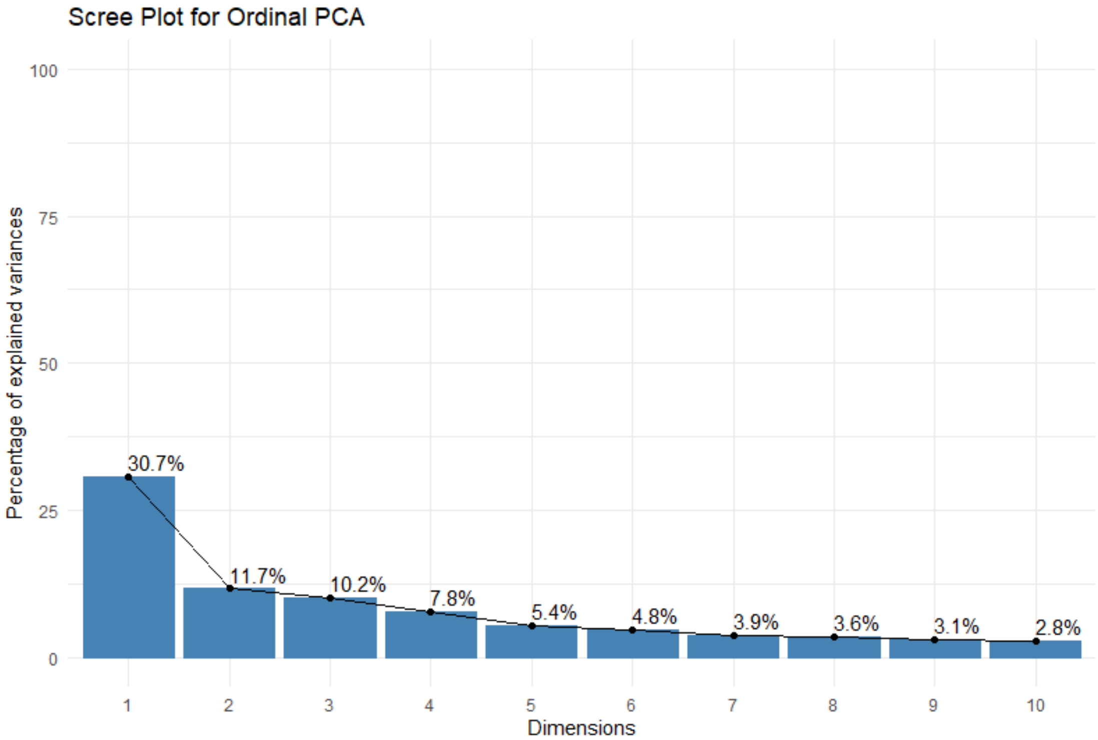
Nous vous remercions sincèrement de votre participation.

Sarah TUNG
Enseignante à Science Po Strasbourg,
Chercheuse-doctorante au BETA-CNRS,
Faculté des Sciences Economiques et de Gestion de l'Université de Strasbourg
Hemisf4ire Design School de l'Université Catholique de Lille.

Mail : stung@unistra.fr ou Sarah.tung@univ-catholille.fr



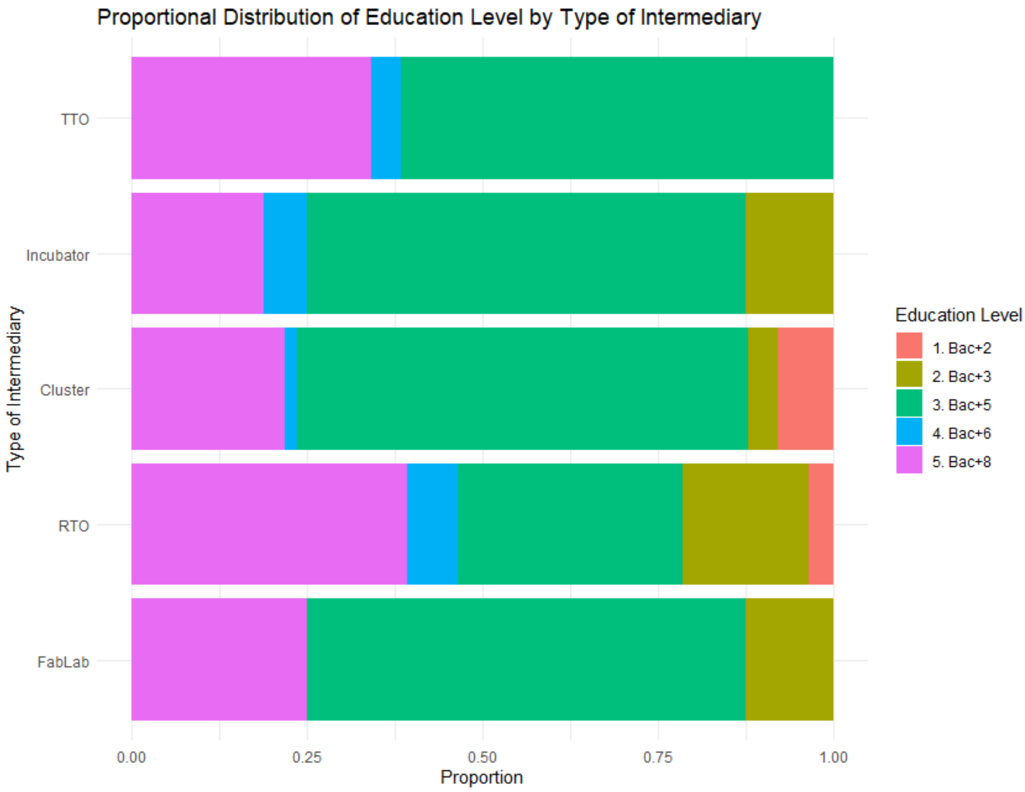
Appendix 7: Scree plot for Ordinal PCA



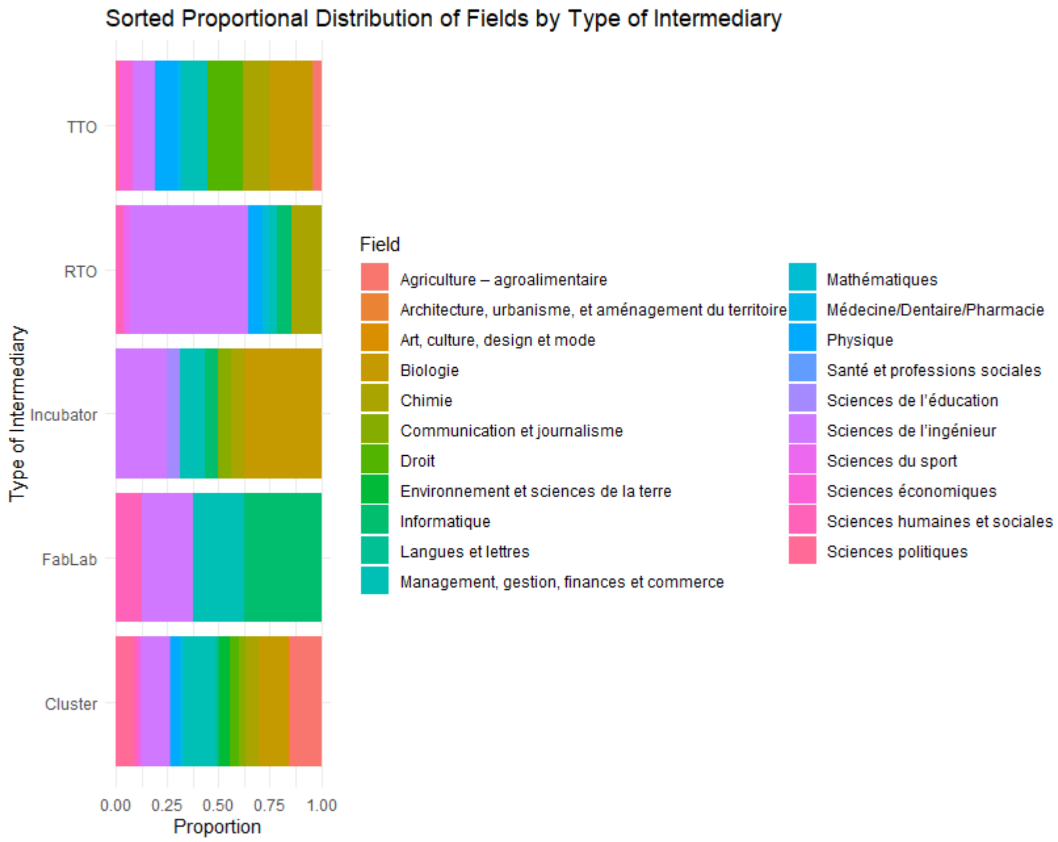
Appendix 8: Contributions of Variables to Dimension 1 and 2

Variable	Contributions to Dim 1	Contributions to Dim 2
Commercial	7.2	1.49
domain_specifc	1.27	22.42
IP	3.65	8.33
Negotiation	6.82	1.48
Management	6.21	3.26
Leadership	7.08	2.92
Networking	8.26	0.65
Information	6.36	4.32
Communication	5.82	8.31
Facilitation	6.89	4.71
Mediation	5.03	4.04
Prototyping	1.94	6.17
Listening	5.77	0.13
techn_watch	2.72	16.89
Entpreneurship	5.46	9
Fundings	5.27	2.23
Systematic	7.05	2.49
public_relation	7.21	1.18

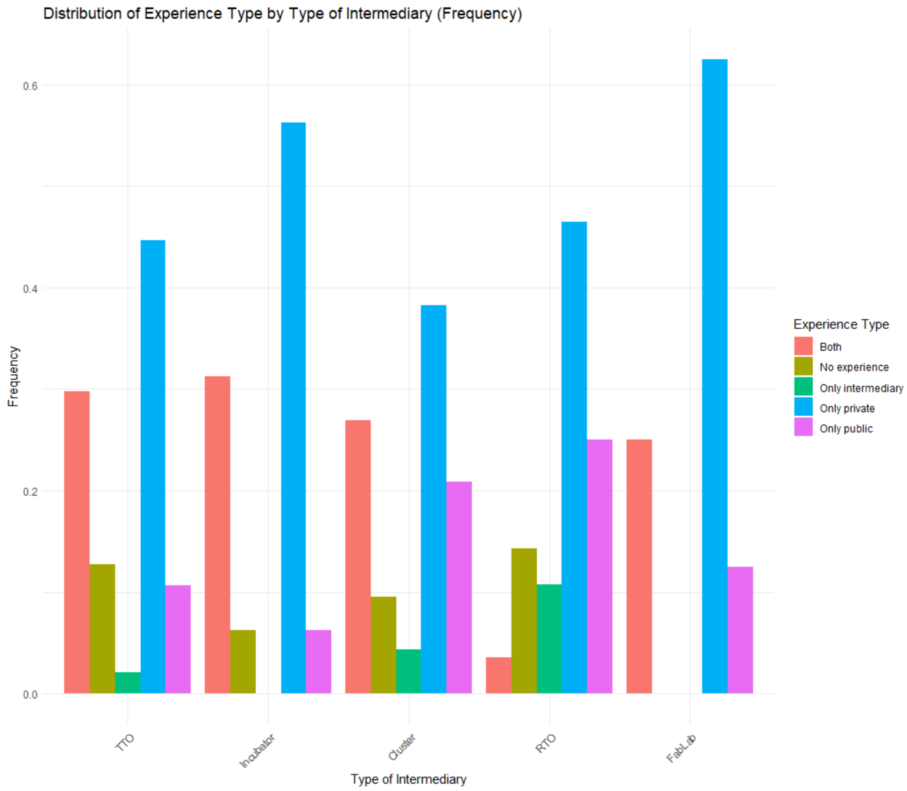
Appendix 9: Distribution of educational level across types of IOs study across IOs



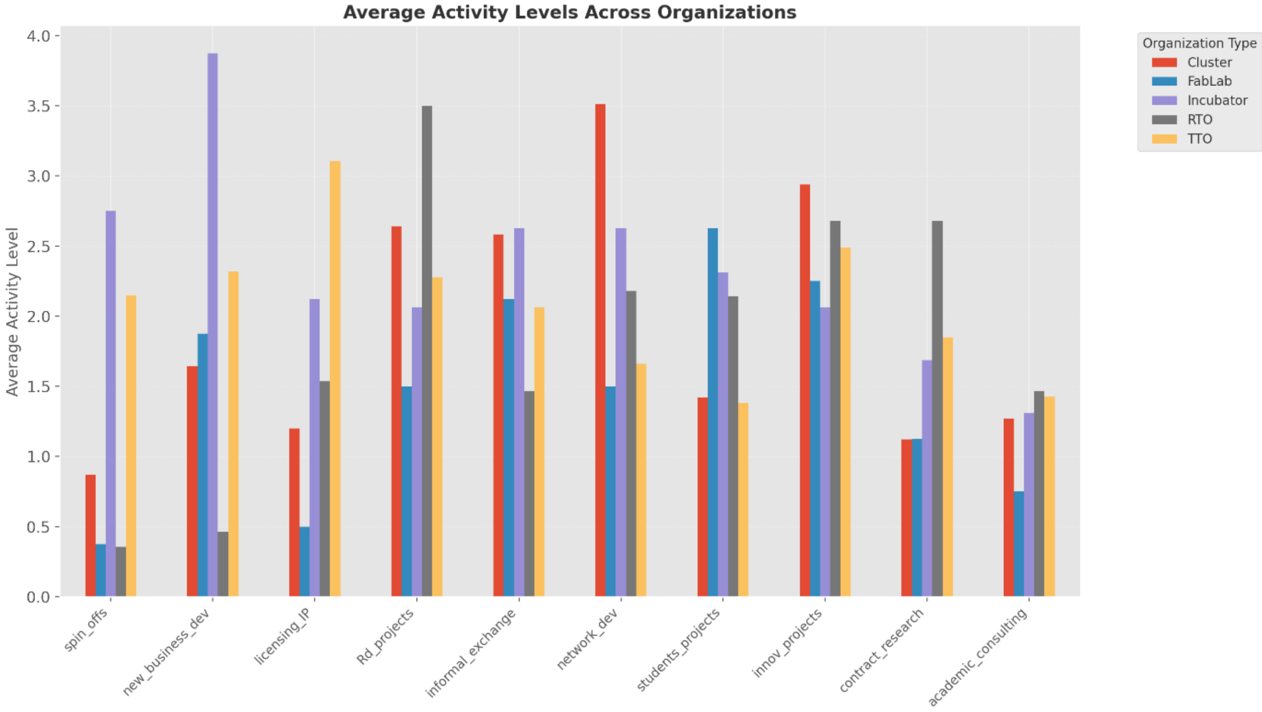
Appendix 10: Distribution of fields by IO



Appendix 11: Distribution of type of experience across IOs



Appendix 12: Average involvement for each activity across IO



Based on the highest average activity involvement for each intermediary, we can see that the distribution of activities across intermediaries align with their specialized roles. Incubators lead in spin-offs and new business development, TTOs dominate licensing, RTOs are most active in R&D projects and contract research, and academic consulting, Clusters excel in informal exchanges, network development, and innovation projects, FabLabs show the highest engagement in student projects.

Appendix 13: Summary statistics of activities variables ordered by decreasing mean value

	Count	Mean	median	std	min	25%	50%	75%	max
network_dev	214	2.84	3	1.42	0	2	3	4	4
innov_projects	214	2.8	3	1.29	0	2	3	4	4
Rd_projects	214	2.65	3	1.40	0	2	3	4	4
informal_exchange	214	2.47	3	1.37	0	1	3	4	4
new_business_dev	214	1.81	2	1.49	0	0	2	3	4
licensing_IP	214	1.63	2	1.42	0	0	2	3	4
students_projects	214	1.51	1	1.32	0	0	1	2	4
contract_research	214	1.49	1	1.40	0	0	1	3	4
academic_consulting	214	1.22	1	1.24	0	0	1	2	4
spin_offs	214	1.15	0	1.40	0	0	0	2	4

Activities such as **Network development, R&D and innovation projects and informal exchanges** have relatively high mean values with an average level of involvement around the mid-range of the scale. Moreover, for these activities, the 25th, 50th (median), and 75th percentiles are relatively close to each other (all in the range of 2 to 4), indicating a consistent level of engagement across many intermediaries. Activities like **new businesses development, licensing and IP** have a medium level of involvement (median of 2) and the 25^{th} percentiles show only 0 values which suggest involvement of intermediary but only in high level. In contrast, **student projects, contract research, academic consulting, and spin-offs** have much lower mean values and show a skewed distribution, with a median of 0 or 1 and a wide interquartile range. This.suggests they are less commonly performed or are niche activities in some intermediaries.

Appendix 14: Excerpt of translated survey on Limesurvey (question 23 and 24 for activities and skills)

Question 23: Regarding your current position, to what extent are you active in the following activities:

[The question presents a table with the following activities to be rated from "Not at all active" to "Very active"]

1. Development of spin-offs
2. Development of new companies
3. Licensing and protection of intellectual property
4. Collaborative research projects (*)
5. Informal exchanges (setting up mechanisms to facilitate proximity)
6. Networking (organizing events, scientific or non-scientific conferences, creating electronic networks...)
7. Student-company projects (student entrepreneurs, internships...)
8. Other collaborative innovation projects (*)
9. Contract research (*)
10. Academic consulting (*)

Definitions:

- A **spin-off** is a company created from knowledge and technologies resulting from research
- **Collaborative research projects:** projects carried out jointly by public researchers and private companies. These can be small-scale projects or strategic partnerships with multiple stakeholders.
- **Academic consulting:** refers to research and advisory services provided by public researchers to industry clients
- **Contract research:** This is research that a private company entrusts to universities or public research institutes. The research is more applied.
- **Other collaborative innovation projects**: projects that involve multiple partners (public, private and/or citizens) with the aim of developing new innovations. These projects do not necessarily have a research objective.

Question 24: In the context of your missions and daily activities, how frequently do you use the following skills?

[The question provides a scale from 1 to 5, where:]

1: I understand what the skill consists of and its importance, but I don't use it at all in my activities
2: I understand what the skill consists of and its importance, but I rarely use it in my activities
3: I understand what the skill consists of and its importance, and I sometimes use it in my activities

4: I understand what the skill consists of and its importance, and I often use it in my activities
5: I understand what the skill consists of and its importance, and I use it very often in my activities

1. **Business awareness:** Knowledge of the business environment and marketing opportunities
2. **Domain-specific knowledge**: Technical and specific knowledge of a product, technology, process, or tool...
3. **Intellectual property rights and licensing skills:** Knowledge of property rights in terms of creativity and the ability to protect returns on investment
4. **Negotiation:** The ability to apply different tactics to reach an agreement
5. **Project management**: The ability to use techniques, methods and tools to plan and execute actions in order to achieve an objective
6. **Leadership and team management**: The ability to supervise, coordinate and encourage a team to achieve a goal
7. **Networking:** The ability to build a network of partners to rely on to advance one's objectives and/or broaden the range of opportunities
8. **Information exchange:** The ability to offer a set of information exchange channels
9. **Communication:** Competence in empathy, perspective change and use of media in a clear, positive and conversational manner
10. **Facilitation:** The ability to set up a framework, methods and processes that allow a group to operate in collective intelligence
11. **Mediation**: The ability to facilitate relationships and resolve conflicts
12. **Co-design and prototyping:** Competence in applying design methods such as design thinking, change theory planning, prototyping, etc.
13. **Listening and translation:** The ability to listen to and understand needs and adapt one's language according to the interlocutor
14. **Technological and scientific watch:** The ability to follow the evolution of technologies and innovations in different sectors and to identify new ones
15. **Entrepreneurship:** Competence in project and business incubation processes
16. **Fundraising:** Competence in financing, grants, crowdfunding
17. **Systems thinking:** Competence to approach challenges holistically and be able to examine the links and interactions between all constituent elements
18. **Public relations**: Competence in promoting and enhancing the image of a brand or projects to targeted audiences (partners, shareholders, media, etc.)

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Summary of thesis

The landscape of science-industry relationships lies has grown increasingly complex, with proliferating intermediary organizations creating intricate support ecosystems that remain poorly understood. While policies have criticized these intermediaries as redundant and lacking coherence, this thesis demonstrate their essential and complementary roles through four methodological approaches articulated in four chapters: a theoretical framework, a historical analysis, a qualitative study based on interviews, and a quantitative survey of intermediary professionals. Three fundamental barriers in science-industry interactions are developed: Merton barriers (cultural/institutional), Williamson barriers (transactional), and Polanyi barriers (tacit knowledge transfer). By tracing intermediaries' evolution from pre-19th century to WWII, this research demonstrates how their functions evolved in response to changing contexts. By analyzing current practices in the Hauts-de-France health sector, the research reveals coordination patterns and introduces 'Arthur barriers' related to network coordination costs. Through extensive analysis of professionals working in these organizations, the study reveals how different types of intermediaries maintain distinct but complementary skill profiles. The findings demonstrate that the multiplicity of science-industry intermediaries can be explained through their complementary functions, diverse expertise profiles, their dynamic evolving functions and their coordinated efforts. This thesis challenges current policy assumptions by demonstrating the positive value of having multiple intermediaries in supporting science-industry links. These insights inform policy and managerial recommendations for public authorities, universities, and organizations aiming to better support science-industry collaboration.

Keywords: intermediary organizations, innovation intermediaries, science-industry links, university-industry interactions, collaboration barriers, technology transfer ecosystem, health sector, intermediary skills

Résumé de la thèse

Le paysage des relations science-industrie est devenu de plus en plus complexe, avec une prolifération d'organisations intermédiaires créant des écosystèmes de soutien complexes qui restent mal compris. Cette thèse démontre leurs rôles essentiels et complémentaires à travers quatre approches méthodologiques : un cadre théorique, une analyse historique, une étude qualitative basée sur des entretiens et une enquête quantitative auprès des professionnels intermédiaires. Trois barrières fondamentales dans les interactions université-industrie sont conceptualisées: les barrières Merton (culturelles/institutionnelles), les barrières Williamson (transactionnelles) et les barrières Polanyi (transfert de connaissances tacites). En retraçant l'évolution des intermédiaires de la période pré-XIX siècle à la Seconde Guerre mondiale, cette recherche démontre comment leurs fonctions ont évolué en réponse aux contextes changeants. En analysant les pratiques actuelles dans le secteur de la santé des Hauts-de-France, la recherche révèle des modèles de coordination et introduit les "barrières Arthur" liées aux coûts de coordination des réseaux. À travers une analyse approfondie des professionnels travaillant dans ces organisations, l'étude révèle comment différents types d'intermédiaires maintiennent des profils de compétences distincts. Les résultats démontrent que la multiplicité des intermédiaires science-industrie peut s'expliquer par leurs fonctions complémentaires, leurs profils d'expertise variés, leurs fonctions évolutives dynamiques et leurs efforts coordonnés. Cette thèse remet en question les hypothèses politiques actuelles en démontrant la valeur positive d'avoir de multiples intermédiaires pour faciliter les liens entre science et industrie. Ces résultats alimentent des recommandations politiques et managériales pour les autorités publiques, les universités et les organisations de support.

Mots-clés : organisations intermédiaires, intermédiaires d’innovation, relations science-industrie, barrières de collaboration, écosystème de transfert de technologie, santé, compétences intermédiaires