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University-Industry Interactions:

Understanding University Licensing Strategies and Beyond

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La Collaboration entre l'Université et l'Industrie:

Comprendre les Stratégies de Licences Universitaire et au-delà

Sıla ÖCALAN ÖZEL

Strasbourg, 12th December 2018

Dedicated to my beloved grandmother

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Résumé de la thèse

Les universités représentent les principales organisations générant et diffusant des connaissances scientifiques, et ce, traditionnellement, à travers la recherche et les missions d'enseignement. Cependant, avec la nouvelle "troisième mission" qui leur a été attribuée, les universités ont été encouragées à contribuer davantage à l'innovation industrielle et à la croissance économique en commercialisant les résultats de leurs recherches, notamment en brevetant et en octroyant des licences sur les produits de leur recherche. Cette thèse vise à étudier l'impact social des stratégies d'octroi de licences des universités, ainsi qu'à analyser les interactions dynamiques entre divers canaux de transfert de connaissances université-industrie. Ainsi, la première question de recherche abordée est la suivante: "Comment les pratiques en matière de licences des universités (et donc de leurs Offices de Transfert de Technologie (OTTs)) peuvent-elles être améliorées, tout en transférant les résultats de la recherche universitaire, financée à travers les fonds publics, à l'industrie?". À cette fin, nous examinons, en particulier, le lien entre le degré d'exclusivité des licences et les caractéristiques des inventions sous licence, en utilisant une approche théorique et économétrique. Les résultats théoriques et empiriques de notre recherche suggèrent que les pratiques des OTTs ne sont peut-être pas optimales, notamment en ce qui concerne le transfert de technologie universitaire financée par les fonds publics, ce qui laisse à penser que des améliorations pourraient encore être apportées. En considérant des environnements d'innovation statiques (non-séquentiels) et dynamiques (séquentiels), notre recherche souligne que le degré d'exclusivité doit être adapté au contexte, et que deux objectifs différents doivent être balancés: (i) inciter les entreprises à investir dans des inventions universitaires, et (ii) assurer la diffusion effective de la technologie en réduisant les coûts sociaux liés aux monopoles. Notre recherche suggère également que les OTTs universitaires pourraient développer des stratégies alternatives de licences Open Source dans certains contextes, en particulier lorsque les inventions sont séquentielles. D'autre part, notre étude souligne le fait qu'il existe une variété de canaux formels et informels par lesquels les universités peuvent contribuer à la croissance économique. Notre deuxième question de recherche est donc: "Comment les canaux formels et informels de transfert de connaissances université-industrie interagissent-ils dans le temps?". En s'appuyant sur une analyse qualitative longitudinale, notre recherche suggère également qu'il existe des complémentarités dynamiques entre les canaux formels et informels du transfert de connaissances. Cette interaction dynamique crée un effet cumulatif important en ce qui concerne l'activité de valorisation de la recherche, et renforce la dimension collective de la valorisation. Notre étude a donc d'importantes implications en termes de management pour les OTTs universitaires et les décideurs politiques des universités qui cherchent à améliorer les interactions université-industrie.

Mots-clés: Interactions université-industrie, droits de propriété intellectuelle, stratégies de licences des universités, clauses d'exclusivité, licences open source, caractéristiques des inventions, Offices de Transfert de Technologie, canaux de transfert de connaissances, économie de l'innovation

Thesis Abstract

Universities are the key organizations that generate and disseminate scientific knowledge, traditionally through research and teaching missions. Yet, with the new "third mission" attributed to universities, they have been encouraged to contribute actively to industrial innovation and economic growth by commercializing their research results, especially through patenting and licensing these outputs. This thesis aims at investigating the social impact of university intellectual property (IP) licensing strategies and at analyzing the dynamic interactions among various university-industry knowledge transfer (UIKT) channels. Thus, the first research question addressed is "how can the licensing practices of universities (and hence their TTOs) be improved while transferring the publicly funded university research output to the industry?". To that end, we examine, in particular, the link between the degree of exclusivity of licenses and the characteristics of the licensed inventions by using game theoretical and econometric methodologies. Both the theoretical and empirical findings of our research suggest that the practices of TTOs may not be optimal with respect to the transfer of publicly funded university technology, underlying the fact that there may still be room for the improvement. Considering both static (non-sequential) and dynamic (sequential) innovation environments, our research emphasizes that the degree of exclusivity should be tailored to the context which should balance two different objectives: (i) providing firms incentives to invest in university inventions, and (ii) ensuring the effective diffusion of technology by reducing the social cost associated with monopolies. Our research also suggests that university TTOs could develop alternative open source licensing (OSL) strategies in certain contexts, in particular, when the inventions are sequential. On the other hand, our study acknowledges the fact that there is a variety of formal and informal channels through which universities can contribute to the economy. Thus, the second research question is "how do formal and informal channels of UIKT interact over time?". Relying on a longitudinal qualitative analysis, our research also suggests that there are dynamic complementarities between formal and informal channels of the transfer. This dynamic interaction creates a strong cumulative effect with respect to the research valorization activity and reinforces the collective dimension of valorization. Our study hence provides important managerial implications for university TTOs and policy makers aiming at improving the university-industry interactions (UIIs).

Keywords: University-industry interactions, intellectual property rights, university licensing strategies, exclusivity clause, open source licensing, invention characteristics, technology transfer offices, knowledge transfer channels, innovation economics

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List of Abbreviations and Acronyms

AAAS	American Association for the Advancement of Science
ANR	National Agency for Research (*Agence Nationale de la Recherche*)
ANVAR	National Agency for the Valorization of Research (*Agence Nationale de Valorisation de la Recherche*)
AT&T	American Telephone and Telegraph Company
AUTM	Association of University Technology Managers
BiOS	Biological Open Source
BSD	Berkeley Software Distribution
CAD	Computer Aided Design
CD	Compact Disc
CEA	Atomic Energy Commission (*Commissariat à l'Energie Atomique*)
CERN	European Organization for Nuclear Research (*Centre Européen pour la Recherche Nucléaire*)
CIFRE	Industrial Contracts for Training through Research (*Conventions Industrielles de Formation par la Recherche*)
CNRS	National Center for Scientific Research (*Centre National de la Recherche Scientifique*)
COCON	Cohort of Contracts
CRC	Collaborative Research Centers
CRITT	Regional Centers for Innovation and Technology Transfer (*Centre Régional d'Innovation et de Transfert de Technologie*)
DOD	Department of Defense
DVD	Digital Video Disc
EPO	European Patent Office
FDA	Food and Drug Administration
FOSS	Free Open Source Software
FSF	Free Software Foundation
GIF	Graphics Interchange Format
GNU	GNU's Not UNIX

GPL	General Public License
GPT	General Purpose Technology
HEW	Department of Health, Education, and Welfare
IAA	Invention Administration Agreement
IBM	International Business Machines Corporation
IC	Insulin Committee
ICT	Information & Communication Technologies
INRA	French National Institute for Agricultural Research (*Institut National de la Recherche Agronomique*)
INSA	National Institute of Applied Sciences (*Institut National des Sciences Appliquées*)
INSEE	National Institute of Statistics and Economic Studies (*Institut National de la Statistique et des Etudes Economiques*)
INSERM	National Institute for Health and Medical Research (*Institut National de la Santé et de la Recherche Médicale*)
IP	Intellectual Property
IPC	International Patent Classification
IPR	Intellectual Property Rights
ISE	Intermediate-Sized Enterprises
JPEG	Joint Photographic Experts Group
KT	Knowledge Transfer
LGPL	Lesser General Public License
LRD	Leuven Research and Development
LZW	Lempel–Ziv–Welch
MIT	Massachusetts Institute of Technology
MRI	Magnetic Resonance Imaging
MTA	Material Transfer Agreement
NIH	National Systems of Innovation
NPE	Non Practicing Entity
NSF	National Science Foundation
OHL	Open Hardware License

OSDD	Open Source Drug Discovery
OSHW	Open Source Hardware
OSHWA	Open Source Hardware Association
OSI	Open Source Innovation
OSL	Open Source Licensing
OSRD	Office of Scientific Research and Development
OTL	Office of Technology Licensing
PhD	Doctor of Philosophy
PIA	Investment for the Future Program (*Programme d'Investissements d'Avenir*)
PRO	Public Research Organization
R&D	Research and Development
rDNA	Recombinant Deoxyribonucleic Acid
SAIC	Service for Industrial and Commercial Activities (*Service d'Activités Industrielles et Commerciales*)
SATT	Technology Transfer Acceleration Company (*Société d'Accélération du Transfert de Technologie*)
SME	Small and Medium-sized Enterprises
SPNE	Subgame Perfect Nash Equilibrium
TC	Total Cost
TTO	Technology Transfer Office
U.S.	United States
UI	University Incubator
U-I	University-Industry
UII	University-Industry Interaction
UIKT	University-Industry Knowledge Transfer
UK	United Kingdom
UT	University of Toronto
WARF	Wisconsin Alumni Research Foundation
WIPO	World Intellectual Property Organization

GENERAL INTRODUCTION

General Introduction

Background and motivations

Universities are the key organizations that generate and disseminate scientific knowledge widely, and university knowledge is a substantial resource for industrial innovation and economic growth (Mowery *et al.*, 2004; D'Este and Patel, 2007; Veugelers and Del Rey, 2014). The strong link between scientific knowledge and industrial innovation is embodied in the interactions between university and industry. Although university-industry interaction (UII) is not a new phenomenon and can be traced back to the 19th century, the last few decades have witnessed an acceleration and institutionalization of the interactions, with the establishment of dedicated intermediary structures such as technology transfer offices (TTOs) (Geuna and Muscio, 2009).

In parallel to this acceleration, UIIs have also gained scholarly attention with the contribution of theories such as the "Triple Helix Model" (Etzkowitz and Leydesdorff, 1995; Etzkowitz and Leydesdorff, 2000) or the "Open Innovation Paradigm" (Chesbrough, 2003), and an important stream of research has focused on universities (e.g. Mowery *et al.*, 2004; Debackere and Veugelers, 2005; D'Este and Perkmann, 2011; Perkmann *et al.*, 2013).

UIIs have been intensified both in volume and in the diversity of channels used in the interaction process (D'Este and Patel, 2007). One important factor determining the intensity of the interactions has been the changing perspectives concerning the link between basic science and applied research. Throughout the 20th century, debates on the relation between science and technology (i.e. basic vs. applied knowledge) have paved the way for the evolution of policies concerning the role of universities. Should they be isolated "ivory towers" producing and disseminating scientific knowledge or should they be more active contributors of innovation by commercializing their research results? The current paradigm has favored the latter and hence attributed universities a "third mission" besides their traditional research and teaching missions (Etzkowitz and Leydesdorff, 2000).

Compared to most European counterparts, U.S. universities have more intensely interacted with industry. This can mainly be attributed to the institutional differences in higher education systems. Historically, American universities were more autonomous and usually lacked centralized control in contrast to most European universities, as can be exemplified by the rigid state control of French universities, which is still the case today (Franzoni and Lissoni, 2009). While universities were only responsible for teaching in France, research activities were assigned to non-academic public research organizations (PROs) such as CNRS (the National Center for Scientific Research). On the other hand, while in France the research has largely been publicly funded, U.S. universities were highly dependent on local industrial funding, which made them more responsive to the needs of their local environment.

These institutional differences made American universities more application-oriented while determining their research agendas and enabled them to establish stronger ties with the industry (Mowery *et al.*, 2004).

Nevertheless, the sources and the scale of funding were radically transformed after the U.S. entry into World War II, with "Big Science" programs (e.g. Manhattan Project) being heavily funded by federal governments during and immediately after the War, which weakened the universities' ties with the local industry (Mowery *et al.*, 2004). An influential figure shaping the postwar federal science policy was Vannevar Bush, who argued in his famous 1945 Report to the President Franklin D. Roosevelt, that the basic research was the source of economic growth. He therefore called for a strong federal support for basic research both in military and nonmilitary areas.

Bush's Report clearly distinguished the spheres of basic and applied knowledge, claiming that these two are incompatible. Therefore universities were deemed to be responsible for the generation and the dissemination of basic research without a commercial purpose. In this regard, Bush's Report is considered as the basis of the "linear model of innovation" (Freeman, 1996; Mowery, 1997; Stokes, 1997) which has long been the dominant paradigm shaping science and technology policies. In the linear model, innovation starts with the basic research, which is then followed by applied research, development, and finally ends with the production and diffusion of innovation.

Yet, Bush's linear vision has been attacked by many scholars (Freeman, 1982; Rosenberg, 1982; Kline, 1985; Kline and Rosenberg, 1986; Gibbons *et al.*, 1994; Pavitt, 1999; Stokes, 1997; Etzkowitz and Leydesdorff, 2000). It has been argued that basic and applied researches are not incompatible but are often complementary; better research could be achieved if these two interact (Stokes, 1997). Furthermore, it was claimed that there isn't a unidirectional flow of knowledge from science to innovation as depicted in the linear model; knowledge flow is multidirectional throughout the innovation process (Kline and Rosenberg, 1986).

The postwar paradigm that emerged from Vannevar Bush's Report in 1945 was radically altered with the passage of the Bayh-Dole Act in U.S. in 1980. Bayh-Dole allowed universities to retain title to patents resulting from federally funded research and mandated universities to patent their commercially valuable research results (Thursby and Thursby, 2011). Therefore, universities were required to actively contribute to innovation and economic growth by engaging in third stream commercial or entrepreneurial activities by patenting their research results and licensing them to industrial partners (Etzkowitz and Leydesdorff, 2000). To stimulate the UIIs by increasing the awareness of intellectual property rights (IPR), emulations of Bayh-Dole resulted in similar legislations in Europe, such as the "Science Law" passed in Spain in 1986 or the "Innovation Act" passed in France in 1999 (Azagra-Caro *et al.*, 2006; Della Malva *et al.*, 2013).

The IPR awareness of universities had already started with the technological developments in commercially attractive fields such as biotechnology and software during the 1970s (Mowery *et al.*, 2004), yet university patenting and licensing boomed after the passage of the Bayh-Dole Act and similar other legislations in other industrialized countries throughout the 1980s and 1990s. Furthermore, intermediary structures such as TTOs proliferated to manage the patenting and licensing activities of universities, as a result of the increasing volume and complexity of transfer activities (Geuna and Muscio, 2009).

This context has attracted a substantial body of research that discussed the potential positive and negative effects of university patenting and licensing (Henderson *et al.*, 1998; Mowery *et al.*, 2001; Jensen and Thursby, 2001; Thursby and Thursby, 2002; Mowery *et al.*, 2004; Geuna and Nesta, 2006; Audretsch and Göktepe-Hultén, 2015). Some scholars argued that patenting university inventions are necessary to incentivize firms to invest in university research results, which are mostly embryonic (Jensen and Thursby, 2001), while some others argued that it is not compatible with the culture of open science (Dasgupta and David, 1994).

As an extension of university patenting, a considerable share of research is devoted to licensing (e.g. Jensen and Thursby, 2001; Thursby *et al.*, 2001; Thursby and Thursby, 2002; Mowery and Sampat, 2004; Conti and Gaule, 2011; Dechenaux *et al.*, 2011; Thompson *et al.*, 2018). Indeed, patenting is not an interaction mechanism alone, because a patent document does not allow by itself the transfer of the technology, since the technology cannot be exploited without getting a legal permission if this technology is protected by a patent. This legal permission is usually given through a licensing contract. Licensing is a means to exploit IPR, that is to say a legal permission which grants rights (either all or in part) to use, reproduce, modify, distribute, sell, import or sublicense an invention, in exchange for an agreed payment which could be in the form of a fixed fee, royalty or an equity share (World Intellectual Property Organization [WIPO], 2015).

This stream of research has advanced our understanding concerning the university licensing activity by examining, for instance, the number of licensing contracts executed, the royalties received from these contracts, or its effect on the scientific knowledge production. Yet, still a very little is known with respect to the content of these licensing contracts, with the exception of research dedicated to the structure of inter-firm licensing contracts (e.g. Bessy and Brousseau, 1998; Anand and Khanna, 2000). This is mainly due to the difficulty of accessing these contracts because of the confidential information contained in them. Also, the complex legal language of these contracts makes it difficult to understand the specific clauses without a legal expertise. In addition, the social impact of the licensing contracts remained understudied in the university licensing context.

Although this thesis focuses primarily on university licensing, it acknowledges that it is not the only mechanism through which university knowledge can be transferred. Concentrating only on this institutionalized mode of transfer would lead to the underestimation of other channels of UIIs built mostly through personal relations (Bodas Freitas *et al.*, 2013). Indeed, there are variety of formal and informal channels allowing universities to contribute to industrial innovation and economic growth (Veugelers and Del Rey, 2014), and a growing body of literature has already provided insights about various channels of transfer (D'Este and Patel, 2007; Link *et al.*, 2007; Bekkers and Bodas Freitas, 2008; Perkmann *et al.*, 2013). Yet, more research is needed to understand the complex interactions between these channels.

Objective of the thesis, methodologies and main results

Given the background, motivations and the research gap, the primary objective of this thesis is to discuss the social impact of university intellectual property (IP) licensing policies. Public universities are non-profit organizations aiming at generating and disseminating the scientific knowledge widely. These missions necessitate a careful design of licensing contracts while transferring their technologies, to ensure the diffusion of knowledge with the least cost to the society. In this research, we examine, in particular, the exclusivity clause of licensing contracts, and then discuss the potential effect of exclusivity decision on social welfare. In fact, a licensing contract includes many different clauses. Among different clauses of the licensing contracts, a specific attention has been devoted to payment schemes (Bray and Lee, 2000; Thursby *et al.*, 2001; Dechenaux *et al.*, 2009; 2011) whereas less is known concerning the exclusivity scheme. The exclusivity decision is a strategic choice which might affect the social welfare through a trade-off between the incentive to invest in university research and the associated monopoly deadweight loss of exclusivity. Thus, it should balance these two contradicting objectives. Moreover, too restrictive licensing policies may hinder the effective diffusion of the invention or knowledge and an appropriate design of the licensing policy is therefore important to ensure that publicly funded research yields the highest benefit for the society (Mowery *et al.*, 2004). Considering universities' social mission, we emphasize that a specific attention must be devoted to the exclusivity clause in university-industry (U-I) licensing contracts.

Since TTOs are the intermediary organizations managing the licensing activities on behalf of universities, a careful attention must be devoted to their licensing practices. There is a vast literature discussing the factors affecting the performance of TTOs (Debackere and Veugelers, 2005; Macho-Stadler *et al.*, 2007; Etzkowitz and Göktepe-Hultén, 2010; Comacchio *et al.*, 2012; O'Kane *et al.*, 2015a). Yet, the social mission of university TTOs remained rather underemphasized. Since the current performance metrics rely mostly on easily measurable activities such as the number of licensing contracts executed or royalties received (Thursby and Thursby, 2002; Thursby and Kemp, 2002), TTOs may be inclined to license the university inventions to the highest bidders, usually with exclusive terms, in order to remain profitable. Although exclusive licensing might be necessary in certain contexts to transfer the university technology, relying constantly on exclusive licensing could be costly for the society due to high monopoly prices and limited diffusion of the knowledge embedded in transferred technology (Colyvas *et al.*, 2002). This brings up the questions of whether the TTOs should focus only on profit maximization or whether they also should pay attention to the social benefit while licensing publicly funded university research. How can the TTOs balance these two competing objectives in the current research valorization landscape?

Given our primary objective, the greater part of this thesis focuses on university licensing. In this regard, we first define different degrees of exclusivities used in licensing (i.e. exclusive, exclusive per field of use, non-exclusive and open source licensing) and identify several factors that may enter into the exclusivity decision of university TTOs. Among the various determinants, we examine the effect of the characteristics of the licensed invention on the degree of exclusivity by combining different methodologies (game theoretical model, empirical tests and conceptual analysis). Our theoretical predictions suggest that the exclusivity decision should be tailored to the context; in particular, the nature of the technology should be taken into account while licensing university inventions. However results of our empirical analysis suggest that the characteristics of the licensed technology do not significantly affect the degree of exclusivity. In particular, as opposed to the theoretical predictions, we cannot link the embryonic inventions to exclusive licenses or generic inventions to non-exclusive licenses. Also, inventions that are both embryonic and generic cannot be linked to exclusive per field of use licenses. Thus, results of our exploratory study suggest that there might still be room for the improvement of the performance of transfer activity.

Our study also suggests that although the publication of research results may allow an efficient transfer in certain contexts (especially when we consider a static (non-sequential) innovation setting), putting research outcomes into the public domain in a dynamic innovation setting may result in the exclusive appropriation of the knowledge pieces in the future. Therefore, through a conceptual analysis, we discuss that open source licensing (OSL) could be an alternative to the traditional licensing strategies or to the publication of research results when considering a cumulative innovation environment. Thus, when coupled with “copyleft” type of patent licenses, OSL might be welfare-enhancing if the inventions are sequential, since OSL allows keeping the upstream university knowledge open for follow-on downstream innovations. Yet, this strategy may work provided that the additional investments required for the development of inventions are not too high (Gambardella and Hall, 2006).

Nevertheless, patenting and licensing are only a part of a pathway which allows transferring the university knowledge to industry and may not even be the best ways (Veugelers and Del Rey, 2014). Even if in some cases patenting may facilitate transferring the technology through the channel of licensing, in many cases transfer or commercialization is still possible through different channels

(Mowery *et al.*, 2004). There exists variety of channels in university-industry knowledge transfer (UIKT), some of them are more formal, while some are more informal (thus less institutionalized). These channels include for instance consulting, research collaborations, spin-off creation, informal networks, conferences, student mobility and so on (D'Este and Patel, 2007; Link *et al.*, 2007; Bekkers and Bodas Freitas, 2008; Perkmann *et al.*, 2013; Veugelers and Del Rey, 2014). However, we still have very little knowledge concerning the channels other than patenting and licensing, and how the various channels interact over time. Therefore, this thesis also aims at providing a more holistic approach to university research valorization activities, by going beyond the rather linear process of licensing through examining the complex interactions among different channels of transfer. Based on longitudinal and qualitative interview data of the valorization activities of two reputable researchers at the University of Strasbourg, we analyze the dynamic interplay and complementarities among various transfer channels. By studying the fields of robotics and pharmaceuticals, we find that dynamic interactions reinforce the collective dimension of research valorization and generate a cumulative effect with respect to the valorization activity. Thus, our research also suggests that the contribution of academic research to innovation and economic growth is way greater than the issue of patenting and licensing. Therefore, TTOs' mission should go beyond mere management of IPR.

Organization of the thesis

This thesis comprises five chapters, each of which is distinct yet, all are interrelated articles dealing with UIIs. The organization of this PhD thesis is as follows:

Chapter 1 entitled "*A Primer on University-Industry Interactions*" aims at providing a background on the issues dealing with UIIs, by reviewing the prominent contributions in this literature. By giving a global perspective, this chapter also aims at complementing the discussions in the subsequent chapters. First, we provide the reader with a detailed presentation of UIIs from a historical perspective by examining the institutional, technological and policy changes. We explain in this chapter how the paradigm concerning the science and technology relation and the role of universities changed through time. Then we discuss the motivations to interact from the university and firm point of views, based on prominent theoretical arguments as well as the barriers to the interactions. Furthermore, we explain the variety of mechanisms used in UIIs by proposing a unified classification of the channels. Since the thesis focuses on university licensing, we examine in detail the case of university patenting and licensing. In this regard, we present the debates on university patenting from various angles and then examine the content of licensing contracts by defining the different provisions (clauses or terms) they contain. Finally, we examine the intermediary organizations, in particular TTOs, aiming at facilitating the UIKT activities. By comparing the cases of U.S. and France, we discuss the roles and objectives of university TTOs.

Chapter 2 entitled "*Exclusive or Open? An Economic Analysis of University Intellectual Property Patenting and Licensing Strategies*"[1]. This chapter aims at examining the determinants of university patenting and licensing strategies, and comparing the welfare implications under different strategies. A licensing strategy may be based on varying degrees of exclusivity granted to firms, from open, non-exclusive to exclusive licensing. We thus analyze how the nature of the technology (i.e. stage of development and specificity) invented by the university might affect the choice of patenting (or publishing) and the licensing strategy as well as the performance of the transfer. We consider a model with one university and four firms in two different sectors. We show that in some cases (for instance when the invention is embryonic), granting an exclusive license could be the strategy allowing the transfer of technology, but that in other cases (for instance when the invention is mature and generic), more open strategies based on publication or non-exclusive licenses could be more efficient. This study hence contributes to the existing literature by offering a conceptual understanding on how the nature of the invention could shape university patenting and licensing versus publishing strategies.

Chapter 3 entitled "*Invention Characteristics and the Degree of Exclusivity of University Licenses: The Case of Two Leading French Research Universities*" is the empirical extension of the theoretical predictions provided in Chapter 2. This chapter aims at analyzing the effect of invention characteristics (i.e. stage of development, specificity and appropriability) on the degree of exclusivity of licenses. We combine the data from license contract codification and from inventor survey collected within the framework of the COCON project.[2] Therefore we obtain a unique and original dataset of 91 inventions contained in 62 IP licensing (and cession) contracts executed by two leading French research universities (i.e. University of Strasbourg and University of Grenoble Alpes) between the periods of 2005-2014. To the best of our knowledge, this research -although exploratory- examines empirically for the first time the link between the exclusivity and various invention characteristics in the university-firm licensing context. Despite its small size, this original and rich dataset allows us not only to observe the degree of exclusivity in relation with the invention characteristics but also with the firm-level and institutional-level characteristics. This chapter also contributes to the literature by enriching the discussions about the performance of university-industry technology transfer.

Chapter 4 entitled "*University Licensing: Exploring the Open Source Possibility*" analyzes the implementation of an alternative licensing strategy by university TTOs. Universities produce upstream knowledge and their mission is to disseminate this knowledge widely. In line with this mission, in a dynamic innovation setting, where innovations progress cumulatively, it is crucial to keep this

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1 This chapter is based on our published article: "Öcalan Özel, S. and Pénin, J. (2016). Exclusive or open? An economic analysis of university intellectual property patenting and licensing strategies. *Journal of Innovation Economics & Management*, *21*(3), 133-153".

2 COCON (COhort of CONtracts) project is funded by ANR (French National Research Agency), which is explained more in detail in Chapter 3.

upstream university knowledge open to various innovating actors in order to avoid the blocking of downstream follow-on innovations. In the context of university licensing, this aim could be achieved through the peculiar use of IPR when coupled with open source licenses. Therefore, in this chapter we propose a framework to analyze in which context university OSL might be an alternative to traditional licensing strategies (i.e. exclusive, exclusive per field of use and non-exclusive licensing). First, we study the open source movement in software industry by revisiting the individual- and firm-level motivations to contribute to open source projects. Then we examine the recent open source innovation (OSI) projects beyond software, such as open source hardware, drug or nanotechnology. Through the analogy with "copyleft" licenses used in free open source software (FOSS), we discuss the unconventional use of patents, which corresponds to the "third face of IPR" (David, 2006), in ensuring the openness for further access and improvements to the open source inventions. Furthermore, we discuss the need to introduce an OSL strategy for the universities and detect the cases in which OSL might be a better alternative to the traditional proprietary strategies by comparing these two. Our study proposes that, contrary to a static innovation setting, in a dynamic innovation setting (i.e. when inventions are sequential) using copyleft-type of open source licenses could be welfare-enhancing. To the best of our knowledge, OSL beyond software has not yet been practiced by university TTOs. Therefore, this chapter aims at providing TTOs alternative licensing strategies for managing their IP portfolios, allowing for a more open and collaborative knowledge transfer process aligned with the university mission.

Chapter 5 entitled "*The Complementarities between Formal and Informal Channels of University–Industry Knowledge Transfer: A Longitudinal Approach*"[3] investigates the dynamic interplay between various formal and informal channels of UIKT. In this chapter, our aim is to broaden our perspective on UIIs and to capture the complexity of the knowledge transfer activity, since we know little about the way different UIKT channels interact. In this regard, we first examine the variety of channels and propose a unified classification of formal versus informal UIKT, based on the existence of a contract and face-to-face interactions. Then we observe the research valorization activities of two reputable researchers in the fields of robotics and pharmaceuticals at the University of Strasbourg, by relying on qualitative and longitudinal interview data. This approach allows us to show how different channels of transfer are exploited by research teams and how these channels are articulated over time. Thus, this chapter maps the variety of channels through which universities can contribute to industrial innovation and economic growth and shows the dynamic interactions among them.

[3] This chapter is based on our published article: "Schaeffer, V., Öcalan-Özel, S. & Pénin, J. (2018). The complementarities between formal and informal channels of university–industry knowledge transfer: A longitudinal approach. *Journal of Technology Transfer*, 1-25. https://doi.org/10.1007/s10961-018-9674-4"

CHAPTER 1

A Primer on University-Industry Interactions

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Abstract

In this chapter we review the literature on university-industry interactions (UIIs) with a specific focus on the case of university patenting and licensing. Thus, this chapter aims at providing a primer on UIIs and at giving a broader perspective on the subjects concerning UIIs to complement the discussions in the following chapters of the thesis. Therefore, we address the following questions and issues on the basis of the existing literature: (1) A historical overview of UIIs in relation with institutional, technical and policy changes (2) what are the reasons behind UIIs from university and firm point of views? (3) what are the various channels of UIIs? (4) the case of university patenting & licensing (5) the role of intermediary organizations, in particular technology transfer offices (TTOs).

Keywords: University-industry interactions, patenting, licensing, technology transfer office

JEL classification: O32, O33, O34

1. Introduction

University-Industry Interaction (UII) is not a new phenomenon, yet UII and its impact on innovation outcomes have gained a considerable attention in recent decades (Geuna and Muscio, 2009). Research on UIIs has gained momentum after the contribution of the theories such as the "Endogenous Growth Theory" (Lucas, 1988; Romer, 1990), the "National Innovation Systems" (Freeman, 1987; Lundvall, 1988; Nelson, 1993), the "Triple Helix Model" (Etzkowitz and Leydesdorff, 1995; Etzkowitz and Leydesdorff, 2000) or the "Open Innovation Paradigm" (Chesbrough, 2003).

An important focus of the research on UIIs was on universities (e.g. Mowery *et al.*, 2004; D'Este and Perkmann, 2011; Perkmann *et al.*, 2013; Azagra-Caro *et al.*, 2017) because universities are mostly regarded as unique and valuable sources of knowledge which is the most crucial asset for firms' competitiveness (Grant, 1996; Grimpe and Hussinger, 2013). As discussed in Dosi *et al.* (2006), the relative impact of scientific knowledge on technological innovation has been increasing (while the rate of innovation is conditional on the strength of the science base), and has become more pervasive since the Industrial Revolution (e.g. Nelson, 1993; Mowery and Nelson, 1999; Mokyr, 2002) and this science base is largely an outcome of publicly funded research (Nelson, 2004).

In the last few decades, universities have been required by governments to contribute actively to innovation and to strengthen their interactions with the industry through the expansion of their activities beyond traditional teaching and research missions (Giannopoulou *et al.*, 2018). With this new "third mission" attributed to universities, they have been expected to contribute more to economic innovation and growth by commercializing their research results, which corresponds to the notion of "entrepreneurial universities" (Etzkowitz and Leydesdorff, 2000).

A specific attention has been devoted to university patenting and licensing in this stream of research (e.g. Henderson *et al.*, 1998; Mowery *et al.*, 2001; Jensen and Thursby, 2001; Thursby and Thursby, 2002; Mowery *et al.*, 2004; Geuna and Nesta, 2006; Audretsch and Göktepe-Hultén, 2015). Increasing involvement of universities in patenting and licensing was the reflection of recent policy changes on Intellectual Property Rights (IPR) in the United States (U.S.), Europe and other industrialized countries since 1980s but also of the recent developments in technologies in sectors such as biotechnology and software during the 1970s (Mowery *et al.*, 2004). Yet, patenting and licensing are only a part of a pathway for transferring the university knowledge from university to industry and may not even be the best ways (Veugelers and Del Rey, 2014). Given this, there is also a growing literature studying a variety of other important and more interesting channels of UIIs such as consulting, research collaborations, student and researchers' mobility, informal networks etc. (D'Este and Patel, 2007; Link *et al.*, 2007; Bekkers and Bodas Freitas, 2008; Perkmann *et al.*, 2013; Veugelers and Del

Rey, 2014). However, the empirical studies concerning these less formalized transfer activities are usually hampered by the availability of large scale data.

This chapter intends to give a primer on UIIs through a general review of the literature in order to provide the reader with a broader perspective. We present more in-depth discussions and information concerning UIIs which we could not address in detail in the subsequent chapters. Therefore, this chapter aims at complementing the following chapters and articulating the ideas developed in the different articles composing this thesis. However, the reader may recognize that we repeat some subjects covered in the following chapters. This recurrence, we believe, is useful in order to ensure the integrity of the issues discussed in this chapter.

In this respect, the following section examines the history of UIIs by exploring the science-technology relation and the evolution of the role of universities through time. Section 3 discusses the motivations to interact from the university and industry point of views. Section 4 addresses the variety of channels (or mechanisms) used in UIIs, and among all these channels, section 5 concentrates on the cases of university patenting and licensing. Finally, section 6 discusses intermediary organizations, in particular TTOs, aiming at facilitating the knowledge transfer (KT), and section 7 concludes.

2. A historical perspective on UIIs: Science-technology relation and the role of universities

2.1. UIIs before World War II: From the origins to the Bush Report

Although the universities' involvement in KT activities has gained popularity in the last three decades, UII is not a new phenomenon (Geuna and Muscio, 2009) and can be traced back to the developments in chemical industry in the nineteenth century, the period in which university professors usually had a direct interaction with companies (Meyer-Thurow, 1982). For instance, in Europe, despite a tension between academic and industrial cultures, the economic crises faced between 1881 and 1885 in the German chemical industry urged firms to approach university scientists (Lenoir, 1998). Lenoir indicates that the increased cost of finding new dyes due to severe competition caused a decline in prices and forced prominent firms in chemistry such as Hoechst, a dyestuffs manufacturer, to search for ways to diversify their products. Eventually, Hoechst approached the directors of university laboratories by establishing consulting arrangements and provided them funding and materials to be used on research with commercial potential for the company.

Historically, the first modern research universities (the first example being the University of Berlin founded in 1810) emerged in Prussia in the mid-19th century through Humboldt reform, which established a model for higher education (Lenoir, 1998). Nevertheless, with the exception of the UK, a considerable portion of cutting edge research has been carried out by non-university institutions in

Europe (Delanghe *et al.*, 2011). For instance, in France, the main function of universities was education, and universities were subject to the heavy control of central government until the 1970s (Geuna and Rossi, 2011). Therefore non-university public research organizations (PROs) such as CNRS (National Center for Scientific Research), CEA (the Atomic Energy Commission) or INSERM (National Institute for Health and Medical Research) have largely been the locus of basic research (Dosi *et al.*, 2006). Similarly, a considerable part of basic research has been performed by Max Plank Institutes in Germany. On the contrary, in the U.S., research has mainly been carried out by universities following the Bush Report (1945) in the aftermath of the World War II, and U.S. research universities have been the center of top quality research as emphasized by Dosi *et al.* (2006). This made the U.S. a leading basic research performer in comparison to other industrialized countries (Mowery and Rosenberg, 1993)

Although the period between 1945 and 1970 witnessed a clear distinction between basic science and applied research, science and industry relations have historically been stronger in the U.S. in comparison to Europe (Stokes, 1997; Mowery *et al.*, 2004). Strong basic research capacity combined with the application oriented research has enabled U.S. universities to develop closer links with the industry. This explains why a great share of the literature dealing with UIIs has focused on the U.S.

In the U.S. context, we can trace back the interactions between academia and industry to the Morill Act of 1862, which led to the creation of state-controlled land grant universities (Mowery *et al.*, 2004). These universities focused on practical applications as well as on the theoretical research to support agriculture and mechanics by training the farmers and workers (Rosenberg and Nelson, 1994). In land grant system, basic research and applied research were intertwined and these universities were expected to meet the demands of the local environment. Mowery *et al.* (2004) discuss that this utilitarian perspective towards science, as well as the decentralized structure of universities, the dependence of public universities on local funding and the strong competition for resources were the distinguishing features of U.S. universities in comparison to their European counterparts. This led to the rapid adoption of various application-oriented new research disciplines in universities such as electrical engineering, chemical engineering and aeronautical engineering in the early 20th century in order to respond to the needs of local industry. The characteristics of the higher education system enabled U.S. universities to gain a pioneering role in developing links with the industry in comparison to many other industrialized countries.

However, starting from post-World War II, U.S. government's perspective on the relation between basic and applied research began to change (Stokes, 1997; Mowery *et al.*, 2004). This postwar paradigm, which strictly distinguished basic research from applied research, led to the evolution of policies regarding the role of universities and of UIIs until the 1970s. The postwar paradigm in the U.S. started with the Bush Report in 1945 and prevailed almost until the passage of the Bayh-Dole Act in 1980, after which many other countries in Europe and elsewhere followed a similar path to that in the U.S.

2.2. UIIs after World War II: From the Bush Report to the Bayh-Dole Act

In 1945, Vannevar Bush, the former director of the Office of Scientific Research and Development (OSRD), presented a policy report titled "Science: The Endless Frontier" to President Roosevelt in which he explained a program for postwar scientific research and emphasized the need for the expansion of government support for science. The report became influential in setting a science vision for the U.S. and led to the establishment of the National Science Foundation (NSF) in 1950 to provide federal funding for basic research (Stokes, 1997; Mowery *et al.*, 2004). This report clearly distinguished the spheres of basic and applied research with an idealized view of universities. According to Bush's Report, there was an inherent tension between basic and applied research, in that "applied research invariably drives out pure" (Stokes, 1997, p.3). The report claimed that new knowledge is generated through basic scientific research and it is "performed without thought of practical ends". Accordingly, universities should only be responsible for carrying out and disseminating basic research without a commercial purpose:

> "Publicly and privately supported colleges and universities and the endowed research institutes must furnish both the new scientific knowledge and the trained research workers. These institutions are uniquely qualified by tradition and by their special characteristics to carry on basic research. They are charged with the responsibility of conserving the knowledge accumulated by the past, imparting that knowledge to students, and contributing new knowledge of all kinds. It is chiefly in these institutions that scientists may work in an atmosphere which is relatively free from the adverse pressure of convention, prejudice, or commercial necessity." (Bush Report, 1945, p.14)

Despite some critics (e.g. Godin, 2006), Bush's Report is considered as the source of the "linear model of innovation" by scholars (e.g. Freeman, 1996; Mowery, 1997; Stokes, 1997) with respect to the relation between scientific knowledge and technological innovation. This influential model is one of the pioneering frameworks establishing the relation between science, technology, and the economy (Godin, 2006). In this model, innovation starts with basic research, followed by applied research, development and finally ends with production and diffusion of the innovation. The model was used as a reference for justifying government support for basic scientific research, which was considered as the basis of innovation (Nelson, 1959), and has long been used to shape the science policies (Godin, 2006). In this regard, the postwar era was drawing an image of the isolated university, the metaphor known as "ivory tower".

This isolated image of universities and the sharp distinction between basic and applied science constituting the postwar paradigm was criticized by many scholars (Freeman, 1982; Rosenberg, 1982; Kline, 1985; Kline and Rosenberg, 1986; Gibbons *et al.*, 1994; Pavitt, 1999; Stokes, 1997; Etzkowitz and Leydesdorff, 2000). The linear vision of science, which was depicted in the Bush Report (1945) and which prevailed during the postwar era, has been proven wrong and eventually paved the way for the attribution of a so called "third mission" to the universities (Etzkowitz and Leydesdorff, 2000). Indeed, the studies have shown that basic and applied researches are not incompatible but often complementary (Stokes, 1997) and that there is no unidirectional flow from science to industry (Kline and Rosenberg, 1986).

The paradigm that prevailed since the Bush Report of 1945 completely shifted with the passage of Bayh-Dole Act in 1980. With this legislation, policies concerning the role of universities considerably evolved. Accompanied by the rapid developments in technology (Mowery *et al.*, 2004), the Bayh-Dole Act induced universities to intensively engage with the industry, notably through the mechanisms of patenting and licensing, since the legislation mandated universities to patent their commercially valuable research results and transfer those findings to industry through licensing (Thursby and Thursby, 2011).

In Europe, early adopters of the Bayh-Dole-like university ownership system were the UK, Spain and Switzerland, followed by other countries such as France and Greece, where the enforcement of institutional ownership was weaker in comparison to the early adopters (Geuna and Rossi, 2011). For instance, the "Science Law" passed in Spain in 1986 required universities to align their objectives with the needs of society but in particular contribute to the economic development by retaining ownership of their research results (Azagra-Caro, 2010). Similarly, the "Innovation Act" passed in France in 1999 aimed at facilitating the commercialization of university research by raising the awareness to IPR and by establishing intermediary structures for transferring their technologies to industry (Azagra-Caro *et al.*, 2006). As a result, universities were expected to contribute more to the industrial innovation and economic growth with this new "third mission", besides their traditional research and teaching missions (Etzkowitz and Leydesdorff, 2000). We elaborate more on the antecedents and consequences of the Bayh-Dole Act in Section 5.

3. Why do university and industry interact?

3.1. On the complementarity between basic and applied research

Despite some support for the linear model (e.g. Balconi *et al.*, 2010), the latter has been highly criticized and has been claimed to lose its validity due to its oversimplified and unidirectional description of the flow of science into technological innovations (Rosenberg, 1982). These critics paved the way to non-linear, interactive model known as the "chain-linked model" of innovation characterized by multidirectional flows and continuous feedbacks at each step (Kline, 1985; Kline and Rosenberg, 1986). In addition, Stokes (1997) criticized this postwar linear paradigm due to its representation of the spectrum of research on a one-dimensional line; at the one extreme seeking for "understanding" (i.e. basic research), and at another extreme seeking for "use" (i.e. applied research). Contrary to this sharp distinction between basic and applied research in the Bush Report, Stokes (1997) argues that these two are often complementary. Thus, instead of this one-dimensional placement, he suggests a two-dimensional placement of basic and applied research in his seminal work, "Pasteur's Quadrant", where the quest for fundamental understanding is represented on the vertical dimension and consideration of use is represented on the horizontal dimension as shown in Table 1.1. In this regard, the use-inspired research of microbiologist Louis Pasteur bridges the gap between basic and applied research by combining these two.

Table 1.1: "Pasteur's quadrant": classification of research activity

	Considerations of use? (Applied Research)		
		No	**Yes**
Quest for fundamental understanding? (Basic Research)	**Yes**	Pure basic research BOHR QUADRANT	Use-inspired basic research PASTEUR QUADRANT
	No		Pure applied research EDISON QUADRANT

Source: Based on Stokes (1997)

Aside from the aforementioned models on the link between science and technological innovation, Baldini (2006) discusses two other prominent theoretical models dealing with the role of universities and the way knowledge is produced. The first one is "Mode 2" (Gibbons *et al.*, 1994) and the second one is "Triple Helix" (Etzkowitz and Leydesdorff, 2000). Mode 2 model suggests that universities are not the sole producers of knowledge in contemporary research, whereas in Mode 1, the knowledge creation is motivated solely by fundamental research rather than practical orientation and leaded by autonomous academic researchers. Mode 1 is also characterized by strictly separated scientific disciplines. Conversely, the knowledge is more multidisciplinary and application-oriented in Mode 2. Furthermore, knowledge production is not under the hegemony of universities alone but it is rather distributed among heterogeneous knowledge producers. Even though universities can also take part in the "technology-innovation subsystem", Mode 2 assumes that the role of universities as unique knowledge producers has diminished, since the knowledge is increasingly produced by heterogeneous actors such as government laboratories and industries. On the other hand, the alternative Triple Helix model attributes rather an enhanced role to the universities by explaining the relationship between government, industry and university in knowledge production and innovation. According to this model, boundaries between these three spheres have faded and their roles have overlapped (Etzkowitz and Leydesdorff, 1999). As a result, universities have become more aware of the economic outcomes of their research and have searched for ways to bring their knowledge to market by forming closer connections to the industrial world or by establishing interface structures such as TTOs and incubators (Etzkowitz, 1998; Baldini, 2006).

As emphasized in the previous section, UII is not a new phenomenon and can be traced back to the 19^{th} century (Geuna and Muscio, 2009). However, since the emergence of "knowledge-based economy", universities have become even more visible actors to private and government institutions (Geuna, 1999) as being important sources of knowledge for industrial innovation and economic growth. To understand how university basic research contributes to innovation and economic growth, multitude of theoretical models of innovation have been developed (Veugelers and Del Rey, 2014). Among the main theoretical contributions, the "Endogenous Growth Theory" (Lucas, 1988; Romer, 1990; Grossman and Helpman, 1991; Acemoglu, 1997; Aghion and Howitt, 1998) has established a framework for understanding the key role of basic research on economic growth, with a particular attention to human capital dimension of technological progress and innovation. Another, "National Systems of Innovation (NIH)" approach (Freeman, 1987; Lundvall, 1988; Nelson, 1993), highlighted the role of the interplay between different actors on the innovation, growth and national competitiveness. In addition, the "Triple Helix Model" (Etzkowitz and Leydesdorff, 1995; Etzkowitz and Leydesdorff, 2000) has discussed the new "third mission" attributed to universities, making them more active actors of innovation in the university-industry-government helix. In the light of these theoretical models, at the macro level, governments' willingness to support UIIs stems from achieving national competitiveness through innovation and growth. Yet, in this section we will concentrate on the reasons or motivations behind UIIs from the university and industry/firm perspectives.

There are several motivations behind the interactions between university and industry. Among others, we can broadly refer to two important factors which seem to contribute to the acceleration of interactions between these two different institutional settings in the last few decades: (1) "Open innovation paradigm" (Chesbrough, 2003) for industrial innovation organization and (2) the "third mission" attributed to universities. The Open innovation paradigm explains the motivations for the industry or firms to interact as being the demand side of knowledge, whereas the latter explains the motivation for the universities as suppliers of knowledge.

3.2. A demand side perspective: The role of the "open innovation paradigm"

In a closed innovation model (or a traditional vertical integration model), research and development (R&D) projects of a firm are developed by using only its own resource base and then the internally developed products and services are distributed in the market by the firm (Chesbrough, 2006). On the other hand, open innovation paradigm (Chesbrough, 2003) describes an alternative and collaborative model for the organization of industrial innovation, which suggests firms to open up their boundaries to external knowledge sources given that organizations increasingly rely on external knowledge

(Perkmann and Walsh, 2007). In this open model, firms allow both the inflow of knowledge created outside of their boundaries (outside-in) to accelerate the internal innovation process and the outflow of internally created but either unused or underutilized knowledge (inside-out) to expand the markets for external uses of innovation (Chesbrough, 2012).

In an open innovation process, firms can insource knowledge and technology at various stages of R&D from different sources. Knowledge is considered as a crucial resource and driver of firm competitiveness according to the knowledge-based view of the firm (Grant, 1996) and universities have usually been regarded as valuable sources of knowledge for firms striving for a competitive advantage (Liebeskind, 1996). Innovation is inevitable for firms' competitiveness and firms need external sources to accelerate this process. There exist survey-based empirical evidences confirming the contribution of basic research to the firms' innovative performance (Mansfield, 1991; 1995; Cohen *et al.*, 2002; Veugelers and Cassiman, 2005). For instance, Mansfield (1991) finds that in the absence of academic research, a certain amount of new products and processes could not have been developed without substantial delays. The study provides evidence that in industries such as drugs, information processing and instruments, the contribution of academic research to industrial innovation has been very important. It has been shown that science-based industries such as biotechnology, pharmaceuticals, organic chemistry and information & communication technologies (ICT) interact with universities as they are very much depended on basic science (Levin *et al.*, 1987; Veugelers and Cassiman, 2005). In addition, even in non-science based industries, the use of basic research helps firms to increase their absorptive capacity and hence facilitate innovation (Veugelers and Del Rey, 2014).

Last but not least, there are various other motivations for firms to interact with universities (Ankrah and Al-Tabbaa, 2015; Bodas Freitas and Verspagen, 2017). From the firm point of view, motivations can be related to accessing university research expertise and infrastructures; improving firm productivity; cost saving; accessing public grants and tax benefits; developing their human capital; finding talented employees or enhancing their corporate image and reputation.

3.3. A supply side perspective: The role of the "third mission" attributed to universities

On the one hand, an open paradigm for industrial innovation organization has pushed firms to keep their innovation process open to external sources in order to be more competitive. On the other hand, universities have also been under increasing pressure of sharing their research results with the industry in order to contribute more to regional and national economic development and growth (Veugelers and Del Rey, 2014).

An important reason for universities to interact with the industry was mainly pecuniary, due to decreasing research funding. As a consequence of decreasing government budget for research, universities were forced to create other financial sources to cover the cost of scientific research. For instance, in the U.S., after the end of the "Cold War" with the fall of the Berlin Wall, government funding of university research for military purposes was decreased, whereas in Europe, budget constraints due to the high expenditures for health and pensions or the introduction of the Euro were responsible in part for the decline in funding (Geuna and Muscio, 2009). As explained further by Geuna and Muscio (2009), to create additional financial sources, universities were encouraged to obtain direct funding for their research either from organizations like research councils, not-for-profit organizations or by engaging in industry through the third stream (or commercial) activities.

Engaging in industry for "valorization" of their research results, in other words for commercializing their scientific outputs, is known as the "third mission" of universities (Etzkowitz *et al.*, 2000). Universities have been further encouraged to engage in third stream activities through legislative changes in various industrialized countries such as the Bayh-Dole Act in the U.S. passed in 1980; the Innovation Act passed in France in 1999 and the subsequent legislations (Della Malva *et al.*, 2013).

Further motivations for university to engage in industry may also include non-pecuniary reasons such as accessing industrial expertise and equipment; testing their inventions at industrial scale or creating employment opportunities for their students (Ankrah and Al-Tabbaa, 2015; Bodas Freitas and Verspagen, 2017). There are also studies investigating the motivations to interact at the individual-level. For instance, D'Este and Perkmann (2011) examine the reasons why academics engage with industry. Based on a survey data of UK investigators in physical and engineering sciences, they find that reasons to engage for most academics linked to advancing their research rather than for commercialization purposes.

3.4. Barriers to UIIs

We have stated that according to the knowledge-based view of the firm (Grant, 1996), knowledge is considered as a crucial resource for firms' competitiveness. However, building a competitive strategy based on knowledge is a challenging task for firms (Grimpe and Hussinger, 2008) due to the public good nature of the knowledge (Arrow, 1962; Jaffe, 1986), which means that everybody can use it without restriction and without paying for it. In this respect, universities could be considered as riskier knowledge sources for firm competitiveness (Grimpe and Hussinger, 2008) because academic logic relies on open disclosure of research results (Dasgupta and David, 1994; Sauermann and Stephan, 2013), that is to say scientific knowledge generated in academia traditionally is disseminated through publications and conferences. This is due to the fact that, dissemination of scientific research is an important reward mechanism for academic scientists allowing the recognition by peers (Merton, 1973). In contrast, commercial logic usually relies on the secrecy (which causes firms to bring restrictions on the disclosure of research results) and on the private appropriation of the financial returns (Sauermann and Stephan, 2013). Differences in institutional logics make collaborations with universities different from any other external private partners.

Since universities and firms are founded on two different institutional logics having different goals, cultures, and structures (Dasgupta and David, 1994; Murray, 2010), conflicting rules and norms described in Mertonian institutional norms of science may create barriers in UIIs. Tartari *et al.* (2012) term these barriers as "Mertonian barriers". They put forward that "Mertonian barriers" are especially prominent when it comes to the mechanisms for disclosing the knowledge, choice of research topics and designing the research for the long term. In addition, they describe another type of barrier which they term as "Williamson barriers" that could be associated with the transaction costs of negotiating the IPR with the industry. Transactional barriers may be aggravated due to conflicts between academic researchers and the university administration or TTOs, which discourage researchers to engage in commercialization activities. According to authors, developing the trust between academics and industry through face-to-face personal interactions may help overcoming these two sets of barriers. That being said, the heterogeneity between universities and industry may also allow accessing the complementary knowledge and creating opportunities to develop new innovations (Villani *et al.*, 2017).

In this section we have examined the reasons behind the UIIs from the university and firm perspectives and discussed briefly the barriers to UIIs. Yet, be it at the institutional or individual level, motivations to interact may differ, and the barriers to UIIs may be overcome depending on the channels used in transferring the knowledge. Thus, in the next section we discuss various channels used in UIIs.

4. Channels of interactions

4.1. Explaining the variety of channels used in UIIs

There is a wide variety of interaction channels or mechanisms allowing knowledge and technology transfer[4] between university and industry (Cohen *et al.*, 2002; D'Este and Patel, 2007; Bekkers and

[4] Although in some parts of this thesis we use the terms technology transfer and knowledge transfer interchangeably, they are different yet inseparable concepts. Studies on technology transfer consider technology as an entity rather than a mere application of basic science (Bozeman, 2000). In this regard, the object of the transfer is not only the product itself but also the knowledge embedded in it (Sahal, 1981; 1982). As discussed in Bozeman (2000), Sahal's concept of technology suggests that when a technology is transferred, the knowledge describing how to use and apply it is also transferred because a physical product cannot be put in use without the knowledge base. This makes the technology and knowledge transfer concepts inseparable.

Bodas Freitas, 2008; Perkmann *et al.*, 2013). Scholars have investigated the factors that may explain this variety. For instance Cohen *et al.* (2002) attribute this variety to the existence of disciplinary and sectoral differences, which is in line with the research claiming that firms in different industries are heterogeneous in terms of learning, innovating, perceiving technological opportunities and barriers (Pavitt, 1984; Marsili, 2001). Therefore firms in different industries may need to exploit different channels of interactions according to their needs and capabilities. Although this sectoral approach may explain the variety of channels up to a certain degree, it doesn't provide a complete picture. There are other factors that may explain the variety and relative importance of channels depending on individual, institutional, organizational and knowledge level characteristics (D'Este and Patel, 2007; Bekkers and Bodas Freitas, 2008).

For instance, through a survey on Dutch industrial and academic researchers, Bekkers and Bodas Freitas (2008) show that the relative importance of the used channels is not significantly affected by the differences in industrial sectors but rather by the basic characteristics of the knowledge (i.e. tacitness, systemicness, breakthroughs expected), by scientific discipline of the knowledge, and to a lesser extent, by the characteristics of individuals and the organizations that are involved in the transfer process (e.g. seniority, publication and patent, entrepreneurial activities, working environment). On the other hand, D'Este and Patel, (2007) find in a study on UK academic researchers that the individual characteristics of researchers have a stronger impact in explaining the variety (as well as the frequency of the channels of interaction) than institutional level characteristics.

The aim of these studies is also to draw the attention of policy makers to the existence of a wide variety of channels in UIIs. The reason is that the major focus is on the commercialization mode of transfer such as patenting, licensing, entrepreneurial activities rather than on those called "academic engagement" such as research collaborations with industry, academic consulting, contractual research and informal relationships, even though the latter are more aligned with the traditional research activities of universities (Perkmann *et al.*, 2013). In fact, the "academic engagement" has long been in practice, as in the case of land grant universities in the U.S. (Mowery *et al.*, 2004). One of the reasons why the commercialization mode of transfer has attracted a great deal of attention is because the output of academic research is relatively easy to measure in that way (Markman *et al.*, 2008). Yet, the "academic engagement" mode is still more attractive and valuable to many companies than patent licensing (Cohen *et al.*, 2002) and usually contributes more to the university income in comparison to the income obtained through the IP-related activities (Perkmann *et al.*, 2011).

4.2. A unified taxonomy for the channels of UII[5]

Despite the existence of different taxonomies or classifications to define the various forms of UIIs (Bonaccorsi and Piccaluga, 1994; Abreu and Grinevich, 2013; Ankrah and Al-Tabbaa, 2015), we can roughly distinguish channels of transfer as formal and informal (Kirchberger and Pohl, 2016). However, this distinction is not always straightforward as there is an absence of consensus regarding which channel is classified as formal or informal. This distinction stems from the use of two different approaches, which are the pure contractual approach, and the pure interactional approach as discussed in Schaeffer *et al.* (2018), the article which constitutes the Chapter 5 of this thesis. Contractual approach presumes that a transfer channel is formal if it is accompanied by a formal contract (Vedovello, 1997; D'Este and Patel, 2007; Landry *et al.*, 2010; Grimpe and Hussinger, 2013; Perkman *et al.*, 2013; Azagra-Caro *et al.*, 2017). In this regard, transfer through the channels such as patenting, licensing, academic consulting or collaborative research is considered as formal, whereas channels such as academic or joint research publications and conferences are considered among the informal channels due to the absence of a contractual relationship.

Although contractual approach captures the effect of codified knowledge, it neglects the tacit dimension which is captured by the interactional approach. This latter approach considers the existence of continuous face-to-face interactions allowing personal exchanges and discussions during the transfer process. Therefore channels such as technical assistance, consulting and collaborative research are rather classified as informal due to the existence of informal communication process (Link *et al.*, 2007). In Chapter 5, resulting from Schaeffer *et al.* (2018), we combine contractual and interactional approaches and propose a unified classification for university-industry knowledge transfer (UIKT) channels as shown in Table 1.2.

Table 1.2: A unified classification of formal versus informal UIKT channels

	Contractual UIKT	Non-contractual UIKT
UIKT without face-to-face interaction	Case A: ***Purely formal channels*** -Material Transfer Agreement (MTA) -Licensing (patents, software)	Case B: ***Informal non-interactive channels*** -Scientific publications
UIKT with face-to-face interaction	Case C: ***Formal interactive channels*** -U-I research collaboration -Academic spin-offs -U-I doctoral theses -Contractual consultancy -Technical assistance	Case D: ***Purely informal channels*** -Doctoral students leaving academia -Teaching activities -Non-contractual consultancy -Academic conferences and workshops -General public conferences

Source: Schaeffer *et al.*, 2018 (table shown in Chapter 5)

[5] This section is mainly based on the discussions in Chapter 5. The recurrence is deemed to be useful for the integrity of subjects covered in Chapter 1. Nevertheless, in this chapter we elaborate more the different channels of interactions.

We obtain a broad (cases A and C) and narrow (case A) definition of formal UIKT channels as well as a broad (cases C and D) and narrow (case D) definition of informal UIKT channels. The remaining (case B) represents the situation in which "knowledge flows in the air", the case which requires neither a contract nor a face-to-face interaction for transferring the knowledge to industry. In order to complement Chapter 5, we elaborate these non-exhaustive lists of channels as follows.

- ***Case A: Purely formal channels***

This category includes channels in which transfer entails a contract but not face-to-face interactions (other than negotiating the terms of the contract). In this regard, Material Transfer Agreement (MTA) and licensing of IPR can be classified as purely formal. MTAs are formal contracts that govern the transfer and exchange of tangible, usually biological, research materials (Mowery and Ziedonis, 2007). On the other hand licensing is a legal permission allowing exploiting the intangible assets, that is to say IPR, which could, for instance, be patents for inventions or copyright for software (WIPO, 2015). The result of a descriptive analysis in Mowery and Ziedonis (2007) suggests that MTAs and patents are complements rather than substitutes and MTAs do not appear to impede commercialization of university research results through patenting and licensing.

- ***Case C: Formal interactive channels***

This category consists of channels associated with the presence of both formal contracts and face-to-face interactions. Research collaborations (or joint research), contractual consultancy, technical assistance, U-I joint doctoral theses and academic spin-offs/start-ups thus fit into this classification. Katz and Martin (1997, p.7) define research collaborations as "the working together of researchers to achieve the common goal of producing new scientific knowledge". Research collaborations can be between individuals (e.g. co-authorship) or organizations. As a means of UIKT channel, we refer to inter-organizational research collaborations. These types of collaborations are rather concerned with the co-development of a technology and resultant IPR than joint publications (Bozeman *et al.*, 2013). In sectors characterized by rapid development of technology, which usually is the case for science-based industries where strong technological opportunities exist (Pavitt, 1984), research collaboration between university and industry is more likely since firms want to be active in different technological trajectories (Belderbos *et al.*, 2004). Contractual consultancy and technical assistance include any advice services (technical or non-technical), "commissioned by non-academic organizations, that do not involve original academic research" (Olmos-Peñuela *et al.*, 2014, p.698). Contractual consultancy and contract research are more important in fields where firms interact less with the university (Meyer-Krahmer and Schmoch, 1998; Schartinger *et al.*, 2002). For instance, through an empirical analysis in Spain, Olmos-Peñuela *et al.* (2014) find that consultancy and contract research are the most frequent relational activities with the non-academic community in the social sciences and humanities given the limitations to the commercial mode of transfer (e.g. patenting and licensing) in this field.

Joint PhDs also constitutes an interesting, yet under investigated channel of transfer. For instance in France, a joint PhD program with industry called CIFRE (*Conventions Industrielles de Formation par la Recherche*) aims at developing the links between science and technology. According to the data provided on the website of "French Ministry of Higher Education, Research and Innovation", CIFRE has brought together 9000 companies, more than 4000 university laboratories and 25.400 doctoral students around research projects since 1981. Furthermore, 96% of CIFRE PhDs get a job in less than a year, 70% in less than 3 months through their connections both with industrial and academic world[6].

Last but not least, there is a growing literature on academic entrepreneurship studying the academic spin-offs[7] as means of transferring university research (e.g. Shane, 2004; O'Shea *et al.*, 2004; 2005; 2008; Gubeli and Doloreux, 2005; Wright, 2007; Rasmussen, 2011; Hayter, 2013). According to the definition provided by Nicolaou and Birley (2003, p. 340), spinoffs (or spinouts so they call) involve "(1) the transfer of a core technology from an academic institution into a new company and (2) the founding member(s) may include the inventor academic(s) who may or may not be currently affiliated with the academic institution." Along with the funding, one of the important factors in spin-off formation is the nature of university science (O'Shea *et al.*, 2008). Spin-off creation rates are significantly higher in biological sciences, computer sciences and chemistry in the U.S. (O'Shea *et al.*, 2005). Similarly, the study by Zucker *et al.* (2002) on university scientists in the U.S. shows that breakthrough discoveries in biotechnology generally are transferred through the spin-offs owned by university scientists. Through a longitudinal case study of university researchers from the University of Strasbourg in France, Schaeffer *et al.* (2018) observe that spin-off creation is an important transfer strategy in the case of pharmaceuticals. Spin-off formation also constitutes one of the most important objectives of French TTOs along with patenting, licensing and technology maturation. In France, as of 1st January 2018, 258 start-ups were created through the intermediation of SATTs (a pool of all regional TTOs) since 2012[8].

6 French Ministry of Higher Education, Research and Innovation's website: http://m.enseignementsup-recherche.gouv.fr/cid67039/cifre-la-convention-industrielle-de-formation-par-la-recherche.html (accessed on 20/07/2018)

7 Although there is a nuance between start-up and spin-off, the literature often uses both terms interchangeably. University spin-offs are a subset of start-up firms (O'Shea *et al.*, 2008).

8 Information is also available on SATT's webpage: https://www.satt.fr/resultats-satt-janvier-2018/ (accessed on 20/07/2018). We provide more information on SATT in section 6.

- ***Case B: Informal non-interactive channels***

Scientific publications are a means of transfer that necessitates neither a formal contract nor a face-to-face interaction. Dissemination of university research results through publications has been at the very heart of "open science" culture (Bush, 1945; Nelson, 1959; Dasgupta and David, 1994; Stephan, 1996) and this culture is not compatible with patents. Thus, studies concerning the substitution and complementarities between channels of transfer have largely been concentrated on the relation between patents and publications. Since the so-called "third mission" attributed to universities, scholars have long been concerned about the possible crowding-out effect of patenting on academic publications (Stephan *et al.*, 2007). This is because in order to obtain patents, inventions should not be put into the public domain, neither through academic publications, nor conferences[9]. Some scholars are concerned about the possible negative effects of patenting, as it might cause significant delays or decreases in academic publications (Pénin, 2010b). Yet, there are many evidences showing that there is no substitution effect between patenting and publications, and that they can even be complementary (e.g. Owen-Smith and Powell, 2001; Carayol and Matt, 2004; Carayol, 2007; Geuna and Nesta; 2006; Van Looy *et al.*, 2006; Murray and Stern, 2006; Czarnitzki *et al.*, 2007; Landry *et al.*, 2007; Stephan *et al.*, 2007; Azoulay *et al.*, 2009). However, Geuna and Nesta (2006) warn that while assessing the impacts of patenting on academic publications, one needs to distinguish between short-run and long-run effects since the former can be misleading. Furthermore, Landry *et al.* (2010) find a complementary effect between publication and other channels, which are patenting, spin-off creation, consulting and informal knowledge-transfer, whereas they find a substitution effect between teaching activity and publications.

- ***Case D: Purely informal channels***

Under this category we examine purely informal channels which are mainly based on face-to-face interactions but not on a contract for transferring the knowledge. Doctoral students leaving academia (or students' mobility), teaching activities, non-contractual consultancy, academic conferences and workshops, general public conferences are amongst the purely informal channels. Meyer-Krahmer and Schmoch (1998) find that replacement of skilled students in industry and informal contacts are important in chemistry whereas Schartinger *et al.*, (2002), find that personal mobility and training courses for firms are important channels of interaction with the industry in economics and other social sciences. Based on a large scale survey on academic researchers in the

[9] However, practices such as "grace period" may help to decrease these concerns since this period gives a right to file a patent even if the invention has been disclosed by any means (Franzoni and Scellato, 2007). Grace period is a country-specific application in patent systems. Not every country has adopted "grace period" and for those who have adopted, the length of the period may differ. For instance, in the U.S., grace period is 12 months whereas in some other countries, this period could be shorter.

UK, D'Este and Patel (2007) find that meetings and conferences are the most widespread channels of interaction in all scientific disciplines studied. As a transfer mechanism, teaching activities may encompass both the traditional teaching for university students and trainings for industrialists. In the former case, knowledge transfer is achieved indirectly, that is to say, when the students graduate and are hired by the companies (Landry *et al.*, 2010).

In this section we have studied various channels of interactions between university and industry, some of which are more formal (e.g. licensing, spin-off formation) some are more informal (e.g. student and researchers' mobility, conferences), classified based on the existence of a contract or face-to-face interactions. Those formal and informal channels are usually complementary (Grimpe and Hussinger, 2013). Various channels of transfer often reinforce each other by interacting over time, as discussed in Schaeffer *et al.* (2018) in Chapter 5. Among all these channels, we concentrate on the university patenting and licensing in the next section, since the majority of this thesis (Chapters 2, 3 and 4) focuses exclusively on the university licensing. However, this is not meant to diminish or underestimate the importance of the variety of interesting knowledge transfer channels discussed in this section. The reason why we concentrate on licensing is not because it is the best channel of transferring the university technology, but because we lack studies concerning the content of licensing contracts and their social impacts. Therefore, in the following section, we elaborate more on the university patenting and licensing. In this regard, first, we present the debates on university patenting and then explain the provisions taking place in a licensing contract.

5. University patenting and licensing

5.1. Debates on university patenting

Historically, university patenting and licensing have been subject to important debates on social welfare and have raised ethical concerns, especially in the medical field (Mowery *et al.*, 2004; Cassier and Sinding, 2008). The central question in this regard was whether universities really needed to patent their inventions for transferring their knowledge and technology to industry, while the academic tradition has long been the "open science" model, in which knowledge is disseminated through the publications of research results. Thus, as stated by Pénin (2010b), there was almost no place for patents in the "Republic of Science" (Polanyi, 1962).

In the U.S., as examined in Mowery *et al.* (2004), the debates over university patenting led to a survey in 1934 by the Committee of Patents, Copyrights, and Trademarks of the American Association for the Advancement of Science (AAAS) which addressed the "patent problem" from different points of views. According to the Committee report, the argument claiming that the dissemination of academic knowledge through publications is already sufficient was found to be unrealistic, since the report asserted that industrialists or capitalists wouldn't risk their money, time and effort without the invention being protected. As a result, inventions that are published and unprotected by an IPR would rarely be exploited unless there is a great commercial interest to the industry. These arguments would also be part of the justifications leading to the Bayh-Dole Act of 1980, through which the role of universities was extended beyond their traditional missions and hence, they were expected to actively contribute to industrial innovation and economic growth. Since then, patents have growingly been an important indicator for measuring universities' contribution to economic development, as it is easier to measure their economic impact due to both the existence of markets for patented inventions and availability of patent data (Bozeman, 2000). Before mentioning the more recent debates on university patenting following the passage of the Bayh-Dole Act, we first present the early debates reported by the Committee of the AAAS based on the study of Mowery *et al.* (2004).

In the early debates, one of the main arguments of the proponents of university patenting was concerning the industry incentives to invest in university inventions as mentioned above. Proponents also claimed that a mere publication wouldn't yield social benefits as it may lead to the wrongful appropriation of research results by "patent pirates", who seek to monopolize the "practical applications of the abstract discoveries of others" (Hoskins and Wiles, 1921, p.691), either by blocking the inventions or charging monopoly prices[10]. Another argument in favor of patenting was "quality control". By patenting their inventions, universities could prevent the industry from harmful uses which would otherwise negatively affect the university reputation. For these reasons, patenting would enhance the social welfare. This argument was also one of the main justifications behind the "Insulin Patent" filed in 1922 by the University of Toronto, even though medical patenting was highly controversial from the ethical point of view (Cassier and Sinding, 2008).

On the other hand, opponents argued that university patenting contradicts with the norms of open science (Merton, 1973) and it was reported by the Committee that patenting the research results is unethical for university scientists. Indeed, contrary to the previously dominant scientific practice of "ethos of secrecy", the "open science" idea, which emerged during the late 16th and early 17th century, changed the norms of science and made scientific researchers commit to the disclosure of knowledge (David, 2005). Historically, in the "open science" model, free and rapid publication of academic research results has been the traditional channel of disseminating public research widely (Bush, 1945; Nelson, 1959; Dasgupta and David, 1994; Stephan, 1996). Given this open philosophy towards the

[10] This argument seems to be in line with the later discussions concerning the "third face of patents" (David, 2006), which relies on the specific use of patents for preventing the future appropriation of pieces of knowledge. The "third face of patents" relies on the specific use of patents "to achieve a purpose quite opposite to the one for which is usually is intended" (David, 2006, p.2). As discussed in Chapter 4 of the thesis, we suggest that this specific use of patents provides a basis towards a model of open source technology licensing.

production and dissemination of new scientific knowledge, opponents feared that patenting may prevent scientists to deal with basic research, increase the secrecy and reduce communalism as emphasized later in Dasgupta and David (1994). Furthermore, another potential negative effect reported by the Committee was that patenting may hinder the progress in a cumulative research setting (Mowery *et al.*, 2004).

Although the Committee report was in favor of university patenting, the direct involvement of universities in patent management was undesirable. This made universities more reluctant to carry out their patenting and licensing activities by themselves and induced them to transfer the management of their IPR to independently organized foundations (Mowery *et al.*, 2004). The policies concerning university patenting and the management of their own patents have considerably changed during and after the 1970s. In parallel to the developments in IP policies, universities' attitude towards IP licensing has also evolved. After the 1980s, along with the couple of legislative and technological changes in the U.S., in Europe and in other developed countries, IP licensing became an important tool for transferring the university technology. Licensing has dramatically grown in number during the 1990s in the U.S. according to the surveys conducted by the Association of University Technology Managers (AUTM) (Thursby and Thursby, 2002; 2007). Based on AUTM survey data of 64 U.S. universities, Thursby and Thursby (2002) attribute the source of the growth in licensing to the increase in the propensity of university and technology managers to engage in commercialization activities and to the dependence of industry to external R&D, rather than an increase in input productivity (i.e. faculty research). In parallel to this growth, licensing has increasingly been used for measuring the performance of university TTOs, both in terms of number of contracts executed and revenues obtained.

After the passage of the Bayh-Dole Act in 1980 and similar legislations in other industrialized countries, debates on university patenting have been intensified and the studies on the consequences of university patenting have grown in number. Scholars have continued to argue about the effects of university patenting, for instance on the "open science" culture, the academic publications, the access to upstream research, the incentives of academic researchers to carry out basic research and the transfer of university technology to industry (Henderson *et al.*, 1998; Mowery *et al.*, 2001; Jensen and Thursby, 2001; Stephan *et al.*, 2007; Mazzoleni and Sampat, 2002; Mowery *et al.*, 2004; Nelson, 2004; Geuna and Nesta, 2006; Verspagen, 2006; Murray and Stern, 2006; 2007; Pénin, 2010b). Verspagen (2006) examines the potential effects of the Bayh-Dole from different angles and observes that empirical evidences provide conflicting results regarding the potential effects of university patenting. Therefore, we examine below current debates regarding university patenting after the passage of the Bayh-Dole.

In line with the Bayh-Dole, proponents put forward once again the "incentives to invest" argument, claiming that patents are important incentive mechanisms for firms to bring the inventions to the market, since they provide an exclusive right over the use of invention and hence facilitate the commercialization (Poyago-Theotoky *et al.*, 2002). Based on a study of licensing practices at 62 U.S. universities, Jensen and Thursby (2001) show that patenting and licensing are necessary to incentivize firms to invest in university inventions, most of which are embryonic. Otherwise, they might remain on the shelves of the lab. Yet, there is a trade-off between incentives and wide diffusion of the technology to the society (Verspagen, 2006). In addition, patenting and licensing can be more important channels for providing incentives in some sectors rather than in others, for instance in pharmaceuticals (Sampat, 2006). It has been shown that in sectors such as biotechnology and pharmaceuticals, patenting facilitate the transfer of technology, whereas in many other sectors patents are not necessary to transfer the technology to industry (Mansfield, 1986; Levin *et al.*, 1987, Cohen *et al.*, 2000) as there exist other channels (Mowery *et al.*, 2004).

Furthermore, concerning the effects on academic publications, there are empirical evidences suggesting that patenting does not decrease the performance of university researchers in terms of publications (Breschi *et al.*, 2005; Van Looy *et al.*, 2006; Carayol, 2007; Murray and Stern, 2006; Stephan *et al.*, 2007). For instance, the study of Breschi *et al.* (2005) suggests that there is no major trade-off between academic patenting and publishing, based on the data of academic inventors in Italy. In line with this, Stephan *et al.* (2007), for the case of the U.S., and Carayol (2007) for the case of France, find a positive relation between patenting and publishing. Through a study on scientists at K.U. Leuven in Belgium, Van Looy *et al.* (2006) find that patenting even reinforces academic publications. Crespi *et al.* (2011) find that patenting complements publishing up to a certain number of patents (about ten patents), but above this level they become substitutes, which suggests that there is an inverted U-shape relation between patenting and publishing.

On the other hand, opponents of the Bayh-Dole still emphasize that university patenting is not compatible with the norms of "open science" (Merton, 1973) as it increases the secrecy and reduces communalism (Dasgupta and David, 1994), which could cripple the accumulation of knowledge and hence the innovation in the long run. Survey based studies on life-sciences find some empirical evidence showing academic patenting and licensing increase the level of secrecy and delay publications (Blumenthal *et al.*, 1997; Louis *et al.*, 2001; Campbell *et al.*, 2002). For instance, through a survey of French academic inventors, Pénin (2010b) finds that patents systematically induce a lag in academic publications. Crespi *et al.* (2011) find that after passing a certain threshold, patents decrease publications and this substitution effect is mainly seen in Chemistry and Physics.

Another concern is the crowding-out effect for basic research. Inventions should have an industrial application to be patented; therefore, research needs to be application-oriented to be rewarded with patents (Pénin, 2010b). This creates concerns among researchers that such a practical orientation towards research may distort the incentives to carry out basic research, while the latter is crucial to enlarge the knowledge base. Basic research is hence the fuel of long run economic growth (Nelson, 1959; 2004). Azoulay *et al.* (2009) find that patenting shifts the research focus of university scientists towards the areas with a potential commercial interest, whereas Thursby *et al.* (2007) suggest, provided that the results of applied research contribute to producing both basic and applied knowledge, that university patenting and licensing have positive effects.

Furthermore, another concern is that patenting may increase the cost of accessing upstream research, especially in fields such as electronics and biotechnology in which the research is more cumulative (i.e. when a single invention contains several patents). In such a cumulative setting, too many ownership rights could eventually bring about the problems such as “patent thickets” (Shapiro, 2000) or “tragedy of anticommons” (Heller and Eisenberg, 1998), which might impede innovations. Murray and Stern (2007) find a modest anticommons effect which may reduce the incentives of scientists to build upon knowledge base in the relevant research fields.

Last but not least, Henderson *et al.* (1998) claim that the Bayh-Dole caused a decrease in the quality of university patents as measured by the number of forward citations. Yet the findings of a similar study conducted by Mowery *et al.* (2004) could not confirm this result. We summarize in Table 1.3, the debates concerning the pros and cons of increasing university patenting following the passage of the Bayh-Dole Act and similar legislations.

Table 1.3: Debates on increasing university patenting: potential pros and cons

Pros of university patenting	Cons of university patenting
Provides incentives for firms to invest in embryonic university research (e.g. Jensen and Thursby, 2001)	Contradicts “open science” culture and promotes secrecy (e.g. Dasgupta and David, 1994; Campbell *et al.*, 2002)
Positive relation between patenting and publishing (e.g. Stephan *et al.*, 2007; Carayol, 2007; Crespi *et al.*, 2011). Patenting reinforces academic publications (e.g. Van Looy *et al.,* 2006).	Decreases or delays academic publications (e.g. Crespi *et al.*, 2011; Pénin, 2010b). Decreases the quality of patents due to rapid increase in number (Henderson *et al.*, 1998).
Facilitates knowledge transfer from public sector to private sector and accelerates commercialization (e.g. Poyago-Theotoky *et al.*, 2002)	Shift in research interest from basic research to more applied research (e.g. Azoulay *et al.*, 2009)
Important in certain sectors such as pharmaceuticals for appropriating returns on investment (e.g. Cohen *et al.*, 2000; Sampat, 2006)	Anticommons effect: may block follow-on research when inventions are cumulative (e.g. Heller and Eisenberg, 1998; Murray and Stern, 2007)

5.2. Understanding the content of licensing contracts

Licensing is a means of exploiting intellectual property (IP), which includes intangible assets as diverse as patents, copyright, know-how, trade secrets, trademarks and industrial designs (WIPO, 2015). A license is a legal permission which grants rights (either all or in part) to use, reproduce, modify, distribute, sell, import or sublicense an invention in exchange for an agreed payment which could be in the form of a fixed fee, royalty or an equity share (WIPO, 2015). In the case of patent licensing, a patent document does not allow by itself the transfer of the technology, since the technology cannot be exploited without getting a legal permission if this technology is protected by a patent[11]. Therefore, in the context of UIIs, patenting is not an interaction mechanism alone but rather "an indication of the commitment of university researchers towards proprietary knowledge and commercialisation activities" (D'Este and Patel, 2007, p.1303). Patents may still allow knowledge spillovers due to the disclosure requirement, which doesn't make them any different from mere publications in this regard (Corroleur *et al.,* 2018). Yet, since the exploitation of knowledge embedded in patent documents is restricted, usually a licensing agreement is needed.

Corroleur *et al.* (2018) explain why we need licensing contracts through the lens of three main theoretical frameworks, which are the "transaction cost theory", the "agency theory" and the "new institutional economics theory". According to the transaction cost theory (Coase, 1937; Williamson, 1979), licensing contracts reduce the costs associated with information searching, negotiating or free-riding behavior and thus facilitate the establishment and management of inter-organizational relationships. Licensing contracts reduce the transaction costs linked to opportunistic behavior by clearly defining the rules of transfer of technology and establishing specific governance structures. From the agency theory point of view (Arora, 1995; Jensen and Thursby, 2001), licensing contracts align the incentives between the licensor and the licensee in the presence of information asymmetry, which may lead to adverse selection and moral hazard (Arrow, 1962). Finally, the new institutional economics theory (Macneil, 1980; North, 1990) considers licensing contracts as coordination devices facilitating the governance of transactions. These coordination devices can be either institutional frameworks defining IPR (collective or formal coordination devices) or the interactions helping the agents to develop trust and reduce opportunism (inter-individual or informal coordination devices) (Ring and Van de Ven, 1994; Bessy and Brousseau, 1998). According to the new institutional perspective, even if the licensing contracts reduce transaction costs and informational asymmetry or facilitate the coordination, they are still incomplete due to imperfections of the IPR system and the

[11] Yet, the reverse may hold, that is to say, an invention can be licensed even in the absence of patents. In the licensing contracts examined for the purpose of this thesis, we have seen rather marginal cases of licensing without grant of patents, yet in most of these cases patents were applied for (or filed) and pending on the date of licensing agreement.

bounded rationality of economic agents, which makes it difficult to draft a licensing contract when it comes to defining rights and obligations (Bessy and Brousseau, 1998; Bessy *et al.*, 2002).

There are at least two parties in a licensing contract: the licensor (university in our context) who is licensing-out the IP and the licensee (firm in our context) who is licensing-in the IP (which can be a patent for an invention, a copyright for software or know-how for understanding how something works). The literature has mostly focused on the inter-firm licensing as part of firms' strategic alliances (Mowery *et al.*, 1996; Teece, 1986; Aulakh *et al.*, 2010). Nevertheless, there is still a growing literature on inter-organizational[12] licensing, including university-to-firm licensing (e.g. Jensen and Thursby, 2001; Thursby *et al.*, 2001; Thursby and Thursby, 2002; 2004; 2007; Mowery and Sampat, 2004; Gambardella *et al.*, 2007; Conti and Gaule, 2011; Dechenaux *et al.*, 2011; Thompson *et al.*, 2018), ever since the active involvement of universities in commercialization activities[13]. Although this stream of literature provides information on the number of academic patents granted, the number of licensing contracts executed or the amount of licensing revenues obtained, still a very little is known regarding the content of these licensing contracts. The reason is that it is very difficult to access these licensing contracts due to their confidential nature. But also, the complex legal language and heterogeneity of clauses make the contracts difficult to understand. However, understanding these legal clauses is important for the economists because they might have important economic implications, in particular concerning industrial competition, incentives to innovate, economic growth and social welfare. Therefore in this section, we define briefly the principal provisions taking place in a licensing contract with the help of both the existing literature and the current practices of TTOs subject to this thesis[14].

A typical licensing contract defines terms on various legal and technology related aspects, as diverse as the parties involved; the invention and the type of IP to be transferred; the restrictions regarding domains of use, geography and time; the type of exclusivity; the remuneration scheme; the grant-back

[12] Organizational and institutional variety indicates that there are different subjects in the transfer process (be it licensing or other channels of interactions). This may include organizations as diverse as private for profit firms, universities and other non-academic public research organizations (PROs), government agencies, and even an entire nation in the framework of international technology transfer literature. These organizations or subjects can sometimes be the sources of technology (and knowledge) by contributing to the creation of it, or sometimes be the receivers of the technology where it is transferred towards. This thesis focuses on UIKT in which the "source" of the technology and knowledge is the university whereas the receiver is for profit private firm.

[13] Most of the studies concerning university-industry licensing concentrate on the case of the U.S., due to its leading role in the institutionalization of university patenting and licensing, which has facilitated the availability of the relevant data. For instance, AUTM (Association of University Technology Managers) carries out large scale surveys on academic licensing activities at U.S. and Canada.

[14] To understand the legal clauses, we resort to the TTO's term sheet (a non-binding template defining the basic provisions of the licensing agreement) and study various licensing contracts executed between university and industry, with the help of lawyers that are expert in IP law, in the framework of COCON project. This process is explained more in detail in Chapter 3.

and the follow-up provisions; the conditions on sub-licensing; the transfer of the rights to a third party; the obligations on exploitation and the conditions in the case of a legal conflict. Even though the parties can protect themselves with additional provisions, most licensing contracts can be reduced into two broad categories (Bessy *et al.*, 2002) as shown in Table 1.4.

Table 1.4: Common clauses (provisions) of licensing contracts

Contractual Safeguards	Governance structures
Payment schemes - *royalties* - *fixed fees,* - *minima and maxima payments,* - *equity share*	**Supervision**
Exclusivity and restrictions - *global exclusive* - *semi-exclusive* - *non-exclusive*	**Renegotiation**
Grant-back and follow-up	**Conflict resolution**
Confidentiality and restitution	

The first category is "contractual safeguards", which consists of clauses on payment schemes; exclusivity and restrictions; grant-back and follow-up; confidentiality and restitution. These contractual safeguards aim at reducing transactional risks (Bessy and Brousseau, 1998; Bessy *et al.*, 2002). The second one is "governance structures". Making the safeguards binding can be difficult, due to legal limitations such as delays in decision making or lack of expertise (Williamson, 1979; 1985) as well as because of technological and commercial uncertainties, which therefore necessitate relational governance provisions such as supervision, renegotiation and resolution of conflicts (Bessy *et al.*, 2002). Following the studies of Bessy *et al.* (2002) and Corroleur *et al.* (2018), we examine the main provisions (or clauses) of licensing contracts as follows:

I. Contractual safeguards

(1) Payment schemes: A considerable share of licensing literature is dedicated to the payment schemes, mostly with a specific focus on inter-firm licensing (e.g. Katz and Shapiro, 1985; Kamien and Tauman, 1986; Fosfuri and Roca, 2004; Sen and Tauman, 2007; Bessy *et al.* 2008; Amir *et al.*, 2014). Licensing contracts are quite heterogeneous regarding the payment scheme. Two contractual hazards related to informational asymmetries (Arrow, 1962) existing between the licensor and the licensee play an important role in this heterogeneity (Bessy *et al.*, 2002). The first one is the (*ex-ante*) adverse selection by the licensee due to the difficulty in assessing the value of the technology prior to the contract; the second problem is the (*ex-post*) double moral hazard concerning the efforts of both the licensor and the licensee after the contract is signed. For instance, the inventor might "shirk" (Dechenaux *et al.*, 2009) if he or she is reluctant to contribute to the maturation of the technology. Similarly, licensee firm may shelve the invention after it is licensed, for instance for strategic reasons such as blocking its competitors. The literature defines four broad categories of payment schemes to overcome these contractual problems:

- ***Royalties:*** This payment form is proportional to the commercial outcome, usually the percentage share of revenues from net or gross sales or a price based on per unit output sold. Uncertainty regarding the value of the technology may lead the licensee to prefer this payment scheme to reduce the commercial risk by sharing it with the licensor, which incites the licensor to put effort for the further development of the technology as the revenues are tied to the success of the transfer (Bessy *et al.*, 2008). Hence, it allows reducing the opportunistic behavior of the licensor (Macho-Stadler *et al.*, 1996). On the other hand, this payment scheme allows the licensor to monitor the licensee's production level and to influence its marginal cost (Bessy *et al.*, 2002).

- ***Fixed fees:*** This is a lump sum payment independent from the commercial outcome of licensed invention. This lump sum can be paid as a whole when the contract is signed, or at different periods of time at recurrent frequencies (annual payment), or when a certain milestone (for instance a development stage such as clinical phases of drug development or a commercialization stage) is reached (Dechenaux *et al.*, 2009). Lump-sum fees are usually preferred by the licensor to deal with the opportunistic behavior of the licensee (Bessy *et al.*, 2002) and discourage the licensee against non-commercialization in case of adverse selection (Dechenaux *et al.*, 2009; 2011). It also guarantees the return on investment from the licensor point of view (Bessy and Brousseau, 1998; Cébrian 2009).

- ***Minima and maxima payments:*** These payment forms are complementary to the royalties and used only if the royalties exist. Minima is an annual lump sum payment if the royalties paid by the licensee do not reach this minimal lump sum, whereas the maxima payment refers to the upper limit of royalties used especially when the licensee needs several licenses to innovate (Corroleur *et al.*, 2018).

- ***Equity share:*** In this form of remuneration, the licensor obtains a share in a company in exchange for the licensing of an IPR. This payment scheme is usually applied when the licensee is a start-up firm with limited financial capacity (Feldman *et al.*, 2002). Equity share might be preferred by the licensee to mitigate the problem associated with inventor moral hazard and to induce the inventor for the further development of the licensed technology (Jensen and Thursby, 2001).

(2) Exclusivity and restrictions*:* Exclusivity provision is used as a contractual hostage to assure the licensee investments on complementary assets and to facilitate the licensing of early stage (embryonic) technologies (Somaya *et al.*, 2011). However, the exclusivity scheme is understudied in the licensing literature or mostly has been the subject of the studies on inter-firm licensing (e.g. Bessy and Brousseau, 1998; Annand and Khanna, 2000; Somaya *et al.*, 2011). Exclusivity decision is a strategic choice which might affect both the licensee's incentives to invest and the social welfare through the associated monopoly deadweight loss. Therefore a specific attention must be devoted to the exclusivity clause in the university-industry (U-I) licensing context. Although exclusivity is usually associated with monopoly deadweight loss, the choice of an exclusivity strategy should be context specific as discussed in Chapters 2, 3 and 4. For instance, we discuss in Chapter 4 the potential negative effect of exclusivity on follow-on innovations, when the inventions are sequential. However, a recent empirical study of Drivas *et al.* (2017) finds that exclusive licensing of university patents increases innovation by non-licensees through the generation of information externalities. In this regard, they suggest that an exclusive license is considered as a signal to non-licensees to follow the "commercially relevant innovation pathways". Yet, more evidence is clearly needed on the effect of university exclusive licensing.

Broadly speaking, licenses can be exclusive or non-exclusive basis. Through the restrictions to the scope, different degrees of exclusivities can be defined. The most common restrictions concern geography, field of use and time (Anand and Khanna, 2000; Cameron, 2010; Somaya *et al.*, 2011). These restrictions can be applied both in the case of exclusive and non-exclusive licensing. Exclusive license might be undesirable from the licensor point of view, since it restricts the collaboration with other commercial partners over the technology, and the licensor bears the risk of non-commercialization or under-exploitation of the technology by the licensee, which could decrease the social welfare. On the other hand, exclusivity is crucial when the substantial investment (e.g. purchasing new equipment, hiring skilled staff, entering into new markets, clinical trials and regulatory approvals) by the licensee is necessary (WIPO, 2015). We can define three degrees of exclusivities[15]:

- ***Global (worldwide) exclusive license:*** In the absence of restrictions, we talk about a global (or worldwide) exclusivity. Through a global exclusive license, the licensor gives a monopoly right to the licensee over the use of the licensed invention without any restriction. This provision excludes any other firm, even the licensor, from commercial

[15] We also consider open source licensing as the least exclusive form of licensing at the spectrum of degrees of exclusivities (Öcalan-Özel and Pénin, 2016) due to its non-discriminatory feature. This specific form of licensing is discussed in detail in Chapter 4.

exploitation in the case of inter-firm licensing. In U-I licensing, contracts usually include a provision on the exploitation of the technology for research purposes. Exclusive contracts are usually justified by the "incentive to invest" argument, especially in the case of embryonic technologies (Jensen and Thursby, 2001). Various meetings with the TTO officers during this study also reveal that in certain scientific fields such as chemicals, where inventing around by unlicensed parties is relatively easy in comparison to computers or electronics, exclusivity is usually regarded as inevitable. Yet, exclusivity is ineffective in restricting the access to the non-licensees if the licensed technology is protected by a weak IPR (Anand and Khanna, 2000).

- ***Exclusive license with restrictions (semi-exclusive license):*** Restrictions may concern geography (territory), field of use (domain) and time (Anand and Khanna, 2000; Cameron, 2010; Somaya *et al.*, 2011). In inter-firm licensing, territorial restrictions protect the licensor from competition, whereas in the U-I licensing context, it allows the reduction of the non-exploitation of the technology, since the technology can be licensed to different firms selling their products or services in distinct geographies. A license can also be granted in a specific field of use (e.g. using the licensed patent in the field of fetal heart-rate monitoring only). Similarly, field of use restrictions reduce the risk of non-exploitation in different sectors when the invention is generic (i.e. a platform or enabling technology with several potential applications in different fields). Finally, exclusivity can be restricted by time. For instance, exclusivity can be granted until the costly development phase is completed to safeguard returns on investment of the licensee. As discussed in Chapters 2 and 4, this was the case for the insulin licensing by the University of Toronto (Cassier and Sinding, 2008). One-year exclusivity was granted to the licensee firm for the further development of the technology. After one-year, insulin was non-exclusively licensed to other companies. All these restriction provisions can limit the potential negative effects of exclusive license (WIPO, 2015).

- ***Non-exclusive license:*** Through non-exclusive licensing, the licensor can contract over the technology with several parties by giving the right to exploit the invention to each one of them. This type of licensing is important if the invention has a generic nature, which means that it can be exploited in different sectors. As discussed in Chapters 2 and 3, this strategy became very successful in the licensing of the Cohen-Boyer technology (a generic invention in biotechnology), which allowed the rapid diffusion of innovations among various sectors (Feldman *et al.*, 2005). Non-exclusive licenses (and even less restrictive strategies such as open source licensing) might also be necessary in the case of sequential inventions, for instance for software, in order not to block the follow-on inventions.

(3) Grant-back and follow-up: Uncertainty over the future value of the technology often necessitates grant-back and follow-up provisions concerning the future improvements to the technology by the licensee and licensor. Grant-back provision allows the licensor to obtain rights to the future developments by the licensee, which cannot be anticipated when the contract is signed. It therefore reduces the licensees' incentive to invent around the technology (Bessy *et al.*, 2002). Likewise, a follow-up clause allows the licensee to benefit from further developments performed by the licensor, which would safeguard the licensee's investments to the technology.

(4) Confidentiality and restitution: These provisions aim at preventing knowledge spillovers to a third-party in the period of validity or in the case of the rupture of contract. Confidentiality clause prevents the undesired dissemination of the knowledge by requiring parties not to disclose, publish or otherwise communicate the information with another party. In the case of the breach of the contract, restitution of technical documentations also reduces the risk of the reproduction of the transferred knowledge (Bessy *et al.*, 2002).

II. Governance structures

(1) Supervision: This provision allows the licensor to monitor the licensee firm's behavior by auditing its industrial facilities and its production or by checking the licensee's books (Bessy *et al.*, 2002). This provision helps parties to reduce potential conflicts in the future. In the U-I licensing context, monitoring is also important to observe whether the licensee puts sufficient effort towards commercialization of the technology, as well as for controlling the quality of products.

(2) Renegotiation: In an environment characterized by high commercial and technical uncertainty, this clause gives flexibility to the parties to renegotiate certain terms of the contract in the future.

(3) Conflict resolution: Because IPR system is incomplete and the legal system is slow, parties need to develop procedures for private resolution of the potential conflicts, especially through arbitration (Bessy *et al.*, 2002), a method for settling the disputes outside the courts.

In this subsection, we examined the main clauses of licensing contracts. Yet, understanding the technical clauses of licensing contracts is a challenging task and requires a legal expertise. To overcome such difficulties, most universities have created intermediary structures which provide them with a legal support, by managing their IP and negotiating the terms of the contracts on behalf of them.

Intermediary organizations, in particular TTOs, are usually deemed to reduce the transaction costs related to partner searching and negotiating the formal contracts. In the next section, we examine the intermediary organizations, with a specific focus on the TTOs.

6. Intermediary organizations in university-industry knowledge transfer (UIKT)

6.1. Institutionalization of UIKT

Prior to the so-called knowledge economy, UIKT activities were mainly performed through direct personal relationships of academic researchers with industry and other government organizations (Geuna and Muscio, 2009), mostly established through professional and social networks (Colyvas *et al.*, 2002). This governance mode of UII corresponds to the "personal contractual mode" defined in Bodas Freitas *et al.* (2013). As explained in Geuna and Muscio (2009) and Bodas Freitas *et al.* (2013), since the rise of the knowledge-based economy, universities have become multi-task organizations with the increasing scale and complexity of research activities. In order to manage and transfer the knowledge created in universities, new governance structures were needed. The governance of UIIs have considerably changed since KT activities have gained a strategic importance for universities to create additional financial sources for research, but also for governments as a policy tool for economic development. Therefore, UIIs have been "institutionalized" especially for transfer activities such as IP licensing and spin-off creation through the direct involvement of universities. This governance mode corresponds to the "institutional mode" or "institutional governance". With the increasing scale and complexity of these tasks, the academic staff has needed support to manage and organize their transfer activities by establishing dedicated intermediary structures. On the other hand, traditional channels such as publishing, conferences, consulting or personal exchanges required little or no changes in governance structure, since they have not been institutionalized (Geuna and Muscio, 2009).

With the increasing involvement of universities in KT activities, institutional governance was usually mediated by administrative structures (Bodas Freitas *et al.*, 2013), and hence paved the way to the creation of intermediary organizations such as Technology Transfer Offices (TTOs), University Incubators (UIs) and Collaborative Research Centers (CRC) (Villani *et al.*, 2017), proof of concept centers (Hayter and Link, 2015), or science parks (Minguillo and Thelwall, 2015). Various barriers to UIIs such as differences in institutional (Bruneel *et al.*, 2010), cultural (Bjerregaard, 2010) and regulatory (Jacobsson and Karltorp, 2013) settings; geographical distance (D'Este *et al.*, 2012) or conflicting sets of rules and norms (Tartari *et al.*, 2012) create a challenge in the KT activities of these two different institutions (Murray, 2010; Sauermann and Stephan, 2013). Intermediating organizations aim at overcoming or reducing these barriers (Howells, 2006).

TTOs serve as brokers by managing the hybrid zone between science and business (Murray, 2010; O'Kane *et al.*, 2015a) whereas, for instance, UIs facilitate knowledge transfer from universities to new technology ventures (Grimaldi and Grandi, 2005; Rothaermel and Thursby, 2005), or CRCs aim to increase intensity of R&D activity in local industries by bringing together academic and industrial researchers (Boardman and Gray, 2010; Knockaert *et al.*, 2014; Wright *et al.*, 2008). Among others, we focus on the intermediary role performed by TTOs. In the following sub-sections we discuss the roles performed by the TTOs by focusing on the U.S. and French contexts.

6.2. Roles performed by TTOs

As stated above, compare to the old model, where academic researchers managed their KT activities through personal links, increased scale and scope of KT activities paved the way to the new governance structures and hence the institutionalization of KT activities (Geuna and Muscio, 2009; Bodas Freitas *et al.*, 2013). As a result, TTOs were created to manage and organize these complex transfer activities. There is a vast literature on TTOs (e.g. Debackere and Veugelers, 2005; Bach and Llerena, 2007; Macho-Stadler *et al.*, 2007; Etzkowitz and Göktepe-Hultén, 2010; Comacchio *et al.*, 2012; O'Kane *et al.*, 2015a). In the U.S., the early successful example is Stanford University's Office of Technology Licensing (OTL) established in 1970 (Mowery *et al.*, 2004; Geuna and Muscio, 2009). In Europe, one of the earliest successful examples of TTOs is LRD (Leuven Research and Development) of Belgium Katholieke Universiteit Leuven established in 1972 (Debackere and Veugelers, 2005).

TTOs are amongst the most prevalent types of intermediary organizations aiming at commercializing university research results through the licensing of IPRs and the creation of start-up or spin-off companies (Alexander and Martin, 2013; Algieri *et al.*, 2013). They bridge the gap between the early stage university knowledge and its industrial application (Etzkowitz and Göktepe-Hultén, 2010). In the framework of transaction cost theory (Coase, 1937; Williamson, 1981; Williamson, 2000), TTOs reduce the transaction costs related to KT activities between universities and firms (Giannopoulou, 2016). In this respect, they are supposed to overcome the "Williamson barriers" (Tartari *et al.*, 2012) associated with partner searching and with managing the IP related formal agreements. Although their missions and priorities may vary in different national or local contexts, the roles (or activities) performed by a TTO broadly include the following:

- Detecting and selecting university inventions with a commercial potential
- Managing universities' intellectual assets such as patents, copyrights or know-how
- Further development/maturation of inventions
- Providing assistance on various KT activities (e.g. start-up/spin-off company creation or facilitating research collaborations)

- Marketing the technology
- Searching and identifying industrial partners
- Negotiating the license agreements on behalf of universities/PROs
- Generating new funding for research
- Providing legal support

Even though the roles performed by the university TTOs are pretty much the same, they are quite heterogeneous in terms of their capability, organization and functioning, which in turn might affect their performance. The literature has identified several factors influencing TTO performance as diverse as scientific and technological resources, incentive structures, organizational structures, environmental and institutional factors, availability of financial resources, capabilities such as business and marketing skills or its social networks (Bercovitz *et al.*, 2001; Polt, 2001; Siegel *et al.*, 2007; Siegel *et al.*, 2003; 2004; Debackere and Veugelers, 2005; Link *et al.*, 2007; Markman *et al.*, 2009). Furthermore, performance metrics used in these studies usually rely on easily measurable research valorization activities such as number of patenting and licensing, number of start-ups/spin-offs created, number of contractual collaborations executed, as well as revenues earned from these activities (see for instance, Thursby and Thursby, 2002; Thursby and Kemp, 2002; Siegel *et al.*, 2003; Caldera and Debande, 2010). Yet, these types of metrics used in measuring the performance may force TTOs to prioritize the revenue maximization objective rather than the objective of wide dissemination of technology. This might cause TTOs to be inefficient actors in reducing the "Mertonian barriers" (Tartari *et al.*, 2012) associated with the conflicts between university and industry over the dissemination of research findings to the large public.

In the French context, performance of TTOs in relation with these two contradicting objectives is studied by Matt and Schaeffer (2012). Through a longitudinal qualitative study, the authors investigate the factors favoring the performance of TTOs by comparing the "knowledge factory" vision with the "knowledge hub" vision of university. According to their study, the first view considered by the relevant literature is the implicit strategic model in which the performance is mainly driven by the revenue maximization objective (Phan and Siegel, 2006). In this linear model, the transfer starts with the disclosure of invention by the faculty or the inventor, leading to an invention disclosure agreement. If the disclosed invention has a potential commercial value, then the TTO makes a patent application (or protects through other mechanisms). Once the patent is granted, the invention is either licensed to established firms or a new spin-off company is created. In this linear process, the TTO is the central agent controlling and managing the entire value chain to reduce the transaction costs in a non-interactive and unidirectional way. Therefore, this model is associated with the "knowledge factory" (Youtie and Shapira, 2008) vision of the university. In the alternative model, TTO's objective is to increase the diffusion and the speed of technology by pooling the resources and sharing the cost. The transfer activity is managed by decentralized actors; it is multidirectional and interactive, which corresponds to the "knowledge hub" (Youtie and Shapira, 2008) vision of the university as illustrated by the case of the University of Strasbourg. On the other hand, at a more aggregate level, the empirical study of Curi *et al.* (2012) on French TTOs' performance finds a substantial inefficiency across French TTOs. Their study shows that efficiency of a TTO depends on the scientific fields as well as the institutional and environmental characteristics. For instance, in the case of science and engineering based universities, the efficiency of the TTOs is found to be higher. Furthermore, efficiency is positively related to the university size and seniority of TTOs.

In the following sub-sections, we investigate the evolution of TTOs in the U.S. and French contexts in relation with the changes in research and IP policies. Furthermore, we discuss the objectives of TTOs by examining two cases (i.e. Stanford's OTL in the U.S and SATT Conectus Alsace in France).

6.2.1. TTOs in the U.S. context

In this section, we mainly follow the work of Mowery *et al.* (2004), in which they provide a historical overview of the evolution of the IPR policies and the TTOs in the U.S. context. Throughout the period of 1925-1970, universities in the U.S. avoided direct involvement in patent and license management due to ethical concerns regarding the norms of science. In 1934, the Committee of Patents, Copyrights, and Trademarks of the American Association for the Advancement of Science (AAAS) published a report, in which university patenting and its management has been discussed from various angles, as we elaborated in section 5. Although the report favored the faculty patenting, its position towards the direct involvement of universities in patent management was quite the reverse. The report rather suggested that this can preferably be done by independent and experienced organizations or companies, which can explain the reluctance of the universities to become directly involved in the management of patents until 1970s. Hence, academic patenting and licensing policies were either managed by an independent third-party or university affiliated but legally separate research foundations.

In 1912, a third party technology transfer agent, namely the Research Corporation, was founded. It was dedicated to managing the patenting and licensing activities of many academic institutions. Several leading research universities such as MIT, Princeton and Columbia "outsourced" the patent management to the third party by signing formal Invention Administration Agreements (IAAs) with the Research Corporation during the 1930s and 1940s. By 1970, it had already more than 200 client institutions.

The first university-affiliated but legally separate entity was the Wisconsin Alumni Research Foundation (WARF), which was founded in 1925. Its success further influenced the other U.S.

universities during the 1930s. In addition, both the financial constraints in the aftermath of the Great Depression and the ownership problem concerning the industry funded research for faculty inventions urged universities to create entities similar to WARF in the period of post-World War I.

Pre-World War II is the period in which universities were quite cautious to develop in-house patent management. Most universities didn't have a proper patent policy (Palmer, 1957). Increased federal funding in university basic research after the World War II led to an expansion in the scale of academic research, which increased the probability of patentable inventions. Furthermore, federal research sponsors required universities to develop formal patent policies. As a result, by the late 1940s, almost all the major universities in the U.S. developed patent policies. Reluctance towards the patent management dramatically changed within the period of 1960-1980. In the 1970s, patenting and the importance of patent management increased, especially with the rapid progress of biomedical research, in particular the molecular biology, which had considerable commercial interest to industry. During this period federal funds were in an already decreasing trend, which made the licensing revenues even more appealing to universities to generate additional income for research. Therefore, universities started to manage their patenting and licensing strategies themselves (Weiner, 1986).

Within the same period, federal patent policies also changed. Universities were allowed to retain title to patents resulting from federally funded research during the mid 1960s and early 1970s, which was initially negotiated case-by-case. For instance, The Department of Defense (DOD) allowed universities to retain title to federally funded inventions. Furthermore, two other federal research funding organizations, namely the Department of Health, Education, and Welfare (HEW) and the National Science Foundation (NSF), established a program called Institutional Patent Agreements (IPAs), which enabled universities to obtain right to own patents and grant exclusive licenses to firms. Later, HEW's concern towards exclusive licensing of university inventions, and a need for more uniform patent policy, would lead to the Bayh-Dole Bill in 1978, and eventually to the Bayh-Dole Act of 1980.

Universities' autonomy in managing their patent portfolios was reflected in the proliferation of the in-house university TTOs during 1970s and 1980s. An early example of successful university TTO is Stanford University's Office of Technology Licensing (OTL). The increasing trend in universities' willingness to manage their patents and licensing activities, which started in 1970s with the success of Stanford's OTL, accelerated even more with the passage of the Bayh-Dole Act, leading to a growth in the number of university-based TTOs (Mowery *et al.*, 2004). Below, we examine the case of Stanford University's OTL more in detail.

Case of the U.S.: Stanford University's OTL[16]

One of the early examples of successful university TTO is the Stanford University's Office of Technology Licensing (OTL) which was founded in 1970 (Geuna and Muscio, 2009). As explained in Mowery *et al.* (2004), technology licensing program developed by Niels Reimers focused more on the marketing of technologies rather than on the legal aspects of patent management. Instead of more patent attorneys, staff skilled in technology evaluation and marketing was employed. This created licensing revenues of $55.000 within the first year compared to the $4.500 earned through the contract with Research Corporation (Reimers, 1998).

Although the Bayh-Dole appeared to mandate the disclosure of faculty inventions resulting from federal funds, it has rarely been enforced (Siegel *et al.*, 2003). As discussed in Mowery *et al.* (2004), until 1994, Stanford's OTL followed a flexible policy towards the disclosure of inventions and allowed inventors to retain all rights to their inventions. But in 1994, it was made mandatory that the university retained title to its inventions if its resources were used to develop these inventions. Among these inventions, biomedical and software inventions have been important in Stanford OTL's IP portfolio.

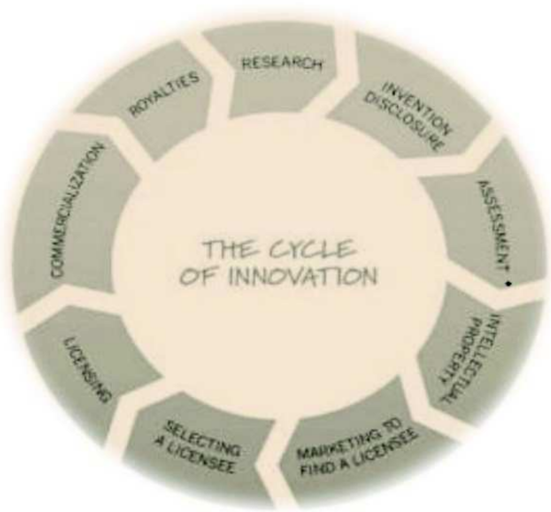

Figure 1.1: The technology transfer process at Stanford's OTL
Source: The website of Stanford University's OTL[17]

Today, the mission of the OTL is "to promote the transfer of Stanford technology for society's use and benefit while generating unrestricted income to support research and education" as defined on its

[16] Information regarding the current transfer activities of the Stanford's OTL is based on their website: https://otl.stanford.edu/ (last accessed on 08/09/2018)

[17] Retrieved from https://otl.stanford.edu/industry/licensing-process (last accessed on 10/09/2018)

website. The technology transfer process (or the licensing process) described by Stanford's OTL is shown in Figure 1.1.

The OTL receives invention disclosures from faculty researchers, students and other staff and then evaluates their commercial potential. The licensing process begins with the inventor involvement. First, the OTL reviews the invention with the inventors to understand potential applications. After that, OTL develops a licensing strategy by considering technical and market risks and decides whether to patent the invention. Inventors are also included at many stages of the licensing process. OTL confers with inventors about the technical and market feasibility of their inventions and gets help from them for finding companies to license the invention. Although inventors are not directly involved in the licensing negotiations with companies, OTL states that it is open to the suggestions of inventors regarding the licensing strategy (e.g. exclusive vs. non exclusive). Once the invention is licensed, royalties collected by the OTL are shared among the inventors, inventors' department and schools.

Some recent key figures regarding the recent licensing activities of Stanford's OTL are as follow: In 2016, 472 new invention disclosures received, 142 licenses concluded and $94.2 million gross licensing revenue generated by the OTL. In 2017, 477 new invention disclosures received, 226 new U.S. patents issued, and $45.5 million generated from licenses[18].

6.2.2. TTOs in the French context

Strategic importance of IP management also allowed the establishment of similar structures across European countries in the early 1980s, which started with the UK and then spread to the other parts of the continent (Geuna and Muscio, 2009). However, Europe is quite heterogeneous in terms of IPR regimes and of its management structures. As opposed to the U.S., one important feature of the European system was the ownership structure of intellectual property rights (IPR). In countries such as Germany and Sweden, university researchers have long had ownership rights on their publicly funded inventions known as "professor's privilege". Whereas in some other European countries, main funders, that are PROs or business companies, owned most of the academic patents (Lissoni *et al.*, 2008; Della Malva *et al.*, 2013). The small number of university owned patents due to these differences in ownership structures usually resulted in the perception of the so-called "European Paradox", which refers to the incapability of European universities to translate their strong scientific potential into commercially exploitable technologies, compared to their U.S. counterparts (Lissoni *et al.*, 2008). Thus, policy changes in some countries targeted first the re-arrangement of these ownership structures, which eventually resulted in a shift in ownership from individual researchers to the university in Germany and Sweden. Conversely, this shift occurred from the university to the inventor

18 The statistics are retrieved from https://otl.stanford.edu/about/about-us/statistics (last accessed on 08/09/2018)

in Italy through a legislation passed in 2001 (Van Looy, 2009). Passage of ownership rights from inventor to universities (or PROs) in many OECD countries necessitated protecting and managing the increasing volume of IP activity, and hence reinforced the need to establish TTOs (Matt and Schaeffer, 2012).

In the French context, the public research system was mainly centralized to promote strategic sectors such as defense or nuclear technologies, and the research programs were implemented by large PROs (Della Malva *et al.*, 2013). In 1982, the Research Act (*Loi d'Orientation et de Programmation*) defined a set of science policy objectives including also commercialization and dissemination of the research resulted in public laboratories, and in 1984, these targets extended in a way to include universities. This led to the creation of an agency called ANVAR (National Agency for the Valorization of Research) dedicated to transferring the technology that resulted from PROs research. Legislations also led to the creation of CRITTs (Regional Centers for Innovation and Technology Transfer) aimed at facilitating the technology transfer between public and private actors at local level. However, even in the early 1990s, the role of IPR in UIIs and the issue of patents resulting from publicly funded research remained unaddressed. While PROs continued to manage the transfer activities through in-house or subsidiary TTOs, universities still did not have such organizations and hence left the IP management to their scientists (Carayol, 2006; Della Malva *et al.*, 2013). This issue was resolved through the Innovation Act of 1999, or, more precisely, "Law on Innovation and Research" (*Loi Allègre*), which led to an increase in university patenting by raising awareness on the IPR ownership (Azagra-Caro *et al.*, 2006, Lissoni *et al.*, 2008). Della Malva *et al.* (2013) state that although the Innovation Act established structures to facilitate university patenting in France, similar to the ones created by the Bayh-Dole; it was not IPR legislation, since the "Intellectual Property Code" of 1992 remained unchanged. However, the Act covered the issues beyond IP. The measures taken through the Innovation Act were complemented by the follow-on legislations (Bach and Llerena, 2007)

Redistribution of ownership rights eventually resulted in higher number of academic patents, some of which are still co-owned with French PROs such as CNRS, CEA, INSERM, INRA which is a common practice in France (Bach and Llerena, 2007; Della Malva *et al.*, 2013)[19]. This law also paved the way to the creation of TTOs as private entities under the generic name of SATT (Technology Transfer Acceleration Companies), which are dedicated to accelerating the transformation of publicly funded French research into innovations through patenting, licensing (or other contractual activities), maturation of inventions and start-up creations.

[19] In France, many university labs are run in association with PROs such as CNRS or INSERM known as joint research units or mixed research units (UMR). This is one peculiarity of French higher education system (Bach and Llerena, 2007; Matt and Schaeffer, 2012)

Prior to the Innovation Act of 1999, some universities had already structures dedicated to transferring their technologies. The Act, first resulted in the creation of internal TTOs called SAIC (Services for Industrial and Commercial Activities), allowing them to recruit external personnel and to run the organization with more flexible financial rules under the favorable tax provisions (Della Malva *et al.*, 2013). Furthermore, the subsequent acts enabled universities to implement more autonomous strategies with respect to their technology transfer activities (Matt and Schaeffer, 2012). Through the call for projects of the ANR (National Agency for Research), in the framework of "Investment for the Future Program" (PIA) launched in 2010, which aimed at pooling the TTOs at the regional level, 14 SATTs were created with the share of universities and PROs. This public program enabled the TTOs to develop more cooperative strategies (Matt and Schaeffer, 2012). Below, we examine the case of SATT Conectus Alsace, the TTO which manages the transfer activities of the University of Strasbourg along with the transfer activities of other universities and PROs in the region.

Case of France: SATT Conectus Alsace[20]

The University of Strasbourg, together with other regional and national public research institutions (CNRS, INSERM, INSA, the University Hospital of Strasbourg and diverse universities in Alsace region), created the TTO called "Conectus" in 2006 (Matt and Schaeffer, 2012). At the time, Conectus was the only shared platform managing KT activities of diverse public institutions in the region. In 2009, Conectus became "Conectus Alsace" and eventually has become "SATT Conectus Alsace" in 2012, in the framework of PIA. SATT Conectus Alsace is a private company founded by public share and continues to manage various KT activities of its shareholders (i.e. the universities and non-university PROs) in Alsace region. Its objective is defined as "to contribute to the competitiveness of French industry, economic development and job creation through the valorization of public research results coming out of Alsace region". To this end, it manages the transfer activities of Alsatian public research organizations and university laboratories mainly through financing of patents, investing in further development or maturation of inventions, negotiating license agreements and administrating industrial partnership contracts.[21]

To facilitate the licensing of inventions and creation of start-ups, Conectus created the first "Maturation Fund" in France, with the contribution of local public authorities, which is used to develop very early stage inventions into proof of concepts or functional prototypes during a period of 12 to 18 months (Matt and Schaeffer, 2012). Investing in the maturation of inventions is one of the

20 The information regarding the KT activities of SATT Conectus Alsace are largely based on the various interviews with the staff of SATT Conectus Alsace, its website, press releases and internal presentations provided by SATT Conectus's employees. A section regarding the licensing process is also provided in Chapter 3. In this chapter we provide more detailed information regarding the commercialization activities of the TTO.

21 http://www.conectus.fr/en/our-activities (last accessed on 09/09/2018).

core activities carried out by its successor, SATT Conectus Alsace, in order to facilitate the research valorization process, be it licensing or spin-off creation. In addition, SATT Conectus Alsace launched in 2013 a program called "co-development in maturation", which allows a company to become involved in the monitoring of the maturation of an invention to ensure its relevance to the industrial expectations without carrying the technical or financial risks of these developments. According to the press release on 12 January 2017, the success of this program is confirmed today, since more than 65% of maturation projects undertaken by SATT Conectus Alsace are in co-development with companies, which are mostly in the same region.[22]

The organization of the licensing process in SATT Concetus Alsace is similar to the cycle of transfer shown in the case of Stanford's OTL. The first step is to identify inventions with commercial potential coming out of the university laboratories. For this, an important effort of communication and prospection is made towards the academic community. Afterwards, the requirements of the market are identified and a patent is applied for. The next step is to invest in the maturation[23] of the invention, if needed, and then to look for a licensee. There are two options at this stage: either, with the assistance of the SATT, the inventor can create her or his own spinoff to which the technology can then be licensed; or the technology can be licensed to an already existing firm, be it a local, domestic or foreign one. When the licensee firm is identified, the last step is to negotiate the terms of the license, which can last up to one year. As in the case of Stanford's OTL, inventors are consulted regarding the technical feasibility of their inventions or to find a company, but they are not directly involved in the negotiation of licensing agreements, especially when the inventor is attached to the spin-off company to which the technology may be licensed, in order to avoid any conflict of interest. Royalties from licenses are shared among the university, faculty and the inventors. In the current legislative context, French academic scientists can earn a significant share of the income derived from patenting and licensing of their inventions. They can earn up to 50% of the net benefits generated by a license.

Regarding its KT activities on behalf of the University of Strasbourg, some key figures provided by SATT Conectus Alsace are as follow: Between the years 2012-2016, 463 new invention disclosures evaluated, 115 patents and know-how managed, €18.4 million invested in the maturation of 62 projects, 14 start-ups created and €23.2 million generated from various contractual activities accounting for 768 contracts. In 2016 alone, 39 new IPs validated (patent and software), 12 new licensing contracts concluded, €1.6 million revenue obtained from IP valorization. Furthermore €4.5 million invested for the maturation of 12 new projects. In 2017 alone, 185 various research valorization contracts other than licensing (e.g. research collaborations, consulting, MTA, CIFRE)

[22] http://www.conectus.fr/sites/default/files/presse/communiques/cp_5ans_conectus_alsace_vff.pdf (last accessed on 10/09/2018).

[23] Maturation activity is more pronounced in the case of SATT Conectus Alsace whereas this activity is not shown on the technology transfer cycle of Stanford's OTL.

concluded which generated €4.8 million. 70% of the contracts (with or without a financial compensation) signed with the partners located in France. The contracts with financial compensation are mostly coming out of the scientific domains of engineering, which is then followed by chemistry and medical sciences. Within the same year, through the IP channel, 96 new inventions disclosed, 38 new IP applications validated (patent and software), €5 million invested in the maturation of 15 projects, 17 new IP valorization contracts signed, 3 new start-ups created.[24] According to these figures, the occurrence of diverse research valorization contracts without an IP appear to be more frequent compared to IP based valorization contracts such as licensing.

6.3. A brief discussion on the objectives of TTOs

Throughout the section 6, we have discussed the role performed by TTOs, with a specific focus on the cases in the U.S. and in France. Although there may exist some organizational particularities regarding, for instance, the experience of TTOs or the volume of activities, we have seen, by comparing the cases, that the licensing processes are quite similar. In this context, an important debate concerning the primary objective of TTOs is that whether TTOs should maximize primarily their revenues or prioritize the social benefit when licensing their inventions (or in general when transferring the university knowledge). Since TTOs are responsible for commercializing the university research results, a social mission should clearly be prioritized, especially when the transferred invention is publicly funded. For instance, Stanford's OTL clearly states on its website that its primary consideration is the effective transfer of the technology for the use and benefit of the society, and that "[a]n essential element of OTL's approach is that financial interests are not the primary consideration when making licensing decisions". It explains further on its website that:

> "Only about 20-25% of Stanford inventions are licensed and generate royalty income. Because OTL is an organization within a university, we can never be (nor do we strive to be) a pure business entity that focuses entirely on maximizing profits. Nonetheless, we aim to be as business-like and business-oriented as we can within the university context. We believe that license agreements mark the beginning of a long-term relationship for Stanford and thus strive for fairness, reasonableness, and consistency in our dealings with industry. We seek to generate the greatest possible royalty revenue for Stanford without negatively impacting its research and education mission."[25]

Similarly, although SATT Conectus Alsace is a private company, this company is founded with public share and it commercializes in many cases publicly funded research in France. Therefore revenue maximization objectives should carefully be balanced with a social mission. Although, more or less explicitly, the TTOs acknowledge their social missions, in practice they might be forced to behave

[24] Statistics regarding the research valorization activities have been collected from internal presentations which were provided by SATT Conectus Alsace. Some of these figures also appear in press releases which can be found on http://www.conectus.fr/en/communiques-de-presse?page=1 (last accessed on 10/09/2018).

[25] https://otl.stanford.edu/otl-and-inventor-roles-technology-transfer (last accessed on 08/09/2018)

more like pure business entities, because the current performance criteria requires them to stay profitable by looking at, for instance, the number of licenses executed or licensing royalties received. Academic studies also use these kinds of metrics as measures of TTO efficiency (e.g. Conti *et al.*, 2007). Yet, balancing these two conflicting objectives is a hard task for TTOs and challenging to resolve for the policy makers.

Solutions to overcome this duality and to better align the objectives of university TTOs with the needs of the society might include developing licensing practices by tailoring the licensing strategy (as regards to exclusivity decision) according to the context (discussed in Chapters 2 and 3); developing alternative licensing strategies such as open source licensing (OSL) beyond software (discussed in Chapter 4), or diversifying the TTO activities in a way that recognizes and facilitates the variety of KT channels (discussed in Chapter 5). All these measures may help TTOs to develop their licensing practices and other KT activities in a more socially beneficial way.

7. Conclusion

In this chapter, we have provided a primer on the issues concerning UIIs through a detailed review of the literature. We have examined briefly the history of UIIs both in the U.S. and Europe, and observed how the role attributed to universities evolved with the changing perspectives concerning the relation between science and technology. In the U.S., the "ivory towers" depicted in the Bush Report in 1945 were made important actors of the economy through the "third mission" attributed with the Bayh-Dole Act in 1980. Europe and other industrialized countries followed these trends with similar legislations. Firms' responsiveness to the "open innovation paradigm" (Chesbrough, 2003) and universities' need for additional financial sources for research have contributed to the rapprochement of these two culturally different organizations and made their interactions more intensive than ever. Those legislations required universities to patent their research results and license them to the industry (Mowery *et al.*, 2004). As a result, UIIs have become more institutionalized and dedicated intermediary structures (TTOs) were established to manage all these complex activities (Geuna and Muscio, 2009).

Due to these policies, university patenting and licensing have long become an important research topic for the studies concerning UIIs. Yet, scholars have also emphasized that there is a wide variety of channels, as diverse as consulting, R&D collaborations, spin-off creation, student and researchers' mobility, informal networks through which universities can transfer their knowledge to the industry (D'Este and Patel, 2007). Policies aiming at stimulating industry-science links should therefore acknowledge the variety of KT channels and also pay attention to the careful design of the IPR regimes, the incentive schemes and the dedicated intermediary structures (Veugelers and Del Rey, 2014).

This chapter aimed at presenting a broader perspective concerning UIIs and complementing the following chapters through a more detailed review of the literature. In the context of UIIs, the following three chapters focus on the university licensing strategies. In this regard, Chapter 2 and 3 examine the choice of degree of exclusivity in relation with the characteristics of the invention. Chapter 4, considers open source licensing (OSL) as a specific mode of licensing, which should enter into the licensing strategies of university TTOs, and discusses carrying this transfer mechanism beyond software. Finally Chapter 5 goes beyond licensing by examining the variety of UII channels and how these channels are articulated over time.

CHAPTER 2

Exclusive or Open? An Economic Analysis of University Intellectual Property Patenting and Licensing Strategies

CHAPTER 2

Exclusive or Open? An Economic Analysis of University Intellectual Property Patenting and Licensing Strategies[26]

Abstract

This chapter examines the determinants and compares the welfare implications of university intellectual property patenting and licensing strategies. A licensing strategy may be based on varying degrees of exclusivity granted to firms, from open, non-exclusive to exclusive licensing. We thus analyze how the nature of the technology invented by the university might affect the choice of patenting (or publishing) and the licensing strategy as well as the performance of the transfer. We consider a model with one university and four firms in two different sectors. We show that if the invention is embryonic and specific, exclusive licensing is the only strategy allowing transferring it to industry. Further, if the invention is generic and embryonic, exclusive licensing per field of use is the best way of transferring the invention. Finally, when the invention is mature, publishing is the optimal strategy. An important result is that at the equilibrium of the game, universities may not always automatically choose the strategy which maximizes social surplus.

Keywords: University licensing, technology transfer, patent, embryonic invention, generic invention

JEL Classification: O32, O33, O34

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1. Introduction

With the aim of making public research organizations (PROs) to contribute more to economic development, in the last three decades, universities all around the world have been encouraged to "valorize" their research results by national and regional governments. University basic research is valorized once it attracts the industry attention and is developed into new technologies for commercial and industrial use (Ho *et al.*, 2014). There exist many channels through which a university invention can be transferred to the industry, some formal and other more informal (Mowery *et al.*, 2001; Mowery and Shane, 2002; Siegel *et al.*, 2003; Grimpe and Fier, 2010; Grimpe and Hussinger, 2013). The main focus of this chapter is on the technology transfer through publication versus formal licensing contracts. In this latter case, and as opposed to the historical tradition of making university research publicly available to firms via scientific publications, universities protect their intellectual property (mostly via patents but also copyrights for software) and then, transfer it to the industry through the use of contractual mechanisms such as licensing.

The attention paid by PROs to this formal model of technology transfer is perfectly illustrated by the worldwide boom of university patenting and licensing (often exclusive licenses) observed since the 1980s (Mowery *et al.*, 2001; Cesaroni and Piccaluga, 2002; Mazzoleni and Sampat, 2002; Mowery and Ziedonis, 2002; Sampat, 2006; Azagra-Caro *et al.*, 2006; Geuna and Nesta, 2006; Carayol, 2007; Lissoni *et al.*, 2008). This evolution in research valorization strategy of universities went hand in hand with the creation or reinforcement of structures dedicated to technology transfer (often called technology transfer offices (TTOs)), and with the evolution of national legal frameworks towards higher financial returns for university research.

Given this situation, it is important to understand the determinants of PROs' publishing versus patenting and licensing strategies, i.e. how the context affects the choice of a strategy, the performance of the transfer, the outcome for the different stakeholders and the surplus for the society. Indeed, choosing the most appropriate strategy is not an easy task for PROs. It depends heavily on different parameters. For instance, Pénin (2010a) proposes that the nature of the invention, the technological regime and the competition regime are important determinants of the licensing strategy (see Table 2.1). More broadly, it also depends on the type of PROs and on their objectives. PROs are not the same in all countries. They evolve in a particular socio-economic and institutional environment, which obviously affects their strategy and, in particular, their objective. In some cases, PROs have set-up independent TTOs whose objective is largely profit driven. In other cases, the transfer follows different, often non-monetary logics. Those things should be kept in mind when reading this chapter. In particular, they oblige us to be very humble and careful when analyzing the implications of our research.

Table 2.1: The determinants of socially optimal university licensing strategy

		Exclusive licensing strategy if	**Non-exclusive licensing or more open strategies if**
Nature of invention	Specificity	Specific	Generic
	Distance to the market	Embryonic	Mature
Technological regime	Appropriability	Weak	Forte
	Complexity	Simple (discrete)	Complex
	Speed of technical progress	Slow	Rapid
Competition regime	Size of market	Small	Large
	Intensity of competition	High	Low
Type of the licensee firm	Firm size	Small	Large
	Firm life stage	Start-up	Mature

Note: This table must be understood *ceteris paribus*. The characteristic attributed for each variable is determined in order to maximize social welfare, not necessarily universities' licensing revenues. (The table is based on Pénin, 2010a)

In this work, we consider the case of a PRO whose objective is to maximize its profits. We seek to understand the strategy that will be chosen and the performance of the transfer according to the nature of the invention, in particular, to two important variables: whether or not the invention is embryonic or mature (Jensen and Thursby, 2001); and whether or not it is generic (general purpose technology) or specific. To do so, we consider a sequential model in which a university wants to transfer an invention to the industry and must choose its valorization strategy. In the first stage, the university must decide whether to publish or to patent its invention. If the invention is patented, in the second stage, the university must decide about its licensing strategy (exclusive license, non-exclusive license, exclusive license per field of use). Then, in the third stage, firms must decide whether or not to adopt the invention. We then investigate in which context, the university should grant exclusive licenses, and in which ones, it should grant non-exclusive licenses or publish its research results.

One of the main results of this work is that university licensing strategies must be tailored to the context. In some cases, exclusive licensing maximizes social welfare (in the case of an embryonic invention for instance). In other cases, more open strategies, based on publication, dominate (when the invention is mature and generic for instance). A second important result is that the university, since it seeks to maximize its profits, may not always automatically adopt the licensing strategy that maximizes social surplus. We believe that our work has therefore important policy implications as to the way TTOs should manage the transfer of technologies coming out of public research.

In section 2, we discuss the welfare implications of licensing strategies with varying degrees of openness by referring to three examples of exclusive and non-exclusive licensing. Section 3 presents the model to analyze the effect of the nature of the invention on technology transfer performance.

Section 4 concludes by discussing the implications of our findings, as well as providing limitations of this study and recommendations for future research.

2. Patenting and licensing university inventions and its welfare implications

2.1. Different degrees of exclusivity

World Intellectual Property Organization (WIPO) defines licensing agreement as “a partnership between an intellectual property rights owner (licensor) and another who is authorized to use such rights (licensee) in exchange for an agreed payment (fee or royalty)”[27]. Thus, in our context, a license can be considered as a contract between the owner of the IPR (university) and the licensee (firm), through which the firm is given a right to use, reproduce and commercialize the invention developed by the university under the specified conditions in the contract.

Among many things that must be specified in licensing contracts, a specific attention must be devoted to the degree of exclusivity granted to the licensee. The licensor (university) can indeed grant a license with varying degrees of exclusivity (Cameron, 2010) (see Figure 2.1). At one extreme of the spectrum, an exclusive license gives the highest degree of exclusivity to the licensee. It indeed excludes everyone, even the licensor, from using the technology (often the licensor includes a clause in the contract which states that it can continue to perform research after the grant of the exclusive license). In this sense, an exclusive license is therefore very similar to a sale of the patent. An important consequence of exclusive license is that since the university grants a license to only one firm, this firm will enjoy a monopoly position over the use and commercialization of the invention.

At the other extreme of the spectrum, open source licenses represent the less exclusive form of licensing. Here, everyone can use the licensed invention and contribute to the improvement of that invention, provided that the others can also use or modify these improvements without any permission (Gambardella and Hall, 2006). We usually see such open source copyright licensing in the case of software. Yet, since open source licensing is very specific and still rare in the case of patents, we will not consider it in this chapter. What we will consider instead, even if from a legal point of view it is not a license, is the case when the university chooses to publish its research results. Indeed, before it chooses its licensing strategy, the university must decide whether it patents or publishes the invention. It is only if it decides to patent that it will have to think about the licensing regime. In the case that university decides to publish the invention, it enters the public domain, i.e. it can be used by everybody without having to pay and to ask permission to the inventor. We need to consider this possibility of publication, because we believe that it does not make sense to disconnect it from the

[27] Retrieved from http://www.wipo.int/sme/en/ip_business/licensing/licensing.htm (last accessed on 30/10/2018).

decision to patent and to license the invention. In our framework, which is about the degree of exclusivity in the exploitation of research results, the scientific publication (even if not being formally a license) stands therefore just in between the open source license and the non-exclusive license (it is less open than the former but more open than the latter).

In between those two extremes, many different degrees of exclusivity can be envisaged. Universities can, for instance, grant non-exclusive license, which means that they can grant a license to many different firms at the same time. This type of licensing contract grants no exclusivity to companies, which may therefore allow competitors also to obtain a license, thus, increases the competition in the market. University may also grant licenses which are exclusive per field of use or exclusive per territory (this is what is called a “semi-exclusive license” in Figure 2.1).

In the first case, the company is granted exclusivity for one specific use or one specific sector and the university can still grant license to other companies for other uses or sectors. Limiting the use of software licenses to a particular machine or limiting the sale of a drug that has several therapeutic indications, to the pre-determined indication can be given as an example to this type of restriction (Cameron, 2010). In the second case, the company is granted exclusivity in a particular territory, but the university can still grant license to other companies in other places. The territory may be limited to particular country, region or specified location. In this case, the firm that is restricted by territory cannot sell the product outside the pre-determined geography. Finally, the university can also grant exclusive license but for a limited time. At the end of the license period, the university can thus decide to grant licenses, exclusive or not, to other companies. In all these cases, an invention can therefore be exclusively licensed multiple times (Lemley, 2008; Thursby and Thursby, 2007; Pénin, 2010a).

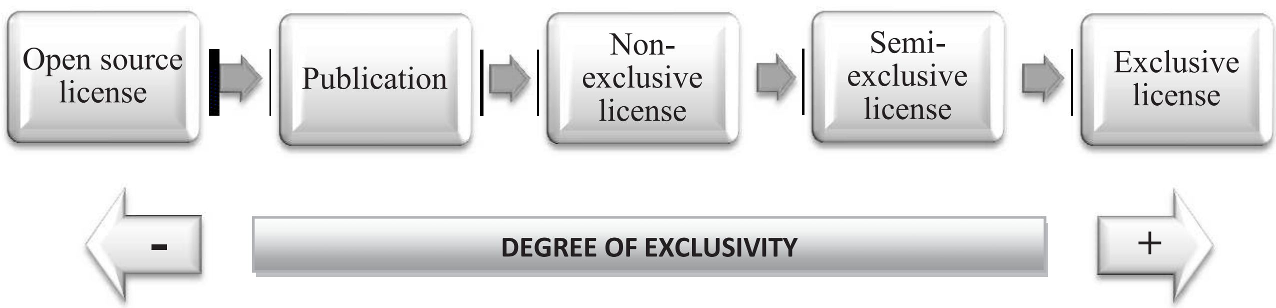

Figure 2.1: Degrees of exclusivity in the exploitation of research results

The decision to grant an exclusive versus non-exclusive or semi-exclusive license or versus publishing the research results may have important implications on the performance of the transfer of the technology. However, as suggested by the three following examples, each type of license can be successful, according to the context.

2.2. A successful case of exclusive license

Although exclusive licensing may induce monopoly deadweight loss and block future innovations, in some cases, they are necessary in order to transfer the invention, i.e. in order to provide firms with incentives to invest in the further development of the invention. This point was emphasized, for instance, by Colyvas *et al.* (2002) who displayed the case of an invention, of which the authors could not reveal the name (invention B in their paper), which was a therapeutic treatment for a common eye disease (it was a proof of concept, i.e. still quite far from the market). Due to the originality of the invention (few scientists thought that it could work) and to its embryonic nature, the TTO of the university had difficulties in finding a company willing to buy a license. Eventually, a company accepted to do so but only if exclusivity was granted to it. After a couple of years and common efforts between both the inventor and the company, the therapy finally obtained FDA approval and hit the market, thus yielding important revenues for the firm, the university and the inventor[28].

More generally, exclusive licenses are usually considered as absolutely necessary in the case of pharmaceutical products. Indeed, a new drug invented by a university must still go through a large number of tests; pre-clinical, clinical, etc., and those tests are very costly. Usually firms are reluctant to invest in those tests without the guaranty of having a monopoly on the drug market, i.e. without having received an exclusive license (Mansfield, 1986; Levin *et al.*, 1987). As an illustration, a survey on French public scientists has showed that, in the case of drugs, all the scientists who have had one of their invented drug transferred to a company considered that without an exclusive license, this transfer would not have been possible (Pénin, 2010b). This unanimity must be compared with the case of other sectors, engineering science for instance, in which most scientists do not believe that exclusivity is necessary to transfer their invention.

2.3. A successful case of non-exclusive license

A famous example where a non-exclusive license enabled the wide diffusion of a technology is Cohen-Boyer technology on recombinant DNA (rDNA) products. In 1973, Stanley Cohen (Stanford University) and Herbert Boyer (University of California in San Francisco) developed the rDNA technology and a patent was quickly applied for by Stanford University in 1974, and was granted in 1980 (other patents did follow on some extensions of the technology). Given the generic nature of the technology, which had many applications in most of the life science sectors (biotechnology,

[28] Interestingly, even if this case stresses the importance of exclusive license in order to incentivize firms, it also puts forward some of the risks of this type of license. Indeed, even after the therapy became a success, Colyvas *et al.* (2002) explain that the inventor was still concerned by the fact that: "all of possible avenues for treatment were not explored, and that the treatment is unnecessarily costly for consumers" (p. 69).

pharmaceutical, chemical, agriculture, food, energy etc.), the University of Stanford decided to adopt a non-exclusive licensing strategy, i.e. they decided to grant a license to any firm which would like to get one at a modest price.

This strategy did not prevent the transfer of the technology to the industry, nor did it imply lower revenue for Stanford. Actually, during the 17 years, where the different patents held by Stanford were in force, Cohen-Boyer technology was non-exclusively licensed to 468 companies, and to the end of 2001, Stanford University generated US $254 million. Furthermore, 2442 new products were developed based on the rDNA technology by the time patent expired, and the commercial products developed by the licensees generated US $35 billion (Feldman *et al.*, 2005; Feldman *et al.*, 2007). According to Feldman *et al.* (2007), Stanford's decision to rely on a non-exclusive strategy was decisive to explain the large diffusion of the technology. If the technology had been licensed exclusively to a single company, the rise of biotechnology industry would have been delayed for years.

2.4. A successful case of mixed license (exclusivity limited in time and then non-exclusivity)

The historical example of the invention of insulin by the University of Toronto illustrates the role of mixed licensing strategy in order to valorize a technology. In this case, an exclusive license limited in time has proved necessary in order to induce a company to invest in the transfer of the technology. But, after the period of exclusivity, open source-like licenses have ensured a wide diffusion of the technology and of its improvements.

In 1922, university of Toronto got a patent on insulin and its manufacturing methods (Cassier and Sinding, 2008). Insulin is an invention with an important social value and the University of Toronto did not want to give a monopoly over this invention to a single firm. They hence decided to opt for the non-exclusive license with grant-back mechanisms, which make this licensing scheme very close to open source licenses (Pénin, 2011). Indeed University of Toronto decided to make not only the technology available to everybody but also its future improvements. To do so, it relied on grant-back mechanisms made possible by the patent it owned, and which obliged the licensees that improve the licensed technology, to share their improvements with the University of Toronto and with the other licensees. In a sense, the University of Toronto developed, what we call today, an “open patent pool” (Cassier and Sinding, 2008). Yet, conscious about the fact that industrialists needed incentives to invest in this still uncertain technology, they first granted an exclusive license for one year to Eli Lilly. Given the embryonic state of the invention, which was still in experimental phase and industrial scale tests were necessary, this one year exclusivity was apparently necessary for Eli Lilly to accept to invest in the further development of the invention. But after this one year exclusivity, the University of Toronto did license non-exclusively the invention and its improvements in an open way to many other companies.

2.5. To summarize

As shown by those examples, there is no systematic licensing scheme that guarantees successful technology transfer. The success of a given strategy depends largely on the context and, in particular, on the nature of the invention. Exclusive licenses may be required in order to induce firms to invest in the development of embryonic, far from the market, invention. But on the other hand, non-exclusive licenses or publication of research results foster competition and the use of the technology by many firms and in many sectors (exclusive licenses induce monopoly deadweight loss). It may therefore also avoid the risk that the technology is never transferred. As to the revenue for the university, an exclusive license usually yields higher royalty rates in the short run. But non-exclusive licenses, if they are sufficiently numerous, can yield higher total amount (even if less per license). In the next section, we develop a formal model in order to capture some of the elements put forward above and to understand better how the different variables interact with each other.

3. A model to analyze the effect of the nature of the invention on the performance of technology transfer

3.1. Main settings of the model

We consider a sequential game with 5 players consisting of 1 university and 4 firms. Furthermore, we assume that two firms (F_{1A} and F_{2A}) are operating in an industry A, and the other two (F_{1B} and F_{2B}) in an industry B. We also assume that the university has made a product invention that it would like to transfer to the firms so that they can sell it on their markets. The two inverse demand functions for this invention are: $p_A = 1 - q_A$ in the market A, and $p_B = 1 - q_B$ in the market B (this means that we consider two markets with the same size). The timing of the game is as follows: In the first stage, university decides either to publish or patent the invention. If university decides to patent, in the second stage, it must decide to license the invention either exclusively, non-exclusively or exclusively per field of use[29].Then, at the last stage of the game, firms must decide whether or not to invest in order to be able to sell the invention and make money out of it.

Hence we have four possible outcomes of the game: 1) the invention is not commercialized in the two industries (the four firms do not want to invest, i.e. the technology remains on the shelves of the university); 2) the invention is exclusively commercialized by one firm (global monopoly case); 3) the invention is licensed exclusively per field of use to firms F_{1A} in industry A, and F_{1B} in industry B and; 4) the invention is non-exclusively licensed or published, i.e. it becomes available to all the four firms

[29] In the case of an exclusive license, we assume, by convention, that the licensee is firm 1, i.e. firm F_{1A} in sector A, and F_{1B} in sector B. We also assume that there is no possibility of sublicensing for the licensee, i.e. the latter cannot grant licenses to other firms.

which all decide to adopt it. In this latter case we assume that the firms compete *à la Cournot* in their respective sectors.

In the case where the invention is patented and licensed, we consider the following licensing fee: Total fee (*TF*) is a function of the royalty rate (t), i.e. the fee per unit of output (q) where $0 < t < 1$. For simplicity we assume that there is no fixed fee[30]. Royalty rate is exogenous and differs when the license is exclusive (t_e), non-exclusive (t_{ne}) or exclusive per field of use (t_{efu}) such that: $0 < t_{ne} < t_{efu} < t_e < 1$[31]. In addition, we assume that t_{ne}, t_{efu}, and t_e are such that licensees' profits are always positive. Similarly, in order to make sure that licensee's monopoly profit is always higher than the duopoly profit we posit that $t_e < \frac{1+2t_{ne}}{3}$. Furthermore, without loss of generality, we can also consider that firms' marginal costs (*MC)* are zero, i.e. when the firm buys a license, the marginal cost equals the royalty rate of the license to the university.

When university patents the invention, it bears a cost (e.g. patent application fee, labor cost, etc.) associated with patenting, denoted by c_p. University decides to patent the invention only if its net income (i.e. royalty revenues minus patenting costs) is positive. In the other case, it decides to publish. In other words, we assume that the objective function of the university is to maximize its net income, irrespective of the implications on social welfare[32]. Similarly, firms accept to invest in the development and commercialization of the invention only if it yields them positive profits.

In this model, we are specifically interested by the influence of the nature of the invention that we consider along two dimensions: (1) *Distance to the market* and (2) *Specificity*.

- Distance to the market indicates whether the invention is embryonic (far from the market) or mature (close to the market). An embryonic invention means that firms must still invest in its development before they can make money out of it. A mature invention means that it is

[30] In reality, many licensing agreements between university and firms do contain a lump-sum, i.e. a fixed part. However, in the model the presence of a fixed part does not significantly affect our results at the equilibrium of the game. We can therefore remove it without any loss of generality.

[31] The fact that $t_{efu} < t_e$ may be justified by some degree of permeability between industries A and B. If the two industries were perfectly impermeable, i.e. if an exclusive license per field of use was enforceable at no cost, then we should have $t_{efu} = t_e$. But, when the enforcement of an exclusive license per field of use is costly, firms may be willing to pay more in order to have a global exclusive license.

[32] If this assumption may be too strong in some cases, it is undisputable that universities increasingly face pressures from policy makers in order to be more "profitable". Also, recent reforms in most developed countries tend to delegate the mission of technology transfer to independent TTOs (example SATT in France) whose objective is more or less explicitly to be profitable. It is therefore not exaggerated to assume that the revenues generated by technology transfer are an important issue either for universities, for TTOs or for both.

immediately usable by firms without further investments[33]. In the model, we capture the embryonic versus mature nature of the invention by introducing a parameter I which indicates the amount of investment that a company must perform before it can sell the invention. For simplicity, we assume that I is a fixed cost, i.e. if the invention is embryonic, the total cost (TC) function of the firm becomes $TC = tq + I$. If $I = 0$ then the invention is mature; the higher I, the more embryonic the invention.

- An invention can also be specific or generic. A generic invention (general purpose technology) may have many different applications and may therefore be used in many different sectors. Conversely, a specific technology can only have a particular application or can be used in a particular sector. In the model, we consider that a generic invention can be used in the two sectors, A and B, whereas a specific invention can only be used in sector A (it has no application in sector B).

3.2. The case of a specific technology

By convention, a specific invention can be used only in industry A. The game is hence reduced to three players (university and firms 1 and 2 in industry A). In this case, it is immediate to stress a first result.

Proposition 1: (a) *If the invention is too embryonic (* $I > \frac{(1-t_e)^2}{4}$*), it does not exist a SPNE in which the invention is commercialized;* ***(b)*** *If the invention is moderately embryonic (* $\frac{(1-t_{ne})^2}{9} < I < \frac{(1-t_e)^2}{4}$*) then the only SPNE of the game which enables the invention to be commercialized is when the university delivers an exclusive license. This equilibrium is reached if and only if* $t_e \frac{(1-t_e)}{2} > c_p$ *;* ***(c)*** *If the invention is mature (* $0 \le I < \frac{(1-t_{ne})^2}{9}$*), then there always exists a SPNE in which the invention is transferred.*

This first proposition is in line with the discussion in section 2. The more embryonic the university invention, the more likely it is to see exclusive licensing. Indeed, since duopoly profits are lower than monopoly profits, it is possible that publishing the invention or granting non-exclusive licenses to firms do not provide them with enough incentives to invest in the development of the technology. Yet,

[33] According to Jensen and Thursby (2001), most university inventions are at embryonic stage, i.e. either are proof of concepts or lab-scale prototypes, thus justifying the grant of exclusive licenses to firms. They conducted a survey on 62 U.S. research universities which showed that over 75 percent of the university inventions were at embryonic stage and only 12 percent were ready for commercial use at the moment of the patent. Also, 31 percent of these inventions were licensed either exclusively or exclusively per field of use, whereas only 10 percent non-exclusively licensed.

when the invention is too embryonic, even the grant of an exclusive license is not sufficient to induce firms to invest in the development of the invention.

Indeed, if $I > \frac{(1-t_e)^2}{4}$ then at the last stage of the game, firms will never decide to commercialize the invention because it would always yield them negative profits. Furthermore, if $\frac{(1-t_{ne})^2}{9} < I < \frac{(1-t_e)^2}{4}$ then firms' duopoly profits are always negative, i.e. firms never accept to commercialize the invention if it is not exclusively licensed. But, because the monopoly profit is positive, under exclusive licensing scheme, firm 1 accepts to commercialize the invention (provided that $0 < t_e < \frac{1}{3}$). Furthermore, the university accepts to patent and delivers an exclusive license to firm 1 if and only if $t_e \frac{(1-t_e)}{2} > c_p$. Finally, if $I < \frac{(1-t_{ne})^2}{9}$ then both monopoly and duopoly profits are positive and firms always accept to commercialize the invention. Hence, under both cases, the technology is transferred. University may choose either to patent or publish depending on its net income. If the cost of patenting is lower than the licensing revenue, that is to say either $c_p < t_e \frac{(1-t_e)}{2}$ or $c_p < 2t_{ne} \frac{(1-t_{ne})}{3}$, then at the SPNE of the game, university patents and grants either an exclusive or a non-exclusive license. But, on the other hand, if the cost of patenting is higher than the licensing revenue, that is to say both $c_p > t_e \frac{(1-t_e)}{2}$ and $c_p > 2t_{ne} \frac{(1-t_{ne})}{3}$, then at the SPNE of the game, the university publishes the invention.

In other words, when the technology is mature it will be transferred in any case. Whatever the choice of the university is, firms decide to commercialize the invention. Yet, all the SPNE of the game may not be in the public interest. This is clearly stated by proposition 2.

Proposition 2: *Assume $I = 0$ (invention is mature). In this case, the social surplus is the highest when the invention is published. But, if $c_p < t_e \frac{(1-t_e)}{2}$ or $c_p < 2t_{ne} \frac{(1-t_{ne})}{3}$ then the university decides to patent the invention, i.e. the SPNE of the game is not socially optimal.*

In order to show whether the publishing gives the highest social surplus when the invention is mature, we should compare the social welfare (SW) under each valorization regime. Table 2.2 summarizes these findings. We see that SW under publishing is always higher than SW under non-exclusive and exclusive licensing if the invention is mature. However, if $c_p < t_e \frac{(1-t_e)}{2}$ or if $c_p < 2t_{ne} \frac{(1-t_{ne})}{3}$, the university net income will be higher under patenting than under publishing, i.e. the university will decide to patent and to deliver an exclusive or non-exclusive license, although it is socially under optimal.

Table 2.2: Social welfare under different licensing strategies (specific invention)

	Social welfare	Firms' profit	Consumer surplus	University net income
Exclusive licensing	$\frac{3}{8}(1-t_e)^2 - I + t_e\left(\frac{1-t_e}{2}\right) - c_p$	$\frac{1}{4}(1-t_e)^2 - I$	$\frac{1}{8}(1-t_e)^2$	$t_e\left(\frac{1-t_e}{2}\right) - c_p$
Non-exclusive licensing	$\frac{4}{9}(1-t_{ne})^2 - 2I + 2t_{ne}\left(\frac{1-t_{ne}}{3}\right) - c_p$	$\frac{2}{9}(1-t_{ne})^2 - 2I$	$\frac{2}{9}(1-t_{ne})^2$	$2t_{ne}\left(\frac{1-t_{ne}}{3}\right) - c_p$
Publishing	$\frac{4}{9} - 2I$	$\frac{2}{9} - 2I$	$\frac{2}{9}$	0

3.3. The case of a generic and mature technology

In the case of a generic technology, the university invention can be used in the two industries, A and B, and can thus be commercialized by the 4 firms in those two industries. A first immediate result is stated in proposition 3 below.

Proposition 3: *If the invention is generic and mature ($I = 0$) then there always exist a SPNE in which the invention is commercialized at least in one sector.*

Indeed, if the invention is mature, then both monopoly and duopoly profits are positive in each sector. Hence firms always accept to commercialize the invention whatever the strategy of the university (patenting or publishing) is. If the university decides to patent, provided that $2t_{efu}\frac{(1-t_{efu})}{2} > t_e\frac{(1-t_e)}{2}$ or $4t_{ne}\frac{(1-t_{ne})}{3} > t_e\frac{(1-t_e)}{2}$, the university always chooses not to give a global exclusivity to a single firm, thus, leading to the commercialization in both sectors. Yet, if those two conditions do not hold then, the university will decide to deliver a global exclusive license to only one firm, thus, leading to commercialization only in sector A. Such a situation might therefore be inefficient as stated in proposition 4.

Proposition 4: *If the invention is generic and mature, the SPNE which yields the highest social surplus is when the invention is published. But if $c_p < t_e\frac{(1-t_e)}{2}$, $c_p < 2t_{efu}\frac{(1-t_{efu})}{2}$ or $c_p < 4t_{ne}\frac{(1-t_{ne})}{3}$), then the university decides to patent the invention, i.e. the SPNE of the game is not socially optimal. The less efficient SPNE is when $t_e\left(\frac{1-t_e}{2}\right) > 2t_{efu}\left(\frac{1-t_{efu}}{2}\right)$ and $t_e\left(\frac{1-t_e}{2}\right) > 4t_{ne}\left(\frac{1-t_{ne}}{3}\right)$, i.e. when the university chooses to grant an exclusive license only to one firm in one sector.*

In order to show whether publishing gives the highest social surplus when the invention is generic and mature, we must compare again SW under each valorization regimes. Table 2.3 summarizes these findings. We see that SW under publishing is higher than SW under exclusive licensing, exclusive license per field of use and non-exclusive licensing. However, if either $c_p < t_e \frac{(1-t_e)}{2}$ or $c_p < 2t_{efu} \frac{(1-t_{efu})}{2}$ or $c_p < 4t_{ne} \frac{(1-t_{ne})}{3}$, university decides to patent (i.e. publishing cannot be a SPNE), leading hence to inefficiency. Furthermore, it is possible that the invention is not commercialized in both sectors if university exclusively and globally license the invention to firm 1 in sector A. University may choose to give a global exclusivity if both $t_e\left(\frac{1-t_e}{2}\right) > 2t_{efu}\left(\frac{1-t_{efu}}{2}\right)$ and $t_e\left(\frac{1-t_e}{2}\right) > 4t_{ne}\left(\frac{1-t_{ne}}{3}\right)$. Intuitively, the inefficiency is higher under global exclusivity since the quantity produced decreases and the invention cannot be commercialized in both sectors.

3.4. The case of a generic and moderately embryonic technology

A last set of results is obtained when the invention is generic and moderately embryonic. In this case, as stated by proposition 5, some degree of exclusivity may be necessary in order to induce firms to invest in the technology.

Proposition 5: *If the invention is generic and moderately embryonic then the only SPNE which allows the invention to be commercialized in both sectors is when the university decides to patent and to deliver exclusive license per field of use. This SPNE is possible if* $2t_{efu}\frac{(1-t_{efu})}{2} > c_p$ *and* $2t_{efu}\left(\frac{1-t_{efu}}{2}\right) > t_e\left(\frac{1-t_e}{2}\right)$.

Table 2.3: Social welfare under different licensing strategies (generic and mature invention)

	Social welfare	**Total profit**	**Consumer surplus**	**University net income**
Exclusive licensing	$\frac{3}{8}(1-t_e)^2 + t_e\left(\frac{1-t_e}{2}\right) - c_p$	$\frac{1}{4}(1-t_e)^2$	$\frac{1}{8}(1-t_e)^2$	$t_e\left(\frac{1-t_e}{2}\right) - c_p$
Exclusive licensing per field of use	$\frac{3}{4}(1-t_{efu})^2 + 2t_{efu}\left(\frac{1-t_{efu}}{2}\right) - c_p$	$\frac{1}{2}(1-t_{efu})^2$	$\frac{1}{4}(1-t_{efu})^2$	$2t_{efu}\left(\frac{1-t_{efu}}{2}\right) - c_p$
Non-exclusive licensing	$\frac{8}{9}(1-t_{ne})^2 + 4t_{ne}\left(\frac{1-t_{ne}}{3}\right) - c_p$	$\frac{4}{9}(1-t_{ne})^2$	$\frac{4}{9}(1-t_{ne})^2$	$4t_{ne}\left(\frac{1-t_{ne}}{3}\right) - c_p$
Publishing	$\frac{8}{9}$	$\frac{4}{9}$	$\frac{4}{9}$	0

Indeed, if the invention is moderately embryonic firms' duopoly profits, whether university publishes or delivers a non-exclusive license, are always negative and firms never accept to commercialize the invention (see proposition 1). Although global exclusivity may allow commercialization in sector A, it will not be possible to have a SPNE which allows the invention to be commercialized in both sectors. Therefore, it is only when firms obtain a monopoly situation in their respective markets (exclusivity per field of use) that they are willing to commercialize the invention. Furthermore, the university accepts to patent and delivers exclusive license per field of use if and only if $2t_{efu}\frac{(1-t_{efu})}{2} > c_p$ and $2t_{efu}\left(\frac{1-t_{efu}}{2}\right) > t_e\left(\frac{1-t_e}{2}\right)$. However, it is also possible that universities do not choose this licensing contract (because it does not maximize their revenues), as stated by proposition 6.

Proposition 6: *If the invention is generic and moderately embryonic and if* $t_e\left(\frac{1-t_e}{2}\right) > 2t_{efu}\left(\frac{1-t_{efu}}{2}\right)$, *the only SPNE is when the university delivers a global exclusive license, i.e. the invention is commercialized only in sector A, which is clearly inefficient*[34].

3.5. Summary of the results

The main results of the model are summarized below and in Table 2.4:

- If the invention is too embryonic and either specific or generic, there is no SPNE in which the technology can be transferred.
- If the invention is moderately embryonic and specific, the only way of transferring the technology is when the university delivers an exclusive license to a firm.
- If the invention is moderately embryonic and generic, then the only way of transferring the technology in both sectors is giving exclusive license per field of use. If university decides to give a global exclusivity, this may lead to inefficiency. This case cannot be excluded under some reasonable conditions.
- If the invention is mature and specific or generic, there always exists a SPNE in which the technology is transferred in all sectors. In this case the optimal strategy is always publishing. However university may choose to patent if c_p is lower than its licensing revenue.
- Finally, if the invention is mature and generic, it is possible (under some extreme conditions) that the university chooses to grant a global exclusive license, thus leading to an under commercialization of the technology as compared to the optimum.

[34] Note that this result holds under the assumption that licensees have no right to deliver sub-license. Without this assumption it would be possible for firm F_{1A} to sell an exclusive license per field of use to firm F_{1B}.

4. Conclusion

The growing interest of the "ivory tower" in valorizing its research through patenting and licensing has raised many questions. In this chapter we have investigated how the nature of the invention (embryonic versus mature; generic versus specific) may affect the patenting strategy of universities and the degree of exclusivity of the licensing contract. We have shown that in some cases delivering an exclusive license is the optimal strategy (for instance when the invention is embryonic), but that in other cases, more open strategies based on publication or non-exclusive licenses are preferable. We have also shown that it may be possible that universities choose to grant licensing contracts which are not in the public interest. This study hence contributes to the existing literature in offering a conceptual understanding on how the nature of the invention should shape universities' intellectual property patenting and licensing strategies.

Some of the findings of our model are clearly in line with recent policy evolutions. For instance, in line with the Bayh-Dole argument, we find out that some degree of exclusivity may be desirable when the invention is embryonic (and clearly many university inventions are embryonic). Also, we find out that even exclusive licenses may not be sufficient to transfer the technology if the latter is too embryonic and hence too costly. Thus, in this case, policy measures that favor academic entrepreneurship, creation of start-up, and/or the collaboration between the academic inventor and the firm might help to develop the technology and transfer the invention (Jensen and Thursby, 2001).

Table 2.4: Summary of the results

NATURE OF INVENTION	**Specific**	**Generic**
Too Embryonic	*Proposition 1(a):* The only SPNEs are publishing and no transfer.	The only SPNEs are publishing and non-commercialization (no transfer).
Moderately Embryonic	*Proposition 1(b)*: The only SPNE which allows commercialization is *exclusive licensing.*	*Proposition 5*: The only SPNE that allows commercialization in both sectors is *exclusive licensing per field of use.* *Proposition 6*: Risk of inefficiency if university grants a global exclusivity.
Mature	*Proposition 1(c)*: All SPNEs allow commercialization. *Proposition 2*: Risk of inefficiency if university does not *publish.*	*Proposition 3*: Most SPNEs allow commercialization in both sectors. *Proposition 4*: Risk of inefficiency if university does not *publish* and even worse if it grants a global exclusivity.

However, our model also points out some possible source of inefficiency if universities decide to rely systematically on exclusive licenses. In particular, this may be detrimental to social welfare when the invention is mature or generic. In this case, an important finding of the model is that more open, non-exclusive licensing strategies may be the most desirable solution. This result must be emphasized, in particular, since budget constraints that apply to countries all around the world may induce governments to increasingly require universities to "sell" their technologies irrespective of their nature and of the impact on social welfare. This short run strategy might sometimes reduce non-exclusive valorization strategies and be detrimental on the longer run to social welfare.

Further research will follow at least two lines of inquiry. First, it will be needed to broaden our theoretical analysis and to consider more sophisticated situation which have been voluntarily excluded in this simple analysis. For instance, one needs to pay more attention to the formation of the royalty rate (which was considered as exogenous here). In practice, the licensor and the licensee negotiate this rate and the modeling of this negotiation might change the results of our model. In the same vein, we did not consider the issue of asymmetry of information, we did not consider the existence of a budget constraint for the universities which may prevent them from patenting their research result, and we did not explore the impact of two markets of different sizes. All those elements can obviously change some of the results obtained in this study. Similarly, it might be interesting to focus on other determinants of university licensing strategies. In this work, we only considered the effect of the nature of the invention. In addition to this, the effects of other parameters (technological regime, size of market, characteristics of the licensee firm, etc.) may also be explored. Further, the research valorization analysis may also be extended to other contractual forms, such as informal or formal collaborations or material transfer agreements.

Second, our theoretical work needs to be completed by an empirical analysis. This is a challenging point since micro data with respect to the research licensing contracts are not easily available. We make a first attempt in Chapter 3, in which we study all the licensing contracts of two leading French research universities and try to understand the determinants of the exclusive versus non-exclusive dimension of the license. In particular, we link exclusivity with the nature and property of the invention which is licensed (whether or not it is embryonic versus mature, generic versus specific, appropriable versus non-appropriable). The results of our exploratory study seem to indicate that, as suggested in this research, the licensing strategy which is effectively implemented might not always be in line with the public interest (mature and generic inventions are sometimes exclusively licensed for instance). Due to the growing importance of university patenting and licensing and to the lack of empirical evidence, we believe that this type of empirical analysis should be deepened in the future with larger scale analysis.

CHAPTER 3

Invention Characteristics and the Degree of Exclusivity of University Licenses: The Case of Two Leading French Research Universities

CHAPTER 3

Invention Characteristics and the Degree of Exclusivity of University Licenses: The Case of Two Leading French Research Universities[35]

Abstract

This chapter examines the determinants of university exclusive versus non-exclusive licenses. We specifically focus on the effect of the characteristics of a licensed invention (i.e. stage of development, specificity and appropriability). We rely on a unique and original dataset of 91 inventions contained in 62 intellectual property licensing contracts executed in the period of 2005-2014 by two leading French research universities. We find that the characteristics of the invention do not significantly affect the licensing strategy. In particular, as opposed to theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses and generic inventions are not significantly linked to non-exclusive licenses. Furthermore, inventions that are both generic and embryonic are not significantly linked to exclusive licenses per field of use. These results, although still exploratory, contribute to feed the discussion on the performance of university-industry technology transfer since they suggest that performance might be improved by taking more into account the characteristics of the licensed invention.

Keywords: University licensing, technology transfer, invention characteristics, degree of exclusivity

JEL Classification: O31, O32, O34

[35] This chapter corresponds to a research paper co-written with Professor Julien Pénin. The revised article has been submitted for publication.

1. Introduction

The last three decades have witnessed a worldwide boom in university patenting and licensing (Mowery *et al.*, 2004; Geuna and Nesta, 2006; Lissoni *et al.*, 2008; Siegel and Wright, 2015). But despite many statistics as to the number of university patents, number of licenses delivered to firms, amount of royalties collected by universities (Thursby *et al.*, 2001; Siegel *et al.*, 2003; Roessner *et al.*, 2013), estimated number of spin-offs or start-ups (Powers and McDougall, 2005; Van Looy *et al.*, 2011) and jobs created, little is known about the content of the licensing contracts and its consequences on the transfer. Yet, licensing contracts are not homogeneous (Bessy *et al.*, 2002) and their characteristics might have important implications on the performance of the transfer of the technology.

A typical licensing contract includes clauses on the parties involved, length of the contract, patents to be exploited, exclusivity and restrictions, remuneration scheme, existence of grant-back mechanism, etc. (Anand and Khanna, 2000; Bessy *et al.*, 2002). Among many different clauses included in the contract, degree of exclusivity granted to the licensee requires a specific attention (Öcalan-Özel and Pénin, 2016). The licensor (university in our case) can grant a license to the licensee (firm in our case) with varying degrees of exclusivity (Anand and Khanna, 2000; Cameron, 2010). Exclusive license represents the highest degree of exclusivity. It gives a monopoly right to the licensee over the use of an invention by excluding everyone else (even the licensor) from using it. On the other hand, open source licensing is the least exclusive form of licensing, since everyone can use and modify the invention or contribute to its development, without any permission, in return for similar rights attached to the improvements (e.g. general public license (GPL) for software inventions) (Scotchmer, 2010). In between these two extreme forms of licensing, different degrees of exclusivities can also be granted to firms. For instance, in the case of non-exclusive licensing, many different firms can receive a license over the use of an invention at the same time. Furthermore, universities may also grant exclusive licenses that are restricted by field of use, by territory or limited in time, which we may refer as restricted exclusivity or semi-exclusive license (Anand and Khanna, 2000; Cameron, 2010).

The degree of exclusivity of the license may have important implications on the performance of the transfer of the invention and, in turn, on social welfare (Mazzoleni, 2006). On the one hand, granting an exclusive license might be necessary, in order to provide firms with incentives to invest in the development of the invention. This might be especially the case for embryonic inventions which are far from being a marketable product (Jensen and Thursby, 2001; Thursby and Thursby, 2007; Dechenaux *et al.*, 2011; Mowery and Ziedonis, 2015). On the other hand, an exclusive license also generates a monopoly deadweight loss for society. Depending on the context, an exclusive license might therefore induce an unnecessary monopoly deadweight loss when, for instance, exclusivity is not required to provide firms with incentives. Alternatively, in other cases, non-exclusive licenses might not provide enough incentives and thus might not ensure the transfer of the invention that remains on the shelves of the university lab (Pénin, 2010a).

Given the aforementioned heterogeneity of possible exclusivity clauses, the objective of this study is to provide a first investigation into the determinants of universities' exclusive versus non-exclusive licenses. In particular, we are interested in the role of invention's characteristics, i.e. how the properties of the invention shape the exclusive versus non-exclusive nature of the license. Many dimensions might indeed influence the choice of a university license. For instance, Jensen and Thursby (2001) show that the embryonic nature of the invention may explain the exclusivity granted to the licensee firm. Pénin (2010a) proposes that the nature of the invention (i.e. distance to market, specificity), the technological regime (i.e. appropriability, complexity, speed of technical progress) and the competition regime (i.e. size of market, intensity of competition) are important determinants of university licenses. Öcalan-Özel and Pénin (2016) develop a theoretical model where they analyze the exclusive versus non-exclusive nature of the license by taking into account two dimensions: whether the invention is embryonic versus mature, and whether it is generic versus specific (in Chapter 2). With regard to empirical work, although a few studies relate certain characteristics of the technology to the selection of the commercialization mode (i.e. licensing versus start-up creation) (Shane, 2004) or to the selection of the business models for commercialization (Pries and Guild, 2011), to the best of our knowledge, there isn't any empirical study trying to explain the exclusive versus non-exclusive nature of university licenses based on the characteristics of the licensed invention. This might be due, among other things, to the difficulty to assess and measure the different dimensions of an invention.

This study aims at contributing to fill this gap by providing a first empirical research, although clearly exploratory, on the impact of the properties of the licensed technology on the nature of the license. We investigate the role of the following dimensions of the licensed invention on the probability to deliver exclusive versus non-exclusive or semi-exclusive licenses: distance to the market (embryonic versus mature inventions), degree of specificity and degree of appropriability. To do so, we rely on the cases of two leading French research universities (University of Strasbourg and University of Grenoble Alpes) for which we have been able to collect a unique and original dataset of 91 inventions contained in 62 licensing (and cession) contracts executed in the period of 2005-2014.

Our exploratory study suggests that characteristics of the invention do not significantly affect the exclusive nature of the license. In particular, as opposed to theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses and generic inventions are not significantly linked to non-exclusive licenses. In addition, inventions that are both generic and embryonic are not significantly linked to exclusive licenses per field of use. These results, although they are based on a limited number of observations and call for further research in order to be generalized, suggest that university-industry licensing contracts might not always be welfare enhancing. In particular, they suggest that the performance of technology transfer can be improved, by taking more into account the characteristics of the licensed invention. They have therefore important implications for policy makers and TTO managers.

The chapter proceeds as follows. In the next section, we build our research hypotheses. Section 3 describes the data and methodology. Section 4 presents the main findings of econometric analysis. Section 5 concludes by discussing the policy and managerial implications of our findings and sketching directions for future research.

2. Theoretical background and research hypotheses

The choice of a license and, in turn, the performance of the transfer might be affected by many dimensions of the licensed invention. In this study, we focus on three dimensions: embryonic versus mature; generic versus specific; appropriable versus easily imitable. In line with Öcalan-Özel and Pénin (2016), we are looking at which type of license (more or less exclusive) leads to maximizing social surplus (to transfer the technology at a minimum cost for society) according to these three characteristics of the licensed technology. In particular, we consider two effects that should determine the type of the license. The first one deals with firms' incentives to use the technology developed by universities. Sometimes universities have to grant exclusivity to firms in order to provide them with incentives to transfer and use the technology (Somaya *et al.*, 2011; Drivas *et al.*, 2017). The other one deals with the social cost of exclusivity. An exclusive license creates monopoly power and may hinder effective diffusion of new technologies (Lemley, 2008), which in turn reduces social welfare. This second effect must be balanced with the incentive effect and, given the different characteristics of inventions, universities (provided that they seek to maximize social surplus) should choose the degree of exclusivity that both provides incentives to transfer the technology and minimizes the social cost associated with monopoly power.

2.1. Embryonic versus mature technology

Jensen and Thursby (2001) put forward that many university inventions are at embryonic stage. Through a survey of 62 U.S. research universities' licensing activities, they showed that 75 percent of the university inventions were at embryonic stage (i.e. either are proofs of concepts or lab-scale prototypes). Furthermore, most of these inventions were licensed either exclusively or exclusively per field of use (31 percent), whereas only a little share (10 percent) were non-exclusively licensed.

The embryonic dimension of university technology should have an impact on the exclusive nature of the license. An embryonic invention requires additional investment from the licensee and firms might be reluctant to invest in order to make the technology operational if they do not retain exclusivity

(Merrill and Mazza, 2011; Drivas *et al.*, 2017). Empirical studies (Anand and Khanna; 2000; Somaya *et al.*, 2011) are also in line with this argument, since they find that allocation of exclusive rights to the licensee is more likely in the case of early stage or prospective technologies compared to already developed technologies. Without the exclusivity, the situation would indeed be equivalent to a public good game. Firms do not want to invest in a technology that can be used by everybody once it is operational. As mentioned by Mazzoleni and Sampat (2002, p. 237): "what is available to everybody is of interest to no one"[36]. For instance, exclusive licenses are usually crucial in the case of pharmaceutical products, since a new drug requires costly and time consuming tests before coming onto the market (Anand and Khanna 2000; Lemley, 2008; Somaya *et al.*, 2011). Therefore, in the absence of such an exclusive right in the drug market, firms are usually reluctant to invest in the further development of the invention (Mansfield, 1986; Levin *et al.*, 1987).

Consequently, although exclusive licensing may induce monopoly deadweight loss and block future innovations[37], in the case of embryonic inventions, they might be necessary in order to transfer the invention, i.e. in order to provide firms with incentives to invest in the further development of the invention (Colyvas *et al.*, 2002). This argument was, in particular, at the heart of the Bayh-Dole discussion in the U.S. (Mowery *et al.*, 2004). We therefore expect a positive effect of the embryonic nature of the technology on the probability of granting an exclusive license to the licensee firm. Conversely, if the invention is close to the market (i.e. mature technology), we expect university technology transfer offices (TTOs) to rely more on open licensing strategies (i.e. non-exclusive license), in order to decrease the social cost associated with unnecessary monopolies. Thus our first hypothesis:

> ***Hypothesis 1 -*** All else equal, the more embryonic the invention, the more likely it is to be exclusively licensed.

2.2. Generic versus specific technology

Another factor that should enter into consideration when deciding about the exclusive dimension of the license, deals with the generic versus specific nature of the invention. A generic invention or

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36 This argument is inspired by an older citation from a pioneer of technology transfer in the U.S., the chemist F.G. Cottrell who wrote in 1912: "what is everybody's business is nobody's business" (Cottrell, 1912, cited in Mowery *et al.*, 2004, p. 59).

37 It is interesting to note that, contrary to the standard argument that exclusive licensing blocks or diminishes the follow-on research, a recent study by Drivas *et al.* (2017) finds that exclusive licensing increases follow-on research by non-licensees (measured by forward citations), since the occurrence of a license sends a signal to potential innovators about further innovation possibilities in the relevant fields. This signal stems from the fact that the licensee firm realizes a financial commitment through licensing the technology and hence reveals important information to non-licensees about the commercial opportunities.

enabling technology (sometimes may also be referred as general purpose technology[38]) may have several applications in many different sectors (Kim and Vonortas, 2006), whereas a specific technology (or a dedicated technology) can only be used in one very specific context (Gambardella and Giarratana, 2013). For a generic invention, an exclusive license might have costly consequences on social welfare, because given the generic nature of the technology, it is impossible for one company to exploit all the possible applications. It might be possible that an exclusive licensee, who has obtained an exclusive license, delivers sublicenses in cases where it does not want to exploit the technology itself. But, still, transaction costs might impede welfare increasing deals. Therefore, since a generic technology has many applications in many different sectors, it is more efficient if it is non-exclusively licensed to many firms (Lemley, 2008). Non-exclusive licenses favor the large dissemination of the technology and its exploitation in many different cases, and increase the probability that all promising applications are explored (Nelson, 2004; Hayter, 2016). On the contrary, when the technology is very specific, when it has applications in only one very limited domain, granting exclusivity to a firm is less costly for the society. At the extreme, if the technology can be used only in the context of one specific firm, granting an exclusivity to this firm does not impact social welfare, since, in any case, even without an exclusivity, the technology does not make sense for other firms.

Non-exclusive licensing of Cohen-Boyer technology, which is one of the very well-known inventions in biomedical research based on recombinant DNA (rDNA), enabled the wide diffusion of the technology across many different fields of use (Feldman *et al.*, 2007). Stanford University applied for a patent for this rDNA technology in 1974, and the patent was granted in 1980. Over the lifespan of the patent, Stanford University non-exclusively licensed the invention to 468 companies and generated US$254 million. Thanks to its generic nature, 2442 new products were developed in sectors as diverse as biotechnology, pharmaceutical, agriculture, energy, food etc. (Feldman *et al.*, 2005; Feldman *et al.*, 2007). Had the technology licensed exclusively, it is possible that such a wide diffusion would not have been possible.

Consequently, in line with the social mission of a university, we expect an invention characterized as generic to decrease the likelihood of granting an exclusive license. Thus our second hypothesis:

> ***Hypothesis 2 -*** All else equal, the more generic the invention, the less likely it is to be exclusively licensed.

[38] General purpose technology (GPT) has a pervasive feature and affects entire economy, as well as pre-existing social and political structures. Some examples of GPT include steam engine, railroad, electricity, automobile, computer, internet, nanotechnology, artificial intelligence and so on (Lipsey *et al.*, 2005).

Taken together, Hypotheses 1 and 2 lead to another proposition dealing with inventions that are both embryonic and generic (Öcalan-Özel and Pénin, 2016). In this case, the embryonic nature of the technology calls for an exclusive license, whereas its generic dimension calls for a non-exclusive license. It is therefore possible to rely on an exclusive license per field of use, i.e. a license that grants exclusivity to licensees, but only in specified domain. The university can thus grant as many exclusive licenses as fields of use. This type of license might provide incentives to licensees, since it gives them exclusivity in the specified field of use, while ensuring a wide dissemination of the technology across other fields of use (Somaya *et al.*, 2011). Therefore our third hypothesis:

> ***Hypothesis 3 -*** All else equal, the more embryonic and generic the invention, the more likely it is to be exclusively licensed per field of use.

2.3. Appropriability of the technology

The appropriability regime depicts the ease of imitation of an invention (Nelson and Winter, 1982; Teece, 1986). We say that appropriability is strong when the invention is difficult to replicate (Teece, 2003). The question of the appropriability of a technology goes beyond the simple patent issue (Teece, 1986). Many parameters affect the possibility for a firm to imitate: the existence of a patent but also the tacit nature of the knowledge base, the existence of complementary assets, the distance to the technological frontier (protection due to lead-time), etc. All these parameters explain why the cost of imitation remains often high, even though the invention is not protected by a patent. Imitative firms must invest in their absorptive capacity (Cohen and Levinthal, 1989). Also, this explains why some innovative companies sometimes choose not to rely on patents in order to prevent imitation (Levin *et al.*, 1987; Cohen *et al.*, 2000). They find alternative ways of protection.

In the case of university licensing, this means that if the technology is easily appropriable without patents, i.e. difficult to imitate because intense in tacit knowledge for instance or protected by the existence of complementary assets, then licensees might not need an exclusive legal right in order to find incentives to transfer and use the technology (Colyvas *et al.*, 2002). Licensees might need some assistance from the university (for instance some help from academic researchers in order to transfer the tacit knowledge associated with the invention), but an exclusive license might not be necessary in order to provide them with incentives. On the contrary, in a weak appropriability regime, licensee firm faces the risk of infringement by third parties, and incentives to develop the licensed technology is reduced (Lee *et al.*, 2017). Therefore, when the university invention is easily imitable, licensees might need an exclusive license in order to find it profitable to exploit the technology. Thus, our fourth hypothesis:

Hypothesis 4 - All else equal, the more appropriable the invention (the more it belongs to a strong appropriability regime), the less likely it is to be exclusively licensed.

3. Data and methodology

The empirical analysis was carried out within the framework of COCON project (COhort of CONtracts), financed by the French National Research Agency (ANR). COCON is a multidisciplinary project conducted by researchers in economics, management and law. We collected information about all the licensing contracts executed between 2005 and 2014 by the University of Strasbourg and the University of Grenoble Alpes, which are among the top French scientific universities according to 2015 Shanghai ranking.

3.1. University TTOs in the French context and their patenting and licensing practices[39]

Recent studies suggest that the organization and management practices of university licensing can significantly affect the performance of the technology transfer to industry (Benassi *et al.*, 2017; Bodas Freitas and Verspagen, 2017). It is therefore important to understand how academic licensing is organized in France. As in most other developed countries, the French university-industry technology transfer landscape has radically evolved in the last two decades, putting much more emphasis on patenting and licensing. These changes contributed to increase the occurrence of university patenting and licensing in France (yet, as we see below, licensing remains small in comparison to U.S. counterparts (Conti and Gaule, 2011)). For instance, in the last years, the CNRS was systematically ranked among the top French patent applicants, INSERM and INRA reaching high rankings too. Similarly, French universities are intensively patenting and licensing, and there are various evidences that this trend is growing (Azagra-Caro *et al.*, 2006; Carayol, 2007; Lissoni *et al.*, 2008).

These changes can, at least partially, be attributed to the law on innovation and research passed in 1999 in France. This law put great emphasis on patents. It led to the creation in all French scientific universities of technology transfer offices, nowadays called SATT in France, that are dedicated to accelerating the transformation of publicly funded French research into innovations, mostly through patenting, licensing, maturation of inventions and start-up creations[40]. It also encouraged university

[39] This section is based on interviews with SATT employees who were part of the COCON project, in particular, with the Head of the legal department of the SATT of the University of Strasbourg, who is in charge of the drafting of the license agreements.

[40] In the framework of "Investment for the Future" program (PIA) of ANR, which aimed at pooling the TTOs, 14 TTOs, called SATT (Technology Transfer Acceleration Company), have been created in France in 2012. However, some universities had already structures dedicated to transferring their technologies prior to SATT. The Innovation Act of 1999 first resulted in the creation of internal TTOs called SAIC (Services for Industrial and Commercial Activities) allowing them to employ external staff and to run the organization

researchers to exploit their research findings by allowing them to create their own companies (strong provision is made to help researchers do so), and to have their inventions patented or co-patented[41]. Emphasis is also placed on the fact that French universities have to retain ownership over their patents (at least they should share it with the firms they have collaborated with). Thus, the law on innovation has mostly contributed to changing the philosophy of French university with regard to patenting. Rather than modifying the legal status of university patents, as was the case in the U.S., the law has introduced a new strategic orientation, and has placed stronger emphasis on licensing and patent ownership.

French TTOs enjoy a large degree of autonomy and are supposed to be able to self-finance their activities. But, in addition, they also share a more socially oriented goal in the sense that they are also supposed to contribute to the dissemination of university based technologies, and to the dynamism of the local economy. Interviews with SATT employees largely confirmed that licensing priority is usually given to local or national firms. Interviews also suggest that a critical issue for French TTOs is to find educated and experienced staff, and to keep them working for the TTO on the long term. Indeed, even if we do not have statistics about TTOs' staff turnover, most interviewees stressed the limitation of turnover as being an important challenge. The creation of SATT, and the important financial effort that came with it, is perceived as an important step in order to retain in house experienced staff.

The organization of the licensing process in French universities is quite similar to international and U.S. standards (see for instance the licensing cycle at Stanford University in Chapter 1). The first step for TTOs' staff is to identify valuable technologies in university labs. An important effort of communication and prospection is therefore made towards the academic community. Then, once a technology has been identified and a patent is applied for, the second step is to look for a licensee. Two options exist at this step: with the assistance of the SATT, the inventor can create her or his own spinoff, to which the technology can then be licensed; or the technology can be licensed to an already existing firm, be it a local, domestic or foreign one. Then, when the licensee firm has been identified, the third step is to negotiate the terms of the license. This step can last up to one year. All interviewees confirm that discussions about exclusivity are critical part of the negotiation. As to the determinants of

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according to more business-like budgeting/accounting rules (Della Malva *et al.*, 2013). Subsequent acts that led to SATT mostly enabled universities to implement more autonomous strategies concerning their technology transfer activities (Matt and Schaeffer, 2012). For further information on SATT, see https://www.satt.fr/ (For SATT Conectus Alsace, the TTO of the University of Strasbourg, see http://www.conectus.fr/fr and for SATT Linksium, the TTO of the University of Grenoble Alpes, see https://www.linksium.fr/).

41 In the current legislative context, French academic scientists can earn a significant share of the income derived from patenting and licensing their inventions (they can earn up to 50% of the net benefits generated by a license), which should therefore encourage them to actively participate in the transfer in order to maximize its chance of success.

the terms of the license, interviewees report that they pay a lot of attention to the expected market of the licensed technology, to its properties (whether it is a technology that can be used in multiple markets, whether it is still far from the market, etc.), and to the ability of the firm to valorize the licensed technology (this last point is reported to be critical, in particular, when an exclusive license is granted). Last, it is important to note that inventors usually do not take part in the negotiation. They have been consulted upstream, but the negotiation of the license with the firm is conducted without them. At the end of the licensing process, it is the president of the SATT who decides to accept or not the terms of the license negotiated between the firm and the TTO staff.

3.2. Collection of the data

The data used in this study have been collected in two stages. In the first stage, we have analyzed and coded the terms of all the licensing contracts of the two universities, i.e. 115 contracts (63 from Grenoble and 52 from Strasbourg). Since this number of licenses might appear quite low for non-European readers, it is important to mention here that i) this number is in line with other European universities[42] and; ii) it represents an exhaustive picture of the two universities we are studying, in the sense that we have collected all the licenses executed by these two universities during the considered period. At the second stage, we have conducted, in September 2015, an online survey sent to 226 inventors (those for whom we found one valid email address) out of the 261 inventors mentioned in the licensing contracts.

3.2.1. The codification of the terms of the contracts

The primary source of data comes from the codification of the license contracts. A license contract is a written, legal document that can be long and complex for people not expert in law. After accessing these confidential contracts, we digitized and coded them, i.e. we reduced them into a set of variables that describe and characterize them. To do this, a coding grill has been established with all the variables that are perceived as relevant for this project, such as the type of contract, names of inventors and inventions, the parties involved and their characteristics, remuneration scheme, exclusivity terms and restrictions, the existence of grant back obligations, etc. Since some information was not always explicitly mentioned in the contract, we completed the data by using various alternative sources (patent databases). This work of translation was realized with the help of lawyers who are part of the COCON project and specialized in contracts and IP law.

[42] A study by Conti and Gaule (2011) reveals that the average number of licenses concluded in 2007 was 26.4 for U.S. universities, whereas it was only 7.8 for European universities (median number was 13 for U.S. and 4 for European universities). This study therefore suggests that the case of the universities of Strasbourg and Grenoble Alpes are not exceptional for European universities. Conti and Gaule (2011) relate the gap between the U.S. and Europe to the differences in basic academic research and in industry experience of TTO staff in favor of the U.S.

In order to minimize the probability of misreads, we have implemented a systematic “double coding” of the contracts, meaning that each contract has been at least partly coded by two different researchers followed by a comparison and consensus discussion. Indeed, even if the coding of some variables, such as the length or the type of contract, is usually straightforward, the coding of other variables can be trickier. For example, it is not always obvious to understand whether a license is exclusive or non-exclusive, in particular, because some contracts can include many different inventions and some of them are exclusively licensed, while others are non-exclusively licensed.

Thanks to this coding phase, for each invention mentioned in the contracts, we have determined the degree of exclusivity, the type of knowledge transferred, the scientific domain, the characteristics of the licensee firm and the institutional environment.

3.2.2. Online inventor survey

The second source of data used in this work comes from an online inventor survey, where inventors were asked questions concerning certain characteristics of their inventions: maturity, specificity and appropriability. This type of information cannot easily be observed and is obviously not found in the licensing contracts. A specific expertise is needed to assess these properties of a technology. Our guess is that inventors can be a valuable source of information in order to evaluate the characteristics of the invention they have authored. We have therefore sent a questionnaire to all the inventors mentioned in our dataset, for whom we had a valid email address, asking them questions about the characteristics of their invention (for a detailed description of the terms used in the questionnaire see the Table A.1 in Appendix). Out of 115 contracts, we have been able to find at least one contact address for 94 contracts, and out of these 94 contracts, we received at least one answer for 62 contracts. Overall, this corresponds to 91 inventions[43] (Table 3.1).

Table 3.1: Number of contracts, inventors and inventions

Number of license and cession contracts *(patent, knowhow and software license and cession contracts)*	62
Number of inventors *(respondents)*	83
Number of inventions *(unit of analysis)*	91

[43] We have been able to detect 241 inventions contained in 108 contracts out of 115 contracts. This is because for a couple of contracts, the bulk of inventions may go up to 20 inventions or even more. For the remaining 7 contracts, we couldn’t find the invention counts because the relevant parts in digitized versions were missing (i.e. the annexes where the inventions were mentioned for some contracts). It was also difficult for some contracts to determine whether the licensed inventions are a single invention or if certain components should be considered as separate inventions (for instance the source code of a software), which requires further technical and legal expertise.

3.2.3. Consistency check

As shown in Table 3.1, the number of licensing contracts is not equal to the number of inventions and to the number of inventors because in some cases, we have more than one invention in a licensing contract and in some cases, we have more than one inventor engaged in an invention (similarly, a single inventor can be mentioned in different inventions). This means that sometimes, for the same invention, we have responses from different inventors. This was the case for 22 inventions. This enables us to compare the responses of these different inventors, and to perform a consistency check in order to verify whether the perception of different inventors as to the characteristics of the same invention is the same. This is important given the complexity of the questions and the fact that some questions in the survey might have been misunderstood by the respondents.

In order to evaluate the consistency of the respondents' answers, we resort to a simple rule. We attribute a value between 0 and 1 for each response. For instance, regarding the embryonic nature of the technology, the inventor can choose among the answers "embryonic", "moderately embryonic" and "mature". We therefore attribute the value 1 to "embryonic", 0.5 to "moderately embryonic" and 0 to "mature" and we consider that the answers provided by the respondents are incoherent when two different respondents gave two different extreme answers, that is to say when the difference between two answers equals to 1 (e.g. one of the inventors considered the invention as mature while another considered as embryonic). We take the ratio of coherent responses in order to check the robustness of the answers. This leads to the following results: for the embryonic versus mature dimension, we have 100% consistent answers; 82% for the specific versus generic one; and 91% for the appropriability one (Table 3.2). Given the relative high value of these convergence rates of answers, we consider that the respondents have correctly understood the questions with regard to the characteristics of the technology.

Table 3.2: Inventors' survey: consistency check

Value	MATURITY	SPECIFICITY	APPROPRIABILITY
1	Embryonic	Generic	Strong appropriability
0.5	Moderately embryonic	Moderately generic	Relatively strong appropriability
0	Mature	Specific	Weak appropriability
Consistency rate	**100%**	**82%**	**91%**

Then, in order to determine which value to attribute to the invention when we have multiple responses, we compute the average value of the answers given by the different respondents. If this average value is equal to or above 0.5, we attribute a value of 1, and if it is below 0.5, we attribute the value 0. To illustrate, again let us take the case of the technological dimension embryonic versus mature and let us assume three respondents, two of whom consider the invention is embryonic and one that it is mature, thus leading to an average answer of 0.66. This average value being above 0.5, we consider that the technology is embryonic.

3.3. Econometric treatment

To ascertain the extent to which the invention characteristics moderate the degree of exclusivity of a licensing contract, we resort to different dependent variables (Table 3.3). As a first approach, we study the probability that the invention has been exclusively licensed (model 1) as a function of the invention's properties and some control variables. To do so, we rely on the variable *Global_excl,* which takes the value 1 if the invention has been granted a global exclusivity and 0 otherwise. Since the dependent variable is a dummy, we rely on a logit model.

As a second approach, we detail a little bit more the dependent variable (model 2). We consider the dependent variable *Order_excl* which takes the value 0 if the invention has been non-exclusively licensed, 1 if it has been licensed exclusively per field of use and 2 if it has been subject to a global exclusive license. This second model is estimated with an ordered logit regression, since we consider that an exclusive license per field of use is an intermediate level of exclusivity in between a non-exclusive and a global exclusive license.

Finally, as a third approach, in order to test hypothesis 3, we study the probability that the invention has been exclusively licensed per field of use (model 3). We thus consider the dependent variable *Exclu_pfu* which takes the value 1 if the invention has been exclusively licensed per field of use and 0 otherwise. We estimate this model with a simple logit regression.

Table 3.3: Description of dependent variables

Model	Variable	Definition	N	Mean	Std. Dev.	Min	Max
model 1	*Global_excl*	Binary variable indicating whether the invention is granted a global exclusivity (unrestricted exclusivity/no field of use restriction)	91	0.28	0.45	0	1
model 2	*Order_excl*	Variable ranked between 0-2. It takes the value 0 if the invention is non-exclusively licensed, 1 if it is licensed exclusively per field of use and 2 if it is subject to a global exclusive license	91	1.10	0.68	0	2
model 3	*Exclu_pfu*	Binary variable indicating whether the invention is granted an exclusive license per field of use (restricted exclusivity)	91	0.53	0.50	0	1

Note: Dependent variables are obtained through the COCON contract codification

3.4. Variable specification

3.4.1. Main explanatory variables

Our main explanatory variables deal with the properties of the invention. The data on the invention characteristics come from the inventor survey. We take into account three technological properties (Table 3.4). *Embryonic* is a binary variable indicating whether the invention is embryonic or not. It takes the value of 1 if the invention is embryonic, and 0 otherwise. *Generic* is a binary variable indicating whether the invention is generic or specific. It takes the value 1 if the invention is generic, 0 otherwise. *Appro* is a binary variable indicating whether the invention is appropriable (indicating therefore that the technology is difficult and costly to imitate even without legal exclusivity). It takes the value 1 if the invention is considered as appropriable, 0 otherwise. Furthermore, *Emgen* is a binary variable which indicates whether the invention is both embryonic and generic. It takes the value 1 when the invention is both embryonic and generic, 0 otherwise.

3.4.2. Control variables

As to the *Controls*, we include different variables that may have an effect on the licensing strategy. First, we control for several characteristics at the technological level. In order to capture the effect of the scientific domain, we include dummy variables for two scientific disciplines that are known as specific as regard to licensing: life sciences & chemistry on the one hand, and software on the other hand.[44] Then, we control for the kind of knowledge that is transferred. We include a dummy variable to control for contracts that also transfer tacit knowledge to some extent. It is indeed more difficult to transfer tacit knowledge as compared to codified one. It requires face-to-face interactions (Kim and Vonortas, 2006), which increases the cost of transfer with the number of licensees (Aulakh *et al.*, 2010). Therefore, in order to minimize the cost of the transfer, non-exclusive licenses should be less often associated to the presence of tacit knowledge.

Second, we control for the various characteristics of the licensee firm. To capture the effect of firm size, we include a dummy *Micro* taking the value 1 when the licensee is a micro enterprise. For this variable, we adopted the INSEE[45] definition and collected the data from AMADEUS database. We

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[44] Colyvas *et al.* (2002) show that scientific domain has an impact on the exclusivity of a contract and stress the specificity of life sciences. Anand and Khanna (2000) find that more than a half of the transfers in chemicals involve some exclusivity clause, 40 % of whom involve a global (or worldwide) exclusivity whereas exclusive contracts are less common in computers (18%). Lemley (2008) also emphasizes the differences in scientific disciplines in relation with the exclusivity of licensing. Similarly, Bessen and Maskin (2009) and Maurer and Scotchmer (2006) stress the specificity of software as regard to licensing.

[45] INSEE (National Institute of Statistics and Economic Studies in France) defines micro-enterprise as a business with fewer than 10 employees and with an annual or total balance sheet not exceeding 2 million Euros. (Accessed on https://www.insee.fr/en/metadonnees/definition/c1079). The other INSEE categories are small and medium-sized enterprises (SMEs), intermediate-sized enterprises (ISEs) and large enterprises.

also include a dummy *Spinoff* in order to capture whether the licensee firm was an academic spin-off of the university[46]. This data comes from contract codification. Entrepreneurial firms such as small academic spin-offs or start-ups usually seek for strong IP protection and hence exclusive licenses (Shane, 2002). However, on the other hand, these small firms also lack the ability to exploit the technology, as compared to incumbent firms, thus making TTOs more reluctant to deliver exclusive license. In addition, we also control for the country where licensee firm is located. *France* is a binary variable taking the value of 1 if the licensee firm is located in France and 0 otherwise. In a study on the inter-firm licensing contracts in U.S., Anand and Khanna (2000) find that probability of exclusive license is slightly higher when the licensee is located within the same country to the licensor. In a similar vein, for the university licensing context, we expect more exclusive licensing deals with firms located in France in compare to those that are not. This might be so because TTOs may want to develop local and national business but also because they may find it easier to monitor an exclusive deal within the same country. IPR system significantly differs from one country to another (Bessy *et al.*, 2010) and exclusive licenses are risky as the dissemination of the technology may result in shelving (Dechenaux *et al.*, 2009), due to weak monitoring by the TTO. Licensor could be reluctant to bare the potential risk of licensee nonperformance at a global scale, especially in the case of global (or worldwide) exclusive licenses (Somaya *et al.*, 2011). Monitoring of the exclusive licensee could thus be easier if the licensee is within the same country.

Third, we control for the institutional environment. In order to capture the effect of different managerial approaches while transferring the university technology, we control for the type of university. *Unistra* is a dichotomous variable taking the value of 1 if the licensor is University of Strasbourg; and 0 if the licensor is University of Grenoble Alpes. We also try to control for the possible role of other public research organizations such as CNRS or INSERM. *Involve_PRO* is a dichotomous variable taking the value of 1 if at least one French public research organization such as CNRS, CEA, INRA was involved in the licensing of a technology along with the university.

3.5. Descriptive statistics

Tables 3.3, 3.5 and 3.6 provide an overview of the data and some descriptive statistics. The vast majority of the 91 inventions was exclusively licensed and mostly restricted (Table 3.3). 28% of the inventions were granted global exclusivity[47]; 53% exclusivity per field of use (restricted exclusivity)

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[46] It should be noted that the two variables *Spinoff* and *Micro* might not necessarily be strongly correlated. When it is created, a spin-off is usually a micro firm but this might not be the case in our database. Indeed, at the time of the study, some spin-offs might have developed and become SMEs. This is the case for a significant number of spinoffs that are not micro firm in our database. Similarly, some micro firms might not be spinoffs of the universities of Strasbourg or Grenoble.

[47] Among the licenses that have been subject to global exclusivity, we have included 8 cession contracts (corresponding to 9 inventions), i.e. contracts which sell the invention to the industrial partner. We consider

and only 19% a non-exclusive license[48]. Regarding the invention characteristics 63% of the inventions are considered as embryonic, 66% as generic, 40% as both embryonic and generic and 70% as appropriable (and hence difficult to imitate even without legal exclusivity)[49].

Concerning the control variables, 35% of licenses include a transfer of tacit knowledge; 54% of all inventions licensed are either in life sciences or in chemistry and 23% are in software[50]. As to the licensee firm characteristics, 65% are micro enterprises, 49% of licensees are academic spin-offs and 82% are located in France. Finally in 42% of licensing, we also observe the involvement of non-university French public research organization such as CNRS or INSERM, etc. Respective correlation coefficients reported in Table A.2 in Appendix.

Table 3.4: Description of explanatory and control variables

Variable	Definition	Source
Main independent variables		
Embryonic	Binary variable indicating whether the invention is embryonic (either embryonic or moderately embryonic)	COCON inventor survey
Generic	Binary variable indicating whether the invention is generic (either generic or moderately generic)	COCON inventor survey
Emgen	Binary variable indicating whether the invention is both *Embryonic* and *Generic*	COCON inventor survey
Appro	Binary variable indicating whether the invention is difficult and costly to imitate (either strong or relatively strong appropriability)	COCON inventor survey
Control Variables:		
Tacit	Binary variable indicating whether the contract includes tacit knowledge (e.g. technical assistance, consultancy services, training of staff etc.) (Definition of Bessy *et al.* (2010) is adopted)	COCON contract codification
Life Sci_or_Chem	Binary variable indicating whether the invention belongs to either the scientific domains of life sciences and/or chemistry	IPC (if patent) and COCON contract codification (if know how)
Software	Binary variable indicating whether the invention belongs to the scientific domain of software	COCON contract codification (we created a new class "I" which is not in IPC)

that, given the objective of our research, it is similar to grant global exclusivity in a license or to sell the invention. In both cases, the licensee obtains the exclusive right over the exploitation of the invention.

48 These figures are in line with what we find in the initial sample of 241 inventions (before we reduced it in order to do the matching with the online inventor survey). Indeed, out of 241 inventions in our initial sample, 19.1 % were granted a global exclusivity, 59.3% were an exclusive per field of use license and 21.6 % were a non-exclusive license.

49 Frequencies are calculated after the exclusion of "don't know" responses from the respective samples. This explains why the number of observations is less than 91.

50 Note that one invention can belong to several disciplines.

Micro	Binary variable indicating whether the size of licensee firm is micro	AMADEUS database (INSEE definition: less than 10 employees and a turnover or total annual balance sheet not exceeding 2 million EURO)
Spinoff	Binary variable indicating whether the licensee firm is an academic spin-off	COCON contract codification
France	Binary variable indicating whether the licensee firm is located in France	COCON contract codification
Unistra	Binary variable indicating whether the licensor is University of Strasbourg	COCON contract codification
Involve_PRO	Binary variable indicating whether there is involvement of a non-university PRO in the licensing process	COCON contract codification

Table 3.5: Descriptive statistics of explanatory variables

Variable	**N**	**Mean**	**Std. Dev.**	**Min**	**Max**
Embryonic	82	0.63	0.48	0	1
Generic	82	0.66	0.48	0	1
Emgen	82	0.40	0.49	0	1
Appro	83	0.70	0.46	0	1
Tacit	91	0.35	0.48	0	1
Life_Sci_or_Chem	91	0.54	0.50	0	1
Software	91	0.23	0.42	0	1
Micro	91	0.65	0.48	0	1
Spinoff	91	0.49	0.50	0	1
France	91	0.82	0.38	0	1
Involve_PRO	91	0.42	0.50	0	1
Unistra	91	0.40	0.49	0	1

Table 3.6: Cross tabulation: degree of exclusivity and invention characteristics

	Maturity			**Specificity**			**Appropriability**		
Exclusivity	*Mature*	*Embryonic*	*Total*	*Specific*	*Generic*	*Total*	*Weak*	*Strong*	*Total*
Non exclusive	9	6	15	5	10	15	4	12	16
Exclusive per field of use	16	32	48	16	32	48	11	37	48
Global exclusive	5	14	19	7	12	19	10	9	19
Total	30	52	82	28	54	82	25	58	83

Table 3.6 cross tabulates the exclusive (global and per field of use) versus non-exclusive dimension of the license with the characteristics of the technology. This gives a first indication about the links between the nature of the license and the properties of the technology. For instance, we can see that mature inventions are more often granted non-exclusive licenses (9 inventions) than global exclusivity (5 inventions). On the other hand, embryonic inventions are more subject to global exclusivity. Similarly, if we look at generic inventions we see that they are more often subject to global exclusivity (12 inventions) than non-exclusive licenses (10 inventions), which runs against our theoretical predictions. Finally, if we look at inventions which are appropriable, we see that they are more likely to be non-exclusively licensed, which is in line with theoretical predictions (non-appropriable inventions are also more likely to be licensed with global exclusivity).

4. Econometric results

The results of the estimations are reported in Table 3.7, Table 3.8 and Table 3.9. In order to test the robustness of our results, we used different specifications in each three models by adding or removing some variables. In Table 3.7 and Table 3.8, columns (1), (2), and (3) show the single effects and column (4) shows the overall effect of the main interest variables on exclusivity. Then we step-wisely introduce control variables. In column (5), we add only the controls regarding technology-level characteristics. In column (6), we add only the firm-level characteristics and in column (7), we add only the institutional-level characteristics. Finally in column (8) we regress on the complete set of variables.

Our results provide a weak support only for hypothesis 4, suggesting that the more appropriable the technology the less likely it is exclusively licensed. This effect is important only in the case of a global exclusivity (model 1), as it is robust to different specifications of the model. However, it disappears when one also considers the other degrees of exclusivities (model 2 and model 3). The rest of the hypotheses are not supported by our empirical results. In particular, we do not observe that the more embryonic or the more specific the technology, the more exclusive the license is. To illustrate, in the case of specificity, the coefficient is not significantly negative. This means that generic technologies are not linked to more non-exclusive licenses, which could possibly reduce the exploitation of possible applications and their effective diffusion. Overall, with an exception for the appropriability dimension, our results do not allow us to conclude that the perceived nature of the technology significantly affect the exclusive versus non-exclusive nature of the license.

As for the control variables, we find that the size of the licensee firm matters. Micro enterprises are significantly more likely to be granted exclusive and even global exclusive license. This is compatible with the literature claiming that firms lacking complementary assets and competitive advantage need more exclusivity to catch-up with their incumbent counterparts (Shane, 2002). Surprisingly, academic spin-offs do not get more exclusive license, as the coefficient is negative and significant. Although spin-offs are also in need of support through exclusive licenses to catch-up with existing companies, this absence of exclusive deals could be related to TTOs' will to maximize the probability of exploitation of the licensed technology, thus leading them to avoid granting an exclusive right to spin-offs.

Table 3.7: Results of logit regression for model 1

Dependent variable	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl	Global_excl
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Embryonic	0.611			0.425	0.503	-0.398	0.515	-0.856
	(0.581)			(0.605)	(0.674)	(0.755)	(0.675)	(1.056)
Generic		-0.154		-0.075	-0.074	0.159	0.382	0.559
		(0.546)		(0.572)	(0.651)	(0.661)	(0.707)	(1.126)
Appro			-1.289**	-1.297**	-1.646**	-1.116*	-1.708**	-2.841**
			(0.546)	(0.557)	(0.644)	(0.655)	(0.678)	(1.206)
Tacit					-0.342			1.237
					(0.802)			(1.515)
Life_Sci_or_Chem					-1.589**			-3.533**
					(0.736)			(1.548)
Software					0.470			-1.568
					(0.807)			(1.721)
Micro						3.201***		5.548**
						(1.156)		(2.291)
Spinoff						-1.158*		-0.520
						(0.679)		(1.081)
French						0.456		-0.728
						(1.006)		(1.563)
Involve_PRO							-2.687***	-3.414**
							(0.879)	(1.382)
Unistra							-0.260	-1.633
							(0.697)	(1.204)
Constant	-1.609***	-1.099**	-0.405	-0.612	0.315	-2.694*	0.198	0.507
	(0.490)	(0.436)	(0.408)	(0.730)	(0.876)	(1.506)	(0.861)	(2.053)
Observations	82	82	83	82	82	82	82	82
LR chi2	1.17	0.08	5.59	6.65	16.95	21.95	22.66	46.36
Prob>chi2	0.2803	0.7783	0.0181	0.0839	0.0095	0.0012	0.0004	0.0000
Pseudo R2	0.0131	0.0009	0.0626	0.0749	0.1909	0.2473	0.2552	0.5222
Log likelihood	-43.8064	-44.3495	-41.8568	-41.0635	-35.9157	-33.4139	-33.0600	-21.2071

Notes: this table reports coefficients of binary logit estimates. Standard errors are in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Concerning the effect of the scientific domain, software inventions do not significantly reduce the probability of exclusive license. Regarding the domain of life sciences and chemistry, we cannot link the inventions in this domain to global exclusive licenses, since the coefficient is negative and significant. Interestingly, the involvement of PROs in the licensing agreement has a negative effect on the granting of global exclusive licenses (model 1), but a positive one on the granting of exclusive licenses per field of use (model 3). One explanation might be that the involvement of multiple public institutions is associated with a more important public support and investment. Thus, in this case, TTOs may choose to limit global exclusivity and to envisage more sophisticated licensing deals, such as licenses per field of use, which they might consider more beneficial to public interest.

Table 3.8: Results of ordered logit regression for model 2

Dependent Variable	Order_excl (1)	Order_excl (2)	Order_excl (3)	Order_excl (4)	Order_excl (5)	Order_excl (6)	Order_excl (7)	Order_excl (8)
Embryonic	0.911* (0.471)			0.739 (0.480)	0.748 (0.482)	0.211 (0.538)	0.765 (0.481)	0.137 (0.550)
Generic		-0.107 (0.457)		-0.088 (0.460)	-0.288 (0.493)	0.049 (0.499)	-0.019 (0.467)	-0.169 (0.535)
Appro			-0.951* (0.490)	-0.991* (0.511)	-1.070** (0.521)	-0.683 (0.537)	-1.010** (0.509)	-0.797 (0.558)
Tacit					0.397 (0.517)			0.681 (0.611)
Life_Sci_or_Chem					-1.099* (0.565)			-1.082* (0.605)
Software					-0.464 (0.806)			-0.875 (0.872)
Micro						2.201*** (0.630)		2.357*** (0.654)
Spinoff						-1.265** (0.528)		-0.973* (0.563)
French						0.978 (0.707)		0.584 (0.778)
Involve_PRO							-0.617 (0.472)	-0.527 (0.518)
Unistra							-0.166 (0.471)	0.045 (0.526)
Constant cut1	-0.968 (0.384)	-1.568 (0.420)	-2.169 (0.483)	-1.910 (0.679)	-2.783 (0.838)	-0.762 (0.852)	-2.294 (0.728)	-2.014 (1.158)
Constant cut2	1.839 (0.436)	1.129 (0.396)	0.580 (0.409)	1.005 (0.656)	0.246 (0.772)	2.824 (0.941)	0.685 (0.689)	1.709 (1.172)
Observations	82	82	83	82	82	82	82	82
LR chi2	3.86	0.05	3.86	7.76	11.87	27.18	10.15	31.70
Prob>chi2	0.0493	0.8148	0.0495	0.0513	0.0649	0.0001	0.0710	0.0009
Pseudo R2	0.0245	0.0003	0.0239	0.0491	0.0752	0.1721	0.0643	0.2007
Log likelihood	-77.0362	-78.9408	-78.7118	-75.0890	-73.0327	-65.3765	-73.8918	-63.1206

Notes: this table reports coefficients of binary logit estimates. Standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 3.9: Results of logit regression for model 3

Dependent variable	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu	Exclu_pfu
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Embryonic	0.336				-0.481	-0.695	-0.324	-0.097	-0.266
	(0.464)				(0.859)	(1.020)	(0.932)	(1.018)	(1.209)
Generic		0.087			-0.839	-1.769*	-1.063	-0.767	-1.761
		(0.472)			(0.844)	(1.037)	(0.892)	(0.974)	(1.084)
Appro			0.808*		0.836	1.278**	0.969*	1.094*	1.697**
			(0.487)		(0.511)	(0.624)	(0.547)	(0.609)	(0.739)
Emgen				0.571	1.419	2.428*	1.509	1.062	2.303
				(0.467)	(1.037)	(1.267)	(1.092)	(1.209)	(1.489)
Tacit						1.311*			1.120
						(0.676)			(0.850)
Life_Sci_or_Chem						1.009			1.321*
						(0.618)			(0.740)
Software						-1.861**			-1.474
						(0.945)			(1.138)
Micro							-0.446		-0.185
							(0.573)		(0.766)
Spinoff							-0.075		-0.351
							(0.560)		(0.724)
French							0.812		1.636
							(0.729)		(1.098)
Involve_PRO								2.325***	2.291***
								(0.604)	(0.694)
Unistra								0.047	-0.005
								(0.591)	(0.695)
Constant	0.134	0.288	-0.241	0.123	0.060	-0.554	-0.373	-1.232	-3.194**
	(0.366)	(0.382)	(0.403)	(0.286)	(0.812)	(0.982)	(0.940)	(1.027)	(1.521)
Observations	82	82	83	82	82	82	82	82	82
LR chi2	0.53	0.03	2.79	1.52	5.17	24.01	6.93	25.48	40.02
Prob>chi2	0.4684	0.8538	0.0950	0.2177	0.2705	0.0011	0.4362	0.0003	0.0001
Pseudo R2	0.0047	0.0003	0.0247	0.0137	0.0464	0.2157	0.0623	0.2290	0.3596
Log likelihood	-55.3742	-55.6201	-55.1150	-54.8773	-53.0529	-43.6343	-52.1718	-42.8955	-35.6284

Notes: this table reports coefficients of binary logit estimates. Standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The results of model 3 are presented in Table 3.9. We follow the same model specifications used in Table 3.7 and Table 3.8, in which we introduce technology-, firm- and institutional-level controls in turn. Here, we particularly aim to test hypothesis 3, which claims that inventions that are characterized both embryonic and generic should be linked to exclusive license per field of use. In order to test this effect, we have introduced in the regression the variable *Emgen*. Again, our results do not support hypothesis 3. Although, the sign of the variable *Emgen* is positive and significant in column (6), it is not robust to other specifications of the model.

5. Discussion and conclusion

In this chapter, we have investigated the role played by the characteristics of the technology in shaping the way that it is licensed by universities. In particular, we have explored whether the different properties of the licensed technology (i.e. distance to market, degree of specificity and degree of appropriability) affect the probability that this technology is exclusively versus non-exclusively licensed. Our prediction was that the properties of a technology should be taken into account when defining the terms of the license, since different technological properties lead to different economic performance of a license. In order to test the relationship between the properties of the licensed technology and the exclusive nature of the license, we relied on a unique and original dataset of 91 inventions contained in 62 intellectual property licensing (and cession) contracts executed by two leading French universities.

Our results are obviously exploratory and must be interpreted with care since they are based on a limited number of observations. However, they indicate that the characteristics of the technology do not significantly affect the nature of the license. In particular, as opposed to theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses and generic inventions are not significantly linked to non-exclusive licenses. Similarly, inventions which are both generic and embryonic are not significantly linked to exclusive licenses per field of use. Finally, and in line with our theoretical predictions, the more appropriable the technology, the less likely it is to be globally exclusively licensed. However, this relation does not hold for the exclusive per field of use licenses.

Two important contributions of this study are particularly worth emphasizing. First, we have obtained unique and very detailed information on the characteristics of university licenses and the properties of the licensed technology (via our inventor survey). This unique and original dataset (obviously limited in size given the workload required to collect the information) has enabled us to explore the link between the nature of the license and some properties of the technology for the first time. As a second contribution, we have been able to show that, as opposed to most of the theoretical predictions, the properties of the technology do not seem to significantly affect the degree of exclusivity of the license.

This result leads to important policy and management implications. It indeed suggests that university licensing might not always be in line with the interest of the public, i.e. might not maximize social welfare. For instance, many technologies in our sample have been considered as mature, and still were exclusively licensed. Similarly, many technologies have been considered as generic, with multiple applications in different domains, and still they were granted a global exclusivity. Why is this so? Why are university technology licensing practices not taking more into account the characteristics of the licensed technology in order to develop welfare enhancing technology deals whereas, at least in France, universities are almost exclusively publicly funded? We see two possible explanations.

First, TTOs' staff might lack skills and competences which might hinder designing optimal licensing contracts. For instance, our interviews show that TTOs' staff is aware of the need to pay attention to the properties of the technology when designing a license. But they might not always be able to assess correctly these properties, which indeed require specific skills and competences difficult and costly to acquire. This suggests that there is room for significant improvements in the management and organization of university technology transfer in order to increase its performance. One possibility for TTOs' staff could be to involve more the inventors in the licensing process, since they have unique and valuable information concerning the characteristics of the technology. To our knowledge, in most French TTOs, inventors are involved in the drafting of the patent but rarely in the drafting of the licensing contract. In addition, TTOs' staff may also lack adequate experience and skills in order to draft and bargain welfare enhancing contracts. Our interviews with the TTOs' managers reveal that to retain experienced and skilled staff is one of the main challenges in the future.

Second, TTOs might lack bargaining power in order to negotiate optimal licensing contracts with firms. The content of a license is indeed the outcome of a bargaining between a university and its TTO and a licensee firm. Therefore, even though the TTO aim at maximizing social welfare, it might lack the bargaining power in order to do so. Firms usually prefer exclusive terms and they will not hesitate to bargain hard in order to get one. It is therefore possible that universities and TTOs, which have important financial constraints, sometimes accept to grant an exclusive license even though they are aware that it is not the ideal solution. They might prefer to grant a license that is not entirely in the interest of its public mission rather than not granting a license at all. From a policy perspective, this means that it might be inefficient to impose tight financial constraints to TTOs. This might encourage them to accept licensing deals that are financially interesting even though detrimental from a social welfare point of view.

This discussion at least calls for a deeper investigation on the primary objective of universities and their TTOs when valorizing their technologies and on how the different objectives are prioritized. What should be the objective of the valorization of university research? Should it be to provide universities with new financial resources? Or should it be to ensure that an invention generates economic wealth? In the second case, what is the best way to transfer the technology? Via a non-exclusive license? Via the creation of a start-up endowed with an exclusive license? Or others? According to the answers to these questions, the design of the license will be largely different.

Finally, our research has some obvious limitations which, in turn, suggest some promising lines of future research. Despite the originality and the richness of information in our dataset, the small number of observations limits the generalizability of the results. This study should therefore be considered more like an exploratory research that aims at opening doors to future investigations. In particular, future research might conduct a larger scale analysis and include more universities in more countries in order to have more observations and more generalizable results. We realize the difficulty of the task, especially in terms of data collection. Yet, these efforts are necessary in order to obtain a more robust answer to our research question. Furthermore, it might also be interesting to compare university-industry licensing with inter-firms licensing. Some studies focused on licensing between firms indeed suggest that the properties of the technology (in particular its embryonic nature) do affect the license (Anand and Khana, 2000; Somaya *et al.*, 2011). Why is it different for university licensing? One way to investigate this point could be to look at the licensing of inventions co-patented between universities and firms and to observe the exclusivity scheme under this different ownership structure. Last, it is important to remind that universities and TTOs are complex organizations that face multiple and sometimes non-aligned objectives. This complexity also needs to be taken into account in the analysis.

CHAPTER 4

University Licensing: Exploring the Open Source Possibility

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Abstract

This chapter proposes a framework to analyze when and how universities could use open source licensing (OSL) in order to transfer their technologies. To explore this possibility, we investigate first the open source movement in software industry and revisit the individual and firm level incentives for participating in open source projects. Then we generalize the open source phenomenon by examining various other open source innovations (OSIs). Through the analogy with the "copyleft" licenses used in the free open source software (FOSS), we discuss the unconventional use of patent licenses in ensuring the openness to access and improve open source inventions. Then we analyze in which context university technology transfer offices (TTOs) may introduce OSL strategy as an alternative to traditional licensing strategies discussed in previous chapters. Our study proposes that in a dynamic innovation setting (i.e. when the inventions are sequential), universities could opt for OSL to preserve the freedom of access to upstream university knowledge in order to facilitate follow-on innovations.

Keywords: University licensing strategies, intellectual property rights, open source licensing, open source innovation, sequential invention

JEL classification: O32, O33, O34

1. Introduction

The open source movement is a "paradigm-shift" in the organization of the software industry (Dalle *et al.*, 2005). Open source software provides a distributed and open model for the innovation organization which can compete with traditional proprietary and closed models (Lakhani and Panetta, 2007). Furthermore, the stunning success of the open source model in various software projects such as the GNU/Linux operating system, the Apache web server or the Perl has raised the issue of expanding the phenomenon beyond software (Lerner and Tirole, 2005). Exporting the model to other industries as diverse as biotechnology, pharmaceutical, nanotechnology, automobile, 3D printers or to geographic information systems and online encyclopedias has become a tempting research area for scholars (Maurer, 2003; Maurer and Scotchmer, 2006; Lakhani and Panetta, 2007; Lounsbury *et al.*, 2009; Sugumaran, 2012).

Against the common belief, an important factor behind the openness of an innovation system is the specific use of patents, which corresponds to "the third face of IPR" (David, 2006). A careful examination of the success behind the free open source software (FOSS) movement shows how the copyrights –"the third face of IPR"- are used as legal devices to sustain the freedom of software when coupled with specific "copyleft" licenses ("share alike" or "viral" licenses). For the open source innovations (OSIs) beyond software, where copyrights cannot be used to protect the research outcomes, patents can be used to prevent exclusive appropriation of further developments. Therefore, we suggest that patents, when coupled with specific viral licenses, might be more "open" than publishing, as the former makes openness sticky.

Situated upstream, universities are responsible for the production and wide dissemination of scientific knowledge. Given their mission, and given the fact that universities are important sources of knowledge (Belderbos *et al.*, 2004), the issues of introducing the open source model to the academic setting and transferring university knowledge to the industry through open source licensing (OSL) are worth investigating. Therefore, the motivation behind this study is the following: while even for-profit firms join open source projects and open up a portion of their IP portfolios, why do universities continue to rely solely on traditional strategies and do not develop open source strategies, which might be better aligned with their social mission? In this regard, our study aims at showing (1) how and when universities should introduce patent-based OSL and (2) in which context OSL strategy could be successful compared to traditional licensing strategies (i.e. exclusive, semi-exclusive and non-exclusive licensing). In particular, we investigate why OSL could be more appropriate in a sequential setting. Indeed, in Chapter 2, we considered a static setting in which inventions were assumed non-sequential. Thus, this chapter aims at complementing the analysis provided in Chapter 2, by examining a sequential and hence dynamic innovation environment.

From the social welfare point of view, this inquiry requires consideration, because compared to a static setting, in a dynamic setting where the innovations are sequential (i.e. when the second generation innovations build on the preceding one), proprietary strategies may cause welfare reductions by blocking the first generation inventions that are necessary for the follow-on research and innovations (Bessen and Maskin, 2009). This problem might be aggravated when universities opt for an exclusive license when the inventions progress cumulatively. While in a static (non-sequential) setting, the problem associated with the exclusive licensing is to balance the innovation incentives with the monopoly deadweight loss, in a dynamic (sequential) setting, the problem goes beyond this basic trade-off, since exclusive licensing might create a holding-up problem over the first generation inventions. Hold-up may occur due to bargaining failure (Green and Scothcmer, 1995), asymmetric information (Bessen and Maskin, 2009) or coordination failure (Galasso and Schankerman, 2010) between the exclusive licensee and the subsequent licensees, which could deter the follow-on innovations in the long run.

To understand the open source phenomenon and to export it to other research domains, where the term "'source code' no longer refers to software per se, [...] it is often necessary to revisit the relevant licenses, the relevant infrastructures, and the relevant modes of collaboration in order to ask whether 'open source' is possible in the same manner." (Lounsbury *et al.*, 2009, p.59). Therefore, in the following section, we begin our analysis by investigating the origins of the open source phenomenon in the software industry, and review the motivations for contribute to open source projects at both the individual- and firm-level. We then carry out the analysis beyond software by examining the common characteristics of all open source-like productions. In section 3, we explain why patents and OSIs should coexist, by comparing both the traditional and unconventional uses of patents. In section 4, we discuss introducing patent-based OSL in the academic context by illustrating the case of the "insulin patent". In section 5, we examine the contexts, in particular the case of sequential inventions, which might make OSL a better alternative compared to traditional licensing strategies. In section 6, we conclude by discussing the managerial and policy implications of our research.

2. Understanding the open source phenomenon: software and beyond

2.1. A brief history of free open source software (FOSS)

The emergence and development of open source software in academic settings such as MIT, Berkeley, or central corporate research facilities such as Bell Laboratories, dates back to the 1960s and 1970s, where no ground rules or legal protection existed for collectively developed software (Lerner and Tirole, 2000). The appropriation of the operating system UNIX, which had been collectively developed by academic and corporate researchers at AT&T's Bell Laboratories, by AT&T, through the enforcement of intellectual property rights (IPR), urged the establishment of the Free Software

Foundation (FSF)[51] by Richard Stallman of the MIT Artificial Intelligence Laboratory in 1983 (Lerner and Tirole, 2005). The foundation set the philosophical as well as legal ground for free (*libre*) software. Here the term "free" does not necessarily mean free of charge, but means that either one can use the software without any permission, or that the permission is granted neutrally (Lessig, 2001) so as to make it widely available (Nelson, 2005)[52]. In order to protect collectively developed software from future appropriation and keep the software free, a formal licensing procedure named "General Public License (GPL)", which is also known as "copyleft", was introduced. This license was initially introduced for the computer operating system called "GNU (GNU's not UNIX)" in order to ensure that its source code[53] would remain open to the users. GPL allows free use, free modification, free distribution of the source code, as well as free distribution of the modified source code. GPL is a "viral" license, meaning that all the derivatives or modifications to the original source code licensed under GPL should also be licensed under the same terms of GPL, in order to preserve its freedom. GPL is also a specific coordination mechanism that might increase the number of contributors to open source projects and sustain the collective knowledge production in certain cases (Gambardella and Hall, 2006).

Starting with the widespread diffusion of internet in early 1990s, the volume of contributors as well as the number of open source projects increased. The kernel of the GNU operating system called Linux[54], which was independently developed by Linus Torvalds, was also introduced in this era. Along with the increase in the volume of projects, alternative, less restrictive licensing approaches, such as LGPL (Lesser General Public License) and BSD (Berkeley Software Distribution) have proliferated. A widely accepted criteria known as "Open Source Definition" was generated in 1997, which defined the common clauses that should take place in an open source software license. The common denominator of these different licensing models is that they allow all the users to access and disseminate the source code (Guadamuz-González, 2006).

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[51] Richard Stallman differentiates between the open source movement and the free software movement, claiming that the former is missing the ethical point while focusing on the development methodology. Despite standing on different philosophical grounds, both movements come together for various projects and both are against the proprietary use of software. For a detailed discussion see: http://www.gnu.org/philosophy/free-software-for-freedom.html (last accessed on 15/09/2018).

[52] Free software is used in the meaning of "libre" software, not necessarily "gratis" software. So it is all about freedom, not price. The famous analogy used by the free software movement is "'free' as in 'free speech' not as in 'free beer'" (GNU Project, The Free Software Definition, http://www.gnu.org/philosophy/free-sw.html.en , last accessed on 15/09/2018).

[53] Source code is the human readable instructions or text written by using a specific computer language. The source code is transformed through a compiler to machine readable binary code, which is comprised of zeros and ones.

[54] Linux is not the name of the operating system but the name of the kernel of GNU operating system. Therefore, while mentioning the whole operating system FSF suggests using the name as GNU/Linux. For more detailed discussion see: http://www.gnu.org/gnu/gnu-linux-faq.html.en (last accessed on 15/09/2018).

2.2. Individual and firm level incentives to participate in open source software projects

The design of incentives to encourage knowledge production and dissemination has already been discussed in the seminal works of Arrow (1962) and Nelson (1959). With the advent of internet and computer networking methods, the issue of incentives has become even more important, because these technologies have decreased the marginal cost of knowledge production to almost zero and hence reduced the incentives to produce such knowledge (Gambardella and Hall, 2006). As a result, knowledge producers have sought for more IPR protection to prevent imitation. Therefore, the open source phenomenon, in comparison to proprietary mode of production and innovation, initially remained a puzzle for economists (Lerner and Tirole, 2000), because it relies on specific incentives that are often not directly monetary, and on a specific mode of coordination based on knowledge communities. Yet, even if by definition open source software needs not necessarily be free of charge, in practice the price is equal to zero, since one can reproduce and distribute the open source software without paying for it. Thus, open source incentives do not stem from profit motives.

Open source relies also on specific intellectual property (IP) licenses, through which IPR is exercised in a peculiar way that is quite opposite to its traditional aim. Maurer and Scotchmer (2006) discuss that in an innovative environment, if the innovative process heavily depends on the prior knowledge (i.e. innovations proceed cumulatively), then the traditional use of patents and copyrights may deter inventive activities, since the right holder cannot automatically identify the future developers and cannot know whom to license. Therefore, there is always a risk that the chosen licensee will not be able to build on the prior knowledge, and innovative activities will therefore be blocked in such a cumulative setting. On the contrary, in an open source regime, there is no need for such identification, since the disclosure is automatic and there is no need to search for whom to disclose the knowledge. Thus, according to the authors, automatic disclosure encourages a lot of new ideas, and increases the contributions to develop prior knowledge. Such a disclosure is still possible without harming the contribution incentives to open source projects.

The incentives to contribute to the open source projects have been analyzed at both individual- and corporate-level. Initially, the literature has focused on the intrinsic and extrinsic motivations at the individual-level. The most prominent motives behind the contribution of open source communities are: education, skill improvement, intellectual curiosity, the need to solve own specific programming needs, enjoying puzzle-solving, obligation/community incentive, recognition by peers or reputation and job market signaling (Raymond, 1999; Lerner and Tirole, 2000; 2005; Lakhani and von Hippel, 2003; Lakhani and Wolf, 2003; Bonaccorsi and Rossi, 2004; Maurer and Scotchmer, 2006; Von Krogh, 2012).

Yet the most stunning fact is the remarkable investments and contributions of large for-profit software (and software-embedded) firms such as IBM, Hewlett-Packard, Computer Associates and Novell to open source projects, even if they may be the direct competitors to open source providers (Bessen, 2006). One of the motivations behind the corporate-level contributions and the release of the source code for free is to get the bugs fixed quickly, as "given enough eyeballs, all bugs are shallow" (Raymond, 1999, p.30). Also, one could get improvements and feedbacks from open source communities without investing substantial amounts of money (Bonaccorsi and Rossi, 2003b; Maurer and Scotchmer, 2006). On the contrary, keeping the source code secret requires employing additional staff to fix the bugs, to update the software or to respond to users' needs (Lounsbury *et al.*, 2009).

Another motivation is to provide complementary services and products that are compatible with the open source product. This strategy is similar to the one used by Gillette Company, that was giving away the razor in order to sell more razor blades. Maurer and Scotchmer (2006, p.7) put forward that "open source incentives will not work if the open source software must itself be a profit center. This is because imitation is its very life blood. Instead, the open source activity must be complementary with something that remains proprietary." This allows firms to remain profitable while contributing to open source software projects. Firms also tend to release the source code if their product is lagging behind the leader. For instance, Netscape's decision to release the portion of its browser Mozilla's source code allowed the complementary segment of the company to be utilized widely in open source projects, and hence increased its profitability (Lerner and Tirole, 2005).

Furthermore, surveys reveal that firms may allow their software programmers to participate in open source projects even within the working hours, so that companies learn more about the open source world and its development approach (Lakhani and Wolf, 2003). There are also surveys showing that commercial firms use the open source collaborations as a way to find new and talented workers (Bonaccorsi and Rossi, 2003b; Henkel, 2006). Securing a good market position through network externalities (Schmidt and Schnitzer, 2003), influencing the standards (Von Hippel, 2002; Varian and Shapiro, 2003), and blocking the market dominance of the large proprietary software firms (Kogut and Metiu, 2000) are among the other strategic reasons of firms' participation in open source collaborations.

2.3. Open source model beyond software

A combination of bazaar mode of organization (Raymond, 1999), which refers to an open, interactive and non-hierarchical organizational design; of open disclosure of the software source code; and of a legal ground in the form of "copyleft" type of license, have brought about the success behind the open source movement in software industry (Pénin, 2011). This success immediately raised the issue of exporting the model to other sectors as diverse as biotechnology, pharmaceuticals, nanotechnology, automobile, 3D printing or to the information goods such as geographic information systems or online encyclopedias (e.g. Wikipedia). A growing body of research has discussed the possible application of the open source model to these specific industries (e.g. Maurer, 2003; Maurer and Scotchmer, 2006; Lakhani and Panetta, 2007; Pénin and Wack, 2008; Lounsbury *et al.*, 2009; Sugumaran, 2012). An immediate concern could be the quality of the outputs when they are produced in an open source way. For instance, in the case of the online encyclopedia Wikipedia, Maurer and Scotchmer (2006, p.28) state that "its accuracy is comparable to its most prestigious IP-supported counterpart*, Encyclopedia Britannica.*" by relying their argument on the peer review tests (Giles, 2005). Yet, this may not necessarily be the case when it is applied to other sectors.

Some scholars are skeptic about whether other sectors can also provide a favorable environment for proliferation of open source projects. For instance, Lerner and Tirole (2005) claim that many biotechnology tasks cannot be broken up into independent and manageable "modules", and not all the users are sophisticated enough to customize the molecules to their own specific needs. In a similar vein, Kogut and Metiu (2001) assert the non-modularity of a molecule. As a counter argument, Maurer and Scotchmer (2006, p.29) indicate that: "The existence of 'me-too' drugs, in which drug companies change existing patented compounds just enough to avoid patent infringement suggests that molecules may be more 'modular' than Kogut and Metiu suspect." Furthermore, Maurer (2006) discusses the divisibility of the drug discovery process, explaining that the companies routinely break the process into subtasks, some of which may be performed as open source collaborations. Thus, Maurer and Scotchmer (2006) state that even if the convincing examples of open source biology is yet non-existent, the similar incentives driving the contributions of software programmers may also exist for biologists.

Yet, a convincing example to open source biology might be the case of BiOS (Biological Open Source), which is examined by some scholars (Guadamuz-González, 2006; Pénin and Wack, 2008). BiOS is the initiative of a non-profit organization Cambia, aiming at finding solutions to inequities in biological innovations, mainly in the field of agronomy, through a decentralized innovation process. The initiative advocates an innovation paradigm based on open source, open science and open society, as well as on patent licenses that promotes the use, improvement and sharing of technology[55].

Another discussion concerns the term "open source" when it is applied beyond software. Although some scholars (e.g. Rai, 2005; Boettiger and Burk 2004) argue that the bioinformatics software projects and science collaborations adopting open source type licensing terms such as HapMap license can be labeled as "open source biology", Maurer (2003) states that bioinformatics is indistinguishable from any other software, and the open science collaborations are fundamentally similar to the

[55] See BiOS website on http://www.bios.net/daisy/bios/home.html (last accessed on 15/09/2018).

traditional big science projects of the 1930s, thus making the term open source "a matter of semantics" (Maurer and Scotchmer, 2006, p.29). To clarify the term "open source", it is then appropriate to ask what the source code of non-software innovations is. Lounsbury *et al.* (2009) try to answer this question for the case of nanotechnology, where they discuss the possibility of an open source nanotechnology project. In the engineering domain, they suggest that the "source code" may include technical designs, schematics, or, for software embedded engineering material, it is the actual source code of the software. When the nanotechnology is applied to the domain of materials chemistry, then the source code may be the detailed instructions for the materials and the steps used in the process of material synthesis. Similarly, the Open Source Hardware Association (OSHWA) defines the source code of hardware (i.e. machines, devices or other physical objects) as "the design from which it is made"[56].

As explained by Lounsbury *et al.* (2009, p.60), what makes any form of open source code different from "a static publication of a method" is that its aspects allow for easy and legal sharing, and modification; encourage reciprocal contributions and collective learning, which thus makes open source inventions dynamic. Therefore, identifying and analyzing the common principles leading to the success of the open source movement is helpful to carry the model beyond software.

Pénin (2011) explores whether the general principles behind the success of the FOSS can be applied to other sectors. He proposes a general definition of "open source innovation (OSI)", which substantially differs from "open innovation" introduced by Chesbrough (2003)[57] and encompasses all open source-like production models, including FOSS (Raymond, 1999), as well as other collective modes of knowledge production such as "open science" (Dasgupta and David, 1994), "collective invention" (Allen, 1983) and "user centered innovation" (von Hippel, 2005). Thus, an innovation process is claimed to be "open source" if (i) the actors of the innovation process voluntarily disclose the knowledge that they produce just as the developers release the source code of software (ii) innovating actors continuously interact in a bazaar mode of organization (iii) knowledge produced remains open to everyone without any discrimination.

All these abovementioned innovation production models fit into this generalized definition. Although these conditions are necessary to conclude that these models are examples of OSI, the conditions are not sufficient to preserve openness. An important distinctive feature of FOSS, among others, is the

56 See OSHWA website on http://www.oshwa.org/definition/ (last accessed on 15/09/2018).

57 The open innovation paradigm (Chesbrough, 2003) proposes that the innovation process should be organized in a way allowing the distribution of knowledge among various heterogeneous actors and hence suggests that firms open up their boundaries to facilitate the inflow and outflow of knowledge. The main difference of OSI from open innovation is that OSI allows anyone a free (libre) access to knowledge, while in the open innovation context, it is not necessarily the case, since knowledge is usually kept secret and shared only with the partners of the firm (Pénin, 2011). In this regard OSI is more open, inclusive and against the idea of appropriation for prohibiting the access.

peculiar use of IPR, which secures the openness of the knowledge production, whereas other open source-like production models lack this legal pillar. They assume a volunteer grant-back to the common knowledge pool and hence are unprotected against the appropriation of the future improvements. The specific use of IPR with viral licenses is one of the important aspects which might have made FOSS a successful and a sustainable model for knowledge production. Nevertheless, it should be kept in mind that grant-back requirement of viral licenses may also discourage some contributors due to the restrictions to their rights concerning the future improvements, as emphasized by Gambardella and Hall (2006).

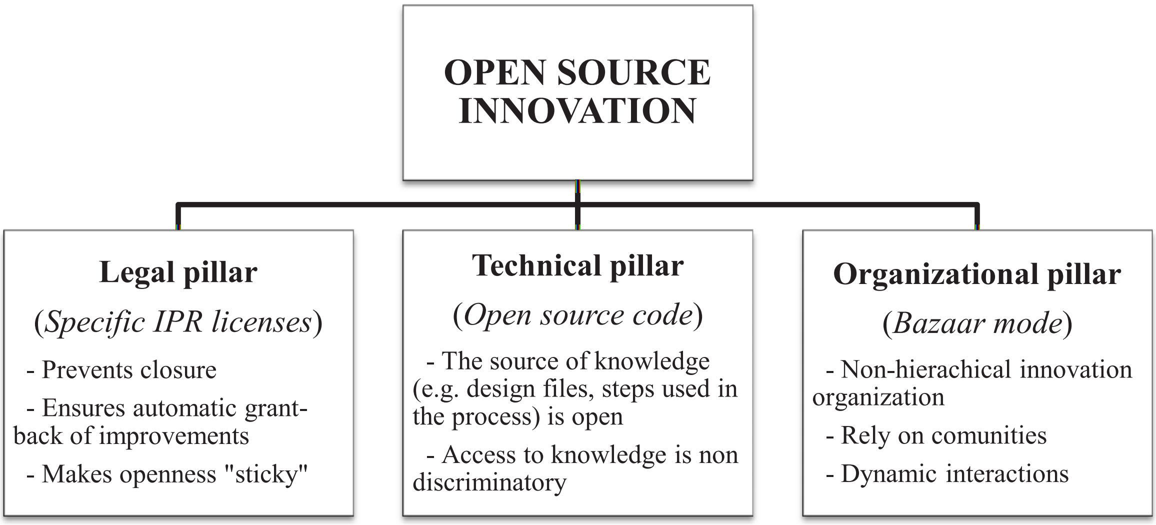

Figure 4.1: Three pillars of open source innovation

As put forward by the prior literature, FOSS stands on three pillars: technical, organizational and legal (Raymond, 1999; Lerner and Tirole, 2001; Bonaccorsi and Rossi, 2003a; Lakhani and Wolf, 2003). Free (*libre*) and open source code constructs the technical pillar; collective, interactive and non-hierarchical bazaar mode of organization constructs the organizational pillar, and, finally, an original "viral" license constructs the legal pillar, through a counterintuitive use of software copyrights in a way that neutralizes its proprietary effect and protects the software and all its derivatives against future appropriation. All these three core dimensions ensure the openness, interactivity and the freedom in knowledge production and its diffusion. OSI also stands on these three pillars (Figure 4.1) and can be used as an umbrella term, since it encompasses all the features of open source-like production models.

2.4. An example of OSI: The case of open source hardware (OSHW)

Open Source Hardware Association (OSHWA) is a growing community that aims at fostering the collaboration and openness by supporting open source hardware (OSHW) projects. OSHWA maintains the OSHW certification, allowing the community to identify and represent the hardware compiling with the OSHW definition, and hosts "Open Hardware Summit" each year to educate the public and encourage OSHW projects.

OSHWA defines OSHW as follows: "Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it." (OSHWA website).[58] Thus, the design files are the "source code" of the hardware. For instance, design files for mechanical objects are the original CAD files, whereas for circuit boards, it is board layout files and original schematics. OSHWA states that although initially the definition referred to electronics and mechanical designs, now it includes all sorts of design files allowing the making of a physical product, which can be applied to fashion, musical instruments, furniture, bioengineering and so on. There are growing communities, individuals and companies around open source hardware projects and successful examples include 3D printers, microcontroller development platforms and satellites.

Design files of an OSHW product and its derivatives can be shared in different platforms and at different stages of development. OSHWA states that some companies share the design files either through their website when the product finishes and goes on sale, while some others store the files on online platforms such as GitHub or Google code, hence keep the files open throughout the development of the product. For some companies, it is possible to release the design files some time after the product is released, provided that this derivative product is not subject to a license which requires open-sourcing the derivative design files.[59]

This brings us to the "legal pillar", the use of licenses which is still quite a complicated issue in the case of hardware, because the design file is subject to a copyright protection, whereas the hardware itself is subject to patent protection. Even if the OSHW participants can patent the improvements, they cannot use their IP rights against the open source practice. Therefore, the participants need to agree on the terms of the licenses chosen by the initial developers. OSHWA differentiates between two broad categories of open-source licenses, which are "copyleft" and "permissive". Copyleft licenses are viral, in the sense that all the derivatives need to be licensed under the same terms and should be open sourced, whereas permissive licenses allow proprietary derivatives. Some examples to copyleft-type

[58] https://www.oshwa.org/definition/ (accessed on 15/09/2018)

[59] https://www.oshwa.org/faq/ (accessed on 15/09/2018)

licenses that are designed for open source hardware are the CERN Open hardware license (OHL) and the TAPR Open hardware license (OHL), whereas the Solderpad Hardware license is a permissive hardware license[60]. Yet, the terms and applications of these licenses are rather complex due to the heterogeneity of patentable technologies, and different from those that are designed for the software.

After different OSHW project experiences, OSHWA states that OSHW can still be commercially successful despite its openness, and this can be due to several factors[61]. First of all, it mentions the barriers related to the capacity to produce the open source technology. That is, accessing design files does not guarantee that everyone can make and sell it, because the entry to the market is costly, as it requires investment to resources (Bessen and Maskin, 2009). Furthermore, innovation activity requires "absorptive capacity"; that is, the ability to recognize, absorb and exploit the new knowledge (Cohen and Levinthal, 1989). To produce, one needs, for instance, to get resources to manufacture and assemble parts of the hardware, implement tests for quality or establish distribution channels.

Besides these, OSHWA puts forward that if the initial producer offers the product at a fair price, it will reduce the incentives of potential competitors to enter an already established market. Another mechanism to appropriate returns from an open source invention is through trust-building. Yet, offering a fair price is still the key to establish this trust. OSHWA claims that the communities developed around the initial producer with an established market would prefer to buy from it instead of buying from an unknown imitator. Another suggested strategy is to do strong branding, for instance through trademarks, which can differentiate the initial producer from the imitator, even if the imitator uses the same design.

The importance of using patents to maintain openness in OSHW projects is an ongoing legal debate, and no ground rules have been established concerning this issue[62]. Therefore, in the next section, we will provide theoretical discussions concerning the role of patents in the open source context, which can either be a bottleneck or a "legal jujitsu" (Benkler, 2006), depending on the objective of the right holder.

3. Open source and patents

3.1. Patents as "bottlenecks"

An important question arising in this context is whether patents and OSIs can coexist. The common view is that patents and open source cannot coexist, because, traditionally, patents are tools used to

60 https://www.oshwa.org/faq/ (accessed on 15/09/2018)

61 https://www.oshwa.org/faq/ (accessed on 15/09/2018)

62 https://www.oshwa.org/2013/12/05/open-hardware-legal-meetup-nyu-nov-11/ (accessed on 15/09/2018)

appropriate the research results and exclude others from using them. Therefore, whereas proprietary invention refers to patented invention, in most cases the automatic assumption behind OSIs is that they should be unpatented and hence in the public domain. For that reason, patents might misleadingly be perceived as kind of a "litmus paper", showing whether the system is proprietary or open source.

Patents were initially designed to provide incentives to innovate and to reap the benefits of innovative efforts, by giving the patent-holder a monopoly right to exclude others. Although different appropriation mechanisms exist, in some sectors (e.g. pharmaceuticals) patents may be an effective incentive tool allowing the innovators to appropriate the returns on their investments (Levin *et al.*, 1987; Cohen *et al.*, 2000). But on the other hand, proprietary use of patents may slow down or block the innovation process, especially when the inventions progress cumulatively. This problem is depicted in the "tragedy of anticommons", a term suggested by Heller and Eisenberg (1998) as the mirror image of the "tragedy of commons" (Hardin, 1968). Hardin's concept suggests that people overuse common resources because they have no incentive to preserve them. Although privatization might be considered as a solution to overcome the tragedy of commons, it creates another tragedy, which causes the underuse, if too many people (or organizations) have the right to exclude (Heller and Eisenberg, 1998). The tragedy of anticommons arises when there are too many patent holders blocking or slowing down the pace of innovation. By studying the case of biomedical research, the authors suggest that too many patent ownership rights would create a high transaction cost associated with bargaining licenses, and this would ultimately impede future developments.

Although early theoretical research of Kitch (1977) suggests that patent rights facilitate cumulative innovations, empirical findings suggest that this might not always be the case for highly cumulative innovations (Murray and Stern, 2007; Williams, 2013; Galasso and Schankerman, 2014). Furthermore, it has been argued that the traditional use of patents may deter the innovative activities in the case of upstream research tools (Pénin and Wack, 2008), because they are typical examples of "platform technologies" that can be applied to diverse research areas (Pray and Naseem, 2005). They are inputs to the sequential innovation process, which then lead to many downstream follow-on innovations (Walsh *et al.*, 2003).

The use of patents might also harm the innovation dynamics in the case of highly complex inventions, such as semiconductors or software, where the inventions contain several patentable components. In such sectors, innovations usually have very high speed of progress and often advance sequentially. Therefore, for instance, in the case of software, the granting of patents is quite debatable. In Europe, although it is blurry, the European Patent Office (EPO) states that the software is not patentable but copyrightable. However, EPO finds the term software ambiguous, and so replaces it with a new concept called “computer-implemented invention”[63], and does not strongly close its doors to software patents. On the other hand, in the U.S., software is both patentable and copyrightable. Compared to copyrights, which protect the expressions, patents protect the ideas. So, in the case of software, each protects the different parts of the software. Copyright protects against the duplication of text-like source code, whereas patent protects the idea embedded in the software, such as a graphical design or an algorithm. For instance, JPEG and LZW algorithm, used in GIF, are protected by patents (Stallman, 2002). Therefore, when we imagine how many patents software programmers try not to infringe, it is not difficult to guess how the patents may dramatically slow down the progress of such a dynamic complex industry.

To emphasize the danger of software patents, Stallman (2002) makes an analogy to musical symphony, which combines many musical ideas, just as any complex technology combines many ideas, and then describes an imaginary case where the governments of Europe in the 1700s decide to implement patents on musical ideas. That is to say, for instance, sequence of notes or rhythmic patterns could be patented. And he makes the case even more striking by stating that:

> “Now imagine that it’s 1800 and you’re Beethoven, and you want to write a symphony. You’re going to find it’s much harder to write a symphony you don’t get sued for than to write one that sounds good, because you have to thread your way around all the patents that exist. If you complained about this, the patent holders would say, ‘Oh, Beethoven, you’re just jealous because we had these ideas first. Why don’t you go and think of some ideas of your own?’” (Stallman, 2002, pp.157-158)

Further, he adds:

> “But nobody, not even a Beethoven, is such a genius that he could reinvent music from zero, not using any of the well-known ideas, and make something that people would want to listen to. And nobody is such a genius he could reinvent computing from zero, not using any of the well-known ideas, and make something that people want to use.” (Stallman, 2002, p.158)

Series of legislations promoting the strengthening of software patents were passed during the 1980s and 1990s in the U.S., with the aim of increasing innovative activity. But it was shown that, contrary to their initial aim, such legislations hindered the innovative activity, because of the sequential and complementary nature of the inventions in the software industry (Bessen and Hunt, 2007). This problem mainly stems from the fact that when the inventions are sequential, patents give a hold-up right over the first generation invention that may impede the incentives to produce second generation inventions (Belleflame and Peitz, 2010). This problem is aggravated in the case of highly complex technologies, where each technology contains thousands of patentable components, as in the case of semiconductors. Hold-up is a primary concern in patent litigation and patent licensing with the

63 Further discussion on software or “computer-implemented invention” patents is available on EPO website: https://www.epo.org/news-issues/issues/software.html (last accessed on 15/09/2018).

proliferation of Non Practicing Entities (NPEs) or "patent trolls" (Lemley, 2008). NPEs do not make products but just hold patents, and wait for subsequent innovators to make irreversible investments and to infringe their patents, so that they can extract money out of patent litigations. These tactics block follow-on innovation, which is known as the hold-up problem.

Thus, when patents are used as tools to create monopolies by exerting exclusive rights on the first generation inventions, they increase the cost of accessing to past technology and hence can be bottlenecks. Therefore, the traditional use of patents may suggest that open source and patents should not coexist when the innovations are highly complex and/or sequential.

3.2. Patents as "legal jujitsu"

Against the common belief, an adequate use of patents may be necessary in the open source context, since patents are flexible instruments that may serve diverse purposes (Pénin and Wack, 2008). Depending on the objective of the holder, patents can be used to exclude the imitators or on the contrary to prevent exclusion (Cohendet *et al.*, 2009). Just as in the case of open source software copyrights, which are used as tools to prevent future appropriation by waiving the "all rights reserved" provision (O'Mahony, 2003), in the case of sequential innovations, patents can be used in the form of a "legal jujitsu" (Benkler, 2006), a term analogous to Japanese martial art Jujitsu used for active self-defense. Patents, when used as a "legal jujitsu", might prevent the clogging of streams of research by patent thickets (Pénin and Wack, 2008).

In principle, such a use is possible through a standard open source or open access patent license (Lounsbury *et al.*, 2009). Indeed, the provisions taking place in this kind of licenses really bound the users, as well as the owner of the exclusive right, as long as the right holder waives any rights preventing freedom of access, modification and distribution of the invention. Thus, a copyleft-type of license, requiring that the further improvements to the patented invention will be put back into the common research pool, through the adoption of a "grant-back mechanism" (Boettiger and Burk, 2004) may coincide with such an ideal.

Similarly, David (2006) mentions "the third face of IPR", which makes them flexible instruments and allows the expansion of "the commons for science" by stating that:

> "It is, like the application of certain forms of copyright licensing – such as the GNU GPL in the case of open source software, a form of 'legal jujitsu', Yochai Benkler's (2006) marvelously acute characterization of the strategy of deploying the law intellectual property rights to achieve a purpose quite opposite to the one for which is usually is intended." (David, 2006, p.2)

An example defending the coexistence of patents with OSIs is from the pharmaceutical industry, namely the Open Source Drug Discovery (OSDD) Project of the Council of Scientific and Industrial Research of India. OSDD promotes the patenting of drugs for neglected diseases such as malaria and tuberculosis, seen mostly in developing countries. Thus, the project "aims at converging patents and open-source innovations" (Sugumaran, 2012, p.1638) through viral licenses like GPL, to ensure affordability and accessibility of such drugs without the enforcement of monopoly prices. Similarly, the legal discussions concerning OSHW reveal why there is a need for patents (OSHWA website)[64]. The idea is to "make openness sticky" by creating enforceable copyleft-type licenses. It has been aimed at using patent licenses for defensive reasons, in order to "avoid having open source hardware patented by another party." Although the copyright protects the design of the hardware, it does not protect the hardware itself as it is a physical object. Thus, in this case, patents serve the same purpose as copyrights do in the case of open source software, which is to create a "sticky" open system.

3.3. Open source patent license versus open science

Open source and open science share the same philosophy, which is keeping the knowledge open and accessible to everyone by means of collective knowledge production and the sharing of research results. However, to achieve this objective, open science culture relies on informal norms and publications (Dasgupta and David, 1994), whereas open source relies on the specific use of IP licenses to ensure that the knowledge will remain open and that the contributors will grant-back the improvements to the open knowledge pool. Indeed, putting the knowledge into the public domain may not guarantee an automatic grant-back, and may result in the future appropriation of knowledge pieces, leading to a situation which might be referred as the "public domain curse". Therefore, in the case of OSI, we need legal weapons, since informal norms would not be sufficient to prevent future appropriation and to ensure that the improvements will be granted back.

As discussed earlier, patents are flexible tools that can be used both for exclusive appropriation or to prevent exclusive appropriation, depending on the stand of the right-holder. Patents can be used in the form of a "legal jujitsu" when coupled with copyleft-type licenses. However, defining the terms of copyleft-type of licenses for patented works is rather a complicated legal issue. As discussed by Guadamuz-González (2006), the problem with patents is that they are subject to lengthy and costly application and registration process. On the contrary, copyrights do not require any registration, which makes the distribution of a copyright license easier and cheaper. Furthermore, the enforcement cost of patents, that is to say, defending a patent in the case of a legal dispute, is even higher, which might discourage small research institutes to patent their research results even if they wish to develop their

[64] http://www.oshwa.org/2013/12/05/open-hardware-legal-meetup-nyu-nov-11/ (accessed on 15/09/2018)

projects in an open source way. They may hence be inclined to publish their research results in such collaborative projects.

That being said, publication might not always be the best option in a sequential innovation setting. In fact, Gambardella and Hall (2006) assert that a misleading inherent assumption is that knowledge will automatically be in the public domain if it is not privately protected. However, what is socially desirable is to make the knowledge remain in the public domain, and this could be achieved by assigning property rights to the public or to the institutions aiming at preserving the public nature of the knowledge (for instance universities), instead of assigning these rights only to private agents, (Gambardella and Hall, 2006). Therefore the authors indicate that IPR should not only be thought of exclusive rights to private agents.

It might be straightforward to claim that once research is made public, appropriation through patents would be prevented, since the publications constitute prior art. However, due to the inefficiencies in the patent system, even the exact copies of published works might be granted patents aiming at proprietary use, especially in highly chaotic patent application processes in fields such as software and biotechnology (Guadamuz-González, 2006). The reason for this inefficiency is that patent officers may not easily identify prior arts in these complex fields. Furthermore, litigation for invalidating such patents is usually long and costly, which may discourage claims against the patents.

Instead of putting the knowledge into the public domain and relying on informal norms, enforcing copyleft-type of patent licenses in the case of OSI might ensure that the pieces of upstream knowledge will not be exclusively appropriated in the future. Enforcing a viral clause might especially be important if the inventions are sequential. When used as a “legal jujitsu”, patents may foster OSIs. What guarantees such a promise of free and open system with patents is the waiving of the traditional exclusive rights through the use of copyleft-type of standard patent licenses.

However, due to the above mentioned specificities of patents, it is difficult to create standard open source patent licenses simply by copying the open source software licenses, but examples exist, as in the case of BiOS patent licenses (Guadamuz-González, 2006)[65]. Another important practical problem associated with such patent licenses is that of their enforcement. A solution found in the case of FOSS is to assign all the copyrights to the FSF, a not-for-profit organization, in order to solve the problems in the case of a legal dispute. Public universities are also not-for-profit organizations and they are not direct competitors to firms. Therefore, we believe universities can be good candidates that can govern the patents for the public interest. Thus, in the following sections, we discuss how patent-based OSL

[65] Terms (clauses) of an appropriate open source patent license is a complicated legal issue, which has already been debated among legal scholars and practitioners, and thus beyond the scope of this study. Yet, one may find a suggested template for open source patent licenses in Guadamuz-González (2006).

may work in the university licensing context, and then discuss the conditions for success in this licensing strategy when compared with traditional licensing strategies.

4. Towards university open source licensing (OSL)

4.1. Introducing OSL to the university context

Introducing OSL to the university context is relevant at least for two reasons. (1) University public mission traditionally relies on the generation and wide dissemination of knowledge without a profit maximization motive, just as open source motivations rely primarily on non-pecuniary incentives. Yet, while transferring university knowledge to the industry, the use of legal tools rather than informal norms might be necessary, due to differences in cultures and motivations. (2) Universities produce upstream knowledge which serves as a springboard for follow-on downstream innovations (Pénin and Wack, 2008). Greater openness of this upstream knowledge allows more diverse and exploratory follow-on innovations (Murray *et al.*, 2016), and the openness could be preserved through OSL.

It is not surprising that the open source software movement has its roots in academia. Indeed, the open source philosophy and academic culture have many parallels (Lerner and Tirole, 2005). First and foremost, the norms of "open science" have traditionally relied on an open and rapid disclosure of knowledge (David, 2005). The common norms of the "Republic of Science" (Polanyi, 1962) documented by Merton (1973) emphasized the communal and open character of scientific knowledge production. These norms have long been the common ethos governing the way science is produced and disseminated by universities. In the same vein, the open source model is also based on collaborative and open knowledge disclosure, the difference being that open science culture stands on the norms, while open source is based on the specific IP licenses as discussed in section 3.3. Both the public mission of universities and the fact that they produce upstream knowledge are compatible with the ideals of open source. Therefore, in the context of technology licensing, OSL might be an appropriate strategy that seems to be more aligned with the traditional role of universities.

OSL may facilitate and accelerate the diffusion of university technologies to the larger public through the continuous interactions of heterogeneous agents (universities, PROs, firms, communities, individuals etc.). Thus, a variety of technologies can be disseminated with shorter time lags. Therefore, we can suggest that OSL strategy may be more compatible with the ideals of academic culture compared to proprietary licensing strategies, since the former is based on openness and sharing.

Yet, university licensing practices rely mostly on conventional licensing strategies, whereas the application of open source licenses are rather limited in number and confined only to software. However, in comparison to OSL, traditional licensing could be highly restrictive, discriminatory and may involve high transaction costs. In this regard, a solution suggested by Dalle and Rousseau (2004) is to implement a dual licensing scheme by mixing traditional technology transfer with a new "academic public license", in order to decrease high transfer costs and to increase the number of open collaborative research development platforms. This duality is rather based on the idea of "segmenting between markets with different products". That is to say, both a viral license for the academic version of the technology, and a traditional licensing scheme for the commercial versions that might allow private actors to have a "complementary proprietary module". Even though the suggested dual licensing scheme is specific to software, it is indicated that a dual transfer mechanism could also be possible beyond software, for instance in the cases of educational resources or biotech databases.

However when it comes to transferring a technology other than software with open source licenses, our knowledge is limited, since both the practices and the theoretical research on university OSL are limited. Among this small number of research, Lounsbury *et al.* (2009) suggest an alternative technology transfer model for the case of open source nanotechnology. The authors explain that nanotechnology focuses on nanometer scale inventions, which have commercial applications as diverse as lighter and more durable sports equipments, wear-resistant tiers, stain-resistant clothing, cosmetics as well as applications for national defense. Governments of developed countries invest huge amounts of money as a result of the increasing nanotechnology race. For such profitable technologies, the research highlights the fact that university TTOs rely more on traditional transfer models aiming at maximizing their profits, and use their IP portfolios to serve that end. By examining a specific invention in the domain of materials chemistry, related to a process of arsenic removal developed at Rice University in U.S. (a project which they claim to be the first candidate for open source nanotechnology), they suggest that open source approaches may be possible for certain technologies, and may even be superior to the existing traditional transfer models.

The research also suggests that TTOs may still continue to use patent metrics as long as the "number of users of a patent" is counted as a measure of success instead of the revenues from patents. To capture the value coming from the "number of users of a patent", they claim that the university should license its patents non-exclusively[66], either for free or for a very low fee with grant-back provisions. They also suggest a dual-licensing scheme, in which the TTOs license their patents non-exclusively with copyleft-like restrictions, and require an additional fee from firms who do not want such a restriction. So that, instead of "betting on a single licensee" by granting the firm an exclusive license

[66] In a non-exclusive license with grant-back provision, even though the number of licensees is sufficiently large, it can still be discriminatory, in the sense that the university may still exclude some firms that want to get a license for its invention, whereas an open source license wouldn't allow for this discriminatory scenario. Because when the invention is licensed open source, it means that the licensee does not need to get permission from the principal for the use of that invention, and as long as the licensee sticks with the terms of the license, she can continue using it. But since we do not yet have a standardized patent based open source license, non-exclusive license with a large number of licensees and with grant-back provision might be considered as a proxy for it.

and expecting the invention to be commercialized, the university TTO will distribute such a risk by "betting on many licensees" in an open source transfer model (Lounsbury *et al.*, 2009). This alternative open source model may allow for socially valuable uses of knowledge and may create a more competitive innovation-based economy.

Indeed, there exist early examples of university licensing practices which are very close to the open source scheme. Although based on a traditional licensing strategy, the non-exclusive licensing of the insulin patent with grant-back may be the closest one to the patent-based OSL. Therefore, in the next subsection, we examine this historical example.

4.2. An early example of the patent based OSL: the case of insulin

The insulin patent may be considered as the ancestor of OSL owing to specific use of patents (Pénin, 2011). The history of the insulin patent is explained in detail by Cassier and Sinding (2008)[67]. In 1922, the University of Toronto (UT) got a patent on insulin and its manufacturing methods and extended its patents to many countries, even though medical ethics did not allow universities to apply for patents for medical inventions at the time.

Privatization of the results of science, and the restriction of the production and sale for financial gains were considered contrary to the traditional norms of academic community. However, insulin is an effective yet a dangerous drug, which necessitates the regulation of its production and sale. In the face of this dilemma, inventors decided to patent the insulin and requested the university to manage it, anticipating the criticism by the medical community, so the patents were assigned to UT. Income from the licensing royalties were agreed to be transferred to the not-for-profit institutions hosting the inventors and to the university research fund.

To administer insulin patents, UT set up an Insulin Committee (IC) which consisted of university governors and insulin discoverers, and then grew with the inclusion of industry members and patent attorneys, in addition to researchers and academicians. University's intention was to use its patents for the public interest, through the control of the standards and the quality of the drugs and the control of the price, by preventing the creation of a monopoly that might have limited the accessibility of the drug. Thus, patents were used to prevent commercial monopoly, because somebody else might have patented the inventions and restricted the use of insulin.

Another debated issue was whether to patent only the process or the substance. In fact, while a process patent does not allow for the control of follow-on improvements by subsequent inventors, a product patent does (Cassier and Sinding, 2008). The first and last exclusive licensee, Eli Lilly (U.S.

[67] This subsection is based on the study of Cassier and Sinding (2008).

pharmaceutical company), was also in favor of UT having strong patent protection. But above all, a broader patent would allow the university to gain more control over insulin. Therefore, UT opted to have a broader patent portfolio.

The licensing strategy regarding exclusivity was carefully designed. Considering the embryonic state of the invention, one year of exclusive license was given to Eli Lilly, which was claimed to have a scientific and industrial experience in the field. This exclusive partnership was aimed at fastening the industrial manufacturing process and standardizing the drug, which would benefit the patients with a shorter time lag.

After a limited exclusivity period, UT licensed the invention and its improvements non-exclusively to many other companies, because the objective of UT was not to use its IP for appropriation or profiting, but to control the insulin industry. It refused to give license to firms that were inexperienced and underequipped and all the licensees were under strict quality control. Insulin prices were also regulated, and in the case of a disagreement between the licensee firm and UT, an arbitration committee would resolve the dispute, or otherwise the license was being terminated. UT was in a position of knowing the exact cost of insulin production, owing to the industrial experience of its lab, and hence was able to regulate the selling prices of its licensees (Cassier and Sindig, 2008).

The first license to Eli Lilly had foreseen any possible risk of surpassing the licensor's invention. Therefore, UT put a grant-back clause in order not to lose control over the insulin. However, this clause did not concern the U.S., where the company operates. Therefore, Eli Lilly wanted to patent the improvements to safeguard its investment against the emerging competitors, despite the objection of UT. But eventually, the company ceded its rights in order not to "lose the benefits of intense scientific cooperation with the university. […] it was better to opt for the university's patronage" (Cassier and Sinding, 2008; p.160). A legal battle with the university would also lead the company to bear the risk of going against the ethical norms accepted by the medical community, which would harm the company's reputation.

Since Eli Lilly's patent was being administrated by UT, and the university intended to grant non-exclusive licenses, the company was about to lose its leadership in the pharmaceutical market. Therefore they advocated for the creation of a common patent pool administrated by the university. As a result, in 1923, IC decided that all licensees shall pool the follow-on patents which would be assigned to UT, so that the university could authorize any other licensees to use the patented methods. This patent pooling policy democratized the IP rights, while ensuring the access to the invention by several companies competing to decrease the cost of the drug. Thus, in the case of insulin, patents played a specific role which is quite contrary to its initial aim:

> "The insulin patenting policy helped to shift the commonly accepted norms in the medical profession and academic world: rather than refusing IP rights altogether, it could be useful to own a patent for the sake of medical ethics and to protect patients. The idea here was not to use the power of the patent to create a commercial monopoly or to extract a rent, but to make it the instrument of a drug biopolicy inspired by the public good. To that end, intellectual property had to be free of commercial goals, monopolies on production and sale, profit-sharing for inventors, and perhaps the collection of royalties." (Cassier and Sinding, 2008, p.166)

UT's patent policy was successful in creating a common patent pool that benefited subsequent innovations through a grant-back mechanism. In this regard, it can be considered as the ancestor of patent-based OSL, even if their non-exclusive licensing policy was still discriminatory. Not all the firms were allowed to access such a critical invention due to quality concerns. Yet, in OSL, everyone can access without authorization[68]. Therefore, in the next section we will discuss what makes OSL different from other traditional licensing policies, by explaining the conditions for success in an open source regime.

5. Conditions for success in OSL

5.1. OSL versus exclusive and non-exclusive licensing

The conditions under which the open source model can be successful have been discussed by scholars (e.g. Maurer and Scothchmer, 2006; Polanski, 2007; Bessen and Maskin, 2009). First and foremost, open source may be welfare-enhancing compared to proprietary regimes when the innovations develop in a cumulative or sequential setting. Maurer and Scothchmer (2006) argue that since follow-on innovators (i.e. potential licensees) cannot automatically be detected by the initial innovators, future innovations might be blocked. In cumulative systems, copyleft-type open source licenses are likely to prevent future developers from appropriating the ideas. In a similar vein, Bessen and Maskin (2009) claim that in a sequential setting, contrary to a static setting, patent protection (in the proprietary sense) is not useful, both for the society and the inventors. They suggest that in an open source regime, even if inventors' current profits decrease, their prospective future profits will increase, because imitation and competition spur follow-on inventions, which might eventually benefit the initial inventors. Their model is based on the assumption that entry to the market is costly (i.e. requires investment to physical and human capital), which prevents initial inventor's profit dropping to zero immediately.

Second, OSL could also be an alternative to traditional licensing strategies in the case of mature and generic inventions when we consider a dynamic (sequential) innovation setting. In the case of mature inventions, a little additional investment is required for the firm to market the technology. This may

[68] In OSL, quality might be ensured through peer reviews or certifications that could be given by standards body.

allow firms to appropriate returns on their investment even in the case of OSL. On the other hand, generic (or enabling) inventions are characterized by their pervasiveness into different sectors, and hence it is important to ensure that all the different technological pathways will be exploited. Therefore, OSL may be an appropriate strategy when the inventions are mature, generic and sequential at the same time. Indeed, this proposition is in line with the proposition we stated in Chapter 2. However, in Chapter 2, we assumed a static setting where inventions are non-sequential, and we excluded OSL from our analysis. Thus, in Chapter 2, we proposed that when the inventions are mature and generic, more open licensing strategies (i.e. non-exclusive licensing) could be welfare enhancing. Moreover, we showed that publication might even be a more efficient research valorization strategy than patenting and licensing when the inventions are mature and generic. Nevertheless, contrary to OSL, non-exclusive licensing might be associated with higher transaction costs related to partner searching, negotiating and monitoring. Furthermore, in a sequential environment, publication of the research results may not be the most efficient strategy, since it may lead to the appropriation of future knowledge pieces and end the sequential progress ("public domain curse").

When we consider the case of both embryonic and sequential inventions, the solution might be more complicated, since the embryonic nature calls for exclusive licensing, by relying on the "incentive to invest" argument, whereas the sequential nature calls for OSL to facilitate follow-on inventions. This duality may necessitate a specific design of licensing contracts. For instance, the university may give an exclusive license limited in time (as in the case of insulin license), while avoiding giving a right to control the improvements to the licensed product. Indeed a dual scheme, mixing proprietary and open source strategies, can be seen in BiOS licenses, which allow the appropriation of the technology by the entity that developed it, but requires the sharing of improvements to this technology (i.e. grant-back)[69]. The license allows a degree of privatization through IP for using and selling of the technology, provided that this technology is made available to any party under a reasonable fee which should not exceed the cost of production. Furthermore, depending on the size of the firm (large, medium, small or very small) and the type of the institution (for-profit or not-for-profit), different annual fees are applied in order to support the development of the technology[70].

OSL may facilitate the knowledge transfer by decreasing the transaction costs related to partner searching and negotiating a license. In OSL, no permission is needed to exploit the technology, thus everyone can access without discrimination. For instance, exclusive license grants the licensee a monopoly right, and is thus the most restrictive type of license. Similarly, an exclusive per field of use license (semi-exclusive license) grants monopoly only to a certain number of firms, limited by the

[69] See BiOS website: http://www.bios.net/daisy/bios/mta/bios-mta-faqs.html (accessed on 18/10/2018)

[70] An example of a BiOS license retrieved from: http://www.bios.net/daisy/bios/3541/version/default/part/AttachmentData/data/CAMBIA%20PMET%20BiOS%20agreement.pdf (accessed on 18/10/2018).

different uses of the technology. Even though a non-exclusive license is potentially the least discriminatory one in the traditional licensing context, the negotiation costs might still limit the number of licensees. As we have seen in the case of SATT Conectus Alsace (in Chapters 1 and 3), license negotiations are long and can take up to a year (even the cost for searching a licensee is too high in many cases). In OSL, as opposed to the traditional licensing strategies, there is no burden of negotiation (Maurer and Scotchmer, 2006), since the licensee has to automatically agree to the predetermined terms of license to use the technology.

Contrary to the previous literature considering an inherent tension between open source and patents, we emphasize once again that the success of open source stems from the unconventional use of IPR. As discussed earlier, putting the knowledge into the public domain allows the exclusive appropriation of improvements in a sequential setting, whereas openness can only be made sticky with the specific use of patent rights. Therefore, in certain cases, university TTOs can opt for licensing a portion of their patents with copyleft-type of patent licenses. Just as copyleft licenses in open source software, such patent licenses should insure free access, use, modification or distribution of the patented technology on the condition that the improvements to the technology will be licensed under the same terms and shall remain open to anyone for further improvements. Therefore, some portion of the patent portfolio can be used against the proprietary purposes with such licenses.

Yet, the degree to which the open source patent license should be permissive is a complicated legal issue, as stated before, and should be adjusted according to the context. Too restrictive open source licenses may hinder both contribution and commercialization efforts due to the requirement of granting back the further improvements to the common pool. For instance, Gambardella and Hall (2006) distinguish between "upstream" and "downstream" activities in the case of software. They put forward that, even though GPL may be an effective coordination mechanism for the production of public goods, it may not be so effective if the important complementary investment for downstream activity is necessary. When considerable amount of investment is necessary, they suggest allowing for a degree of privatization, by using less restrictive open source licenses (e.g. LGPL) so that firms can raise resources needed for investment, but when such downstream investments are less important, they claim that GPL can still be more socially desirable. Thus, use of a viral OSL may be appropriate in a context where the technology is sequential and the additional investments are unsubstantial. In Table 4.2 below we summarize our discussions by comparing three different degrees of exclusivities in licensing, that are open source, non-exclusive and exclusive (see Figure 2.1 in Chapter 2).

Table 4.1: OSL versus non-exclusive and exclusive licensing

Open source licensing (OSL)	Non-exclusive licensing	Exclusive licensing
Might be relevant when the inventions are mature, generic and sequential	Might be relevant when the inventions are mature and generic	Might be relevant when the inventions are embryonic
Free/libre and open knowledge flow	Knowledge flow is restricted	Knowledge flow is highly restricted
Non-discriminatory	Discriminatory	Highly discriminatory (monopoly)
Low transaction cost (no cost related to partner searching & negotiating; it proceeds automatically)	Very high transaction cost (high cost related to partner searching & negotiating with multiple licensees)	High transaction cost (cost related to partner searching & negotiating with the licensee)
Automatic grant-back requirement	Optional grant-back requirement	Optional grant-back requirement
Promotes collective knowledge production	Promotes collective knowledge production only if grant-back to the common knowledge pool exists	Not promote collective knowledge production
Continuous interaction (dynamic knowledge flow among all contributors)	Not interactive in the absence of grant-back to the common knowledge pull	Not interactive (spot knowledge flow only between the licensor and the licensee even with grant-back)
Patents as "legal jujitsu"	Patents for proprietary purposes	Patents for proprietary purposes
Associated with higher number of users but does not generate high royalties	Could be associated with both high royalties and high number of users (e.g. Cohen-Boyer technology)	Associated with higher royalties since the grant of a monopoly right
Might facilitate follow-on inventions in a sequential setting and hence encourage innovations	Might facilitate follow-on inventions in a sequential setting if knowledge is granted-back to the common knowledge pool and hence encourage innovations	Might block follow-on inventions in a sequential setting and hence deter innovations (hold-up problem)
Might lower incentives due to strict restrictions to contributors' rights	Might lower incentives to invest	Might increase incentive to invest
Might not be an appropriate strategy when additional/complementary investments are high	Might not be an appropriate strategy when additional/complementary investments are high	Might be an appropriate strategy when additional/complementary investments are high

One may also argue that OSL wouldn't bring any pecuniary benefit to the university compared to the traditional licensing strategies. We should emphasize once again that OSL does not need to be "free of charge" or "royalty-free". University TTOs may choose to collect a reasonable fee from the licensees. Or, commitments from participants, such as dedicating a share of earnings from open source projects for funding research, may incentivize further open source projects (Dalle and Rousseau, 2004). But, even if OSL may not bring direct pecuniary benefits, it might facilitate the marketing of proprietary segment of inventions, by reducing the asymmetric information and developing the trust between university and the industry. During the open source projects, firms may establish closer links with the university researchers and observe their contribution efforts. The successful efforts of university researchers in open source projects send a signal to firms about the perceived quality of other proprietary technologies developed by the same researchers (or teams). It may also help universities to monitor the commercialization efforts of firms, and hence to choose the right partners when they license other technologies exclusively or non-exclusively. As a result, OSL might also increase the probability of success in proprietary licensing strategies. In this respect, OSL may be complementary to proprietary licensing.

To sum up, OSL could be an appropriate strategy when the inventions are mature, generic and sequential. Provided that the cost of additional investments for further improvement is low, OSL may allow transferring the technology. OSL may also complement and contribute to the success of traditional licensing strategies, by developing the relations between the university and firms. Yet, we emphasize that the success of OSL is conditional on the specific use of patents to preserve the openness in a sequential setting. In the next section we analyze in more detail the case of sequential inventions.

5.2. Case of sequential inventions

By its very nature, the knowledge production is a cumulative process. In her seminal work, Scotchmer (1991) states that the innovation process is a cumulative action rather than an action in complete isolation, by quoting Sir Isaac Newton's famous expression: "If I have seen far, it is by standing on the shoulders of giants." Indeed, cumulativeness is an important feature of many modern innovations (Galasso and Schankerman, 2014). Therefore, in this section, among various other determinants that may enter into the licensing decision of a university[71], we focus on the case of sequential inventions, because we believe that it is a favorable context for OSL.

A sequential invention is a kind of cumulative invention[72] where "each successive invention builds on the preceding one" (Bessen and Maskin, 2009, p.612). For instance as shown in Figure 4.2, the laser is a first generation invention which led to many second generation inventions such as spectroscopy,

[71] We discuss these determinants in the traditional licensing context in Chapters 2 and 3.

[72] Belleflame and Peitz (2010) distinguish between two types of cumulative inventions, each of which may lead to different patent problems. The first one is "*sequential inventions*", in which a particular invention leads to **many** second generation inventions. As illustrated in Figure 4.2, the invention of laser led to many second generation inventions such as spectroscopy, laser surgery or CDs/DVDs. In this case, the main problem is the hold-up right over the first generation invention that may impede the incentives to produce second generation inventions. Ex-ante licensing (i.e. licensing before the second innovator has sunk investment in R&D) may mitigate the hold-up problem. The second one is "*complementary inventions*", in which a combination of **different** first-generation inventions enters as input to the production of a second-generation invention. For instance, to produce new peripherals to be combined with personal computers or video game consoles. In this case the main problem is the "tragedy of anti-commons" (Heller and Eisenberg, 1998) caused by patent thickets. Cross licensing or patent pools might solve this problem.

laser surgery or CDs/DVDs. Cumulative or sequential innovations are quite common in sectors such as information technologies and biotechnology (Belleflame and Peitz, 2010). For instance, in the software sector, VisiCalc (Visible Calculator) was the first spreadsheet program, which became the seed of the Lotus spreadsheet, and then the Lotus became the basis for Microsoft's Excel (Bessen and Maskin, 2009). Similarly, in biotechnology, a technique for inserting viral DNA into bacterial DNA, known as recombinant DNA (rDNA), developed by Herbert Boyer and Stanley Cohen in the early 1970s, has become the seed to the works of most molecular biologists in various sectors.

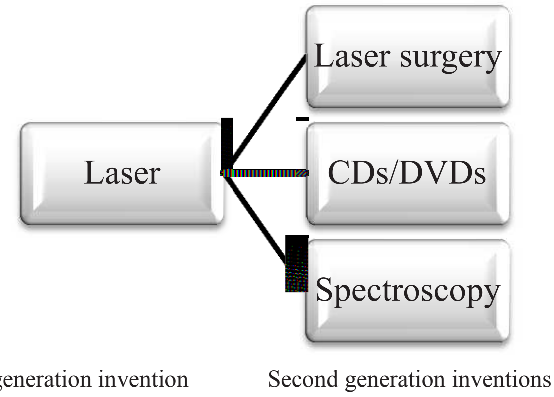

Figure 4.2: Example of a sequential invention
Source: Based on Paul Belleflamme[73]

Since the first generation inventions are the seeds of second generation inventions, the use of patent rights over the first generation inventions is a critical issue, because it affects the follow-on innovations. Therefore, a careful design of patents is crucial to ensure that both the initial and later innovators are compensated enough for their contributions, so that the incentive to innovate could persist at both the upstream and downstream levels.

It is well known in the innovation literature that the proprietary use of patents increases incentives to innovate, but on the other hand, it reduces the total surplus due to high monopoly prices. But, besides this basic trade-off, patents may generate a dynamic cost by blocking the follow-on innovations in a sequential setting if the bargaining failure impedes the licensing of first generation inventions (Galasso and Schankerman, 2014). The impact of traditional patent protection on follow-on innovations has been analyzed primarily through theoretical studies that focused only on firms (e.g. Kitch, 1977; Scotchmer, 1991; Green and Scothcmer, 1995; Bessen and Maskin, 2009). For instance, contrary to the studies showing the negative effect of patents in a cumulative environment, the Kitch's (1977) prospect theory of patents suggests that patents facilitate follow-on innovations, because they enable upstream inventor to organize efficiently the follow-on investments and to alleviate the potential rent dissipation due to patent races at the downstream level. But on the other hand, Green and Scothcmer

[73] Retrieved from http://www.ipdigit.eu/2014/10/a-primer-on-cumulative-innovations/ (accessed on 29/09/2018).

(1995) show that patents may block follow-on innovations if the bargaining failure occurs between the first and second generation inventors. They model the division of profit between first and second generation innovators by studying the breadth (or scope) of patents. The main idea is that if the patents are too broad, it provides very little incentives for follow-on innovators to undertake the invention, due to the excessive appropriation of the initial innovator over the first generation invention. But if it is too narrow, second generation inventor could yield most of the profit by inventing around the first generation invention, and the initial innovator wouldn't therefore be compensated enough. Bessen and Maskin (2009) also claim that patents may encourage innovations in a static (non-sequential) setting, while they may inhibit innovations in a dynamic (sequential) setting and hence reduce welfare. They show that licensing may fail due to informational asymmetry, since the patent holder may not be able to choose a mutually profitable licensing fee, as she doesn't know the potential future profit of the rival. In addition, Galasso and Schankerman (2010) show that coordination failure may block subsequent innovations when downstream innovators need to license several upstream patents.

Furthermore, there are empirical findings showing the effect of the traditional use of patents in a cumulative setting, yet the results are heterogeneous across fields. For instance, Sampat and Williams (2015) find no effect of patents on follow-on innovations by studying patents on human genes. On the other hand, Murray and Stern (2007) and Williams (2013) find that patents impede follow-on research in the biomedical field. Galasso and Schankerman (2014) study different technological fields by using the patent invalidation decisions of the U.S court. They find that patents block downstream innovations in highly cumulative sectors such as computers, electronics and medical instruments, whereas it is not the case for drugs, chemicals or mechanical technologies. Even though patents may be important incentive tools to kickoff first generation inventions, especially in biomedical innovations (Levin *et al.*, 1987; Cohen *et al.*, 2000), if the patent protection is too strong, the cost of accessing the first generation innovations increases, and this may impede the second generation innovations (Heller and Eisenberg, 1998; Nelson, 2004; David, 2006). One way to overcome these problems is to develop efficient licensing strategies taking into account this sequentiality. Thus, in the next section we compare static and dynamic innovation environments and discuss how OSL can be used when the inventions are sequential.

5.3. University licensing: static versus dynamic innovation setting

The reason why OSL may be a favorable strategy when the inventions are sequential is because traditional licensing strategies do not allow for dynamic interactions among the participants, which may impede the follow-on innovations. For instance, in exclusive licensing without a grant-back provision, university licenses the technology to the firm; the firm improves and commercializes the technology. This is a spot disclosure of knowledge, since the interaction occurs only at one point in time. Yet, in OSL, ideally, there is a continuous and multi-directional flow of knowledge among all the participants. As illustrated in Figure 4.3, although exclusive license may be preferred in a static setting (non-sequential) when the inventions are embryonic, in a dynamic setting (sequential), it may impede follow-on inventions (i.e. invention$_2$,…, invention$_i$), where the innovation chain is broken immediately after invention$_1$. While the problem of choosing exclusive license in a static setting boils down to a trade-off between creating incentives to invest versus the associated monopoly deadweight loss, in a dynamic setting, it goes beyond this basic trade-off, due to the risk of blockage. The risk of blockage may arise when subsequent inventors are discouraged due to the excessive appropriation of the exclusive licensee over the first generation invention, which increases the cost of further developing the technology. Bargaining failure (Green and Scothcmer, 1995), asymmetric information (Bessen and Maskin, 2009) or coordination failure (Galasso and Schankerman, 2010) between the exclusive licensee and the subsequent licensees may lead to the end of the sequential process if the exclusive licensee is also granted a right to control the improvements. However, it is interesting to note that, contrary to the standard argument stating that exclusive licensing blocks or diminishes the follow-on research, a recent empirical study by Drivas *et al.* (2017) finds that exclusive licensing increases follow-on research (measured by forward citations) by non-licensees, since the occurrence of a license sends a signal to potential innovators about further innovation possibilities in the relevant fields. This signal stems from the fact that the licensee firm realizes a financial commitment through licensing the technology and hence reveals important information to non-licensees about the commercial opportunities.

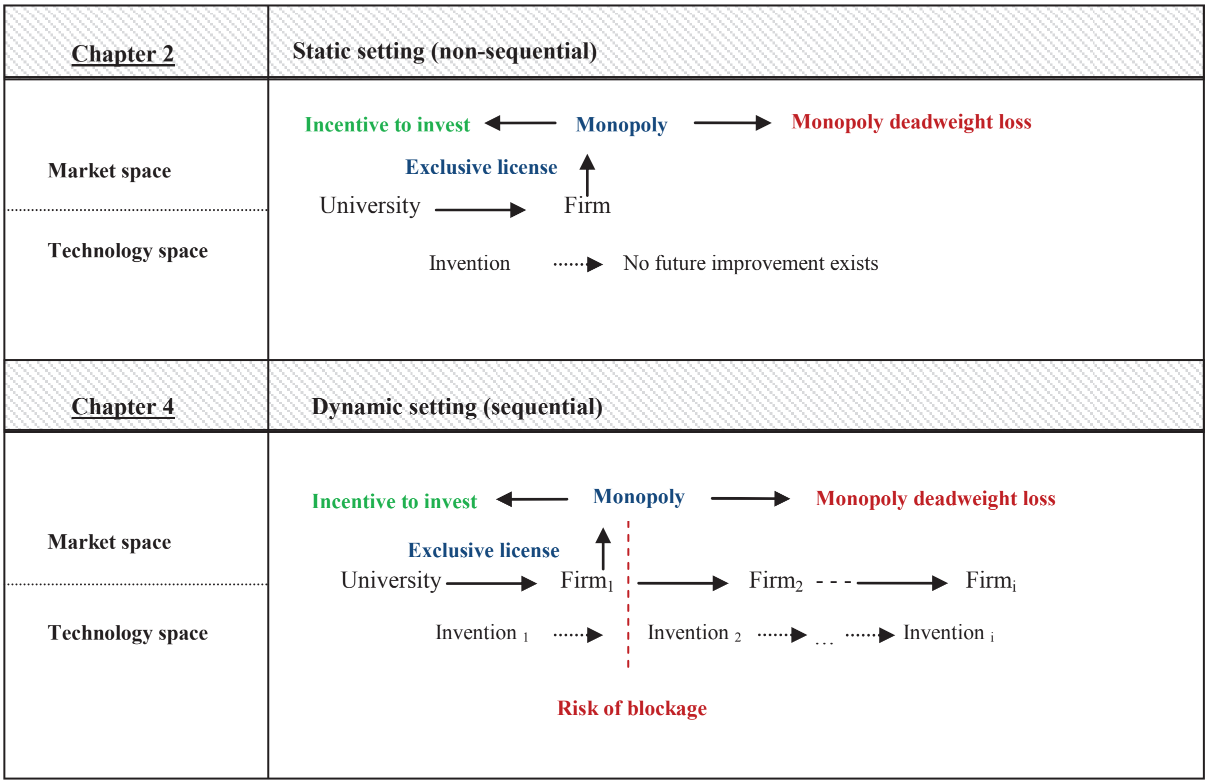

Figure 4.3: Exclusive licensing in static versus dynamic setting

Non-exclusive licensing in the absence of grant-back requirement also does not allow the exchange of knowledge among the licensee firms. Even if the traditional licensing contract includes a grant–back provision (i.e. improvements to the licensed invention by the licensee will be granted back to the university), knowledge flow remains only between the two parties (the firm and the university). On the contrary, in OSL, granting back to the common knowledge pool would be automatic for all the contributing parties which could facilitate follow-on innovations in a cumulative setting.

Therefore, at the upstream level, by using a portion of their patents in the form of a "legal jujitsu", universities may act as gatekeepers ensuring that the follow-on innovations will not be blocked. In a sequential setting, copyleft-type of patent licenses may allow for the wide dissemination of university technology, by making the openness sticky. In fact, Polanski (2007) considers a model with a sequence of innovations, where he compares the performance of proprietary licensing with the GPL in the case of software. His findings suggest that proprietary licensing may end the sequential innovations at very early phases because of the holding-up problem. Provided that the projects are sufficiently convex (meaning that projects have increasing returns to scale) and modular (meaning that projects have high number of development stages), open source with GPL is a successful mechanism in sustaining sequential knowledge production. Yet, this model should be replicated for the inventions other than software.

On the other hand, some scholars are skeptic about the effects of copyleft-type of licenses on innovation, as it is seen as too restrictive. For instance, Gambardella and Hall (2006) discuss the opposing effects of viral licenses. They claim that even if GPL may trigger more participation due to its openness compared to a privatized regime, it can also discourage some contributors due to the restrictions to the contributors' rights. Similarly, Comino *et al.* (2007) show that the probability to reach an advanced version of software decreases with highly restrictive licensing terms. Yet, more empirical evidence is clearly needed in this regard and the studies should be extended to different technological fields.

From the view point of the firm, licensing the university technology based on viral OSL terms may reduce the short-run profit along with an increase in the competition, and hence may deter incentives to invest in open-sourced technologies. However in a sequential setting, such a competition raises the probability of follow-on innovations and increases the firm profit in the long run (Bessen and Maskin, 2009). Profitability could also increase with more product differentiation (Belleflamme and Peitz, 2010). The higher the product differentiation, the more independent the demands for products are. Furthermore, differentiated products give a way to different R&D paths and increase innovative complementarities, and hence technological diversity (Bessen and Maskin, 2009).

Another factor increasing the firms' profits in a sequential setting may arise from cost reduction (Scotchmer, 2010). The collective nature of open source innovations allows larger contributions to the common knowledge pool through the grant-back requirement of university OSL. Knowledge will flow freely between university and firms as well as among firms. In turn, this may decrease the R&D costs of the innovating firms and decrease the time to market the innovations. Moreover, industry profit may be higher under a GPL regime. Scotchmer (2010) shows that, even if proprietary licensing yields larger profits for the first innovator, it creates larger profit losses for second innovators than the profit gains for first the innovator. Thus, she asserts that a commitment to GPL as a whole industry is more advantageous in a sequential setting, and that the second generation invention can be made compatible only if the first generation technology is open for follow-on research. Such an OSL mechanism increases the social value of an innovation, and hence the social welfare, by allowing compatibility of sequential innovations (Scothchmer, 2010).

Moreover, OSL strategies may promote the competitive power of young small firms. By using OSL as a transfer mechanism, universities allow small size firms or new born start-up firms with limited resources to access the university technology without discrimination, and this might be a springboard for such firms to compete or even catch-up with large incumbent firms. Indeed, in a sequential setting, even if OSL might not initially be effective to incentivize large number of firms to invest in first generation university technology, it might still incentivize small start-ups or spin-offs that usually have closer ties with universities, and then may attract large incumbent firms to join the collective innovation chain for producing next generation technologies. Thus, when universities commit to a viral license in a sequential setting, provided that the complementary investments are small, the probability of second generation innovations coming to the market could be higher, which would eventually enhance the social welfare.

6. Conclusion

It is not surprising that the open source movement proliferated in an academic setting, where knowledge production is primarily driven by non-monetary incentives. The movement has grown further in the hands of independent software developer communities relying on a specific non-hierarchical mode of organization, but also attracted for-profit firms to join open source projects for various reasons. The bazaar mode of organization, along with an open source code and specific use of intellectual property licenses, brought about the success of FOSS. Thus, its success immediately raised the issue of exporting it to other industries.

In this chapter we examined the "open source" concept by going beyond software, and discussed why universities should introduce patent-based OSL as an alternative to traditional licensing strategies. Instead of relying solely upon traditional licensing strategies, we argue that university TTOs could introduce OSL strategies in certain contexts, in particular when the inventions are sequential. While in a static setting (non-sequential), the problem associated with the exclusive licensing is to balance the innovation incentives with monopoly deadweight loss, in a dynamic setting (sequential), the problem goes beyond this basic trade-off, since exclusive licensing might create holding-up problem and hence deter innovations in the long run. Therefore, when the technology is sequential, university TTOs may consider using open source licenses with a "viral" clause, provided that the additional investment for improving the technology is small.

We also argue for the coexistence of patents and open source innovations. Patents, just as copyrights for software, can be used in the form of a "legal jujitsu" (Benkler, 2006) to avoid future appropriation when coupled with appropriate copyleft-type of licenses and to preserve the openness in a sequential innovation setting. Thus, contrary to the possibility of appropriation of further developments when the first generation invention is put into the public domain, specific patent licenses serve as a legal pillar guaranteeing openness. Therefore, compatible with their social mission, universities (and their TTOs) should introduce OSL as a part of their licensing transfer strategy. Even if this may seem to be challenging to incentivize firms to invest at the initial stage, the success of FOSS in motivating the firms to invest in open source projects indicates that this scenario is possible for other technologies, as long as the complementary investments are not too high (Gambardella and Hall, 2006).

This chapter discussed the issue of transferring university inventions with patent based OSL strategies, even if such a case is not yet practiced by the TTOs, to the best of our knowledge. This being an important limitation, our analysis hence calls for more research regarding this issue. This study contributes to the literature by discussing when and how patent-based OSL should be introduced in universities, and by examining the context under which the OSL can be used as an alternative to the traditional licensing strategies. Our study has therefore important managerial and policy implications. This research provides university TTOs with new ways of managing part of their IP portfolios, which might align their objectives with the needs of society. Yet, introducing open source transfer mechanisms to the academic context clearly calls for governments' financial support, and a re-design of the IPR system for promoting systematic open source collaborations in universities. Especially, facilitating the granting of such "open patents" to universities and reducing their cost might help the proliferation of open source projects that could spur innovation and growth in the long term.

CHAPTER 5

The Complementarities between Formal and Informal Channels of University-Industry Knowledge Transfer: A Longitudinal Approach

CHAPTER 5

The Complementarities between Formal and Informal Channels of University-Industry Knowledge Transfer: A Longitudinal Approach[74]

Abstract

In this chapter, we study the interplay between formal and informal channels of university-industry knowledge transfer (UIKT) over time. To do so, we rely on longitudinal and qualitative interview data analysis allowing us to observe the notable research and valorization trajectories of two reputable researchers in the fields of robotics and pharmacy at the University of Strasbourg. Our findings show that: (1) dynamic complementarities between formal and informal UIKT are important; (2) at the individual and team level, such interactions contribute to creating a strong cumulative effect with regard to valorization activity; (3) They also reinforce the collective dimension of valorization, which is performed by teams rather than by isolated individuals; and (4) the best academic entrepreneurs make use of the different UIKT channels in an entrepreneurial way with a clear long-run valorization strategy in mind. These results have strong managerial and policy implications with regard to the valorization of academic research.

Keywords: University research valorization, formal and informal technology transfer, academic entrepreneurship, university industry linkages

JEL Classification: O32, O34

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1. Introduction

A large body of the literature on university-industry knowledge transfer (UIKT) has focused on formal aspects managed by technology transfer offices (TTOs) and resulting in patents, licenses, royalty agreements, or start-up creations (Thursby and Thursby, 2002; Lockett *et al.*, 2005; Phan and Siegel, 2006). Many papers have referred directly or indirectly to the Bayh-Dole Act of 1980 and have studied the effects of this act on universities' technology transfer activities (Agrawal, 2001; Thursby and Thursby, 2003). Implicitly, these approaches are based on a linear model of innovation starting with a scientific discovery and ending with the commercialization of a technology or the creation of a start-up (Bradley *et al.*, 2013).

However, the linear model is not sufficient to capture the complexity of technology transfer processes. It reduces the role of universities to the maximization of revenues through the exploitation of intellectual property rights, thus ignoring the different aspects of universities' contributions to economic development, especially at the regional level (Colyvas and Powell, 2006; Bozeman *et al.*, 2015). Other technology transfer channels such as, for instance, technical assistance, consulting activities, collaborative research, transfer through teaching activities, student placements and joint PhDs with industry also represent significant channels of diffusion of scientific knowledge (Levin *et al.*, 1987; Agrawal and Henderson, 2002; Cohen *et al.*, 2002; Siegel *et al.*, 2003; D'Este and Patel, 2007; Link *et al.*, 2007; Stephan, 2009; Perkmann *et al.*, 2013; Hayter *et al.*, 2017).

We know little about the way different UIKT channels interact, in particular formal and informal UIKT channels (D'Este and Patel, 2007; Bradley *et al.*, 2013; Perkmann *et al.*, 2013). However, they are likely to interact as stated by Link *et al.* (2007): "Research suggests that formal and informal technology transfer may go well together in that informal contacts improve the quality of a formal relationship or that formal contracts are accompanied by an informal relation of mutual exchange on technology-related aspects." The literature provides some static evidence based on cross-section studies which suggest that the different UIKT channels are correlated (D'Este and Patel, 2007; Grimpe and Hussinger, 2013). Yet, little attention has been paid to the dynamic setting, which enables an understanding of how the different UIKT channels interact over time and shows specific dynamic patterns of interactions. An exception is a recent research study by Azagra-Caro *et al.* (2017) which focuses on the case of a highly cited university patent that provides an interesting insight into the temporality and spatial dimension of the interplay between formal and informal UIKT channels.

The aim of this chapter is therefore to investigate the dynamics of the interactions between formal UIKT related to the commercialization of knowledge and informal UIKT channels. We explicitly focus on the complementarities between the two. To do so, we adopt an empirical approach relying on longitudinal and qualitative analysis of the trajectories of two notable researchers at the University of

Strasbourg who are highly involved in technology and knowledge transfer activities. This approach allows us to characterize the temporality and the linking mechanisms between distinct UIKT channels. Our work therefore contributes to the literature by shedding light on the temporal dimension and complex links between various formal and informal transfer activities of individual researchers. In particular, as distinguished from the existing literature that mostly focuses on cross-section analysis and pairwise relationship between UIKT channels, we focus on the dynamics of the interaction between different UIKT channels and we consider the interplay of many UIKT channels.

The main results of our case study are that: (1) Although there are strong disciplinary and sectoral distinctions, formal and informal UIKT activities are highly interdependent; (2) the dynamic interactions of UIKT channels contribute to creating a strong cumulative effect with regard to the commercialization of knowledge; (3) activities related to the commercialization of knowledge have a collective dimension and are not performed by isolated individuals but by teams led by notable researchers; (4) the best academic entrepreneurs mobilize the different UIKT channels in an entrepreneurial way with a clear long-run strategy in mind. With regard to managerial and policy implications, this research suggests in particular that we should be very careful when evaluating mechanisms of research valorization at a single point in time. For instance, limiting evaluation by counting patent licensing royalties at a given point in time neglects not only the various impacts of UIKT on society, but also the importance of informal channels as a stimulator of formal channels and most of the interactions that patents might have with other UIKT channels such as start-up creation and formal collaborations.

In the next section we first come back to the multiplicity and variety of UIKT channels and propose a typology of formal versus informal UIKT channels. We then review the theoretical arguments and empirical studies which explain how different UIKT channels might be dynamically interrelated. We specifically focus on the complementarity between them. Section 3 presents the case study of the valorization trajectories of two notable French researchers at the University of Strasbourg. Sections 4 and 5 display the main results of this qualitative research and analyze them with regard to the existing literature. Section 6 concludes and discusses managerial and policy implications.

2. On the variety of UIKT channels and their complementarity

2.1. Beyond intellectual property, licensing, and start-up creation

A large stream of work on UIKT has been centered on formal channels such as patenting, licensing, or spin-off creation (Jensen and Thursby, 2001; Thursby and Thursby, 2002; Mowery *et al.*, 2004; Mowery and Sampat, 2004; O'Shea *et al.*, 2005; Azoulay *et al.*, 2009). Abreau and Grinevich (2013) discuss the way that current literature on academic entrepreneurship has focused mainly on patent-based formal activities such as licensing and spin-off creation, while informal transfer activities are neglected despite being also entrepreneurial in nature. D'Este and Patel (2007) reach the same conclusion by pointing out that the focus of the literature and of policymakers is on the generation and exploitation of intellectual property rights and the creation of new ventures.

However, the transfer of knowledge from universities to industries can take many different forms. Arvanitis *et al.* (2008) identify channels as diverse as informal informational contacts, contacts through phone and email, joint laboratories or technical infrastructure, contacts through graduates or former staff employed in the company, student participation in corporate R&D projects, thesis or doctoral projects in collaboration with firms, research cooperation agreements or research consortiums, academic consulting, conferences, exhibitions and workshops, and educational activities such as joint teaching courses. Cohen *et al.* (2002) show that different channels such as consultancy, conferences, and collaborative research are used in conjunction with one another. They also stress that the informal channels of transfer of knowledge appear to be more important than IP licensing or collaborative research (Levin *et al.*, 1987; Agrawal and Henderson, 2002). The most important channels for firms to access public research are public channels such as publications and conferences, and personal channels based on informal relations, which can be informal advice given occasionally without formal consultancy contracts (Faulkner and Senker, 1994).

A recent and growing body of literature continues to shed some light on these diverse UIKT channels (e.g. Abreau and Grinevich, 2013; Grimpe and Hussinger, 2013; Perkmann *et al.*, 2013; Olmos-Peñuela *et al.*, 2014; Ramos-Vielba *et al.*, 2016; Iorio *et al.*, 2017). Hayter *et al.* (2017) and Boh *et al.* (2016) put forward the important role of graduate and PhD/postdoctoral students as participants of academic spin-off creation. In line with D'Este and Patel (2007), Iorio *et al.* (2017) distinguish between the breadth of knowledge transfer, which corresponds to the number of UIKT channels that are used, and the depth of the knowledge transfer, which accounts for the frequency of knowledge transfer activities that are conducted. In doing so, they show that not only the variety of UIKT channels (the breadth) matters, but the intensity (depth) is also important. Use and selection of these alternative transfer mechanisms may depend on factors as diverse as the intrinsic and extrinsic motivations of academic researchers, and the external environment absorbing the knowledge produced at universities or on the scientific field of knowledge. For instance, based on a survey of UK university researchers, D'Este and Patel (2007) stress that individual researchers' characteristics have a stronger impact than institutional characteristics in explaining the variety and frequency of interactions with the industry. In particular, previous experience of collaborative research increases the variety and frequency of interactions. They conclude that supporting a variety of interaction channels promotes an enduring relationship between science and technology. This is in line with other studies which show that scientists with previous knowledge transfer experience and an extensive network of collaborators are more likely to be involved in a wide range of transfer channels (Gerbin and Drnovsek, 2016).

Finally, with regard to distinctions relating to discipline, Batistella *et al.* (2016) emphasize through a literature analysis that industries such as high-tech (e.g. ICT), biotechnology and pharmaceuticals require particular attention due to their peculiarities concerning technology transfer. Similarly, Olmos-Peñuela *et al.* (2014) extend our understanding of knowledge transfer activity in social sciences and humanities (SSH) by studying research groups in the Spanish context. Their findings suggest that UIKT activities of research groups in SSH are based on relational activities such as consultancy and contract research rather than commercial activities. This is in line with Abreau and Grinevich (2013) who also find that informal commercial and non-commercial transfer activities are especially prominent in disciplines such as social sciences, humanities, and creative arts based on micro-data of academics in the UK.

2.2. A typology of formal versus informal UIKT channels

UIKT channels are usually roughly divided into formal and informal (Kirchberger and Pohl, 2016). Yet, in the literature there is clearly an absence of consensus regarding what is formal and what is informal. Some channels are considered to be formal by some authors and informal by others. For instance, for Perkmann *et al.* (2013) collaborative research and consulting are considered to be formal whereas Link *et al.* (2007) consider them to be informal. Our view is that these divergences stem from the use of two very different approaches to determine whether a channel is formal or informal: first, a purely contractual approach; and second, a purely interactional one.

The contractual approach considers a UIKT channel to be formal if it is structured by a formal contract (Vedovello, 1997; D'Este and Patel, 2007; Landry *et al.*, 2010; Grimpe and Hussinger, 2013; Perkman *et al.*, 2013; Azagra-Caro *et al.*, 2017). This may be, for instance, a license to transfer a certain technology, a research contract to frame collaborative research or consulting activity, a contract to organize a joint PhD, and so forth. On the other hand, as defined by Grimpe and Hussinger (2013, p.685), an informal channel is a “mechanism that does not involve any contractual relationship between the university scientist and the firm.” Informal activities thus include non-contractual mechanisms such as conferences, joint research publications, links with industry established through student placements, etc. (Cohen *et al.*, 2002; Arvanitis *et al.*, 2008; Boardman and Ponomariov, 2009).

Table 5.1: A unified classification of formal versus informal UIKT channels

	Contractual UIKT	Non-contractual UIKT
UIKT without face-to-face interaction	Case A: ***Purely formal channels*** -Material Transfer Agreement (MTA) -Licensing (patents, software)	Case B: ***Informal non-interactive channels*** -Scientific publications
UIKT with face-to-face interaction	Case C: ***Formal interactive channels*** -U-I research collaboration -Academic spin-offs -U-I doctoral theses -Contractual consultancy -Technical assistance	Case D: ***Purely informal channels*** -Doctoral students leaving academia -Teaching activities -Non-contractual consultancy -Academic conferences and workshops -General public conferences

The contractual approach is simple and coherent, hence explaining why it seems to be the dominant view in the literature. Yet, this view ignores the tacit dimension of knowledge transfer and the existence of personal interactions. For instance, from the contractual point of view, research collaborations and patent licensing agreements are both formal mechanisms. However, they can entail very different patterns of knowledge transfer since research collaboration might involve face-to-face continuous interaction and thus the transfer of tacit knowledge, whereas a patent licensing agreement does not entail, *a priori*, such transfer of knowledge. It is simply a transfer of formal rights. Put in another way, in UIKT channels which are considered to be formal from a purely contractual point of view, there are sometimes many informal interactions such as personal exchanges and discussions.

This is, we believe, what Link *et al.* (2007, p.642) wish to put forward when they claim that an "informal technology transfer mechanism is one facilitating the flow of technological knowledge through informal communication processes, such as technical assistance, consulting, and collaborative research." Indeed, in order to transfer knowledge, one usually needs face-to-face interaction, i.e. informal communication. This view clearly builds on the contract-based view, which does not consider whether or not face-to-face personal interaction between firms and academic researchers takes place. It is therefore important to enrich the contractual approach by adding this distinction and distinguishing between channels which involve face-to-face interaction and the transfer of knowledge and those which do not (Bozeman, 2000; Agrawal, 2001; Amesse and Cohendet, 2001). When we cross the two approaches, the contractual and the interactional, we obtain the classification displayed in Table 5.1.

This allows us to distinguish between two definitions of a formal UIKT channel versus an informal UIKT channel. First, as stated above, a formal channel can be defined with regard to the existence or not of a contract, irrespective of the existence of face-to-face interaction. Examples include contractual research collaboration, contractual consultancy, technical assistance, consulting activity, and patent licensing agreements. This is a ***broad definition of formal UIKT channels***. It is in line with the contractual view put forward above. Against this broad definition, which corresponds to cases A and C in Table 5.1, we can oppose a ***narrow definition of formal UIKT channels,*** which supposes that the transfer entails a contract and no interaction (Link *et al.*, 2007). Patent or software licensing agreements and MTAs fit this narrow definition of UIKT, but research collaboration does not. This narrow definition corresponds to case A in Table 5.1.

Similarly, one can distinguish ***a broad and a narrow definition of informal UIKT channels***. The broad definition mirrors the narrow formal one and encompasses any UIKT channels which involve face-to-face personal interaction. It corresponds to cases C and D in Table 5.1. The narrow definition encompasses any UIKT channels which involve informal interaction, and which do not entail a formal contractual agreement. It corresponds to case D in Table 5.1. The final case—case B in Table 5.1—accounts for standard knowledge externalities; i.e. when "knowledge flows in the air" and is not transferred via any contractual or face-to-face mechanism. Some authors focus more on the contractual aspect of the transfer, and therefore adopt a broad definition of formal UIKT channels, whereas other studies focus more on the knowledge side of the transfer, which leads them to adopt a narrow definition of a formal channel. Thus, both definitions are valid.

In our research, we focus on the interactions between UIKT channels based on contractual agreements and informal channels. The adoption of this broad definition of formal UIKT is coherent with our objective, which is to explore coordination mechanisms of knowledge transfer activities linked to the commercialization of knowledge (patents, licenses, spin-offs, collaborative research, contractual consultancy, etc.) and informal UIKT over time.

2.3. On the complementarity between formal and informal UIKT channels

Although distinguished as such, formal and informal transfer activities are not fully independent. Academic researchers engage in distinct transfer activities that can be substitutes or complementary (Landry *et al.*, 2010). In this chapter, we focus on the complementarity between formal and informal UIKT channels, i.e. we examine how they reinforce each other. However, even if it is beyond the scope of this research, it is important to mention that other studies focused on the substitution between knowledge transfer activities and showed that some activities might be detrimental to others. In particular, the fact that researchers have limited time and cognitive effort (Rentocchini *et al.*, 2014) creates a costly trade-off between different knowledge transfer activities (Toole and Czarnitzki, 2010).

Substitution effect may be especially present between the commercially oriented UIKT channels and non-commercial UIKT channels such as scientific publications. For example, D'Este and Perkmann (2011) claim that although joint research, contract research, and consulting may be complementary to academic research; patenting and academic entrepreneurship may not be conducive to academic output, since for the former set of academic engagement activities, motivations are research-related, while for the latter, motivations are exclusively commercial. Even though, as discussed below, most studies show that researchers who patent the most are also those who publish the most, some studies find that patenting may lead to less publications (Calderini *et al.*, 2009) or may delay the publication date of scientific research (Murray and Stern, 2007; Huang and Murray, 2009). Crespi *et al.* (2011) find an inverted U-shaped relationship between academic patenting and publishing, suggesting that up to a certain level, patenting and publishing are complementary, but then show indications of a substitution effect. They show that this curvilinear pattern is also seen between patenting and several other knowledge transfer channels such as joint research, consultancy, contract research and joint PhD training. There is also evidence suggesting academic spin-off creation might have a detrimental effect on publishing both in quantity and quality (Buenstorf, 2009; Toole and Czarnitzki, 2010). Similarly, Rentocchini *et al.* (2014) find a negative correlation between consulting activities and publications. They also find that substitution effect of consulting on research output varies across scientific disciplines and depends on the intensity of consulting activity. Furthermore, there is recent research suggesting direct industrial funding might have a negative effect on research productivity in terms of quantity and quality of publications (Hottenrott and Thorwarth, 2011; Hottenrott and Lawson, 2017) when industrial partners limit research freedom through research topic selection or secrecy (Cohen *et al.*, 1998).

Nevertheless, notwithstanding the relevance of substitution effect in some cases, many studies also confirm the existence of strong complementarity effect between different UIKT channels. The complementarity hypothesis suggests that returns to doing more of one thing increases with doing more of another thing (Milgrom and Roberts, 1995). In the context of knowledge transfer activity, such complementarity arises from the fact that some transfer channels might be mutually reinforcing (Grimpe and Hussinger, 2013), or that outputs of certain knowledge transfer activities become inputs to other transfer activities thus creating a leverage effect (Landry *et al.*, 2010). Also, there is often a learning effect that induces cumulativity in the knowledge transfer activities: involvement in one channel may trigger involvement in other channels. For example, D'Este and Patel (2007) show that researchers with experience in one knowledge transfer activity are more likely to engage in a variety of transfer channels in the future.

Complementarity might even be stronger between formal and informal UIKT channels, when the potential risks associated with the knowledge transfer activities are considered. Indeed, in any technology transfer activities, there are risks of opportunism that a combination of formal and informal interactions might help to mitigate. Cooperation and alliances are hybrid forms of coordination between hierarchy and markets (Williamson, 1979; 1991), in which the two parts remain autonomous but are mutually interdependent. Contracts can, to some extent, lower the risk of opportunistic behaviors. However, they are doomed to remain incomplete (Bessy and Brousseau, 1997; Agrawal, 2006). They cannot anticipate all possible contingencies or preserve the adaptability of relations to unpredictable events. The counterpart of this incompleteness is the importance of trust to mitigate problems stemming from opportunism. The stability of relations over time contributes to an increase of trust, which constitutes a relational asset, specific to each inter-organizational relation (Dyer and Singh, 1998). This is why the combination of formal and informal channels is usually a prerequisite in the success of long-term interactions and why we observe this mutual enrichment between the two.

Furthermore, both formal and informal channels may also be used simultaneously, as firms usually want both the transfer of a property right and continuous interaction between parties that is necessary for a successful transfer of tacit knowledge (Perkmann and Walsh, 2007; Grimpe and Fier, 2010; Dahlborg *et al.*, 2017). Indeed, purely formal channels usually only allow the transfer of codified knowledge. However, knowledge transfer based on codification is incomplete, because it fails to account for the tacit and implicit parts of the knowledge. To exploit a technology, codified knowledge contained in patents and other formal channels must be complemented with tacit knowledge. Yet, the transfer of tacit knowledge usually requires socialization, and continuous and enduring face-to-face interactions (Amesse and Cohendet, 2001; Zucker *et al.*, 2002; Perkmann and Walsh, 2008).

A considerable part of the empirical literature on the complementarity hypothesis is dedicated to pairwise relations between different channels, such as patents and publications (Czarnitzki *et al.*, 2007; Azoulay *et al.*, 2009); academic and entrepreneurial activities (Owen-Smith, 2003; Van Looy *et al.*, 2004); or formal and informal channels (Grimpe and Hussinger, 2013). For instance, using a survey of more than 2,000 German manufacturing firms, Grimpe and Hussinger (2013) show that the use of informal channels, which are defined as mechanisms that do not include any contractual relationships, increases the marginal return of formal technology transfer and the firm's innovative performance. Therefore, to achieve the full potential of a formal technology transfer, firms need to establish close informal ties with universities.

However, this pairwise approach fails to capture the complexity of simultaneous interaction between many different channels. Through the lens of a system perspective to the complementarity issue, Landry *et al.* (2010, p.1389) argue that "the total effects on knowledge transfer performance that are generated from increasing all the knowledge transfer activities together are greater than the sum of the impacts of the individual knowledge transfer activities". In this regard, Landry *et al.* (2010) examine six broad knowledge transfer activities, namely publications, teaching activities, informal knowledge transfer, patenting, consulting, and spin-off creation, and consider the cases of 1,554 researchers who can simultaneously choose to engage in multiple transfer channels. The study aims to show the conditions under which these transfer activities are complementary, substituting, or independent. They find a complementary effect among various transfer activities consisting of publications, patenting, consulting, spin-off creation, and informal knowledge transfer (whereas they find that teaching and publications substitute for each other and teaching is independent of the other transfer activities). Therefore, they suggest that the simultaneous coordination of multiple transfer activities by academics lowers the cost of transferring knowledge by creating economies of scope.

To summarize, depending on the scientific discipline as well as on the region and the institutional context, the pattern of interactions may differ; but both the theoretical and empirical evidences show that formal and informal UIKT channels may exhibit important complementarities. However, the temporal dimension of the interaction between formal and informal UIKT channels has largely been neglected in the literature, although the existence of a temporal continuity between UIKT channels is likely to be linked to the issue of complementarity (Faulkner and Senker, 1994; D'Este and Patel, 2007). In a recent research, Azagra-Caro *et al.* (2017) have attempted to analyze a temporal sequence of UIKT channels. Through a longitudinal case study on a highly cited university patent, they analyze the succession of formal and informal channels of transfer and the localization of their economic impact. Their findings suggest that local impact is highly dependent on this complex and dynamic interplay among formal and informal knowledge transfer channels. In line with Azagra-Caro *et al.* (2017), our objective is to focus on the dynamic interplay between formal UIKT associated with the commercialization of knowledge and informal UIKT. To do so, we adopt a methodology based on the direct and qualitative study of the case of individual academic researchers highly involved in different formal and informal UIKT.

3. Methodology and selection of cases

3.1. A qualitative longitudinal approach

This research took place within the framework of the COCON project aimed at analyzing the COhort of CONtracts resulting from university research valorization to produce indicators to help understand: strategies employed in technology and knowledge transfer; factors of success and failure; as well as socioeconomic impacts in terms of innovation. The COCON project is a four-year research contract (2012-2016) funded by the French National Research Agency (ANR) and conducted by researchers in economics, management, and law bringing an interdisciplinary contract approach to formal university technology transfer.

We used a methodology based on case studies to identify the micro mechanisms of interaction between formal and informal channels (Eisenhardt, 1989). The influence of the basic or applied nature of research on the technology transfer activities (D'Este and Patel, 2007, Perkmann *et al.*, 2013) led us to choose case studies in two different research fields, which were both conducive to UIKT activities

(O'Shea, *et al.*, 2005), but more basic for organic chemistry and more applied for robotics. In concordance with the inductive approach adopted in this research, we focused on two cases of special interest rather than multiplying the cases studied (Eisenhardt, 1989; Yin, 1994). This should not be viewed as a limitation of our research, as shown by Cunningham *et al.* (2017), who carried out a review of qualitative studies conducted in the field of technology transfer research. In particular, they conclude that:

> "The question of how many cases are sufficient for a qualitative case methods study is one that is of concern for qualitative case methods researchers. Our findings show that the majority of researchers used less than four cases or more than twenty-five cases [...] This suggests that there are two case extremes emerging, those studies that rely on a small number of cases and authors that used a significant number of cases for their studies. We suggest that this heterogeneity in the number of cases is beneficial for the field of technology transfer research as it gives case methods researchers continued flexibility as to the number of cases […] Small numbers of cases allow for in-depth analyses. Larger numbers of cases might support the generalizability of the findings." (Cunningham *et al.*, 2017, pp. 937-938 and p. 941)

We selected the cases of two researchers who had been highly involved in knowledge transfer activities for a long time, and used several knowledge transfer channels in order to obtain rich data to observe the mechanisms of complementarity between the different channels. The first researcher we called Professor Pharma, a specialist in organic chemistry, and the second we called Professor Rob, a specialist in robotics[75]. Both are researchers at the University of Strasbourg in France and are among the most invested in UIKT at their university.

Professor Pharma and Professor Rob are not representative of researchers at their university. They are notable cases constituting ideal types according to Yin (1994)'s definition. Their high involvement in UIKT activities allows us to observe links between a large spectrum of formal and informal UIKT channels. Furthermore, they present the criteria identified in the literature as characterizing academic researchers able to be involved in many knowledge transfer channels: They belong to a university highly engaged in the development of UIKT meaning that they benefit from a favorable organizational environment (Moray and Clarysse, 2005). Furthermore, the University of Strasbourg has a critical mass of faculties that generate world-class research (Colombo *et al.*, 2010), which is also usually shown as a favorable factor for UIKT activities (Clarysse *et al.*, 2011). Finally, the fact that they are both experienced researchers—of 52 and 53 years old—allows us to consider links between UIKT channels over long periods of time—eighteen years in one case and twenty-five in the other.

We used a qualitative approach based on interviews to identify the micro-mechanisms of the links between the different channels and to collect information about the perceptions of the actors involved concerning the relation between different forms of UIKT (King, 2004). In order to obtain precise data about the phenomenon studied, concrete and precise situations were the focus of interviews (Kvale,

[75] For the sake of anonymity, all names in this section have been changed.

1983). Since links between different UIKT occur over time, we adopted a processual approach (Hartley, 1994; Pettigrew, 1997) based on the reconstitution a posteriori of the succession of events.

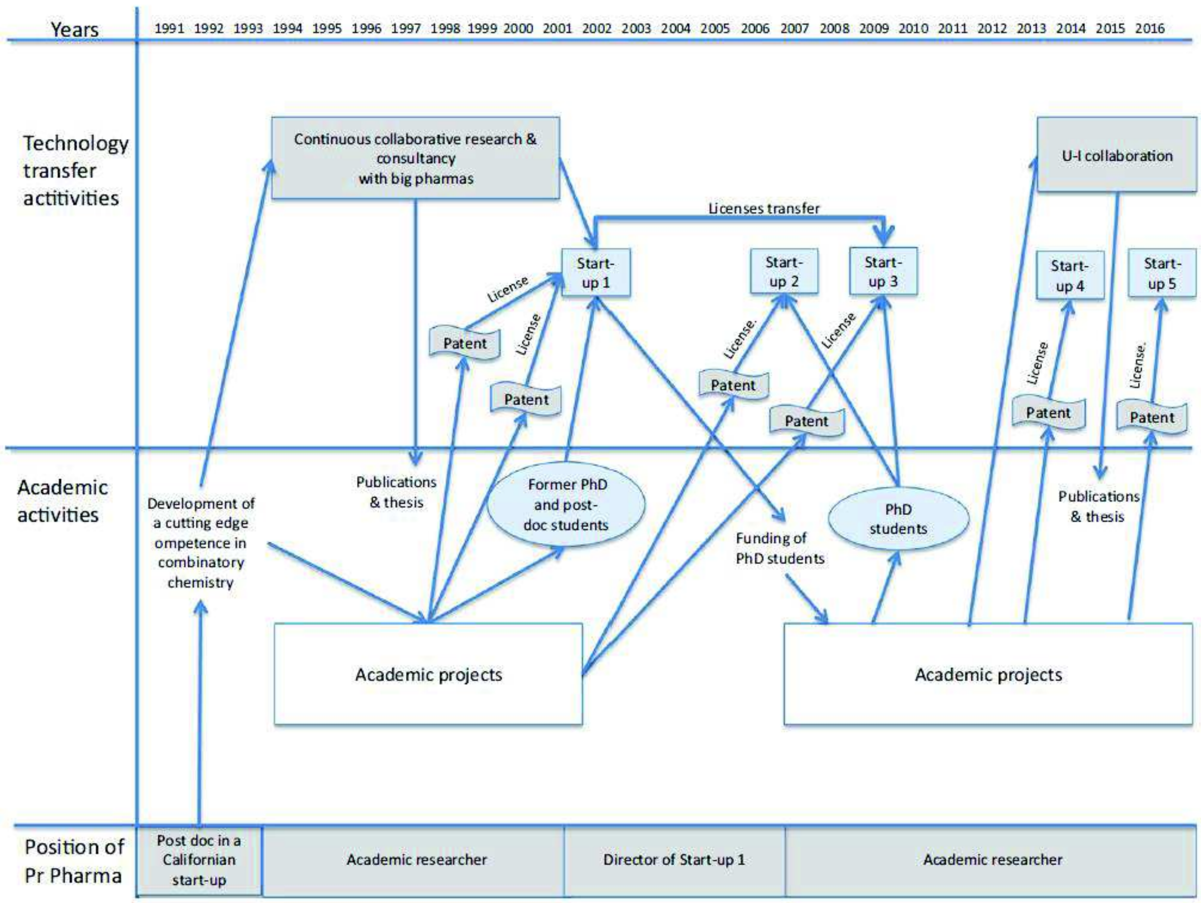

Figure 5.1: Technology transfer activities of Prof. Pharma

This retrospective methodology runs the risk of missing out some events, but according to Huber (1985) participants in organizational processes do not forget key events. Furthermore, Leonard-Barton (1990) argues that when an event is forgotten by interviewees, it can be considered to be unimportant. To limit the risk of omission, we asked the researchers to send us their detailed résumés before the interview, which were thirty-five and thirty-eight pages long. The advantage of a résumé is that it is regularly updated by the researchers throughout their careers and therefore constitutes a kind of traceability tool for the different activities. In addition, thanks to the COCON research project, we collected information about their formal UIKT activities: patents, licenses, research collaborations with industry and consultancy contracts. We also collected information about their PhD students and their careers, and about start-ups created.

We synthesized the researchers' UIKT activities into a one-page document, which displayed a timeline along which different events mentioned in their résumés relating to UIKT activities were indicated. We gave them this document at the beginning of the interview, and asked them to tell us the succession of events leading up to the UIKT activities situated on the timeline and the relations between different activities. We conducted the interview in a very flexible way to let the interviewees develop their own vision of the interaction between the different UIKT (Kvale, 1983). The lengths of the interviews were an hour and a half for Prof. Pharma and two hours for Prof. Rob. We recorded the interviews and transcribed them in written documents of seventeen and twenty-four pages. In a first stage, we reported the links between different UIKT activities, and between UIKT activities and other activities in figures (Figures 5.1, 5.2, 5.3, and 5.4), according to a wide perception of academic engagement (Perkmann *et al.*, 2013).

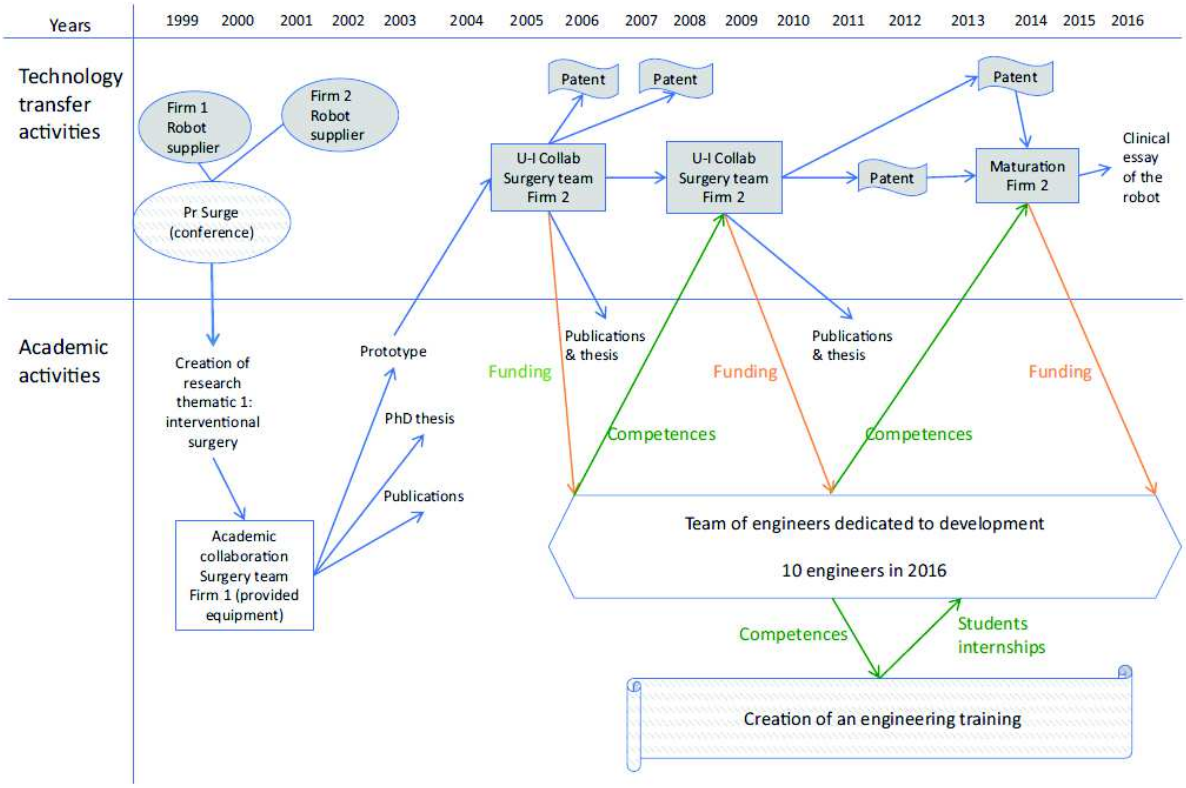

Figure 5.2: Technology transfer activities of Prof. Rob linked to the first research topic

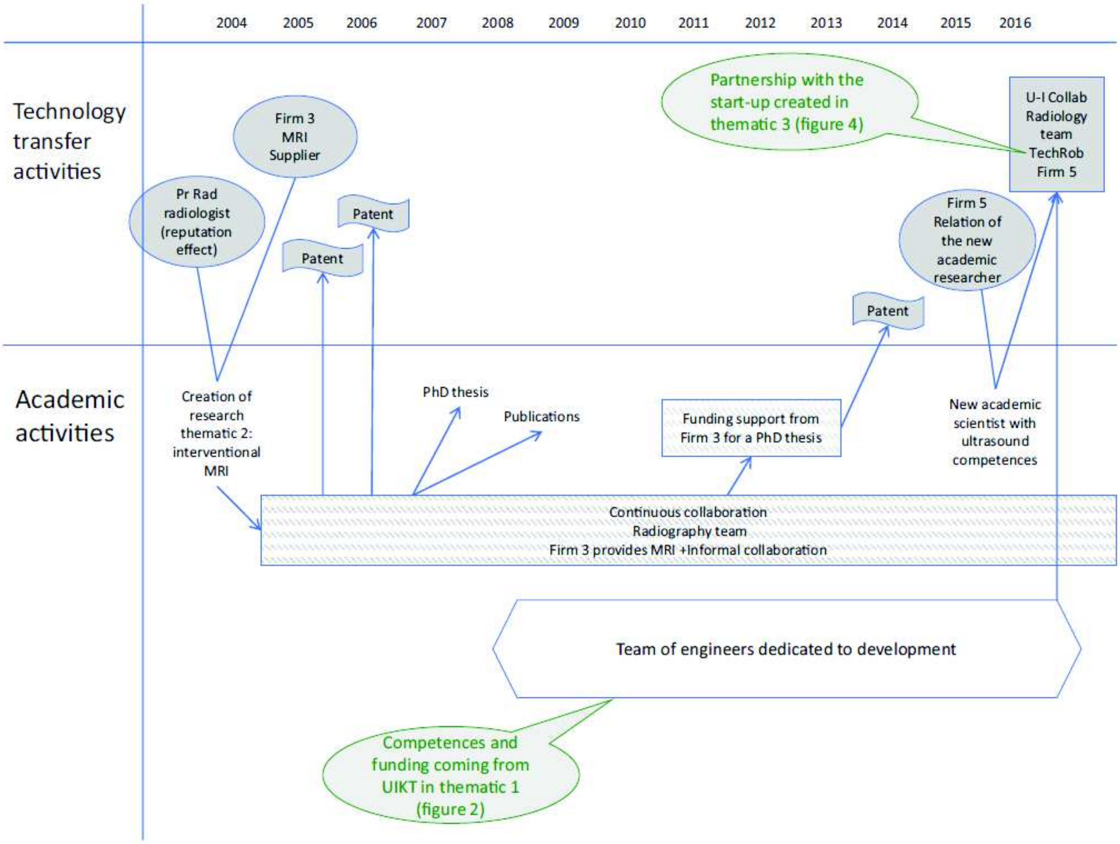

Figure 5.3: The technology transfer activities of Prof. Rob linked to the second research topic

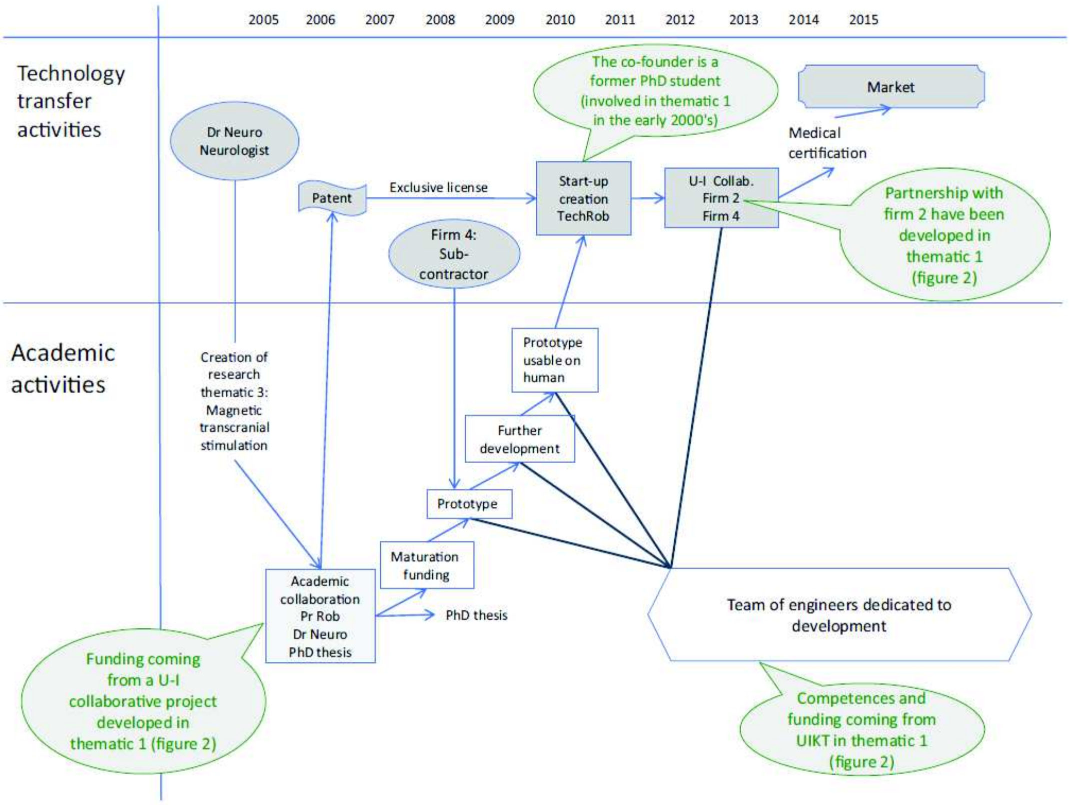

Figure 5.4: Technology transfer activities of Prof. Rob linked to the third research topic

In a second stage, we identified the different links reported in the figures—the mechanisms supporting the complementarity of the UIKT. In a third stage, we compared the mechanisms identified for each case and distinguished the common mechanisms, independent of the field of research, and the specific mechanisms depending on the research context of the two researchers.

We sent the first version of this study to Prof. Pharma and Prof. Rob to be sure that they agreed with the way we had presented their involvement in technology transfer activities. They did not request any modifications.

3.2. Presentation of case studies

3.2.1. The case of UIKT in the pharmaceutical field

Prof. Pharma is specialized in organic chemistry. He is 52 years old. His involvement in technology transfer activities is described in Figure 5.1.

After a PhD thesis in Strasbourg, he spent three years in California as a postdoctoral student at a start-up in San Francisco. He was working with a scientist with a very high international reputation and developed a specific cutting-edge skill in combinatorial chemistry. When he returned to France as a researcher in a public research organization, the CNRS, this skill constituted a strong asset in creating his own research team, with the support of big pharmaceutical firms. An industrial partner funded PhD projects, consultancy activities and contractual research. Beside these contractual activities, Prof. Pharma developed his own research project and filed two patents. Based on these, in 2002 he created start-up 1, specialized in contractual research. This activity was successful and after a short period, the start-up had forty employees. Prof. Pharma left his academic position for five years to work full time in start-up 1. After five years, he went back to fulltime academic work to start new fields of research and to develop the potential to make new inventions, and created new start-ups that were more profitable than start-up 1. Prof. Pharma set-up a strategy of systematic patenting and start-up creation to valorize his research. He developed academic research activities in fields with technology transfer potential, built teams around his skills, managed these teams, obtained patents, created start-ups, and transferred technology through a license. This strategy is also a way to place PhD students and postdocs formed in the laboratory. He filed four patents from 2006 to 2015 and created four start-ups from 2006 to 2016. He is currently working on the creation of another start-up for next year.

3.2.2. The case of UIKT in the robotics field

After a PhD at Carnegie Mellon University, Prof. Rob became associate professor at the University of Strasbourg in 1993, where he worked on purely theoretical subjects related to robotics. He decided to carry out a long-term research strategy based on the development of the application of robotics in the medical field. His strategy was based on partnerships with highly recognized firms in the medical field; the selection of partners considered as key opinion leaders; and the development of deep expertise in the academic field. Researchers in his team grew up from three in 1999 to twenty-six in 2016. Prof. Rob developed the expertise and skills of his laboratory in three main fields of application in robotics: surgery by visual control (Figure 5.2); interventional MRI (Figure 5.3); and transcranial magnetic stimulation (Figure 5.4). Each of these has led to technology transfer activities that are largely interdependent (although we present them separately in three figures for greater visibility).

The starting point was an informal meeting at a conference in 2000 between Prof. Rob and Prof. Surge, who is a surgeon internationally recognized for his skills in minimally invasive surgery. They decided to engage in an academic collaboration to develop medical robots guided by visual control. The industrial partner (Firm 1) provided a robot necessary for the researchers' experimentation. The team was then engaged in formal collaborations with industrial partners from 2005, when it reached a critical mass in terms of human resources and competences. The different collaboration projects are successive steps of the development of the same product (a medical robot) over ten years.

The second research topic leading to technology transfer activities presented in Figure 5.3 also began with a meeting with a leading actor in the medical field, Prof. Rad, who was considered as key opinion leader. This meeting was a consequence of the increasing local scientific reputation of the academic team of Prof. Rob in the early 2000s. The collaboration between Prof. Rob and Prof. Rad, aimed at developing new tools to increase possibilities relating to interventional MRI, led to three patents obtained in 2005, 2006, and 2014. They resulted from continuous informal relations between the industrial partner, the medical team, and the academic team. The industrial partner was not very interested in patents and left the ownership to the academic partners. In this field, only the clusters of patents have value for big firms.

As with the first two, the third topic of research also began with a new medical problem and the informal meeting with an academic partner, Dr. Neuro, a neurologist (Figure 5.4). Neurologist practitioners have a need for new robotized tools, to practice transcranial magnetic stimulation. The collaboration began with a shared PhD thesis project lasting three years. The patent obtained in 2006 led to a start-up project around 2009 and the resulting creation in 2011. Between 2006 and 2011, the project had the continuous support of the academic team with the involvement of the engineers from the laboratory, who developed the technology over five years in order to obtain a prototype enabling it to be used on human beings.

4. Results

Regarding UIKT channels and their interactions, these two cases present many similarities and some differences. The main insights shaping the patterns of these interactions are discussed below.

4.1. Common features

4.1.1. Social capital and financial resources: the engine of the cumulative effects of UIKT activities

Our cases confirm the critical role played by social networks in the success of a technology transfer project. Both cases show the role of personal and professional ties. This role of interpersonal contacts explains most of the interactions among the different UIKT channels. Prof. Pharma used the personal contacts he had developed in his postdoctoral studies in San-Francisco to find both an investor (the first venture capital company which invested in his start-up was led by a former colleague he met during his California postdoc) and the manager of the first start-up he created (who was also a former colleague he had met in California). The research contracts he obtained, throughout the seventeen years considered in our analysis, resulted from his professional and often informal relations with the industrial scientists of big pharmaceutical firms. Similarly, Prof. Rob was able to develop different medical robots thanks to informal meetings at different stages with a surgeon, a neurologist, and a radiologist. The relations he developed with firms 1, 2 and 3 also resulted from these meetings, because they were partners of the medical actors. According to Prof. Rob:

> "The contracts with the different partners are a way to retrace the events, but behind them there is the history of the relations with the Research Institute against Digestive Cancer, with Prof. 'Surge' and the others."

Over time, past valorization activities tend to boost others. They provide material or financial resources, and increase the specific resources of the academic teams through the development of scientific knowledge, skills, networks, credibility, and reputation, thus putting them in a better position to develop other projects. Prof. Pharma explicitly acknowledged that:

> "The first start-up gave credibility, contact with investors, and an experience with regard to intellectual property."

It is the same for Prof. Rob. The first UIKT, in 2005, greatly affected subsequent UIKT activities. It created ties with new industrial partners, with whom researchers have been involved in several projects over time. The financial effect of the first collaborative project has allowed the development of internal technical skills and the funding of a purely academic PhD thesis in the early collaboration with Dr. Neuro. In addition to these network and financial effects, the cases also highlight the flow of knowledge from one project to another. Each project contributes to the development of the academic research team's skills, which are then used in other UIKT activities.

4.1.2. The central role of teams in the success of UIKT activities

A second element appearing in both cases deals with the collective dimension of UIKT activities, which is illustrated by the importance of the placement of PhD students or postdocs in firms in order to guide the knowledge transfer as emphasized by Boh *et al.* (2016). In both cases, former PhD students from the laboratory were largely involved in the creation of start-ups, because they possessed the skills necessary to exploit the technology licensed. Academic entrepreneurs are rarely isolated. They usually rely on a team of junior and senior researchers involved both in the production of good science and in the valorization of this science.

This collective dimension of valorization might be related to the fact that complex UIKT activities rely on the deep interdependence of explicit and tacit knowledge constituting technological knowledge. Even when technologies are formalized in patents, their exploitation relies on the transfer of tacit knowledge that is not completely formalized. In the case of robotics, Prof. Rob indicated that:

> "If you transfer a patent to a big firm with a large R&D department, they have the internal competence to develop the skills necessary to use the technology. However, when you transfer it to a small firm which is highly specialized in a technology, as in the case of robotics, the patent will be useful only if the formal transfer is guided by the lab [...] The firm will be interested in hiring the researcher who has patented the technology, to have his or her expertise. But, generally, the senior researcher will not be interested in spending one to two years transferring the knowledge."

Therefore, the placement of the PhD students or postdocs in the firm, who have formerly worked in the lab, facilitates the transfer of the tacit knowledge associated with the transferred technology.

In addition, the collective dimension of UIKT activities is also related to the growing complexity of research projects in the considered disciplines. Research and its valorization cannot be handled by a single researcher. The involvement of academic researchers throughout the valorization process is hardly compatible with long term academic excellence. It is for this reason that Prof. Rob developed a team of around ten engineers inside the academic laboratory to support researchers in their activities, and who are involved in the maturation of technologies at different stages of the maturation process.

4.1.3. An explicit long-term strategy: the entrepreneurial behavior of academic scientists

Prof. Rob and Prof. Pharma explicitly share a long-term strategy in the trajectory of their research and the development of their UIKT activities. For them, UIKT is not a temporary, short-term affair. It requires time and many attempts. This is also why they mobilize many different channels. The performance of technology transfer relies on the availability of human resources involved in the activities of laboratories to guide the maturation of projects and the transfer of technology to firms. Prof. Rob compared the academic engagement towards valorization with the management of a small firm:

> "You have to be present in the different aspects. Upstream PhD students and publications are needed in order to be recognized, but you also need to manage a team of engineers, to have contracts in order to support the financing of the team, etc. It is like a small firm."

This long-term view is accompanied by a very strong motivation with regard to the valorization of their research. Both researchers are convinced that the activity of valorization is important. As indicated by Prof. Rob:

> "For me it is different: I do this because of personal aspiration. I am motivated. I wanted to see a robot designed in our academic laboratory used on humans."

Interestingly, both researchers explicitly realized this long-term aspect of valorization very early in their career. Since their first valorization attempt two decades ago, they both have seen valorization as a long-term strategy which needs to be slowly carried out, step-by-step. This is, for instance, why, after the successful creation of his first start-up, Prof. Pharma decided to go back for a couple of years to his university lab to perform upstream research. He realized that he needed cutting-edge research again in order to pursue his strategy of valorization. This is also why Prof. Rob decided to engage in several valorization and collaboration projects and to progressively increase the size of his team. Both researchers do not engage in valorization activities, because they have perceived a short term opportunity. Valorization for them is not a punctual transfer of a technology that they have already developed in their academic laboratory. They both perceive their activity of research valorization as an ongoing and endless process that has to be coupled with their scientific strategy.

4.2. Specific features: domain specificity matters

4.2.1. The pattern of interactions between formal and informal channels

The two cases show significant differences regarding links between technology transfer activities. In pharmaceuticals, transfer relies on a limited number of patents that are exclusively licensed. In the development of robots, transfer appears more complex, takes more time, and involves more channels. One explanation is to link these differences to the nature of the technologies, as patterns of interaction may change across different scientific disciplines (Bekkers and Bodas Freitas, 2008).

In the field of pharmaceuticals, academic and industrial scientists involved have a background in chemistry, even if each develops their own skills along the course of their research. Moreover, the transfer of a technology can be based on a limited number of patents, which are licensed to a start-up or a big pharmaceutical firm. In addition, the signaling of academic skills through publications is an important informal UIKT in pharmaceuticals. Big pharmaceutical firms have R&D departments open to the academic world and attentive to their publications and the knowledge they diffuse through conferences. According to Prof. Pharma:

> "The contracts I obtained with big pharmaceutical firms result from the conjunction of the specific competence in combinatory chemistry I have developed and the scientific reputation of the laboratory."

In pharmaceuticals, the valorization cycle is closer to the logic of the linear model than in the case of robotics. It is based on a scientific discovery, leading to a patent and the creation of a start-up, with the granting of a license; and this pattern appears to be repeated regularly. The role of the codification of knowledge is important in this field; however, we show that tacit knowledge embedded in skills is necessary to exploit the technology. This explains the fundamental role of former PhD or postdoctoral students in the creation of start-ups, as underlined by Hayter *et al.* (2017). For example, in the case of the first start-up created by Prof. Pharma:

> "Our academic research leads us to develop a new technology that we have patented. An exclusive license has been granted to Start-up 1 and the PhD student who has made the first proof of concept became the co-founder of the society."

Conversely, for the development of robots, the technological artifact is complex and the technological knowledge it embodies belongs to different fields such as mechanics, electronics, software, etc. This results in a complexity of the development process, which consists of many trial-and-error cycles and long-term relations between partners that makes informal relations very important. The stability of relations is then very important during the process of the development of a product, which takes around eight to ten years for a robot that is usable on humans. The length of the whole development process is therefore longer than the time of a specific research collaboration, and this leads to a succession of UIKT activities throughout the development process, with many interactions to develop common knowledge, new combinations of knowledge, and the creation of technological knowledge.

As a consequence, in the robotics field, the link and complementarity between the different UIKT channels seem to be less simple and linear. Product development relies greatly on tacit knowledge, in trial-and-error logic, far from the linear model. The complexity of the robot leads to the progressive development of a set of diversified competences in the academic laboratory. The academic team possesses tacit knowledge about the development of robots, and is involved in a succession of projects throughout the development process, which can last up to ten years after initiation.

4.2.2. The role of patents in promoting technology transfer and start-up creation

In both cases, patents appear to play a critical role. They protect the invention and constitute tangible proof of credibility for potential partners or financial backers. But the role of the patent in each case is not the same. The differences in the nature of the technology lead to different protection strategies (Levin *et al.*, 1987; Cohen *et al.*, 2000). These are omnipresent in the case of Prof. Pharma, whereby each start-up creation is preceded by one or more patents which are then exclusively licensed to the start-up.

> "Each start-up has its own economic model and the competences involved are not the same in the different start-ups."

This is a well-known model in pharmaceuticals where it is necessary to protect a molecule to preserve its commercial value. Without a patent, it would be very difficult, if not impossible, to create a start-up.

However, the situation seems to be different in robotics. In the case of Prof. Rob, the role of patents is more strategic. A robot is made of many components, and a single robot relies on several patents. A single patent therefore has little value. Firms must form patent portfolios.

> "My first industrial partner has disappeared in a patent war against its main competitor. I understood that without any patent you have no chance to survive. The role of patent is purely defensive. It is almost like in the automotive industry where a firm that has no patent cannot defend itself against competitors which have patents."

The value of patents in the field of robotics is therefore most of all a defensive one. Patents contribute to increasing firms' bargaining power and to preserving their freedom to operate. Prof. Rob also insists on the role of patents as important signaling tools, necessary in applying to funding programs or to develop new collaborations. They mostly constitute elements of credibility.

5. Discussion

Our work suggests the existence of strong and enduring complementarities between formal and informal UIKT channels. The mutual interdependence between formal and informal UIKT activities (Azagra-Caro *et al.*, 2017), which mutually reinforce one another (Grimpe and Hussinger, 2013) over time, induces a strong cumulative effect with regard to the knowledge commercialization activities (D'Este and Patel, 2007). The combination of transfer activities entails the flow and the capitalization of knowledge, both tacit and codified, in academic teams over time, which opens the door to further possible transfer activities which in turn generate revenue for universities.

At the level of the researcher and of the lab, first experiences of formal UIKT often trigger others. Within their activities of knowledge transfer, researchers develop personal informal contacts with potential collaborators and financers, and specific expertise and skills with regard to knowledge transfer activities (for instance, legal expertise on firm creation, patent applications, etc.). Colombo and Grilli (2005) show that firms created by entrepreneurs with prior experience of new venture creation have higher growth than others. Our cases show the effect of previous experience on the quality of future experiences. The accumulation of know-how and know-who lowers the barriers and the costs of future valorization activities. This reinforcing and cumulative effect helps explain why involvement in formal UIKT often seems to rely on a few notable researchers who are serial entrepreneurs. Their initial entrepreneurial initiative is reinforced over time and calls for successive steps of knowledge transfer through formal and informal UIKT.

This finding is in line with the literature claiming that formal and informal channels are correlated and mutually reinforcing (D'Este and Patel, 2007; Landry *et al.*, 2010; Grimpe and Hussinger, 2013). On the one hand, informal links tend to facilitate the development of formal interactions such as research contracts or start-up creation. On the other hand, formal relationships also contribute to increasing researchers' informal social networks which, in turn, might lead to further future collaborations.

Past experiences of valorization matter, thus contributing to the creation of a cumulative process of UIKT activities as shown by D'Este and Patel (2007). The more the researchers are involved in UIKT, the easier it becomes for them to be involved in the future. First, this cumulative effect is linked to the fact that UIKT activities are, on the one hand, fed by good science and, on the other hand, nurture good science. Indeed, the diversity and the intensity of UIKT require good science. Although the activity of valorization takes a lot of time and energy and might divert scientists from fundamental science, both researchers emphasized the importance of being at the frontier of science, of developing cutting-edge technologies—the only thing which can attract industrial partners. Moreover, our two cases show that the transfer of academic knowledge enriches scientific activity by providing new challenges but also by offering new resources, materials, and financing. Second, the cumulative effect is reinforced by interactions between the different UIKT activities. First valorization experiences are made possible by prior personal contacts and, at the same time, contribute to enriching the social network of scientists, thus increasing their ability to develop further valorization activities, as argued by Gerbin and Drnovsek (2016).

The interplay between formal and informal UIKT channels also favors a collective dimension of the knowledge commercialization activity, which is usually performed not by isolated individuals but by teams led by notable researchers. The multiplication of knowledge transfer channels and the necessity to combine them make it indeed more and more difficult for one single and isolated individual to handle the process alone. A continuous activity of valorization must be nurtured by good academic research. The entrepreneur must therefore remain connected to the frontier of academic research within his or her research lab. On the other hand, valorization requires links with industry, contracts with firms, sometimes also the creation of a start-up. It is usually impossible for one single entrepreneur to develop this ambidexterity and to handle all these activities simultaneously. It therefore becomes important for notable entrepreneurs to constitute valorization teams composed of PhD students, postdocs, and research engineers. The team remains close to the knowledge frontier and helps the division of labor between academic and industrial work. In this sense, contracts with firms are important to finance and hire research engineers who can help perform good academic research. But PhD students and postdocs are also important to feed the activity of valorization and, eventually, to be hired by firms and start-ups after their research training in the academic lab (Stephan, 2009; Hayter *et al.*, 2017).

This collective aspect is a well-known feature of contemporary science (Wuchty *et al.*, 2007; Black and Stephan, 2010). However, to our knowledge, it has never been highlighted in the case of the valorization of science. Still, our two cases clearly suggest that, increasingly, UIKT activities rely on mixed teams of academic and industrial researchers. As indicated above, many researchers work both in a start-up and in the lab. There is important human resources mobility between two worlds, which is also something that the leader must manage. Academic entrepreneurs have to be entrepreneurs in the sense that they have to transfer their inventions and academic knowledge into innovation. But they also have to become entrepreneurs in the sense that they must manage heterogeneous teams.

The collective dimension of the valorization activity implies that one key competence of academic entrepreneurs is their ability to build and animate teams. Interestingly, this point is usually underestimated in the literature which, although it has for long put forward the collective dimension of research, usually neglects the collective dimension of the valorization activity. Past studies often put forward the important personality traits of academic entrepreneurs which are showed to behave alone and to face hostile environment. Clarysse *et al.* (2011) showed that individual qualities of academic researchers are the most important determinant of their entrepreneurial abilities, even if the environment plays a role. They underline the specific ability of the most successful entrepreneurs to detect opportunities and the role of previous experience in new venture creation. Our cases show that the ability to build and to manage a research team is also a crucial competence. If academic entrepreneurs are indeed notable individuals, as shown by our two cases, they seldom operate alone.

Last, our case study shows that the best academic entrepreneurs do not view knowledge transfer activities as a one-shot action. Indeed, it seems that academic inventors, at least the most prolific ones, do not behave according to short term, punctual opportunities. Conversely, they mobilize the different UIKT channels with a clear and explicit long run entrepreneurial strategy in mind. The fact that researchers develop a long-run strategy as to their academic research may not be new (O'Kane *et al.*, 2015b). However, to our knowledge, this is a fairly new element with regard to the valorization of the research. The activity of valorization is very often considered to be a by-product of good research. Implicitly, it is assumed that researchers have only short-term strategies of valorization based on their long-term research strategy, although some studies suggest that scientists usually have a broader strategy with regard to the valorization activity and broader research agenda in order to promote their career (Franzoni and Lissoni, 2009). In line with these statements, our academic entrepreneurs also present the profile of research designers characterized by O'Kane *et al.* (2015b). They pursue challenging research projects alongside a long-term scientific intention articulated around the resolution of big scientific questions. They have a deep commitment to the resolution of problems on which they work and are very concerned by the originality of their research trajectory. And, alongside their scientific strategies, they develop long-term strategies of commercialization of knowledge.

Moreover, as it was already emphasized above, prolific academic entrepreneurs do not envisage the commercialization of knowledge as a byproduct of their scientific activity, rather it goes hand in hand with the scientific strategy (Franzoni and Lissoni, 2009). The different channels of valorization are linked in order to optimize the long-run strategy of commercialization and production of scientific knowledge. Contracts with industries are developed in order to finance quality research, which can then lead to patents, licenses, or the creation of start-ups. Similarly, patents are applied for specifically to help the creation of a start-up in the future. Our case studies strongly suggest that the commercialization of knowledge, in order to be successful, requires a long-run strategy built around a scientific strategy.

6. Conclusion

The objective of our study was to contribute to the understanding of the dynamic links between the different UIKT channels and, in particular, between formal UIKT related to the commercialization of knowledge and informal ones. To do so, we adopted an empirical approach relying on longitudinal and qualitative analysis of two notable trajectories of researchers at the University of Strasbourg. This approach allowed us to characterize the sequence of distinct knowledge and technology transfer activities, the kinds of resources exploited, and the way different networks are developed over time. Thus, our work contributes to the literature mostly by shedding light on the temporal dimension and complex linkages between various formal and informal transfer activities of individual researchers. Despite some specificities of the links between scientific and technological knowledge in different fields (the role of the patent system for example), due essentially to the different technological regimes underlying different sectors, our research shows some similar patterns in the interplay between formal and informal UIKT channels. In particular, our case study suggests that: First, the strong dynamic interactions between UIKT channels contribute to creating a cumulative effect with regard to the commercialization of knowledge; Second, activities related to the commercialization of knowledge have a collective dimension and are not performed by isolated individuals but by teams led by notable researchers; Third, the best academic entrepreneurs mobilize the different UIKT channels in an entrepreneurial way with a clear long-run strategy in mind.

These results have important implications for policy makers, scientists interested by UIKT issues and practitioners involved in UIKT activities. For example, in a linear approach of UIKT, universities are seen as knowledge factories that commercialize knowledge with the objective of maximizing intellectual revenues fulfilled by the TTO (Bradley *et al.* 2013). The cumulative effect of UIKT and the complementarity between formal and informal channels lead us to consider a wider range of strategies deployed by universities behaving as knowledge hubs (Youtie and Shapira, 2008, Schaeffer and Matt, 2016). In this model, universities are deeply involved in the development of the regional system of innovation, foster the development of local interactions among a wide range of stakeholders (other TTOs, incubators, university managers, public authorities, investors, firms, start-ups, students, alumni) and able to be involved in different kinds of UIKT.

TTOs' missions are also wider than the mere management of intellectual property. As underlined by Arvanitis *et al.* (2008, p.1,880): "They seem to fulfill well their function as 'specialized consultants' with respect to patenting, licensing and the promotion of new firms. But they seem to perform less well as 'KTT intermediaries'." In line with this statement, our cases suggest that TTOs should better articulate the different UIKT channels and develop boundary-spanning functions in order to contribute to fostering the development of interactions between different stakeholders. In addition, the fact that valorization activities exhibit a strong cumulative effect also implies that it might be efficient to encourage academic entrepreneurs early in their academic career to boost increasing returns. Furthermore, the collective dimension of the valorization activity puts forward new missions for supporting organizations such as TTOs. As mentioned above, TTOs are usually viewed as intermediaries facilitating the finding of industrial partners and managing academic intellectual property. But more than that, they could also facilitate the formation of teams around academic entrepreneurs. With regard to this objective, a closer proximity between university TTOs and academic incubators might be helpful.

This research also has important implications for the evaluation of the academic research valorization activity, concerning the way policymakers measure and evaluate the contribution of academic research to society. Too often, public evaluations are based on performance indicators that are biased towards short run and formal channels; typically, the amount of patents or the amount of licensing royalties or the number of start-ups generated by a university over a given period. However, we should be very careful when evaluating mechanisms of knowledge transfer at a single point in time. It is obvious that these measures miss most informal university transfer activities. But, above all, they miss the interactions between the different UIKT channels. Clearly, a systemic evaluation of UIKT activities is needed.

At the end, and although we believe that the insights put forward in this research open many doors, it is also important to underline the limitations of this research. Our two cases have a high degree of internal validity but are likely to present a low degree of external validity, especially in fields distinct from the ones analyzed here. Robotics and pharmaceuticals might exhibit strong specificities when it comes to UIKT. Results obtained in these cases might therefore not be true for other domains. A first objective of future research is therefore to analyze the interactions between formal and informal UIKT activities in other scientific fields. Furthermore, while the revelation of the logic of actors involved in the transfer requires qualitative approaches based on interviews, some results such as the cumulative effect of knowledge transfer activities or its collective dimension could be confirmed by quantitative approaches. Yet, before we can do so, an important work of data collection is required since we need to invest into the development of original dataset.

GENERAL CONCLUSION

General Conclusion

This thesis aims at investigating the social impact of university intellectual property (IP) licensing strategies and at analyzing the dynamic interplay among various transfer channels used in university-industry interactions (UIIs). In this regard, we examined the university licensing strategies with different degrees of exclusivity, and then showed the dynamic interactions among various channels used in knowledge transfer. The greatest part of this thesis focuses on university licensing strategies. Thus, we first raised the question of *"how can the licensing practices of universities (and hence their TTOs) be improved while transferring the publicly funded university research output to the industry?"*. To that end, we examined the link between different degrees of exclusivity and the various determinants, in particular the characteristics of the licensed invention.

In fact, universities have been important sources of knowledge for industrial innovation throughout the 20th century, but much of these economic contributions have been made through channels other than patenting and licensing (Mowery *et al.*, 2004). Therefore, to show the complexity of the knowledge transfer activity, we expanded our study, in Chapter 5, by going beyond licensing, and examining the various other channels of transfer. In this chapter, we dealt with the question of "*how do formal and informal channels of university–industry knowledge transfer (UIKT) interact over time?"*. Thus, in this last chapter, we investigated the complex and dynamic interactions among different channels of transfer.

Chapter 1 aimed at presenting a broader picture of UIIs, in order to complement the subsequent chapters studying licensing and beyond. In this chapter, we provided a historical overview of the UIIs, focusing on cases in the U.S. and Europe. Yet, we observed that most of the research on UIIs was centered on the U.S. The case of U.S. provides a fertile ground for study, because, historically, the research at U.S. universities was more application oriented, and universities were more dependent on local industrial funding, which made U.S. universities establish stronger ties with the industry compared to their European counterparts (Mowery *et al.*, 2004).

However, in the post World War II era, Vannevar Bush's influential Report clearly distinguished the spheres of basic and applied science, and insisted that universities in U.S. were to be kept away from any commercial purposes. Yet, this paradigm was totally changed after the passage of the Bayh-Dole Act in 1980, and similar legislations emulating Bayh-Dole in Europe and in other continents proliferated. Bayh-Dole-like legislations catalyzed the growth in university patenting and licensing. The increasing volume and complexity of commercialization activities has led to the institutionalization of the governance of transfer activities, and resulted in the establishment of intermediary structures such as TTOs, dedicated to managing universities' intellectual property (Geuna and Muscio, 2009). Thus, by examining the cases of TTOs in the U.S. and the France, we raised the issue concerning the primary objective of TTOs when licensing the publicly funded university inventions.

Therefore, in **Chapter 2**, we investigated how the licensing practices of university TTOs can be improved so that their objectives could be aligned with the needs of the society. To that end, we defined different degrees of exclusivity in the exploitation of research results, ranging from open source license to exclusive license including publishing. Then, we detected the factors that should enter into the patenting and licensing decision of TTOs. Among these factors, we investigated how the nature of the invention (i.e. stage of development and specificity) affects the patenting and licensing strategies with the help of a simple game theoretical model. We considered a model with one university and four firms in two different sectors. We showed that if the invention is too embryonic, it cannot be transferred to the industry; therefore further efforts for maturation are needed. Conversely, when the invention is mature, publishing is the optimal strategy. If the invention is embryonic and specific, exclusive licensing is the only strategy that allows its transfer to the industry. Furthermore, if the invention is generic and embryonic, exclusive licensing per field of use is the best way of transferring the invention. An important result of this study is that at the equilibrium of the game, universities may not always automatically choose the strategy maximizing the social surplus.

In **Chapter 3**, we tested empirically some of the results presented in Chapter 2. However, in Chapter 3, we eliminated the publishing strategy, and focused only on the case of licensing. Relying on a unique and original dataset, we examined 91 inventions contained in 62 IP licensing and patent cession contracts executed by two leading French research universities within the period of 2005-2014. We constructed our dataset in the framework of the COCON project, by combining the contract codification data with the inventor survey data. As distinct from the previous research, which linked the exclusivity to **per contract**, we linked the exclusivity to **per invention,** since one license contract may contain more than one invention, and these inventions may be subject to different exclusivity terms.

In this regard, we believe that our exploratory research brings new insights to analyze licensing data. The results of this research reveal that the characteristics of the invention do not significantly affect the licensing strategy. In particular, as opposed to the theoretical predictions, embryonic inventions are not significantly linked to more exclusive licenses, and generic inventions are not significantly linked to non-exclusive licenses. Furthermore, inventions that are both generic and embryonic are not significantly linked to exclusive licenses per field of use. Finally, in line with our theoretical predictions, the more appropriable the technology (i.e. imitation is difficult or costly), the less likely it is to be globally exclusively licensed, but this relation does not hold for the exclusive per field of use licenses. Yet, due to our small sample size, our conclusions might not generalize, and larger-scale analyses are therefore needed.

Both Chapter 2 and 3 excluded the open source licensing strategy (OSL) and concentrated on the traditional licensing strategies, since OSL is a specific form of licensing, and is still rare in the case of patents. Furthermore, Chapter 2 considered a static setting, assuming that the innovations do not progress sequentially. Thus, in **Chapter 4**, we focused on the case of university OSL beyond software inventions (as exemplified by open source hardware, open source drug or open source nanotechnology) in a dynamic setting, where innovations are sequential. In this chapter, we discussed the possibility of introducing such a strategy to the university knowledge transfer context, and looked at the conditions under which this alternative strategy could replace traditional strategies. We argued that OSL is the least exclusive research valorization strategy, even when compared to publishing of research results, which is the common practice of the "Open Science" regime. The reason is that, when the inventions are sequential, putting knowledge into the public domain may result in the future appropriation of knowledge pieces. Therefore, in this chapter we discussed the specific role of patents in preserving the openness of open source innovations (OSI), when used in the form of a "legal jujitsu" (Benkler, 2006).

As opposed to the conventional view, that states that patents and open source are incompatible, we claim that patents may be necessary in order not to block the follow-on innovations in a cumulative setting, as long as the patent-holder does not use patents to exclude, through the analogy with "copyleft" licenses used for copyrighted free (libre) open source software (FOSS) (Pénin and Wack, 2008). In fact, a legal pillar (be it a copyright for software or patent for inventions) is one of the important characteristics defining the open source mode of innovations, along with a bazaar mode of organization and free (libre) release of the source code (Raymond, 1999).

Our discussions throughout the Chapter 2, 3 and 4 aimed at analyzing the ways to improve the university licensing strategies, yet licensing is not the only channel through which universities can interact with the industry (D'Este and Patel, 2007; Bekkers and Bodas Freitas, 2008; Perkmann *et al.*, 2013). Therefore, in **Chapter 5**, we broaden our perspective by studying various other channels of interactions. In this chapter, we showed how formal and informal channels are articulated over time. For this, we relied on a longitudinal and qualitative interview data analysis, allowing us to observe the notable research and valorization trajectories of two reputable researchers in the fields of robotics and pharmaceuticals at the University of Strasbourg. The main findings of this research are: (1) formal and informal channels interact in a dynamic way and are complementary (2) such interactions contribute to creating a strong cumulative effect with regard to the valorization activity, both at the individual and team level (3) the interplay between these channels also reinforces the collective dimension of valorization, which is performed by teams rather than isolated individuals (4) the best academic entrepreneurs exploit the different UIKT channels in an entrepreneurial way with a clear long-run valorization strategy in mind.

Contributions of the thesis

This thesis contributes both to the theoretical and empirical literature on UIIs, by examining the social impact of the licensing practices of university TTOs, and by extending our understanding of how various formal and informal channels of transfer interact over time, by going beyond the licensing. We can identify at least five contributions of our study.

First of all, our research contributes to the literature by examining the content of university licensing contracts, which is a rarely tackled issue in the literature. In fact, accessing the licensing contracts is a challenging task due to the confidential information they contain. Furthermore, a detailed analysis of the content of contracts requires a legal expertise in the field, which calls for a multidisciplinary research collaboration. The few existing studies concentrated mostly on the content of inter-firm licensing contracts (e.g. Bessy and Brousseau, 1998; Anand and Khanna, 2000; Somaya *et al.*, 2011). However, in contrast to firms, public universities are non-profit organizations aiming at generating and disseminating the scientific knowledge. Given their public mission, university licensing contracts should be designed carefully in order to ensure that the university knowledge will be disseminated widely, while preserving the incentives for the further development of the university technology. To this end, we specifically focused on the exclusivity clause of the licensing contracts. In this regard, our study differs from the literature focusing on the payment scheme of university licensing contracts (e.g. Jensen and Thursby, 2001; Dechenaux *et al.*, 2009; 2011). We discuss how the degree of exclusivity can be adjusted according to different context. Following Pénin (2010a), we identify various determinants that should enter into the licensing decision of universities (i.e. nature of invention, technological regime, competition regime, type of the licensee firm). Then, among these determinants, we focus on the nature of the invention (i.e. stage of development and specificity) in determining the degree of exclusivity, and discuss the social impact of the choice of exclusivity (in Chapter1).

This brings us to the second contribution of this thesis. To the best of our knowledge, we provide for the first time an empirical (yet exploratory) investigation concerning the link between the degree of exclusivity and the characteristics of the invention (in Chapter 3). In particular, we examine the effects of the stage of development (embryonic versus mature), specificity (generic versus specific) and appropriability (appropriable versus non-appropriable) on the degree of exclusivity (i.e. global exclusive, exclusive per field of use, non-exclusive).

Third, our empirical study also contributes to the literature by constructing a unique and original dataset that combines the data from the codification of university licensing contracts and the inventor survey. Although small in size, this rich dataset allows us to analyze the relation between exclusivity and various invention characteristics. Furthermore, contrary to the studies linking exclusivity per contract, we link the exclusivity per invention, since the licensing contracts may contain inventions that are subject to different exclusivity terms. We believe that this methodological approach may bring new insights for future studies.

Fourth, we open a discussion concerning university OSL, and investigate in which context this licensing strategy could be relevant (in Chapter 4). We discuss the issue of OSL beyond software, by emphasizing the specific use of patents in making the openness “sticky”. Although, patent-based OSL is not a current practice of universities (to the best of our knowledge), our study brings new insights to the literature by discussing the possibilities beyond the traditional licensing strategies.

Finally, our research contributes to the literature by broadening the analysis regarding the dynamic interactions and complementarities among different knowledge transfer mechanisms (in Chapter 5). In particular, as distinct from the literature focusing on cross-section analysis and pairwise relationship between UIKT channels (e.g. Czarnitzki *et al.*, 2007; Azoulay *et al.*, 2009; Grimpe and Hussinger, 2013), we focus on the temporal dimension, and consider the interplay among different UIKT channels, which allows us to observe the complexity of interactions. Moreover, our study contributes to the literature by combining two different approaches regarding the formal and informal transfer channels, and, hence, by providing a unified taxonomy based on the existence of a contractual relation and face-to-face interactions.

Managerial and policy implications

Our research has several implications for practitioners and policy makers. First and foremost, our study reveals some possible source of inefficiency when TTOs systematically rely on exclusive licenses, regardless of the invention characteristics. A possible explanation could be the lack of skills and industrial experience of the TTOs’ staff, which might hinder the design of an optimal licensing contract. The difficulty of assessing the specific properties of the technology may also obstruct the optimal design. This certainly requires TTOs’ staff to establish closer ties with the inventors throughout the technology transfer process, since the inventors have unique and valuable information regarding the characteristics of their technologies.

Another explanation could be that university TTOs lack bargaining power while negotiating the exclusivity clause. Firms always prefer exclusivity, since it gives them a monopoly power over the exploitation of inventions. Therefore TTO managers should develop strategies to increase their bargaining power so that the inventions can be widely diffused. To increase their bargaining power, TTOs should reduce the uncertainty associated with university inventions, by, for instance, investing in the maturation of early stage inventions (as in the case of SATT Conectus). However, bargaining power is also related to the quality of the technology, which requires universities to increase their reputation through cutting-edge research. Moreover, developing alternative solutions, such as OSL mechanisms under specified conditions, might promote collaborative improvements and trust, which could hence facilitate the wide diffusion of university technology.

Also, decreasing the government budget to university research may induce universities to "sell" their technologies to the highest bidders with exclusive terms, and this may be detrimental to the social welfare in the long run. Therefore, our research insists on the importance of public funding for university research.

Furthermore, we also emphasize that TTOs' missions should be wider than managing universities' IP portfolio. TTO managers should recognize the variety of channels and contribute to foster the interactions between different actors of UIIs. This also calls for policy makers to consider different channels, and hence different measures, when evaluating academic research valorization activities, since the evaluations are mostly narrowly based on performance metrics such as the number of patents, licensing contracts, start-ups and amount of royalties. Last but not least, TTOs should not only focus on reducing the barriers related to the transaction costs, but should also take more measures in order to smooth the cultural barriers preventing the knowledge transfer between university and industry.

Avenues for future research

Our study brings nuance to the discussions of technology transfer, and shows that university licensing might be suboptimal. We have emphasized the public mission of universities, and hence highlighted the point that the university licensing process should be managed so as to maximize social welfare. To that end, we investigated the possible sources of inefficiency, by focusing on the relation between exclusivity and technology-level characteristics. Yet, there remain multiple dimensions to be explored in order to understand the ways to improve the university licensing practices or, more globally, the UIIs.

Our study has some limitations, which in turn suggest some promising lines for future research. The first limitation is that we consider that the exclusivity decision is taken by university TTOs, while in practice, it is the outcome of a negotiation process. Our model in **Chapter 2** makes some simplistic assumptions. For instance, we consider the royalty rate as exogenous, while this rate is also subject to negotiation. Also, we do not consider the issue of asymmetric information. Further research should relax these assumptions. We also depict a rather linear view of technology transfer, while the transfer activity is non-linear, as knowledge flows in both directions. Moreover, we study a static setting where we assume that innovations are not sequential, while modeling a sequential setting could be an interesting research avenue. It could also be interesting to model the effects of variables other than the nature of the invention, as, for instance, the impact of markets with different sizes.

A substantial limitation that we encounter in **Chapter 3** is the small sample size, despite the originality and richness of the dataset. This prevents us from generalizing the results of our research. Therefore, our exploratory research calls for a larger scale analysis. An interesting line of research could be to examine the exclusivity scheme under different ownership structures, for instance, when the inventions are co-patented with the industry. One can also enrich the dataset by adding different characteristics of the technology, such as, for instance, the complexity or the existence of network externalities. Last but not least, further empirical research should expand the variables defining firm-level characteristics, and institutional-level characteristics which could be important determinants of exclusivity.

An obvious limitation of **Chapter 4** is that, to the best of our knowledge, OSL beyond software is not currently practiced by university TTOs, which implies that we cannot empirically validate our propositions. However, further research should extend theoretical models beyond software inventions and compare traditional and OSL strategies in the case of sequential inventions.

Finally, one of the limitations of **Chapter 5** is that, although the research based on a small number of cases allows a more in-depth analysis, it prevents us from generalizing the findings of our study. We examined cases only in the fields of robotics and pharmaceuticals. Although these cases represent a high degree of internal validity, the results cannot be generalized to all domains. Therefore, future research should carry the analysis to different scientific fields to observe the different patterns of interaction. Moreover, our qualitative approach needs to be complemented with a quantitative study, to validate, for instance, whether the transfer activity exhibits complementarity, cumulative effects or whether the research valorization is an outcome of a collective process.

Bibliography

Abreu, M., & Grinevich, V. (2013). The nature of academic entrepreneurship in the UK: Widening the focus on entrepreneurial activities. *Research Policy*, *42*(2), 408-422.

Acemoglu, D. (1997). Training and innovation in an imperfect labour market. *The Review of Economic Studies*, *64*(3), 445-464.

Aghion, P., & Howitt P. (1998). *Endogenous growth theory*, Cambridge, MA: MIT Press.

Agrawal, A. (2006). Engaging the inventor: Exploring licensing strategies for university inventions and the role of latent knowledge. *Strategic Management Journal, 27*(1), 63–79.

Agrawal, A. K. (2001). University-to-industry knowledge transfer: Literature review and unanswered questions. *International Journal of Management Reviews, 3*(4), 285–302.

Agrawal, A., & Henderson, R. (2002). Putting patents in context: Exploring knowledge transfer from MIT. *Management Science, 48*(1), 44–60.

Alexander, A. T., & Martin, D. P. (2013). Intermediaries for open innovation: A competence-based comparison of knowledge transfer offices practices. *Technological Forecasting and Social Change*, *80*(1), 38-49.

Algieri, B., Aquino, A., & Succurro, M. (2013). Technology transfer offices and academic spin-off creation: the case of Italy. *The Journal of Technology Transfer*, *38*(4), 382-400.

Allen, R. C. (1983). Collective invention. *Journal of Economic Behavior & Organization*, *4*(1), 1-24.

Amesse, F., & Cohendet, P. (2001). Technology transfer revisited from the perspective of the knowledgebased economy. *Research Policy, 30,* 1459–1478.

Amir, R., Encaoua, D., & Lefouili, Y. (2014). Optimal licensing of uncertain patents in the shadow of litigation. *Games and Economic Behavior*, *88*, 320-338.

Anand, B. N., & Khanna, T. (2000). The structure of licensing contracts. *The Journal of Industrial Economics*, *48*(1), 103-135.

Ankrah, S., & Al-Tabbaa, O., (2015). Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management*, *31*(3), 387-408.

Arora, A. (1995). Licensing tacit knowledge: intellectual property rights and the market for know-how. *Economics of Innovation and New Technology*, *4*(1), 41-60.

Arrow, K. J. (1962). Economic welfare and the allocation of resources of invention. In R.R. Nelson (Ed.), *The rate and direction of inventive activity: Economics and social factors*. (pp. 609-625). Princeton: Princeton University Press.

Arvanitis, S., Kubli, U., & Woerter, M. (2008). University-industry knowledge and technology transfer in Switzerland: What university scientists think about co-operation with private enterprises. *Research Policy, 37*(10), 1865–1883.

Audretsch, D. B., & Göktepe-Hultén, D. (2015). University patenting in Europe. In A.N. Link, D. Siegel & M. Wright (Eds.), *The Chicago handbook of university technology transfer and academic entrepreneurship* (pp. 188-217). Chicago: University of Chicago Press.

Aulakh, P. S., Jiang, M. S., & Pan, Y. (2010). International technology licensing: Monopoly rents, transaction costs and exclusive rights. *Journal of International Business Studies*, *41*(4), 587-605.

Azagra-Caro, J. (2010). Do public research organisations own most patents invented by their staff? *Science and Public Policy, 38* (3), 237–250.

Azagra-Caro, J. M., Barberá-Tomás, D., Edwards-Schachter, M., & Tur, E. M. (2017). Dynamic interactions between university-industry knowledge transfer channels: A case study of the most highly cited academic patent. *Research Policy, 46*(2), 463–474.

Azagra-Caro, J. M., Carayol, N., & Llerena, P. (2006). Patent production at a European research university: Exploratory evidence at the laboratory level. *The Journal of Technology Transfer*, *31*(2), 257-268.

Azoulay, P., Ding, W., & Stuart, T. (2009). The impact of academic patenting on the rate, quality and direction of (public) research output. *The Journal of Industrial Economics, 57*(4), 637–676.

Bach, L., & Llerena, P. (2007). Indicators of higher-education institutes and public-research organizations technology transfer activities: insights from France. *Science and Public Policy*, *34*(10), 709-721.

Balconi, M., Brusoni, S., & Orsenigo, L. (2010). In defence of the linear model: An essay. *Research Policy*, *39*(1), 1-13.

Baldini, N. (2006). University patenting and licensing activity: A review of the literature. *Research Evaluation*, *15*(3), 197-207.

Battistella, C., De Toni, A. F., & Pillon, R. (2016). Inter-organisational technology/knowledge transfer: A framework from critical literature review. *The Journal of Technology Transfer, 41*(5), 1195–1234.

Bekkers, R., & Bodas Freitas, I. M. (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy*, *37*(10), 1837-1853.

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., & Veugelers, R. (2004). Heterogeneity in R&D cooperation strategies. *International Journal of Industrial Organization*, *22*(8-9), 1237-1263.

Belleflame, P., & Peitz, M. (2010). *Industrial Organization: Markets and Strategies*. Cambridge: Cambridge University Press.

Benassi, M., Landoni, M., & Rentocchini, F. (2017). *University management practices and academic spin-offs* (Working Paper No. 2017-11). University of Milan.

Benkler, Y., (2006). *The wealth of networks: How social production transforms*. New Haven, CT: Yale University Press.

Bercovitz, J., Feldman, M., Feller, I., & Burton, R. (2001). Organizational structure as a determinant of academic patent and licensing behavior: An exploratory study of Duke, Johns Hopkins, and Pennsylvania State Universities. *The Journal of Technology Transfer*, *26*(1-2), 21-35.

Bessen, J. E. (2006). Open source software: Free provision of complex public goods. In J. Bitzer, J. & P. J. H. Schroder (Eds.), *The economics of open source software development* (pp. 57-81). Amsterdam: Elsevier.

Bessen, J., & Hunt, R. M. (2007). An empirical look at software patents. *Journal of Economics & Management Strategy*, *16*(1), 157-189.

Bessen, J., & Maskin, E. (2009). Sequential innovation, patents, and imitation. *The RAND Journal of Economics*, *40*(4), 611-635.

Bessy, C., & Brousseau, E. (1997). Brevet, protection et diffusion des connaissances: une relecture néoinstitutionnelle des propriétés de la règle de droit. *Revue d'Economie Industrielle, 79*(1), 233–254.

Bessy, C., & Brousseau, E. (1998). Technology licensing contracts features and diversity. *International Review of Law and Economics*, *18*(4), 451-489.

Bessy, C., Brousseau, E., & Saussier, S. (2002). The diversity of technology licensing agreements. Unpublished manuscript, Université de Paris 1.

Bessy, C., Brousseau, E., & Saussier, S. (2008). Payment schemes in technology licensing agreements: a transaction cost approach. Unpublished working paper.

Bessy, C., Brousseau, E., & Saussier, S. (2010). Hazards in transferring knowledge and contractual architecture: The case of payment schemes in technology licensing agreements. Unpublished manuscript. IDHE, CNRS, France. Retrieved from https://www.webssa.net/files/Bessy-Brousseau-Saussier-30_01_10.pdf

Bjerregaard, T. (2010). Industry and academia in convergence: Micro-institutional dimensions of R&D collaboration. *Technovation*, *30*(2), 100-108.

Black, G. C., & Stephan, P. E. (2010). The economics of university science and the role of foreign graduate students and postdoctoral scholars. In C. T. Clotfelter (Ed.), *American universities in a global market* (pp. 129–161). Chicago: University of Chicago Press.

Blumenthal, D., Campbell, E. G., Anderson, M. S., Causino, N., & Louis, K. S. (1997). Withholding research results in academic life science: Evidence from a national survey of faculty. *Jama*, *277*(15), 1224-1228.

Boardman, C., & Gray, D. (2010). The new science and engineering management: cooperative research centers as government policies, industry strategies, and organizations. *The Journal of Technology Transfer*, *35*(5), 445-459.

Boardman, P. C., & Ponomariov, B. L. (2009). University researchers working with private companies. *Technovation, 29*(2), 142–153.

Bodas Freitas, I. M., & Verspagen, B. (2017). The motivations, institutions and organization of university-industry collaborations in the Netherlands. *Journal of Evolutionary Economics, 27*(3), 379-412.

Bodas Freitas, I. M., Geuna, A., & Rossi, F. (2013). Finding the right partners: Institutional and personal modes of governance of university–industry interactions. *Research Policy*, *42*(1), 50-62.

Boettiger, S., & Burk, D. L. (2004). Open source patenting. *Journal of International Biotechnology Law*, *1*(6), 221-231.

Boh, W. F., De-Haan, U., & Strom, R. (2016). University technology transfer through entrepreneurship: Faculty and students in spinoffs. *The Journal of Technology Transfer, 41*(4), 661–669.

Bonaccorsi, A., & Piccaluga, A. (1994). A theoretical framework for the evaluation of university–industry relationships. *R & D Management, 24*, 229–247.

Bonaccorsi, A., & Rossi, C. (2004). Altruistic individuals, selfish firms? The structure of motivation in Open Source software. *First Monday*, 9(1). Retrieved from http://firstmonday.org/ojs/index.php/fm/article/view/1113/1033

Bonaccorsi, A., & Rossi, C. (2003a). Why open source software can succeed. *Research Policy*, *32*(7), 1243-1258.

Bonnacorsi, A. & C. Rossi, (2003b), Licensing schemes in the production and distribution of open source software: an empirical investigation, Sant' Ana School for Advanced Studies Institute for Informatics and Telematics, *Mimeo*.

Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Research Policy*, *29*(4-5), 627-655.

Bozeman, B., Fay, D., & Slade, C. P. (2013). Research collaboration in universities and academic entrepreneurship: The-state-of-the-art. *Journal of Technology Transfer*, *38*(1), 1-67.

Bozeman, B., Rimes, H., & Youtie, J. (2015). The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy, 44*(1), 34–49.

Bradley, S. R., Hayter, C. S., & Link, A. (2013). Models and methods of university technology transfer. *Foundations and Trends in Entrepreneurship, 9*(6), 571–650.

Bray, M. J., & Lee, J. N. (2000). University revenues from technology transfer: Licensing fees vs. equity positions. *Journal of Business Venturing*, *15*(5-6), 385-392.

Breschi, S., Lissoni, F., & Montobbio, F. (2005). From publishing to patenting: Do productive scientists turn into academic inventors? *Revue d'Economie Industrielle*, *110*(1), 75-102.

Bruneel, J., D'Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university–industry collaboration. *Research policy*, *39*(7), 858-868.

Buenstorf, G. (2009). Is commercialization good or bad for science? Individual-level evidence from the Max Planck Society. *Research Policy, 38,* 281–292.

Bush, V. (1945). Science the endless frontier: A report to the president on a program for postwar scientific research. Washington, D.C.: U.S. Government Printing Office.

Caldera, A., & Debande, O. (2010). Performance of Spanish universities in technology transfer: An empirical analysis. *Research Policy*, *39*(9), 1160-1173.

Calderini, M., Franzoni, C., & Vezzulli, A. (2009). The unequal benefits of academic patenting for science and engineering research. *IEEE Transactions on Engineering Management, 56*(1), 16–30.

Cameron, D. M. (2010). Licensing. In *Cameron's Canadian Patent and Trade Secrets Law*. Retrieved from http://www.jurisdiction.com/patweb13.pdf.

Campbell, E. G., Clarridge, B. R., Gokhale, M., Birenbaum, L., Hilgartner, S., Holtzman, N. A., & Blumenthal, D. (2002). Data withholding in academic genetics: Evidence from a national survey. *Jama*, *287*(4), 473-480.

Carayol, N. (2006). La production de brevets par les chercheurs et enseignants-chercheurs. *Economie & Prévision*, (4), 117-134.

Carayol, N. (2007). Academic incentives, research organization and patenting at a large French university. *Economics of Innovation and New Technology*, *16*(2), 119-138.

Carayol, N., & Matt, M. (2004). Does research organization influence academic production? Laboratory evidence from a large European university. *Research Policy, 33*(8), 1081–1102.

Cassier, M., & Sinding, C. (2008). 'Patenting in the public interest:' Administration of insulin patents by the University of Toronto. *History and Technology*, *24*(2), 153-171.

Cebrián, M. (2009). The structure of payments as a way to alleviate contractual hazards in international technology licensing. *Industrial and Corporate Change*, *18*(6), 1135-1160.

Cesaroni, F., & Piccaluga, A. (2002, March). *Patenting Activity of European Universities. Relevant? Growing? Useful?*. Paper presented at the SPRU NPRnet Conference 'Rethinking Science Policy: Analytical Frameworks for Evidence-Based Policy', Brighton, UK. Retrieved from https://www.researchgate.net/profile/Fabrizio_Cesaroni/publication/228805999_Patenting_Activity_of_European_Universities_Relevant_Growing_Useful/links/0fcfd51127c4ac96fc000000/Patenting-Activity-of-European-Universities-Relevant-Growing-Useful.pdf

Chesbrough, H. (2006). Open innovation: A new paradigm for understanding industrial innovation. In H. Chesbrough, W. Vanhaverbeke, and J. West (Eds.) *Open innovation: Researching a new paradigm*, (pp. 1-12). New York: Oxford University Press.

Chesbrough, H. (2012). Open innovation: Where we've been and where we're going. *Research-Technology Management*, *55*(4), 20-27.

Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*. Cambridge, MA: Harvard Business School Press.

Clarysse, B., Valentina, T., & Salter, A. (2011). The impact of entrepreneurial capacity, experience and organizational support on academic entrepreneurship. *Research Policy, 40,* 1084–1093.

Coase, R., 1937. The nature of the firm. *Economica*, *4*(16), 386–405.

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R & D. *The Economic Journal*, *99*(397), 569-596.

Cohen, W. M., Florida, R., Randazzese, L., & Walsh, J. (1998). Industry and the academy: Uneasy partners in the cause of technological advance. *Challenges to Research Universities, 171*(200), 59.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2000). *Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not)* (NBER Working Paper No. w7552). National Bureau of Economic Research.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science*, *48*(1), 1-23.

Cohendet, P., Farcot, M., & Pénin, J. (2009). *Intellectual property in a knowledge-based economy: Patents to include vs. patents to exclude* (BETA Working Paper No. 2009-15). Bureau d'Economie Théorique et Appliquée, University of Strasbourg.

Colombo, M. G., D'Adda, D., & Piva, E. (2010). The contribution of university research to the growth of academic start-ups: An empirical analysis. *The Journal of Technology Transfer, 35*(1), 113–140.

Colombo, M., & Grilli, L. (2005). 'Founders' human capital and the growth of new technology-based firms: A competence-based view. *Research Policy, 34,* 795–816.

Colyvas, J. A., & Powell, W. W. (2006). Roads to institutionalization: The remaking of boundaries between public and private science. *Research in Organizational Behavior, 27,* 305–353.

Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R. R., Rosenberg, N., & Sampat, B. N. (2002). How do university inventions get into practice? *Management Science*, *48*(1), 61-72.

Comacchio, A., Bonesso, S., & Pizzi, C. (2012). Boundary spanning between industry and university: the role of Technology Transfer Centres. *The Journal of Technology Transfer*, *37*(6), 943-966.

Comino, S., Manenti, F. M., & Parisi, M. L. (2007). From planning to mature: On the success of open source projects. *Research Policy*, *36*(10), 1575-1586.

Conti, A., & Gaule, P. (2011). Is the US outperforming Europe in university technology licensing? A new perspective on the European Paradox. *Research Policy*, *40*(1), 123-135.

Conti, A., Gaulé, P., & Foray, D. (2007). *Academic licensing: A European study*. (CEMI Working paper No. 2007—01).

Corolleur F., Matt M., & Pénin J. (2018). Everything you ever wanted to know about university-industry licensing contracts. An empirical investigation of the case of two French scientific universities, *Mimeo.*

Crespi, G., D'Este, P., Fontana, R., & Geuna, A. (2011). The impact of academic patenting on university research and its transfer. *Research Policy*, *40*(1), 55-68.

Cunningham, J. A., Menter, M., & Young, C. (2017). A review of qualitative case methods trends and themes used in technology transfer research. *The Journal of Technology Transfer*, *42*(4), 923-956.

Curi, C., Daraio, C., & Llerena, P. (2012). University technology transfer: How (in) efficient are French universities? *Cambridge Journal of Economics*, *36*(3), 629-654.

Czarnitzki, D., Glänzel, W., & Hussinger, K. (2007). Patent and publication activities of German professors: An empirical assessment of their co-activity. *Research Evaluation, 16*(4), 311–319.

Dahlborg, C., Lewensohn, D., Danell, R., & Sundberg, C. J. (2017). To invent and let others innovate: A framework of academic patent transfer modes. *The Journal of Technology Transfer, 42*(3), 538–563.

Dalle, J. M., & Rousseau, G. (2004, May). Toward collaborative open-source technology transfer. Paper presented at the 4th Workshop on Open Source Software Engineering.

Dalle, J. M., David, P. A., Ghosh, R.A. & Steinmueller, W. E. (2005). Advancing Economic Research on the Free and Open Source Software Mode of Production. In M. Wynants & J. Cornelis. (Eds.), *Building Our Digital Future: Future Economic, Social, & Cultural Scenarios Based on Open Standards* (pp. 395-428). Brussels: VUB Press, Brussels.

Dasgupta, P., & David, P. A. (1994). Toward a new economics of science. *Research Policy*, *23*(5), 487-521.

David, P. (2005). From keeping ‘nature's secrets’ to the institutionalization of ‘open science’. In R. Ghosh (Ed.), *CODE: Collaborative ownership and the digital economy* (pp. 85–108). Cambridge, MA: MIT Press.

David, P. A. (2006, September). *Using IPR to expand the research common for Science: New moves in ‘legal jujitsu’.* Paper presented at the Conference on Intellectual Property Rights for Business and Society, London, UK. Retrieved from http://www.dime-eu.org/files/active/0/david.pdf

Debackere, K., & Veugelers, R. (2005). The role of academic technology transfer organizations in improving industry science links. *Research Policy*, *34*(3), 321-342.

Dechenaux, E., Thursby, J., & Thursby, M. (2011). Inventor moral hazard in university licensing: The role of contracts. *Research Policy*, *40*(1), 94-104.

Dechenaux, E., Thursby, M., & Thursby, J. (2009). Shirking, sharing risk and shelving: The role of university license contracts. *International Journal of Industrial Organization*, *27*(1), 80-91.

Delanghe, H., Muldur, U., & Soete, L. (Eds.). (2011). *European science and technology policy: towards integration or fragmentation?*. Cheltenham, UK: Edward Elgar Publishing.

Della Malva, A., Lissoni, F., & Llerena, P. (2013). Institutional change and academic patenting: French universities and the Innovation Act of 1999. *Journal of Evolutionary Economics*, *23*(1), 211-239.

D’Este, P., & Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, *36*(9), 1295-1313.

D’Este, P., & Perkmann, M. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. The *Journal of Technology Transfer*, *36*(3), 316-339.

D'Este, P., Guy, F., & Iammarino, S. (2012). Shaping the formation of university–industry research collaborations: What type of proximity does really matter? *Journal of Economic Geography*, *13*(4), 537-558.

Dosi, G., Llerena, P., & Labini, M. S. (2006). The relationships between science, technologies and their industrial exploitation: An illustration through the myths and realities of the so-called 'European Paradox'. *Research Policy*, *35*(10), 1450-1464.

Drivas, K., Lei, Z., & Wright, B. D. (2017). Academic patent licenses: Roadblocks or signposts for nonlicensee cumulative innovation? *Journal of Economic Behavior & Organization*, *137*, 282-303.

Dyer, J. H., & Singh, H. (1998). The relational view: Cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review, 23*(4), 660–679.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532–550.

Etzkowitz, H. (1998). The norms of entrepreneurial science: Cognitive effects of the new university–industry linkages. *Research Policy*, *27*(8), 823-833.

Etzkowitz, H., & Göktepe-Hultén, D. (2010). Maybe they can? University technology transfer offices as regional growth engines. *International Journal of Technology Transfer and Commercialisation*, *9*(1-2), 166-181.

Etzkowitz, H., & Leydesdorff, L. (1995). The Triple Helix—university-industry-government relations: A laboratory for knowledge based economic development. *EASST Review*, *14*(1), 14-19.

Etzkowitz, H., & Leydesdorff, L. (1999).The future location of research and technology transfer. *Journal of Technology Transfer*, *24*(2-3), 111-123.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy*, *29*(2), 109-123.

Etzkowitz, H., Webster, A., Gebhardt, C., & Terra, B. R. C. (2000). The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. *Research Policy*, *29*(2), 313-330.

Faulkner, W., & Senker, J. (1994). Making sense of diversity: Public–private sector research linkage in three technologies. *Research Policy, 23*(6), 673–695.

Feldman, M., Colaianni, A., & Liu, K. (2005). Commercializing Cohen–Boyer 1980–1997. (DRUID Working Paper 05-21). Copenhagen Business School.

Feldman, M., Feller, I., Bercovitz, J., & Burton, R. (2002). Equity and the technology transfer strategies of American research universities. *Management Science*, *48*(1), 105-121.

Feldman, M.P., Colaianni, A., Kang, L. (2007). Lessons from the commercialization of the Cohen-Boyer patents: The Stanford University licensing program. In A. Krattiger, R. T. Mahoney, L. Nelsen, *et al.* (Eds.), *Intellectual property management in health and agricultural innovation: A handbook of best practices* (pp. 1797-1807). MIHR: Oxford, UK, and PIPRA: Davis, USA. Retrieved from http://www.iphandbook.org/handbook/ch17/p22/

Fosfuri, A., & Roca, E. (2004). Optimal licensing strategy: Royalty or fixed fee? *International Journal of Business and Economics*, *3*(1), 13.

Franzoni, C., & Scellato, G. (2007, September). *Paper in the drawer. Estimating the determinants of the patent-publication lags in Europe and the USA*. Paper presented at the second conference European Policy for Intellectual Property (*EPIP), Lund*, Sweden. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.461.6361&rep=rep1&type=pdf

Franzoni, C., Lissoni, F. (2009). Academic entrepreneurs: Critical issues and lessons for Europe. In A. Varga (Ed.), *Universities, knowledge transfer and regional development: Geopgraphy, entrepreneurship and policy* (pp. 163-190). Cheltenham, UK: Edward Elgar.

Freeman, C. (1982). *The economics of industrial innovation*. London : Francis Pinter.

Freeman, C. (1987). *National systems of innovation: The case of Japan technology policy and economics performance: Lessons from Japan*. London: Francis Pinter.

Freeman, C. (1996). The greening of technology and models of innovation, *Technological Forecasting and Social Change*, *53*, 27-39.

Galasso, A., & Schankerman, M. (2010). Patent thickets, courts, and the market for innovation. *The RAND Journal of Economics*, *41*(3), 472-503.

Galasso, A., & Schankerman, M. (2014). Patents and cumulative innovation: Causal evidence from the courts. *The Quarterly Journal of Economics*, *130*(1), 317-369.

Gambardella, A., & Giarratana, M. S. (2013). General technological capabilities, product market fragmentation, and markets for technology. *Research Policy*, *42*(2), 315-325.

Gambardella, A., & Hall, B. H. (2006). Proprietary versus public domain licensing of software and research products. *Research Policy*, *35*(6), 875-892.

Gambardella, A., Giuri, P., & Luzzi, A. (2007). The market for patents in Europe. *Research Policy*, *36*(8), 1163-1183.

Gerbin, A., & Drnovsek, M. (2016). Determinants and public policy implications of academic-industry knowledge transfer in life sciences: a review and a conceptual framework. *The Journal of Technology Transfer, 41*(5), 979–1076.

Geuna, A. (1999). *The economics of knowledge production: Funding and the structure of university research*. Cheltenham: Edward Elgar Publishing.

Geuna, A., & Muscio, A. (2009). The governance of university knowledge transfer: A critical review of the literature. *Minerva*, *47*(1), 93-114.

Geuna, A., & Nesta, L. J. (2006). University patenting and its effects on academic research: The emerging European evidence. *Research Policy*, *35*(6), 790-807.

Geuna, A., & Rossi, F. (2011). Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy*, *40*(8), 1068-1076.

Giannopoulou, E. (2016). *The role of Research and Technology Organizations (RTOs) in open service innovation: A dual perspective* (doctoral dissertation), University of Strasbourg, Strasbourg, France.

Giannopoulou, E., Barlatier, P. J., & Pénin, J. (2018). Same but different? Research and technology organizations, universities and the innovation activities of firms. *Research Policy*. https://doi.org/10.1016/j.respol.2018.08.008

Gibbons, M. (Ed.). (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London: Sage Publications.

Giles, J. (2005). Internet encyclopaedias go head to head. *Nature*, *438*(7070), 900-901.

Godin, B. (2006). The linear model of innovation: The historical construction of an analytical framework. *Science, Technology & Human Values*, *31*(6), 639-667.

Grant, R. M. (1996). Toward a knowledge- based theory of the firm. *Strategic Management Journal*, *17*(S2), 109-122.

Green, J. R., & Scotchmer, S. (1995). On the division of profit in sequential innovation. *The RAND Journal of Economics*, *26*(1) 20-33.

Grimaldi, R., & Grandi, A. (2005). Business incubators and new venture creation: an assessment of incubating models. *Technovation*, *25*(2), 111-121.

Grimpe, C., & Fier, H. (2010). Informal university technology transfer: a comparison between the United States and Germany. *The Journal of Technology Transfer*, *35*(6), 637-650.

Grimpe, C., & Hussinger, K. (2008). *Formal and informal technology transfer from academia to industry: Complementarity effects and innovation performance* (ZEW Discussion Paper No. 08-080). Center for European Economic Research.

Grimpe, C., & Hussinger, K. (2013). Formal and informal knowledge and technology transfer from academia to industry: Complementarity effects and innovation performance. *Industry and Innovation*, *20*(8), 683-700.

Grossman, G. H., & Helpman, E. (1991). *Innovation and growth in the global economy*. Cambridge: *MIT Press.*

Guadamuz-González, A. (2006). Open science: open source licenses in scientific research. *North Carolina Journal of Law & Technology, 7*(2), 321-366.

Gübeli, M. H., & Doloreux, D. (2005). An empirical study of university spin-off development. *European Journal of Innovation Management*, *8*(3), 269-282.

Hardin, G. (1968). The tragedy of the commons. *Science* , *162*(3859), 1243-1248.

Hartley, J. F. (1994). Case studies in organizational research. In C. Cassell & G. Symon (Eds.), *Qualitative methods in organizational research. A practical guide* (pp. 208–229). London: Sage Publications.

Hayter, C. S. (2013). Harnessing university entrepreneurship for economic growth: Factors of success among university spin-offs. *Economic Development Quarterly*, *27*(1), 18-28.

Hayter, C. S. (2016). A social responsibility view of the "patent-centric linear model" of university technology transfer. *Duquesne Law Review*, *54*, 7-52.

Hayter, C. S., & Link, A. N. (2015). On the economic impact of university proof of concept centers. *The Journal of Technology Transfer*, *40*(1), 178-183.

Hayter, C. S., Lubynsky, R., & Maroulis, S. (2017). Who is the academic entrepreneur? The role of graduate students in the development of university spinoffs. *The Journal of Technology Transfer, 42*(6), 1237–1254.

Heller, M. A., & Eisenberg, R. S. (1998). Can patents deter innovation? The anticommons in biomedical research. *Science*, *280*(5364), 698-701.

Henderson, R., Jaffe, A. B., & Trajtenberg, M. (1998). Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. *Review of Economics and Statistics*, *80*(1), 119-127.

Henkel, J. (2006). Selective revealing in open innovation processes: The case of embedded Linux. *Research Policy*, *35*(7), 953-969.

Ho, M. H. C., Liu, J. S., Lu, W. M., & Huang, C. C. (2014). A new perspective to explore the technology transfer efficiencies in US universities. *The Journal of Technology Transfer*, *39*(2), 247-275.

Hoskins, W., & Wiles, R. (1921). Promotion of scientific research. *Chemical and Metallurgical Engineering*, *24*, 689-691.

Hottenrott, H., & Lawson, C. (2017). Fishing for complementarities: Research grants and research productivity. *International Journal of Industrial Organization, 51,* 1–38.

Hottenrott, H., & Thorwarth, S. (2011). Industry funding of university research and scientific productivity. *Kyklos, 64*(4), 534–555.

Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy*, *35*(5), 715-728.

Huang, K. G., & Murray, F. E. (2009). Does patent strategy shape the long-run supply of public knowledge? Evidence from human genetics. *Academy of Management Journal, 52*(6), 1193–1221.

Huber, G. P. (1985). Temporal stability and response-order biases in participant descriptions of organizational decisions. *Academy of Management Journal, 28*(4), 943–950.

Iorio, R., Labory, S., & Rentocchini, F. (2017). The importance of pro-social behaviour for the breadth and depth of knowledge transfer activities: An analysis of Italian academic scientist. *Research Policy. 46*(2), 497-509.

Jacobsson, S., & Karltorp, K. (2013). Mechanisms blocking the dynamics of the European offshore wind energy innovation system–Challenges for policy intervention. *Energy Policy*, *6*3, 1182-1195.

Jaffe, A. B. (1986). Technological opportunity and spillovers of R&D: Evidence from firms' patents, profits, and market values. *American Economic Review,76*(5), 984-1001.

Jensen, R., & Thursby, M. (2001). Proofs and prototypes for sale: The licensing of university inventions. *American Economic Review*, *91*(1), 240-259.

Kamien, M. I., & Tauman, Y. (1986). Fees versus royalties and the private value of a patent. *The Quarterly Journal of Economics*, *101*(3), 471-491.

Katz, J. S., & Martin, B. R. (1997). What is research collaboration? *Research policy*, *26*(1), 1-18.

Katz, M. L., & Shapiro, C. (1985). On the licensing of innovations. *The RAND Journal of Economics*, 504-520.

Kim, Y., & Vonortas, N. S. (2006). Determinants of technology licensing: the case of licensors. *Managerial and Decision Economics*, *27*(4), 235-249.

King, N. (2004). Using interviews in qualitative research. In C. Cassell & G. Simon (Eds.), *Essential guide to qualitative methods in organizational research* (pp. 11–22). London: Sage Publications.

Kirchberger, M. A., & Pohl, L. (2016). Technology commercialization: A literature review of success factors and antecedents across different contexts. *The Journal of Technology Transfer, 41*(5), 1077–1112.

Kitch, E. W. (1977). The nature and function of the patent system. *The Journal of Law and Economics*, *20*(2), 265-290.

Kline, S. J. (1985). Innovation is not a linear process. *Research Management*, *28*(4), 36-45.

Kline, S. J., & Rosenberg, N., (1986). An overview of innovation. In R. Landau & N. Rosenberg (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275–306). Washington, DC: National Academy Press.

Knockaert, M., Spithoven, A., & Clarysse, B. (2014). The impact of technology intermediaries on firm cognitive capacity additionality. *Technological Forecasting and Social Change*, *81*, 376-387.

Kogut, B., & Metiu, A. (2000). *The emergence of e-Innovation: Insights from open source software development*. (Reginald H. Jones Center Working Paper). Wharton School, University of Pennsylvania, Philadelphia.

Kogut, B., & Metiu, A. (2001). Open source software development and distributed innovation. *Oxford Review of Economic Policy*, *17*(2), 248-264.

Kvale, S. (1983). The qualitative research interview: A phenomenological and a hermeneutical mode of understanding. *Journal of Phenomenological Psychology*, *14*(2), 171–196.

Lakhani, K. R., & Panetta, J. A. (2007). The principles of distributed innovation. *Innovations: Technology, Governance, Globalization*, *2*(3), 97-112.

Lakhani, K. R., & Von Hippel, E. (2003). How open source software works: “Free” user-to-user assistance. *Research Policy*, *32*(6), 923-943.

Lakhani, K., & Wolf, R. G. (2003). *Why hackers do what they do: Understanding motivation and effort in free/open source software projects*. (MIT Sloan Working Paper No. 4425-03). MIT Sloan School of Management.

Landry, R., Amara, N., & Ouimet, M. (2007). Determinants of knowledge transfer: Evidence from Canadian university researchers in natural sciences and engineering. The *Journal of Technology Transfer*, 32(6), 561–592

Landry, R., Saïhi, M., Amara, N., & Ouimet, M. (2010). Evidence on how academics manage their portfolio of knowledge transfer activities. *Research Policy, 39,* 1387–1403.

Lee, J. S., Park, J. H., & Bae, Z. T. (2017). The effects of licensing-in on innovative performance in different technological regimes. *Research Policy*, *46*(2), 485-496.

Lemley, M. A. (2008). Are universities patent trolls? *Fordham Intellectual Property, Media and Entertainment Law Journal*, *18*(3), 611-631.

Lenoir, T. (1998). Revolution from above: the role of the state in creating the German research system, 1810-1910. *American Economic Review*, *88*(2), 22-27.

Leonard-Barton, D. (1990). A dual methodology for case studies: Synergistic use of a longitudinal single site with replicated multiple sites. *Organization Science, 1*(3), 248–266.

Lerner, J., & Tirole, J. (2001). The open source movement: Key research questions. *European Economic Review*, *45*(4), 819-826.

Lerner, J., & Tirole, J. (2005). The economics of technology sharing: Open source and beyond. *Journal of Economic Perspectives*, *19*(2), 99-120.

Lerner, J., & Triole, J. (2000). *The simple economics of open source* (NBER Working Paper No. w7600). National Bureau of Economic Research.

Lessig, L. (2002). *The future of ideas: The fate of the commons in a connected world*. New York: Random House.

Levin, R. C., Klevorick, A. K., Nelson, R. R., Winter, S. G., Gilbert, R., & Griliches, Z. (1987). Appropriating the returns from industrial research and development. *Brookings Papers on Economic Activity*, *1987*(3), 783-831.

Liebeskind, J. P. (1999). Knowledge, strategy, and the theory of the firm.In M. H. Zack (Ed.), *Knowledge and strategy* (pp. 197-219). Boston: Butterworth-Heinemann

Link, A. N., Siegel, D. S., & Bozeman, B. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change*, *16*(4), 641-655.

Lipsey, R. G., Carlaw, K. I., & Bekar, C. T. (2005). *Economic transformations: General purpose technologies and long-term economic growth*. New York: Oxford University Press.

Lissoni, F., Llerena, P., McKelvey, M., & Sanditov, B. (2008). Academic patenting in Europe: New evidence from the KEINS database. *Research Evaluation*, *17*(2), 87-102.

Lockett, A., Siegel, D., Wright, M., & Ensley, M. D. (2005). The creation of spin-off firms at public research institutions: Managerial and policy implications. *Research Policy*, *34*(7), 981-993.

Louis, K. S., Jones, L. M., Anderson, M. S., Blumenthal, D., & Campbell, E. G. (2001). Entrepreneurship, secrecy, and productivity: A comparison of clinical and non-clinical life sciences faculty. *Journal of Technology Transfer*, *26*(3), 233-245.

Lounsbury, M., Kelty, C., Yavuz, C. T., & Colvin, V. L. (2009). Towards open source nano: Arsenic removal and alternative models of technology transfer. *Advances in the Study of Entrepreneurship, Innovation and Economic Growth*, *19*, 51-78.

Lucas Jr, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*(1), 3-42.

Lundvall, B. A. (1988). Innovation as an interactive process: from user-producer interaction to the national system of innovation. In G. Dosi, C., Freeman, R., Nelson, G. Silverberg & L. Soete, (Eds.), *Technical Change and Economic Theory (*pp. 349–369). London: Pinter

Macho-Stadler, I., Martinez-Giralt, X., & Perez-Castrillo, J. D. (1996). The role of information in licensing contract design. *Research Policy*, *25*(1), 43-57.

Macho-Stadler, I., Pérez-Castrillo, D., & Veugelers, R. (2007). Licensing of university inventions: The role of a technology transfer office. *International Journal of Industrial Organization*, *25*(3), 483-510.

MacNeil, I. R. (1980). *The new social contract: An inquiry into modern contractual relations*. New Haven and London: Yale University Press.

Mansfield, E. (1986). Patents and innovation: an empirical study. *Management Science*, *32*(2), 173-181.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy*, *20*(1), 1-12.

Mansfield, E. (1995). Academic research underlying industrial innovations: Sources, characteristics, and financing. *The Review of Economics and Statistics*, *77*(1), 55-65.

Markman, G. D., Gianiodis, P. T., & Phan, P. H. (2009). Supply side innovation and technology commercialization. *Journal of Management Studies*, *46*(4), 625-649.

Markman, G. D., Siegel, D. S., & Wright, M. (2008). Research and technology commercialization. *Journal of Management Studies*, *45*(8), 1401-1423.

Marsili, O. (2001). *The anatomy and evolution of industries: Technological change and industrial dynamics*. Cheltenham: Edward Elgar.

Matt, M. & Schaeffer, V. (2012). The cooperative strategy of technology transfer offices: A longitudinal study. In D. Audretsch, E. Lehmann, A. Link & A. Starnecker (Eds.), *Technology transfer in a global economy. International studies in entrepreneurship* (pp. 51-72). Boston: Springer.

Maurer, S. (2006). Other Business: Choosing the Right Investment Strategy for Tropical Disease Research. *Bulletin of the World Health Organization*, *84*, 376-381.

Maurer, S. M. (2003, November). *New institutions for doing science: From databases to open source biology*. Paper presented at European Policy for Intellectual Property Conference, Maastricht, Netherlands.

Maurer, S. M., & Scotchmer, S. (2006). *Open source software: the new intellectual property paradigm* (NBER Working Paper No. w12148). National Bureau of Economic Research.

Mazzoleni, R. (2006). The effects of university patenting and licensing on downstream R&D investment and social welfare. *The Journal of Technology Transfer*, *31*(4), 431-441.

Mazzoleni, R., & Sampat, B. N. (2002). University patenting: An assessment of the causes and consequences of recent changes in strategies and practices. *Revue d'Economie Industrielle*, *99*(1), 233-248.

Merrill, S. A., & Mazza, A. M. (Eds.) (2011). *Managing university intellectual property in the public interest.* National Research Council, Washington, D.C.: National Academy Press.

Merton, R. K. (1973). *The sociology of science: Theoretical and empirical investigations*. Chicago: The University of Chicago press.

Meyer-Krahmer, F., & Schmoch, U. (1998). Science-based technologies: University–industry interactions in four fields. *Research Policy, 27*(8), 835–851.

Meyer-Thurow, G. (1982). The industrialization of invention: a case study from the German chemical industry. *Isis*, *73*(3), 363-381.

Milgrom, P., & Roberts, J., (1995). Complementarities and fit strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics*, *19*, 179–208.

Minguillo, D., & Thelwall, M. (2015). Which are the best innovation support infrastructures for universities? Evidence from R&D output and commercial activities. *Scientometrics*, *102*(1), 1057-1081.

Mokyr, J. (2002). *The gifts of Athena: Historical origins of the knowledge economy*. Princeton: Princeton University Press.

Moray, N., & Clarysse, B. (2005). Institutional change and resource endowments to science-based entrepreneurial firms. *Research Policy, 34*(7), 1010–1027.

Mowery, D. C. (1997). The Bush Report after Fifty Years – Blueprint or Relic?. In C. E. Barfield (Ed.), *Science for the 21st Century: The Bush Report Revisited* (pp. 24-41), Washington, DC: AEI Press.

Mowery, D. C. & Rosenberg, N. (1993). The U.S. National Innovation System. In R. R. Nelson (Ed.), *National Systems of Innovation: A Comparative Analysis* (pp. 29-75). New York: Oxford University Press.

Mowery, D. C., & Sampat, B. N. (2004). The Bayh-Dole Act of 1980 and university–industry technology transfer: A model for other OECD governments? *The Journal of Technology Transfer*, *30*(1-2), 115-127.

Mowery, D. C., & Shane, S. (2002). Introduction to the special issue on university entrepreneurship and technology transfer. *Management Science*, *48*(1), v-ix.

Mowery, D. C., & Ziedonis, A. A. (2002). Academic patent quality and quantity before and after the Bayh Dole act in the United States. *Research Policy*, *31*(3), 399-418.

Mowery, D. C., & Ziedonis, A. A. (2007). Academic patents and materials transfer agreements: Substitutes or complements? *The Journal of Technology Transfer*, *32*(3), 157-172.

Mowery, D. C., & Ziedonis, A. A. (2015). Markets versus spillovers in outflows of university research. *Research Policy*, *44*(1), 50-66.

Mowery, D. C., Nelson, R. R., Sampat, B. N., & Ziedonis, A. A. (2001). The growth of patenting and licensing by US universities: An assessment of the effects of the Bayh–Dole Act of 1980. *Research Policy*, *30*(1), 99-119.

Mowery, D. C., Nelson, R. R., Sampat, B. N., & Ziedonis, A. A. (2004). *Ivory tower and industrial innovation: University-industry technology transfer before and after the Bayh-Dole Act*. Stanford, CA: Stanford University Press.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. (1996). Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal*, *17*(S2), 77-91.

Mowery, D.C., & Nelson, R.R. (1999). *Sources of Industrial Leadership*. Cambridge: Cambridge University Press.

Murray, F. (2010). The oncomouse that roared: Hybrid exchange strategies as a source of distinction at the boundary of overlapping institutions. *American Journal of Sociology*, *116*(2), 341-388.

Murray, F., & Stern, S. (2006). When ideas are not free: The impact of patents on scientific research. *Innovation policy and the economy*, *7*, 33-69.

Murray, F., & Stern, S. (2007). Do formal intellectual property rights hinder the free flow of scientific knowledge?: An empirical test of the anti-commons hypothesis. *Journal of Economic Behavior & Organization*, *63*(4), 648-687.

Murray, F., Aghion, P., Dewatripont, M., Kolev, J., & Stern, S. (2016). Of mice and academics: Examining the effect of openness on innovation. *American Economic Journal: Economic Policy*, *8*(1), 212-52.

Nelson, R. R. (1959). The simple economics of basic scientific research. *Journal of Political Economy*, *67*(3), 297-306.

Nelson, R. R. (1993). *National systems of innovation: A comparative analysis*. New York, NY: Oxford University Press.

Nelson, R. R. (2004). The market economy, and the scientific commons. *Research Policy*, *33*(3), 455–471.

Nelson, R. R. (2005). Linkages between the market economy and the scientific commons. In K. E. Maskus & J. H. Reichman (Eds.), *International public goods and transfer of technology under a globalized intellectual property regime* (pp. 121-138). Cambridge: Cambridge University Press.

Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change.* Cambridge: Harvard University Press.

Nicolaou, N., & Birley, S. (2003). Academic networks in a trichotomous categorisation of university spinouts. *Journal of Business Venturing*, *18*(3), 333-359.

North, D. (1990). *Institutions, institutional change and economic performance.* Cambridge, U.K.: Cambridge University Press.

O'Kane, C., Cunningham, J., Mangematin, V., & O'Reilly, P. (2015b). Underpinning strategic behaviours and posture of principal investigators in transition/uncertain environments. *Long Range Planning, 48*(3), 200–214.

O'Kane, C., Mangematin, V., Geoghegan, W., & Fitzgerald, C. (2015a). University technology transfer offices: The search for identity to build legitimacy. *Research Policy*, *44*(2), 421-437.

O'Mahony, S. (2003). Guarding the commons: How community managed software projects protect their work. *Research Policy, 32*(7), 1179–1198.

O'Shea, R. P., Chugh, H., & Allen, T. J. (2008). Determinants and consequences of university spinoff activity: A conceptual framework. *The Journal of Technology Transfer*, 33(6), 653-666.

Öcalan-Özel, S., & Pénin, J. (2016). Exclusive or open? An economic analysis of university intellectual property patenting and licensing strategies. *Journal of Innovation Economics & Management*, *21*(3), 133-153.

Olmos-Peñuela, J., Castro-Martínez, E., & D'Este, P. (2014). Knowledge transfer activities in social sciences and humanities: Explaining the interactions of research groups with non-academic agents. *Research Policy*, *43*(4), 696-706.

O'Shea, R. P., Allen, T. J., Chevalier, A., & Roche, F. (2005). Entrepreneurial orientation, technology transfer and spinoff performance of US universities. *Research Policy*, *34*(7), 994-1009.

O'Shea, R., Allen, T. J., O'Gorman, C., & Roche, F. (2004). Universities and technology transfer: A review of academic entrepreneurship literature. *Irish Journal of Management*, *25*(2).

Owen-Smith, J. (2003). From separate systems to a hybrid order: Accumulative advantage across public and private science at Research One universities. *Research Policy, 32*(6), 1081–1104.

Owen-Smith, J., Powell, W.W. (2001). To patent or not: Faculty decisions and institutional success at technology transfer. *Journal of Technology Transfer, 26(1-2)*, 99–114.

Palmer, A. M. (1957). *Patents and Nonprofit Research*. Washington, D. C.: US Government Printing Office.

Pavitt, K. (1999). *Technology, management and systems of innovation*. Cheltenham, UK: Edward Elgar Publishing.

Pavitt, K., 1984. Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy*, *13*(6), 343–373.

Pénin, J. (2010a). Quelle politique de licence de brevet pour les organismes publics de recherche? Exclusivité versus modèles plus ouverts. *Management International*, *14*(3), 47-58.

Pénin, J. (2010b). On the consequences of patenting university research: Lessons from a survey of French academic inventors. *Industry and Innovation*, *17*(5), 445-468.

Pénin, J. (2011). Open source innovation: Towards a generalization of the open source model beyond software. *Revue d'Economie Industrielle*, *136*(4), 65-88.

Pénin, J., & Wack, J. P. (2008). Research tool patents and free-libre biotechnology: A suggested unified framework. *Research Policy*, *37*(10), 1909-1921.

Perkmann, M., & Walsh, K. (2007). University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews*, *9*(4), 259-280.

Perkmann, M., & Walsh, K. (2008). Engaging the scholar: Three types of academic consulting and their impact on universities and industry. *Research Policy*, *37*(10), 1884-1891.

Perkmann, M., King, Z., & Pavelin, S. (2011). Engaging excellence? Effects of faculty quality on university engagement with industry. *Research Policy*, *40*(4), 539-552.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., et al. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy*, *42*(2), 423-442.

Pettigrew, A. M. (1997). What is a processual analysis? *Scandinavian journal of management*, *13(4)*, 337-348.

Phan, P., & Siegel, D. S. (2006). The effectiveness of university technology transfer. *Foundations and Trends in Entrepreneurship*, *2*(2), 77-144.

Polanski, A. (2007). Is the general public licence a rational choice?. *The Journal of Industrial Economics*, *55*(4), 691-714.

Polanyi, M. (1962). The republic of science: Its political and economic theory. *Minerva*, *1*(1), 54-73.

Polt, W., Gassler, H., Schibany, A., Rammer, C., & Schartinger, D. (2001). Benchmarking industry—science relations: the role of framework conditions. *Science and public policy*, *28*(4), 247-258.

Powers, J. B., & McDougall, P. P. (2005). University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship. *Journal of Business Venturing*, *20*(3), 291-311.

Poyago-Theotoky, J., Beath, J., & Siegel, D. S. (2002). Universities and fundamental research: Reflections on the growth of university–industry partnerships. *Oxford Review of Economic Policy*, *18*(1), 10-21.

Pray, C. E., & Naseem, A. (2005). Intellectual property rights on research tools: Incentives or barriers to innovation? Case studies of rice genomics and plant transformation technologies. *AgBioforum*, *8*(2-3), 108-117.

Pries, F., & Guild, P. (2011). Commercializing inventions resulting from university research: Analyzing the impact of technology characteristics on subsequent business models. *Technovation*, *31*(4), 151-160.

Rai, A. K. (2005). Open and collaborative research: A new model for biomedicine. In R. W. Hahn (Ed.), *Intellectual Property Rights in Frontier Industries: Software and Biotechnology* (pp. 131-158). Washington, D.C.: AEI-Brookings Press.

Ramos-Vielba, I., Sánchez-Barrioluengo, M., & Woolley, R. (2016). Scientific research groups' cooperation with firms and government agencies: Motivations and barriers. *Journal of Technology Transfer*, *41*, 558-585.

Rasmussen, E. (2011). Understanding academic entrepreneurship: Exploring the emergence of university spin-off ventures using process theories. *International Small Business Journal*, *29*(5), 448-471.

Raymond, E. (1999). The cathedral and the bazaar. *Knowledge, Technology & Policy*, *12*(3), 23-49.

Reimers, N. J., & Hughes, S. S. (1998). *Stanford's Office of Technology Licensing and the Cohen/Boyer Cloning Patents*. Oral history conducted in 1997 by Sally Smith Hughes, Ph.D., Regional Oral History Office. The Bancroft Library, University of California, Berkeley, CA.

Rentocchini, F., D'Este, P., Manjarrés-Henríquez, L., & Grimaldi, R. (2014). The relationship between academic consulting and research performance: Evidence from five Spanish universities. *International Journal of Industrial Organization*, *32*, 70-83.

Ring, P. S., & Van de Ven, A. H. (1994). Developmental processes of cooperative interorganizational relationships. *Academy of Management Review*, *19*(1), 90-118.

Roessner, D., Bond, J., Okubo, S., & Planting, M. (2013).The economic impact of licensed commercialized inventions originating in university research. *Research Policy*, *42*(1), 23-34.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5), 71-102.

Rosenberg, N. (1982). *Inside the black box: technology and economics*. Cambridge, UK: Cambridge University Press.

Rosenberg, N., & Nelson, R. R. (1994). American universities and technical advance in industry. *Research policy*, *23*(3), 323-348.

Rothaermel, F. T., & Thursby, M. (2005). University–incubator firm knowledge flows: assessing their impact on incubator firm performance. *Research Policy*, *34*(3), 305-320.

Sahal, D. (1981). Alternative conceptions of technology. *Research Policy,10*, 2–24.

Sahal, D. (1982). The form of technology. In D. Sahal (Ed.), *The transfer and utilization of technical knowledge* (pp. 125–139). Lexington, MA: Lexington Publishing.

Sampat, B. N. (2006). Patenting and US academic research in the 20th century: The world before and after Bayh-Dole. *Research Policy*, *35*(6), 772-789.

Sampat, B. N., & Williams, H. L. (2015). *How do patents affect follow-on innovation? Evidence from the human genome* (NBER Working Paper No. w21666). National Bureau of Economic Research.

Sauermann, H., & Stephan, P. (2013). Conflicting logics? A multidimensional view of industrial and academic science. *Organization Science*, *24*(3), 889-909.

Schaeffer, V., & Matt, M. (2016). Development of academic entrepreneurship in a non-mature context: The role of the university as a hub-organisation. *Entrepreneurship & Regional Development, 28*(9–10), 724–745.

Schaeffer, V., Öcalan-Özel, S., & Pénin, J. (2018). The complementarities between formal and informal channels of university–industry knowledge transfer: a longitudinal approach. *The Journal of Technology Transfer*, 1-25. https://doi.org/10.1007/s10961-018-9674-4

Schartinger, D., Rammera, C., Fischer, M.M., & Fröhlich, J. (2002). Knowledge interactions between universities and industry in Austria: Sectoral patterns and determinants. *Research Policy, 31*(3), 303-328.

Schmidt, K. M., & Schnitzer, M. (2003). Public subsidies for open source? Some economic policy issues of the software market. *Harvard Journal of Law and Technology*, *16*(2), 473–505.

Scotchmer, S. (1991). Standing on the shoulders of giants: cumulative research and the patent law. *The Journal of Economic Perspectives*, *5(*1), 29-41.

Scotchmer, S. (2010). Openness, open source, and the veil of ignorance. *American Economic Review*, *100*(2), 165-171.

Sen, D., & Tauman, Y. (2007). General licensing schemes for a cost-reducing innovation. *Games and Economic Behavior*, *59*(1), 163-186.

Shane, S. (2002). Executive forum: university technology transfer to entrepreneurial companies. *Journal of Business Venturing*, *17*(6), 537-552.

Shane, S. A. (2004). *Academic entrepreneurship: University spinoffs and wealth creation*. Cheltenham, UK: Edward Elgar Publishing.

Shapiro, C. (2000). Navigating the patent thicket: Cross licenses, patent pools, and standard setting. *Innovation policy and the economy*, *1*, 119-150.

Siegel, D. S., & Wright, M. (2015). University technology transfer offices, licensing, and start-ups. In A. N. Link, D. S. Siegel, M. Wright (Eds.), *Chicago handbook of university technology transfer and academic entrepreneurship* (pp.1-40). Chicago: The University of Chicago Press.

Siegel, D. S., D. Waldman & A. N. Link (2003). Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study, *Research Policy*, *32*, 27–48.

Siegel, D. S., Waldman, D., & Link, A. (2004). Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies. *Journal of Engineering and Technology Management*, *21*(1-2), 115-142.

Siegel, D.S., Veugelers, R., & Wright, M. (2007). Technology transfer offices and commercialization of university intellectual property: performance and policy implications. *Oxford Review of Economic Policy*, *23*(4), 640-660.

Somaya, D., Kim, Y., & Vonortas, N. S. (2011). Exclusivity in licensing alliances: Using hostages to support technology commercialization. *Strategic Management Journal*, *32*(2), 159-186.

Stallman, R. (2002). *Free software, free society: Selected essays of Richard M. Stallman*. J. Gay (Ed.). Boston, M.A.: GNU Press.

Stephan, P. E. (1996). The economics of science. *Journal of Economic Literature*, *34*(3), 1199-1235.

Stephan, P. E. (2009). Tracking the placement of students as a measure of technology transfer. In G.D. Libecap (Ed.), *Measuring the social value of innovation: A link in the university technology transfer and entrepreneurship equation* (pp. 113-140). Bingley: Emerald Group Publishing Limited.

Stephan, P. E., Gurmu, S., Sumell, A. J., & Black, G. (2007). Who's patenting in the university? Evidence from the survey of doctorate recipients. *Economics of Innovation and New Technology*, *16*(2), 71-99.

Stokes, D.E. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation*, Washington, D.C: Brookings Institution Press.

Sugumaran, G. (2012). Open source drug discovery-redefining IPR through open source innovations. *Current Science*, *102*(12), 1637-1639.

Tartari, V., Salter, A., & D'Este, P. (2012). Crossing the Rubicon: exploring the factors that shape academics' perceptions of the barriers to working with industry. *Cambridge Journal of Economics*, *36*(3), 655-677.

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy*, *15*(6), 285-305.

Teece, D. J. (2003). Essays in technology management and policy: Selected papers of David J. Teece. Singapore: World Scientific Publishing.

Thompson, N. C., Ziedonis, A. A., & Mowery, D. C. (2018).University licensing and the flow of scientific knowledge. *Research Policy*, *47*(6), 1060-1069.

Thursby, J. G., & Kemp, S. (2002). Growth and productive efficiency of university intellectual property licensing. *Research Policy*, *31*(1), 109-124.

Thursby, J. G., & Thursby, M. C. (2002). Who is selling the ivory tower? Sources of growth in university licensing. *Management Science*, *48*(1), 90-104.

Thursby, J. G., & Thursby, M. C. (2003). University licensing and the Bayh–Dole act. *Science, 301*(5636), 1052.

Thursby, J. G., & Thursby, M. C. (2004). Are faculty critical? Their role in university–industry licensing. *Contemporary Economic Policy*, *22*(2), 162-178.

Thursby, J. G., & Thursby, M. C. (2007). University licensing. *Oxford Review of Economic Policy*, *23*(4), 620-639.

Thursby, J. G., & Thursby, M. C. (2011). Has the Bayh-Dole act compromised basic research? *Research Policy*, *40*(8), 1077-1083.

Thursby, J. G., Jensen, R., & Thursby, M. C. (2001). Objectives, characteristics and outcomes of university licensing: A survey of major US universities. *The Journal of Technology Transfer*, *26*(1-2), 59-72.

Thursby, M., Thursby, J., & Gupta-Mukherjee, S. (2007). Are there real effects of licensing on academic research? A life cycle view. *Journal of Economic Behavior & Organization, 63*(4), 577-598.

Toole, A. A., & Czarnitzki, D. (2010). Commercializing science: is there a university "brain drain" from academic entrepreneurship? *Management Science, 56*(9), 1599–1614.

Van Looy, B. (2009). The role of universities within innovation systems: An overview and assessment, *Review of Business and Economics*, 54(1), 62-82.

Van Looy, B., Callaert, J., & Debackere, K. (2006). Publication and patent behavior of academic researchers: Conflicting, reinforcing or merely co-existing? *Research Policy*, *35*(4), 596-608.

Van Looy, B., Landoni, P., Callaert, J., Van Pottelsberghe, B., Sapsalis, E., & Debackere, K. (2011). Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. *Research Policy*, *40*(4), 553-564.

Van Looy, B., Ranga, M., Callaert, J., Debackere, K., & Zimmermann, E. (2004). Combining entrepreneurial and scientific performance in academia: Towards a compounded and reciprocal Matthew-effect? *Research Policy, 33*(3), 425–441.

Varian, H. R., & Shapiro, C. (2003). Linux adoption in the public sector: An economic analysis. Unpublished Manuscript. University of California, Berkeley.

Vedovello, C. (1997). Science parks and university-industry interaction: Geographical proximity between the agents as a driving force. *Technovation*, *17*(9), 491-531.

Verspagen, B. (2006). University research, intellectual property rights and European innovation systems. *Journal of Economic Surveys*, *20*(4), 607-632.

Veugelers, R., & Cassiman, B. (2005). R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing. *International Journal of Industrial Organization*, *23*(5-6), 355-379.

Veugelers, R., & Del Rey, E. (2014). The contribution of universities to innovation, (regional) growth and employment. EENEE Analytical Report No. 18.

Villani, E., Rasmussen, E., & Grimaldi, R. (2017). How intermediary organizations facilitate university–industry technology transfer: A proximity approach. *Technological Forecasting and Social Change*, *114*, 86-102.

Von Hippel, E. (2005). *Democratizing innovation*. Cambridge, MA: MIT press.

Von Hippel, E. A. (2002). *Open source projects as horizontal innovation networks-by and for users.* (MIT Sloan Working Paper No. 4366-02). MIT Sloan School of Management.

Von Krogh, G., Haefliger, S., Spaeth, S., & Wallin, M. W. (2012). Carrots and rainbows: Motivation and social practice in open source software development. *MIS Quarterly*, *36*(2) 649-676.

Walsh, J. P., Arora, A., & Cohen, W. M. (2003). Effects of research tool patents and licensing on biomedical innovation. In W. M. Kohen & S. A. Merrill (Eds.), *Patents in the Knowledge-based Economy* (pp. 285-340). Washington, D. C.: The National Academies Press.

Weiner, C. (1986). Universities, professors and patents: A continuing controversy. *Technology Review*, 33-41.

Williams, H. L. (2013). Intellectual property rights and innovation: Evidence from the human genome. *Journal of Political Economy*, *121*(1), 1-27.

Williamson, O. E. (1979). Transaction-cost economics: The governance of contractual relations. *The Journal of Law and Economics*, *22*(2), 233-261.

Williamson, O. E. (1981). The economics of organization: the transaction cost approach. *American Journal of Sociology*, *87*(3), 548–577.

Williamson, O. E. (1985). Assessing contract. *Journal of Law, Economics, & Organization*, *1*(1), 177-208.

Williamson, O. E. (1991). Comparative economic organization: The analysis of discrete structural alternatives. *Administrative Science Quarterly, 36,* 269–296.

Williamson, O. E. (2000). The new institutional economics: Taking stock, looking ahead. *Journal of Economic Literature*, *38*(3), 595–613.

World Intellectual Property Organization (2015). *Successful Technology Licensing* (Publication No. 903E). Retrieved from http://www.wipo.int/edocs/pubdocs/en/licensing/903/wipo_pub_903.pdf

Wright, M. (2007). *Academic entrepreneurship in Europe*. Cheltenham, UK: Edward Elgar Publishing.

Wright, M., Clarysse, B., Lockett, A., & Knockaert, M. (2008). Mid-range universities' linkages with industry: Knowledge types and the role of intermediaries. *Research Policy*, *37*(8), 1205-1223.

Wuchty, S., Jones, B. F., & Uzzi, B. (2007). The increasing dominance of teams in production of knowledge. *Science, 316*(5827), 1036–1039.

Yin, R. (1994). *Case study research: Design and methods*. Beverly Hills: Sage Publications.

Youtie, J., & Shapira, P. (2008). Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development. *Research Policy*, *37*(8), 1188-1204.

Zucker, L. G., Darby, M. R., & Armstrong, J. S. (2002). Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. *Management Science, 48*(1), 138–153.

Appendix

Table A.1: Inventors' survey

Invention characteristics	Definition
MATURITY	
Embryonic	Completely embryonic (very distant from the market): Industrialist still had to invest heavily and the time before the development was very important.
Moderately embryonic	Not fully operational: Industrialist had to invest a certain time was necessary before developing it.
Mature	Close to the market: Industrialist was able to develop as it was and without incurring any additional investment (or otherwise marginal).
I don't know	
SPECIFICITY	
Generic	Highly generic: It can be used in a very large number of contexts.
Moderately generic	Moderately generic: It can be used in a small number (greater than one) of different contexts and sectors.
Specific	Highly specific (targeted): It can only be used in one very specific context.
I don't know	
APPROPRIABILITY	
Appropriable	Very difficult to imitate: It is very long and very costly for industrial competitors of licensee to imitate the invention if it is not protected by an intellectual property right (IPR).
Relatively appropriable	Relatively difficult to imitate: It is relatively expensive and takes long time for competitors to imitate licensed technology even if it is not protected by an IPR.
Non-appropriable	Easily imitable: If it is not protected by IPR it can be reproduced by industrial competitors of the licensee very quickly and at very low cost.
I don't know	

Table A.2: Pairwise correlation matrix

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1.Global_excl	1.00													
2.Exclu_pfu	**-0.67**	1.00												
3.Embryonic	0.12	0.08	1.00											
4.Generic	-0.03	0.02	-0.07	1.00										
5.Emgen	0.02	0.14	**0.62**	**0.59**	1.00									
6.Appro	**-0.27**	0.18	-0.15	0.05	-0.07	1.00								
7.Tacit	0.04	0.10	-0.01	**0.24**	0.13	0.13	1.00							
8.Life_Sci_or_Chem	**-0.39**	**0.40**	-0.06	-0.07	-0.14	-0.01	0.08	1.00						
9.Software	**0.35**	**-0.42**	0.10	0.01	0.08	0.07	0.20	**-0.59**	1.00					
10.Micro	**0.41**	-0.14	**0.43**	-0.05	0.20	-0.20	-0.04	-0.17	**0.29**	1.00				
11.Spinoff	0.06	-0.03	0.18	0.19	**0.31**	0.01	0.05	-0.14	**0.24**	**0.27**	1.00			
12.France	0.16	0.03	0.03	**0.26**	0.13	-0.19	0.10	-0.14	-0.02	0.20	**0.46**	1.00		
13.Involve_PRO	**-0.44**	**0.53**	-0.01	0.05	0.09	0.02	0.12	**0.29**	**-0.31**	-0.12	0.05	-0.02	1.00	
14.Unistra	**-0.21**	**0.23**	-0.09	0.12	0.08	-0.06	0.16	**0.21**	**-0.23**	-0.20	-0.13	-0.16	**0.36**	1.00

Correlation coefficients in bold are significant at a 5% level

Résumé étendu en français

La Collaboration entre l'Université et l'Industrie:

Comprendre les Stratégies de Licences Universitaire et au-delà

Introduction Générale

Contexte et motivation

Les universités sont les principaux organismes générant et diffusant des connaissances scientifiques; connaissances qui représentent une ressource importante pour l'innovation industrielle et la croissance économique (Mowery *et al.*, 2004; D'Este et Patel, 2007; Veugelers et Del Rey, 2014). Le lien fort entre la connaissance scientifique et l'innovation industrielle s'incarne dans les interactions entre l'université et l'industrie. Bien que les Interactions Université-Industrie (IUI) ne sont pas un phénomène nouveau et remontent au 19ème siècle, ces dernières décennies ont été marquées par une accélération et une institutionnalisation de ces interactions, avec la mise en place de structures intermédiaires telles que les Offices de Transfert de Technologies (OTTs) (Geuna et Muscio, 2009).

Parallèlement à cette accélération, les IUI ont également attiré l'attention de nombreux chercheurs, grâce notamment à l'apport de théories telles que le "Modèle à Triple Hélice" (Etzkowitz et Leydesdorff, 1995; Etzkowitz et Leydesdorff, 2000) ou encore le "Paradigme de l'Innovation Ouverte" (Chesbrough, 2003), alors qu'un important courant de recherche s'est concentré sur le rôle des universités (par exemple, Mowery *et al.*, 2004; Debackere et Veugelers, 2005; D'Este et Perkmann, 2011; Perkmann *et al.*, 2013).

Les IUI se sont intensifiées à la fois en volume ainsi que dans la diversité des canaux utilisés dans le processus d'interaction (D'Este et Patel, 2007). L'évolution des perspectives concernant le lien entre la science fondamentale et la recherche appliquée a été un facteur déterminant expliquant le décuplement de ces interactions. Tout au long du 20ème siècle, les débats sur la relation entre la science et la technologie (à savoir, entre les connaissances fondamentales et les connaissances appliquées) ont ouvert la voie à l'évolution des politiques relatives au rôle des universités. Devraient-elles être des "tours d'ivoire" isolées, produisant et diffusant des connaissances scientifiques, ou devraient-elles contribuer davantage à l'innovation en commercialisant les résultats de leurs recherches? Le second rôle a été jugé plus approprié, et il a ainsi été attribué aux universités une "troisième mission", en plus de leurs traditionnelles missions de recherche et d'enseignement (Etzkowitz et Leydesdorff, 2000).

Comparées à la plupart des universités européennes, les universités américaines ont eu des interactions plus intenses avec le secteur industriel. Ceci est principalement dû à des différences institutionnelles entre les systèmes d'enseignement supérieur. Historiquement, les universités américaines étaient plus autonomes et n'étaient pas strictement contrôlées, contrairement à la plupart des universités européennes, comme en témoigne, toujours aujourd'hui, le contrôle rigide des universités françaises par l'État (Franzoni et Lissoni, 2009). Alors que les universités françaises n'étaient responsables que de l'enseignement, les activités de recherche étaient confiées à des organismes de recherche publics non-universitaires, tels que le CNRS (Centre National de la Recherche Scientifique). D'autre part, alors qu'en France la recherche était principalement financée par des fonds publics, les universités américaines étaient fortement dépendantes de financements industriels locaux, ce qui les rendait plus sensibles aux besoins de leur environnement. Ces différences institutionnelles ont incité les universités américaines à entreprendre des recherches plus "appliquées", leur permettant ainsi d'établir des liens plus étroits avec l'industrie (Mowery *et al.*, 2004).

Néanmoins, les sources et le montant des financements ont radicalement changé après l'entrée des États-Unis dans la Seconde Guerre Mondiale. En effet, le fait que les programmes "Big Science" (par exemple, le projet Manhattan) aient été lourdement financés par les gouvernements fédéraux, pendant et immédiatement après la guerre, a fortement affaibli les liens entre les universités et le secteur industriel (Mowery *et al.*, 2004). Vannevar Bush a joué un rôle déterminant dans la politique scientifique de l'après-guerre, en arguant, dans son fameux rapport de 1945 au Président Franklin D. Roosevelt, que la recherche fondamentale était la source de la croissance économique. Il a donc appelé à un soutien fort à la recherche fondamentale de la part des gouvernements fédéraux, dans les domaines militaire et non-militaire.

Le rapport de Bush distingue clairement le domaine des connaissances fondamentales de celui des connaissances appliquées, affirmant que ces deux domaines étaient incompatibles. Par conséquent, les universités devaient être considérées comme étant responsables de la création et de la diffusion de la recherche fondamentale, sans aucun but commercial. À cet égard, le rapport de Bush est considéré comme étant la base du "Modèle Linéaire d'Innovation" (Freeman, 1996; Mowery, 1997; Stokes, 1997), qui a longtemps été le paradigme dominant façonnant les politiques en matière de science et de technologie. Dans le modèle linéaire, l'innovation commence par la recherche fondamentale, suivie par la recherche appliquée et le développement, et se termine par la production et la diffusion de l'innovation.

Cependant, de nombreux chercheurs ont attaqué la vision linéaire de Bush (Freeman, 1982; Rosenberg, 1982; Kline, 1985; Kline et Rosenberg, 1986; Gibbons *et al.*, 1994; Pavitt, 1999; Stokes, 1997; Etzkowitz et Leydesdorff, 2000). Il a été avancé que la recherche fondamentale et la recherche appliquée n'étaient pas incompatibles, mais souvent complémentaires: une recherche de meilleure qualité pourrait être menée si ces deux éléments interagissaient (Stokes, 1997). En outre, il a été défendu qu'il n'existait pas qu'un seul flux de connaissances (unidirectionnel) allant de la science vers l'innovation, comme le décrit le modèle linéaire; le flux de connaissances est multi-directionnel tout au long du processus d'innovation (Kline et Rosenberg, 1986).

Le paradigme d'après-guerre issu du rapport de Vannevar Bush en 1945 a radicalement été altéré avec l'adoption de la loi Bayh-Dole aux États-Unis en 1980. La loi Bayh-Dole a autorisé les universités à conserver un titre de propriété sur les brevets résultant de recherches financées par les gouvernements fédéraux, et a obligé les universités à breveter les résultats de leur recherche (Thursby et Thursby, 2011). Il était donc attendu des universités à ce qu'elles contribuent activement à l'innovation et à la croissance économique en se livrant à des activités commerciales ou entrepreneuriales, en brevetant les résultats de leurs recherches et en octroyant des licences à leurs partenaires industriels (Etzkowitz et Leydesdorff, 2000). Afin de stimuler les IUI, des émulations de la loi Bayh-Dole ont pu être observées en Europe, avec, notamment, la "Loi sur la Science" adoptée en Espagne en 1986, ou la "Loi sur l'Innovation" adoptée en France en 1999 (Azagra-Caro *et al.*, 2006; Della Malva *et al.*, 2013).

La sensibilité des universités aux Droits de Propriété Intellectuelle (DPI) était déjà grandissante dans les années 1970, à la suite de développements technologiques dans les domaines de la biotechnologie ou des logiciels (Mowery *et al.*, 2004). Cependant, les brevets et les licences accordées par les universités n'ont connu une forte expansion qu'après l'adoption de la loi Bayh-Dole et d'autres lois similaires dans les pays industrialisés au cours des années 1980 et 1990. Des structures intermédiaires, telles que les OTTs, se sont multipliées afin de gérer les activités de délivrance de brevets et de licences des universités, en raison du volume et de la complexité croissante des activités de transfert (Geuna et Muscio, 2009).

Ce contexte a attiré un corpus important de travaux examinant les potentiels effets positifs ou négatifs des brevets et licences accordées par les universités (Henderson *et al.*, 1998; Mowery *et al.*, 2001; Jensen et Thursby, 2001; Thursby et Thursby, 2002; Mowery *et al.*, 2004; Geuna et Nesta, 2006; Audretsch et Göktepe-Hultén, 2015). Certains chercheurs ont avancé que la brevetabilité des inventions universitaires était nécessaire afin d'inciter les entreprises à investir dans les résultats de la recherche universitaire, qui sont pour la plupart embryonnaires (Jensen et Thursby, 2001), tandis que d'autres ont argué que cela n'était pas compatible avec la culture de la "science ouverte" (Dasgupta et David, 1994).

Dans le prolongement des brevets universitaires, une grande partie de la recherche est aujourd'hui consacrée aux licences (par exemple, Jensen et Thursby, 2001; Thursby *et al.*, 2001; Thursby et Thursby, 2002; Mowery et Sampat, 2004; Conti et Gaule, 2011; Dechenaux *et al.*, 2011; Thompson *et al.*, 2018). En effet, la brevetabilité n'est pas un mécanisme d'interaction à part entière, puisqu'un brevet ne permet pas à lui seul de transférer la technologie. La technologie, si elle est protégée par un brevet, ne peut être exploitée sans autorisation légale. Cette autorisation légale est généralement transférée à travers un contrat de licence. La licence est un moyen d'exploiter les DPI, c'est-à-dire qu'elle représente une permission légale donnant le droit (complet ou partiel) d'utiliser, de reproduire, de modifier, de distribuer, de vendre, d'importer ou encore de ré-octroyer une licence pour l'invention, en échange d'un paiement qui peut prendre la forme d'un montant forfaitaire, d'une redevance ou d'une participation au capital (Organisation Mondiale de la Propriété Intellectuelle [OMPI], 2015).

Ces recherches ont permis de mieux comprendre l'activité de concession de licences universitaires en examinant, par exemple, le nombre de contrats de licence exécutés, les redevances perçues sur ces contrats, ou encore leur incidence sur la production de connaissances scientifiques. Cependant, le contenu de ces contrats de licence est encore très peu connu, à l'exception de la structure des contrats de licence inter-entreprises (par exemple, Bessy et Brousseau, 1998; Anand et Khanna, 2000). Ceci est principalement dû à la difficulté d'accéder à ces contrats en raison des informations confidentielles qu'ils contiennent. De plus, le langage juridique complexe utilisé dans ces contrats rend difficile la compréhension des clauses sans expertise juridique. Aussi, l'impact social des contrats de licence reste sous-étudié dans le contexte des licences accordées par les universités.

Bien que cette thèse se concentre principalement sur les licences universitaires, nous reconnaissons que ce n'est pas le seul mécanisme par lequel les connaissances universitaires peuvent être transférées. Se concentrer uniquement sur ce mode de transfert institutionnalisé conduirait à une sous-estimation d'autres canaux d'IUI, construits principalement à travers le biais de relations personnelles (Bodas Freitas *et al.*, 2013). En effet, il existe une variété de canaux formels et informels permettant aux universités de contribuer à l'innovation industrielle et au développement économique (Veugelers et Del Rey, 2014), et un nombre croissant de publications a déjà fourni des informations sur ces différents canaux de transfert (D'Este et Patel, 2007; Link *et al.*, 2007; Bekkers et Bodas Freitas, 2008; Perkmann *et al.*, 2013). Cependant, davantage de travaux sont nécessaires afin de comprendre les interactions complexes entre ces canaux.

Objectif de la thèse, méthodologie et principaux résultats

Compte tenu du contexte, des motivations et du déficit de recherche, l'objectif principal de cette thèse est de discuter l'impact social des politiques de concession de licences des universités. Les universités publiques sont des organisations à but non lucratif visant à générer et à diffuser largement les connaissances scientifiques. Cette mission nécessite une conception minutieuse des contrats de licence lors du transfert de leurs technologies, afin de garantir la diffusion des connaissances au moindre coût pour la société. Dans cette thèse, nous examinons, en particulier, la clause d'exclusivité des contrats de licence, puis discutons du potentiel effet de la décision d'exclusivité sur le bien-être social. Un contrat de licence comprend de nombreuses clauses différentes. Parmi les différentes clauses des contrats de licence, une attention particulière a été accordée aux systèmes de paiement (Bray et Lee, 2000; Thursby *et al.*, 2001; Dechenaux *et al.*, 2009; 2011), alors que l'on en sait beaucoup moins sur les systèmes d'exclusivité. La décision d'exclusivité est un choix stratégique susceptible d'affecter le bien-être social, avec d'un côté la nécessité d'inciter à investir dans la recherche universitaire, et de l'autre, le besoin de minimiser le coût lié à un éventuel monopole. Il convient donc d'équilibrer ces deux objectifs opposés. De plus, des politiques de licence trop restrictives peuvent entraver la diffusion efficace de l'invention ou des connaissances. Il est donc important de concevoir efficacement les politiques de licence afin de s'assurer que la recherche financée par les fonds publics procure le plus grand bénéfice à la société (Mowery *et al.*, 2004). Compte tenu de la mission sociale des universités, nous soulignons qu'une attention particulière doit être accordée à la clause d'exclusivité dans les contrats de licence Université-Industrie.

Les OTTs étant les organisations intermédiaires gérant les activités de licence pour le compte des universités, il convient de porter une attention particulière à leurs pratiques en matière de licence. Il existe une vaste littérature investiguant les facteurs affectant la performance des OTTs (Debackere et Veugelers, 2005; Macho-Stadler *et al.*, 2007; Etzkowitz et Göktepe-Hultén, 2010; Comacchio *et al.*, 2012; O'Kane *et al.*, 2015a); pourtant, la mission sociale des OTTs est restée plutôt sous-estimée. Étant donné que les indicateurs de performance actuels reposent principalement sur des activités facilement mesurables, telles que le nombre de contrats de licence exécutés ou les redevances perçues (Thursby et Thursby, 2002; Thursby et Kemp, 2002), les OTTs pourraient être enclins à octroyer des licences universitaires aux plus offrants, généralement avec des conditions exclusives, afin de rester rentable. Bien que, dans certains contextes, des licences exclusives puissent être nécessaires pour transférer la technologie universitaire, le recours permanent à des licences exclusives pourrait être coûteux pour la société, en raison de prix élevés liés à une situation de monopole, ou de la diffusion limitée des connaissances incorporées dans la technologie transférée (Colyvas *et al.*, 2002). Nous en venons ainsi à nous demander si les OTTs doivent se concentrer uniquement sur la maximisation de leurs profits, ou s'ils doivent également prêter attention aux conséquences sociales de leurs stratégies de concession de licences universitaires. Comment les OTTs peuvent-ils concilier ces deux objectifs opposés dans le paysage actuel de valorisation de la recherche?

Compte tenu de notre objectif principal, la majeure partie de cette thèse est axée sur les licences universitaires. À cet égard, nous définissons d'abord les différents degrés d'exclusivité utilisés dans les licences (licences exclusives, licences exclusives par domaine d'utilisation, licences non-exclusives et licences open source), et identifions ensuite plusieurs facteurs pouvant entrer dans la décision d'exclusivité des OTTs. Parmi les différents déterminants, nous examinons l'effet des caractéristiques de l'invention sous licence sur le degré d'exclusivité, en combinant différentes méthodologies (modèle théorique, tests empiriques et analyse conceptuelle). Nos prédictions théoriques suggèrent que la décision d'exclusivité devrait être adaptée au contexte; en particulier, la nature de la technologie devrait être prise en compte lors de la délivrance de licences universitaires. Cependant, les résultats de notre analyse empirique suggèrent que les caractéristiques de la technologie concédée n'influencent pas, de manière significative, le degré d'exclusivité. En particulier, contrairement aux prévisions théoriques, nous ne pouvons pas lier les inventions embryonnaires à des licences exclusives, et nous ne pouvons pas non plus lier les inventions génériques à des licences non-exclusives. De plus, les inventions embryonnaires et génériques ne peuvent pas être liées à des licences exclusives par domaine d'utilisation. Ainsi, les résultats de notre étude suggèrent qu'il pourrait être possible d'améliorer encore les performances de l'activité de transfert.

Notre étude suggère également que, même si la publication des résultats de recherche peut permettre un transfert efficace des connaissances dans certains contextes (en particulier lorsque nous considérons un cadre d'innovation statique (non-séquentiel)), l'introduction des résultats de la recherche dans le domaine public dans un environnement d'innovation dynamique (séquentiel) peut, à travers le temps, amener à l'appropriation exclusive des connaissances. Par conséquent, nous arguons, à travers une analyse conceptuelle, que les licences open source peuvent constituer une alternative aux stratégies de licences traditionnelles (ou à la publication des résultats de la recherche) lorsqu'un environnement d'innovation cumulatif est considéré. Ainsi, lorsqu'elles sont associées à des licences de type "copyleft", et lorsque les inventions sont séquentielles, les licences open source peuvent améliorer le bien-être social car elles permettent de garder les connaissances universitaires, en amont, ouvertes aux innovations ultérieures, en aval. Néanmoins, cette stratégie ne peut fonctionner qu'à condition que les investissements supplémentaires nécessaires au développement d'inventions ne soient pas trop élevés (Gambardella et Hall, 2006).

Il est cependant important de noter que les brevets et les licences ne représentent qu'un sous-ensemble des canaux par lesquels les connaissances universitaires sont transférées vers l'industrie, et il est même possible que ces canaux ne soient pas les plus efficaces (Veugelers et Del Rey, 2014). Même si, dans certains cas, la brevetabilité peut faciliter le transfert de technologie via le canal de la licence, dans d'autres cas, le transfert ou la commercialisation est toujours possible via différents canaux (Mowery *et al.*, 2004). Il existe une variété de canaux de transfert de connaissances Université-Industrie, certains d'entre eux étant formels, d'autres étant informels (donc moins institutionnalisés). Ces canaux incluent, par exemple, le conseil, les collaborations de recherche, la création de spin-offs, les réseaux informels, les conférences, la mobilité des étudiants, etc. (D'Este et Patel, 2007; Link *et al.*, 2007; Bekkers et Bodas Freitas, 2008; Perkmann *et al.*, 2013; Veugelers et Del Rey, 2014). Cependant, nous n'avons encore que très peu de connaissances sur les canaux autres que les brevets et les licences, et sur la manière dont les différents canaux interagissent au fil du temps. Par conséquent, cette thèse vise également à proposer une approche plus holistique des activités de valorisation de la recherche universitaire, en allant au-delà du processus linéaire de licence en examinant les interactions complexes entre les différents canaux de transfert. En s'appuyant sur des données longitudinales et qualitatives (entretiens) sur les activités de valorisation de deux chercheurs réputés de l'Université de Strasbourg, nous analysons les interactions dynamiques et les complémentarités entre les différents canaux de transfert. En étudiant les domaines de la robotique et de la pharmacie, nous trouvons que les interactions dynamiques renforcent la dimension collective de la valorisation de la recherche et génèrent un effet cumulatif vis-à-vis de l'activité de valorisation. Ainsi, nos recherches suggèrent également que la contribution de la recherche universitaire à l'innovation et à la croissance économique est bien plus importante que la simple question des brevets et des licences. La mission des OTTs devrait donc aller au-delà de la simple gestion des DPI.

Organisation de la thèse

Cette thèse comprend cinq chapitres, chacun étant distinct, mais tous traitent des IUI. L'organisation de cette thèse est la suivante:

Le **Chapitre 1**, intitulé "*A Primer on University-Industry Interactions*", vise à fournir des informations de base sur les problèmes liés aux IUI, en passant en revue les contributions importantes des précédentes recherches. En donnant une perspective globale, ce chapitre vise également à complémenter les discussions des chapitres suivants. Premièrement, nous fournissons au lecteur une présentation détaillée des IUI d'un point de vue historique, en examinant les changements institutionnels, technologiques et politiques. Nous expliquons, dans ce chapitre, comment le paradigme concernant la relation science-technologie et le rôle des universités a changé au fil du temps. Ensuite, nous discutons les incitations à interagir du point de vue l'université ainsi que du point de vue de l'entreprise, sur la base d'arguments théoriques bien connus, ainsi que des obstacles aux interactions. De plus, nous détaillons la variété des mécanismes utilisés pour les IUI, en proposant une classification unifiée des canaux. Étant donné que la thèse porte sur les licences universitaires, nous examinons en détail le cas des brevets et des licences universitaires. À cet égard, nous présentons les débats sur le brevetage universitaire sous différents angles, puis examinons le contenu des contrats de licence en définissant les différentes provisions (clauses ou termes) qu'ils contiennent. Enfin, nous examinons les organisations intermédiaires, en particulier les OTTs, qui visent à faciliter le transfert de connaissances entre les universités et l'industrie. En comparant le cas des États-Unis à celui de la France, nous discutons du rôle et des objectifs des OTTs.

Le **Chapitre 2** est intitulé "*Exclusive or Open? An Economic Analysis of University Intellectual Property Patenting and Licensing Strategies*"[76]. Ce chapitre vise à examiner les déterminants des stratégies de brevetage et de concession de licences des universités, ainsi qu'à comparer l'incidence de différentes stratégies sur le bien-être social. Une stratégie de licence peut être basée sur différents degrés d'exclusivité octroyés aux entreprises, allant d'une licence ouverte, non-exclusive à une licence

[76] Ce chapitre est basé sur notre article publié: "Öcalan-Özel, S. et Pénin, J. (2016). Exclusive or Open? An Economic Analysis of University Intellectual Property Patenting and Licensing Strategies. *Journal of Innovation Economics & Management*, *21* (3), 133-153".

exclusive. Nous analysons comment la nature de la technologie (c'est-à-dire le stade de développement et la spécificité) inventée par l'université pourrait affecter son choix de breveter, de publier, ou d'octroyer une licence, ainsi que la performance du transfert. Nous considérons un modèle avec une université et quatre entreprises dans deux secteurs différents. Nous montrons que dans certains cas (par exemple, lorsque l'invention est embryonnaire), l'octroi d'une licence exclusive pourrait être la stratégie permettant le transfert de technologie le plus efficace, mais que dans d'autres cas (par exemple, lorsque l'invention est mature et générique), des stratégies plus ouvertes basées sur la publication ou sur des licences non-exclusives seraient plus adaptées. Cette étude contribue donc à la littérature existante en offrant une compréhension conceptuelle de la manière dont la nature de l'invention pourrait influencer les stratégies de brevet, de licence et de publication des universités.

Le **Chapitre 3** intitulé "*Invention Characteristics and the Degree of Exclusivity of University Licenses: The Case of Two Leading French Research Universities*" est l'extension empirique des prédictions théoriques présentées dans le Chapitre 2. Ce chapitre a pour objectif d'analyser l'effet des caractéristiques de l'invention (c'est-à-dire le stage de développement, la spécificité et l'appropriabilité) sur le degré d'exclusivité des licences. Nous combinons des données de la codification de contrats de licence avec celles d'interviews d'inventeurs collectées dans le cadre du projet COCON.[77] Nous obtenons ainsi une base de données unique et originale de 91 inventions, contenues dans 62 contrats de licence (et de cession), exécutés par deux grandes universités françaises (à savoir l'Université de Strasbourg et l'Université de Grenoble-Alpes), durant la période 2005-2014. À notre connaissance, cette recherche—bien qu'exploratoire—examine pour la première fois, de manière empirique, le lien entre le degré d'exclusivité et diverses caractéristiques de l'invention dans le contexte de l'octroi de licences universitaires aux entreprises. Malgré sa petite taille, cette base de données originale et riche nous permet non seulement d'observer le degré d'exclusivité en relation avec les caractéristiques de l'invention, mais également avec les caractéristiques de l'entreprise et du cadre institutionnel. Ce chapitre contribue également à la littérature en enrichissant les discussions sur la performance du transfert de technologie Université-Industrie.

Le **Chapitre 4**, intitulé "*University Licensing: Exploring the Open Source Possibility*", analyse la mise en œuvre d'une stratégie de licence alternative par les OTTs. Les universités produisent des connaissances en amont, et leur mission est de les diffuser largement. Conformément à cette mission, dans un contexte d'innovation dynamique (séquentiel), où les innovations progressent de manière cumulative, il est essentiel de laisser ces connaissances universitaires accessibles à divers acteurs innovants, afin d'éviter le blocage des innovations ultérieures, en aval. Dans le contexte des licences universitaires, cet objectif pourrait être atteint à l'aide d'une utilisation particulière des DPI associés à

[77] Le projet COCON (COhort of CONtracts) est financé par l'ANR (Agence Nationale de la Recherche), ce qui est expliqué plus en détail dans le Chapitre 3.

des licences open source. Par conséquent, dans ce chapitre, nous proposons une analyse du contexte dans lequel une stratégie de licence open source de la part des universités pourrait constituer une alternative plausible aux stratégies de licence traditionnelles (c'est-à-dire exclusives, exclusives par domaine d'utilisation, et non-exclusives). Tout d'abord, nous étudions le mouvement open source dans l'industrie du logiciel, en discutant les motivations des individus et des entreprises à contribuer aux projets open source. Ensuite, nous examinons les récents projets d'innovation open source au-delà des logiciels, tels que dans l'hardware, les médicaments ou les nanotechnologies. À travers une analogie avec les licences "copyleft" utilisées dans les logiciels libres et open source, nous discutons de l'utilisation non-conventionnelle des brevets, qui correspond au "troisième visage des DPI" (David, 2006), qui peuvent garantir l'accès aux améliorations des inventions open source. De plus, nous discutons de la nécessité de mettre en place une stratégie de licence open source pour les universités, et analysons les cas dans lesquels une telle stratégie pourrait constituer une meilleure alternative aux stratégies de licence traditionnelles, en comparant ces deux méthodes. Notre étude propose que, contrairement à un cadre d'innovation statique, dans un environnement d'innovation dynamique (c'est-à-dire, lorsque les inventions sont séquentielles), l'utilisation de licences open source de type "copyleft" pourrait améliorer le bien-être social. À notre connaissance, des licences open source au-delà des logiciels n'ont pas encore été utilisées par les OTTs. Par conséquent, le présent chapitre vise à fournir aux OTTs des stratégies alternatives en matière de licences, permettant ainsi un processus de transfert de connaissances plus ouvert et plus collaboratif, aligné sur la mission de l'université.

Le **Chapitre 5**, intitulé "*The Complementarities between Formal and Informal Channels of University–Industry Knowledge Transfer: A Longitudinal Approach*"[78] examine l'interaction dynamique entre différents canaux formels et informels du transfert de connaissances Université-Industrie. Dans ce chapitre, notre objectif est d'élargir notre perspective sur les IUI et de saisir la complexité de l'activité de transfert de connaissances, dans la mesure où nous n'en savons que très peu sur la manière dont les différents canaux de transmission des connaissances interagissent. À cet égard, nous examinons d'abord la variété des canaux et proposons une classification unifiée des transferts de connaissances Université-Industrie, formels et informels, basée sur l'existence d'un contrat et d'interactions personnelles. Ensuite, nous observons les activités de valorisation de la recherche de deux chercheurs de renom dans les domaines de la robotique et des produits pharmaceutiques à l'Université de Strasbourg, en s'appuyant sur des données qualitatives et longitudinales (entretiens). Cette approche nous permet de montrer comment les équipes de recherche exploitent les différents canaux de transfert, et comment ces canaux s'articulent dans le temps. Ainsi, ce chapitre cartographie les divers canaux par lesquels les universités peuvent contribuer à

[78] Ce chapitre est basé sur notre article publié: "Schaeffer, V., Öcalan-Özel, S. & Pénin, J. (2018). The Complementarities between Formal and Informal Channels of University–Industry Knowledge Transfer: A Longitudinal Approach. *Journal of Technology Transfer*, 1-25. https://doi.org/10.1007/s10961-018-9674-4"

l'innovation industrielle et à la croissance économique, et décrit les interactions dynamiques qui les unissent.

Conclusion Générale

Cette thèse vise à étudier l'impact social des stratégies d'octroi de licences universitaires, ainsi qu'à analyser l'interaction dynamique entre les différents canaux de transfert utilisés dans les Interactions Université-Industrie (IUI). À cet égard, nous avons examiné les stratégies d'octroi de licences universitaires ayant différents degrés d'exclusivité, puis avons décrit les interactions dynamiques entre les différents canaux utilisés dans le transfert de connaissances. La plus grande partie de cette thèse porte sur les stratégies de licence des universités. Ainsi, nous avons d'abord posé la question suivante: *"Comment les pratiques en matière de licences des universités (et donc de leurs Offices de Transfert de Technologies (OTTs)) peuvent-elles être améliorées, tout en continuant à transférer les résultats de la recherche universitaire (financée à l'aide de fonds publics) vers l'industrie?"*. À cette fin, nous avons spécifiquement examiné le lien entre différents degrés d'exclusivité et les caractéristiques de l'invention sous licence.

Alors que les universités ont constitué d'importantes sources de connaissances pour l'innovation industrielle tout au long du 20ème siècle, une grande partie de ces contributions économiques ont été apportées à travers d'autres canaux que les brevets et les licences (Mowery *et al.*, 2004). Par conséquent, afin de décrire la complexité de l'activité de transfert de connaissances, nous avons élargi notre étude, dans le Chapitre 5, en allant au-delà de la simple concession de licences et en examinant les divers autres canaux de transfert. Dans ce chapitre, nous avons abordé la question suivante: *"Comment les canaux formels et informels de transfert de connaissances Université-Industrie interagissent-ils dans le temps?"*. Ainsi, dans ce dernier chapitre, nous avons étudié les interactions complexes et dynamiques entre les différents canaux de transfert.

Le **Chapitre 1** visait à présenter une image plus complète des IUI, afin de complémenter les ultérieurs chapitres qui étudient les licences universitaires mais aussi les divers autres possibles canaux de transfert. Dans ce chapitre, nous avons fourni un aperçu historique des IUI, en nous concentrant sur des cas aux États-Unis et en Europe. Nous avons observé que la plupart des recherches sur les IUI étaient centrées sur les États-Unis. Le cas des États-Unis offre un terrain d'étude fertile car, historiquement, la recherche menée dans les universités américaines était davantage axée sur les applications, ces universités dépendant principalement de financements industriels. Ceci leur a permis d'établir des liens plus étroits avec le secteur industriel, comparées à leurs homologues européennes (Mowery *et al.*, 2004).

Cependant, après la Seconde Guerre Mondiale, l'influent rapport de Vannevar Bush distinguait clairement les sphères de la science fondamentale et de la science appliquée, et insistait sur le fait que les universités américaines devaient être tenues à l'écart de toutes activités commerciales. Pourtant, ce paradigme a totalement changé après l'adoption de la loi Bayh-Dole en 1980 et la prolifération de législations similaires en Europe et sur d'autres continents. Les législations de type Bayh-Dole ont catalysé la croissance des brevets et des licences universitaires. Le volume et la complexité croissante des activités de commercialisation ont conduit à l'institutionnalisation de la gouvernance des activités de transfert, et, notamment, à la mise en place de structures intermédiaires telles que les OTTs, dédiées à la gestion de la propriété intellectuelle des universités (Geuna et Muscio, 2009). Ainsi, en examinant le cas des OTTs aux États-Unis et en France, nous avons soulevé la question de l'objectif principal de ces structures lors de l'octroi de licences universitaires.

Par conséquent, dans le **Chapitre 2**, nous avons étudié les moyens d'améliorer les pratiques d'octroi de licences des OTTs, de telle sorte à ce que leurs objectifs puissent être alignés sur les besoins de la société. À cette fin, nous avons défini différents degrés d'exclusivité dans l'exploitation des résultats de recherche, allant de la licence open source à la licence exclusive, tout en prenant en compte la publication. Ensuite, nous avons investigué les facteurs qui devraient entrer dans la décision de brevetage et de licence des OTTs. Parmi ces facteurs, nous avons étudié comment la nature de l'invention (à savoir, son stade de développement et sa spécificité) influençait les stratégies en matière de brevets et de licences, à l'aide d'un simple modèle théorique. Nous avons considéré un modèle avec une université et quatre entreprises dans deux secteurs différents. Nous avons montré que l'invention ne peut pas être transférée à l'industrie si elle est trop embryonnaire; par conséquent, des efforts supplémentaires de maturation sont nécessaires. Au contraire, lorsque l'invention est mature, la publication est la stratégie optimale. Si l'invention est embryonnaire et spécifique, la licence exclusive est la seule stratégie permettant son transfert à l'industrie. En outre, si l'invention est générique et embryonnaire, une licence exclusive par domaine d'utilisation est le meilleur moyen de transférer l'invention. Un résultat important de cette étude est qu'à l'équilibre du modèle, les universités ne choisissent pas toujours automatiquement la stratégie maximisant le surplus social.

Dans le **Chapitre 3**, nous avons testé empiriquement certains des résultats présentés dans le Chapitre 2. Toutefois, dans ce chapitre, nous avons supprimé la stratégie de publication et nous nous sommes concentrés uniquement sur le cas de la concession de licences. S'appuyant sur une base de données unique et originale, nous avons examiné 91 inventions contenues dans 62 contrats de cession de brevets et de licences de propriété intellectuelle, exécutés par deux grandes universités françaises durant la période 2005-2014. Nous avons construit notre base de données dans le cadre du projet COCON, en combinant des données de codification des contrats avec des données d'enquêtes auprès des inventeurs. À la différence de précédentes recherches, qui liaient l'exclusivité **à chaque contrat**, nous avons lié l'exclusivité **à chaque invention**, puisqu'un contrat de licence peut contenir plus d'une invention, et que ces inventions peuvent être soumises à des conditions d'exclusivité différentes.

À cet égard, nous pensons que notre recherche, bien qu'exploratoire, apporte de nouvelles idées à l'analyse de données de licence. Les résultats de cette recherche révèlent que les caractéristiques de l'invention n'affectent pas de manière significative la stratégie de licence. En particulier, contrairement aux prédictions théoriques, les inventions embryonnaires ne sont pas liées de manière significative à des licences exclusives, et les inventions génériques ne sont pas davantage liées à des licences non-exclusives. De plus, les inventions génériques et embryonnaires ne sont pas liées de manière significative aux licences exclusives par domaine d'utilisation. Enfin, conformément à nos prédictions théoriques, plus la technologie peut être facilement appropriée (c'est-à-dire que l'imitation est difficile ou coûteuse), moins elle est susceptible d'être sous licence exclusive; cependant, cette relation ne tient pas pour les licences exclusives par domaine d'utilisation. Néanmoins, en raison de la petite taille de notre échantillon, nos conclusions pourraient ne pas être généralisées, et des analyses à plus grande échelle sont donc nécessaires.

Les chapitres 2 et 3 excluaient la stratégie de licence open source et se sont concentrés sur les stratégies de licence traditionnelles, dans la mesure où la licence open source est une forme spécifique de licence et reste rare dans le cas des brevets. En outre, le chapitre 2 a considéré un environnement statique, en supposant que les innovations ne progressent pas de manière séquentielle. Ainsi, dans le **Chapitre 4**, nous nous sommes concentrés sur le cas de la licence universitaire open source, au-delà des logiciels (comme c'est le cas dans le secteur de l'hardware, des médicaments ou encore des nanotechnologies), dans un environnement dynamique dans lequel les innovations sont séquentielles. Dans ce chapitre, nous avons discuté de la possibilité d'introduire une telle stratégie dans le contexte du transfert de connaissances universitaires, et avons étudié les conditions dans lesquelles cette stratégie pourrait remplacer des stratégies plus traditionnelles. Nous avons argué que la licence open source était la stratégie de valorisation de recherche la moins exclusive, même lorsqu'elle est comparée à la publication des résultats de la recherche, qui est une pratique courante dans le domaine de la "science ouverte". La raison est que, lorsque les inventions sont séquentielles, le fait de placer le savoir dans le domaine public peut entraîner une appropriation future de ce même savoir. Par conséquent, dans ce chapitre, nous avons abordé le rôle spécifique que les brevets pouvaient jouer dans la préservation de "l'ouverture" des innovations open source, lorsqu'ils sont utilisés sous la forme d'un "jujitsu juridique" (Benkler, 2006).

Contrairement à la vision conventionnelle selon laquelle les brevets et l'open source sont incompatibles, nous affirmons que, dans un contexte cumulatif, les brevets peuvent être nécessaires afin de ne pas bloquer les innovations subséquentes, aussi longtemps que le titulaire du brevet n'utilise pas son droit à exclure. Nous faisons ainsi l'analogie avec les licences "copyleft" utilisées pour les logiciels libres et open source (Pénin et Wack, 2008). Il s'avère qu'un pilier juridique (qu'il s'agisse d'un droit d'auteur pour un logiciel ou d'un brevet d'invention) est l'une des principales caractéristiques définissant le mode d'innovation open source, aux côtés d'un mode d'organisation de type "bazar" et de la délivrance du code source (Raymond, 1999).

Les discussions que nous avons menées tout au long des chapitres 2, 3 et 4 visaient à analyser les moyens d'améliorer les stratégies d'octroi de licences universitaires. Néanmoins, la licence n'est pas le seul moyen par lequel les universités peuvent interagir avec le secteur industriel (D'Este et Patel, 2007; Bekkers et Bodas Freitas, 2008; Perkmann *et al.*, 2013). Par conséquent, dans le **Chapitre 5**, nous élargissons notre perspective en étudiant divers autres canaux d'interaction. Dans ce chapitre, nous avons montré comment s'articulent les divers canaux formels et informels au fil du temps. Pour cela, nous nous sommes appuyés sur une analyse longitudinale et qualitative de données d'entretiens, ce qui nous a permis d'observer les trajectoires de recherche et de valorisation de deux chercheurs de renom, dans les domaines de la robotique et de la pharmacie, à l'Université de Strasbourg. Les principaux résultats de cette recherche sont les suivants: (i) les canaux formels et informels interagissent de manière dynamique et sont complémentaires, (ii) de telles interactions contribuent à créer un effet cumulatif fort en ce qui concerne l'activité de valorisation, tant au niveau individuel qu'au niveau de l'équipe, (iii) l'interaction entre ces canaux renforce également la dimension collective de la valorisation, réalisée par des équipes plutôt que par des individus isolés, (iv) les meilleurs entrepreneurs universitaires exploitent les différents canaux de transfert de connaissances avec, à l'esprit, une stratégie de valorisation claire à long terme.

Contributions de la thèse

Cette thèse contribue à la fois à la littérature théorique et empirique sur les IUI, en examinant l'impact social des pratiques d'octroi de licences des OTTs et en élargissant notre compréhension sur la façon dont les divers canaux de transfert formels et informels interagissent au fil du temps, en allant au-delà des simples licences. Nous pouvons identifier au moins cinq principales contributions de notre étude.

Tout d'abord, notre recherche contribue à la littérature en examinant le contenu des contrats de licence universitaire, un sujet très peu abordé dans la littérature. Il s'avère qu'accéder aux contrats de licence est une tâche difficile, en raison des informations confidentielles qu'ils contiennent. En outre, une analyse détaillée du contenu des contrats nécessite une expertise juridique, ce qui demande une collaboration multidisciplinaire. Les quelques études existantes se sont principalement concentrées sur le contenu des contrats de licence inter-entreprises (Bessy et Brousseau, 1998; Anand et Khanna, 2000; Somaya *et al.*, 2011, par exemple). Cependant, contrairement aux entreprises, les universités sont des organisations à but non lucratif visant à générer et à diffuser des connaissances scientifiques. Compte tenu de leur mission publique, les contrats de licence des universités se doivent d'être conçus avec soin afin de garantir une large diffusion des connaissances, tout en préservant les incitations au développement ultérieur de la technologie universitaire. À cette fin, nous nous sommes concentrés sur la clause d'exclusivité des contrats de licence. À cet égard, notre étude se démarque de la littérature consacrée au système de paiement des contrats de licence universitaires (par exemple, Jensen et Thursby, 2001; Dechenaux *et al.*, 2009; 2011). Nous discutons de la manière dont le degré d'exclusivité peut être ajusté en fonction du contexte. Suivant Pénin (2010a), nous avons identifié diverses caractéristiques qui devraient entrer dans la décision des universités en termes de licences (à savoir, la nature de l'invention, le régime technologique, le régime de concurrence, le type de société titulaire de la licence, etc.). Ensuite, parmi ces caractéristiques, nous nous sommes concentrés sur la nature de l'invention (c'est-à-dire le stade de développement et la spécificité) en tant que déterminant du degré d'exclusivité, et avons discuté l'impact social du choix d'exclusivité (Chapitre 1).

Ceci nous amène à la deuxième contribution de cette thèse. À notre connaissance, nous proposons pour la première fois une enquête empirique (bien qu'exploratoire) concernant le lien entre le degré d'exclusivité et les caractéristiques de l'invention (Chapitre 3). En particulier, nous examinons les effets du stade de développement (embryonnaire ou mature), de la spécificité (générique ou spécifique) et de la potentielle appropriation (appropriable ou non-appropriable) de l'invention sur le degré d'exclusivité (c'est-à-dire exclusif, exclusif par domaine d'utilisation, ou non-exclusif).

Troisièmement, notre étude empirique contribue également à la littérature avec la construction d'une base de données unique et originale, combinant des données de la codification de contrats de licence universitaires et d'enquêtes auprès d'inventeurs. Bien que de petite taille, cette base de données nous permet d'analyser la relation entre le degré d'exclusivité et diverses caractéristiques de l'invention. De plus, contrairement aux études liant l'exclusivité à chaque contrat, nous avons lié l'exclusivité à chaque invention, dans la mesure où les contrats de licence peuvent contenir des inventions soumises à des conditions d'exclusivité différentes. Nous pensons que cette approche peut apporter de nouvelles perspectives pour les études futures.

Quatrièmement, nous ouvrons une discussion sur les licences open source des universités, et examinons dans quel contexte cette stratégie d'octroi de licences pourrait être pertinente (Chapitre 4). Nous discutons de la question de la licence open source au-delà des logiciels, en mettant l'accent sur l'utilisation spécifique des brevets pour garder l'innovation "ouverte". Bien qu'à notre connaissance la licence open source ne représente pas une pratique courante pour les universités, notre étude apporte de nouvelles perspectives à la littérature en discutant des possibilités au-delà des stratégies de licence traditionnelles.

Enfin, notre recherche contribue à la littérature en élargissant l'analyse sur les interactions dynamiques et les complémentarités entre différents mécanismes de transfert de connaissances (Chapitre 5). En particulier, à la différence de la littérature consacrée à l'analyse transversale et à la relation par paire des canaux de transfert de connaissances Université-Industrie (Czarnitzki *et al.*, 2007; Azoulay *et al.*, 2009; Grimpe et Hussinger, 2013), nous nous concentrons sur la dimension temporelle, et considérons l'interaction entre les différents canaux de transfert, ce qui nous permet d'apprécier la complexité de ces interactions. De plus, notre étude contribue à la littérature en combinant deux approches différentes concernant les canaux de transfert formels et informels et, par conséquent, en fournissant une taxonomie unifiée basée sur l'existence d'une relation contractuelle et d'interactions personnelles.

Implications managériales et en termes de politiques publiques

Notre recherche a plusieurs implications pour les praticiens et les décideurs politiques. Tout d'abord, notre étude révèle une possible source d'inefficacité lorsque les OTTs cèdent systématiquement des licences exclusives, quelles que soient les caractéristiques de l'invention. Une possible explication pourrait être le manque de compétences et d'expérience industrielle du personnel des OTTs, qui pourrait gêner la conception d'un contrat de licence optimal. La difficulté d'évaluer les propriétés spécifiques de la technologie peut également entraver une conception optimale. Cela devrait certainement obliger le personnel des OTTs à établir des liens plus étroits avec les inventeurs tout au long du processus de transfert de technologie, dans la mesure où les inventeurs disposent d'informations uniques et précieuses concernant les caractéristiques de leurs technologies.

Une autre explication pourrait être que les OTTs manquent de pouvoir de négociation lors de la négociation de la clause d'exclusivité. Les entreprises préfèrent toujours l'exclusivité, car cela leur confère un pouvoir monopolistique sur l'exploitation des inventions. Par conséquent, les gestionnaires des OTTs devraient développer des stratégies leur permettant d'augmenter leur pouvoir de négociation, afin que les inventions puissent être largement diffusées. Pour accroître leur pouvoir de négociation, les OTTs devraient réduire l'incertitude associée aux inventions universitaires, en investissant, par exemple, dans la maturation des inventions en phase initiale (comme c'est le cas pour la SATT Conectus). Cependant, ce pouvoir de négociation est également lié à la qualité de la technologie, ce qui oblige les universités à mener des recherches de pointe. De plus, le développement de solutions alternatives, telles que la licence open source, pourrait, dans certaines conditions, favoriser la confiance et augmenter les collaborations, ce qui pourrait faciliter la large diffusion de la technologie universitaire.

En outre, la réduction du budget gouvernemental consacré à la recherche universitaire peut amener les universités à “vendre” leurs technologies aux meilleurs offrants, avec des conditions exclusives, ce qui peut nuire au bien-être social à long terme. Par conséquent, notre recherche insiste sur l'importance du financement public de la recherche universitaire.

De plus, nous soulignons également que les missions des OTTs devraient être plus larges que la simple gestion du portefeuille de propriété intellectuelle des universités. Les gestionnaires des OTTs se doivent de reconnaître la diversité des canaux Université-Industrie et de contribuer à favoriser les interactions entre les différents acteurs des IUI. Les décideurs politiques devraient également reconnaître ces différents canaux, et donc mettre en place différentes mesures, lors de l'évaluation des activités de valorisation de la recherche universitaire, dans la mesure où les évaluations sont essentiellement basées sur des indicateurs de performance facilement observables tels que le nombre de brevets, les contrats de licence, les start-ups et le montant des redevances. Enfin, les OTTs ne devraient pas seulement viser à réduire les obstacles liés aux coûts de transaction, mais devraient également prendre davantage de mesures visant à éliminer les obstacles culturels empêchant le transfert de connaissances entre les universités et l'industrie.

Pistes pour de futures recherches

Notre étude apporte des nuances aux discussions sur le transfert de technologie, et montre que les stratégies de licence des universités pourraient ne pas être optimales. Nous avons mis l'accent sur la mission publique des universités, et avons ainsi avancé que le processus d'attribution de licences universitaires devrait être géré de telle sorte à ce que le bien-être social soit maximisé. À cette fin, nous avons étudié les possibles sources d'inefficacité, en nous concentrant sur la relation entre le degré d'exclusivité et les caractéristiques technologiques. Cependant, il reste de nombreuses dimensions à explorer afin de mieux comprendre les possibilités d'amélioration des pratiques en matière de licences universitaires et, plus généralement, des IUI.

Notre étude présente certaines limites, qui suggèrent des pistes prometteuses pour les recherches futures. Une première limite est que nous considérons que la décision d'exclusivité est prise par les OTTs, alors qu'en pratique, elle résulte d'un processus de négociation. Le modèle présenté dans le **Chapitre 2** repose sur des hypothèses simplistes. Par exemple, nous considérons le taux de redevance comme exogène, alors que ce taux est également sujet à négociation. En outre, nous ne considérons pas la question de l'asymétrie de l'information. Des recherches ultérieures devraient assouplir ces hypothèses. Nous décrivons également une vision assez linéaire du transfert de technologie, alors qu'en réalité l'activité de transfert est non-linéaire, le transfert de connaissances étant multi-directionnel. De plus, nous étudions un environnement statique dans lequel nous supposons que les innovations ne sont pas séquentielles, alors que la modélisation d'un environnement dynamique (séquentiel) pourrait constituer une piste de recherche intéressante. Il pourrait également être intéressant de modéliser l'effet de variables autres que la nature de l'invention, comme, par exemple, l'impact de marchés de différentes tailles.

Une limitation importante que nous rencontrons au **Chapitre 3** est la petite taille de l'échantillon, malgré l'originalité et la richesse de notre base de données. Ceci nous empêche de généraliser les résultats de nos recherches. Par conséquent, notre travail exploratoire nécessite une analyse à plus grande échelle. Une piste de recherche intéressante pourrait être de considérer le système d'exclusivité sous différentes structures de propriété, par exemple, lorsque les inventions universitaires sont brevetées conjointement avec l'industrie. Il pourrait également être intéressant d'enrichir la base de données en ajoutant différentes caractéristiques de la technologie, telles que, par exemple, sa complexité ou l'existence d'externalités de réseau. Enfin, les futurs travaux empiriques devraient prendre en compte les caractéristiques de l'entreprise et celles des institutions, qui pourraient représenter d'importants déterminants du degré d'exclusivité.

Une limite évidente du **Chapitre 4** est qu'à notre connaissance, la licence open source, au-delà des logiciels, n'est actuellement pas utilisée par les OTTs, ce qui implique que nous ne pouvons pas valider empiriquement nos propositions. Cependant, de futures recherches devraient étendre les modèles théoriques au-delà des innovations dans le secteur du logiciel, et comparer les stratégies traditionnelles de licence avec la licence open source, notamment dans le cas d'inventions séquentielles.

Enfin, l'une des limites du **Chapitre 5** est que, bien que la recherche fondée sur un petit nombre de cas permette une analyse plus approfondie, elle nous empêche de généraliser les résultats de notre étude. Nous avons uniquement examiné des cas dans les domaines de la robotique et des produits pharmaceutiques. Bien que ces cas ont un degré élevé de validité interne, les résultats ne peuvent pas être généralisés à tous les domaines. Par conséquent, de futures recherches devraient étendre l'analyse dans différents domaines scientifiques afin d'étudier les différentes façons d'interagir. De plus, notre approche qualitative devrait être complémentée par une étude quantitative, afin de confirmer, par exemple, si l'activité de transfert dépend bien de complémentarités, d'effets cumulatifs, ou si la valorisation de la recherche est le résultat d'un processus collectif.

Sıla ÖCALAN ÖZEL

La Collaboration entre l'Université et l'Industrie:

Comprendre les Stratégies de Licences Universitaire et au-delà

Résumé

Cette thèse porte principalement sur les stratégies de licence des universités. Afin de comprendre l'impact social des stratégies de licences universitaires, nous examinons le lien entre le degré d'exclusivité des licences et les diverses caractéristiques des inventions sous licence. Les résultats théoriques et empiriques de nos recherches suggèrent que les pratiques des OTTs ne sont peut-être pas toujours optimales, ce qui laisse à penser que des améliorations pourraient encore être apportées. Lorsque les innovations sont séquentielles, les universités pourraient introduire des stratégies alternatives de licences open source. Nous élargissons notre étude en examinant les interactions dynamiques entre divers canaux formels et informels de transfert de connaissances. Notre analyse qualitative longitudinale suggère que l'interaction dynamique crée un effet cumulatif important vis-à-vis de l'activité de valorisation de la recherche, et renforce la dimension collective de la valorisation.

Mots clés : Droits de propriété intellectuelle, licences universitaires, clauses d'exclusivité, caractéristiques de l'invention, canaux de transfert de connaissances

Abstract

This thesis primarily focuses on university licensing. To understand the social impact of the university licensing strategies, we examine the link between the degree of exclusivity of licenses and the various characteristics of the licensed inventions. The theoretical and empirical findings of our research suggest that the practices of university technology transfer offices (TTOs) may not always be optimal, underlying the fact that there may still be room for the improvement. We also suggest that, when the innovations are sequential, universities might introduce alternative open source licensing (OSL) strategies. Furthermore, we expand our study by examining the dynamic interactions between various formal and informal channels of transfer. Our longitudinal qualitative methodology suggests that, dynamic interaction creates a strong cumulative effect with respect to the research valorization activity and reinforces the collective dimension of valorization.

Keywords : Intellectual property rights, university licensing, exclusivity clause, invention characteristics, knowledge transfer channels