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An economic analysis of formal technology transfer activities of universities, research institutes and firms

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Summary

The aim of this thesis is to contribute to a better understanding of formal technology transfer activities of universities, research institutes and firms in Europe. It analyses the interactions between these actors at different levels, the country, the region and the organisational level. The thesis furthermore analyses internal and external factors influencing the technology transfer activities of these actors. The thesis consists of five main chapters that draw on survey results that have been conducted to collect information on the technology transfer activities of universities, research institutes and firms. These activities have often been referred to as either knowledge transfer or technology transfer. However as discussed in Chapter 1 knowledge transfer is a broader and more encompassing concept compared to technology transfer. This thesis refers to both knowledge transfer and technology transfer but focusses on activities which are in some way recorded at universities, research institutes or firms, and often involve some form of intellectual property. The surveys which resulted in the data used in this thesis were part of larger studies on knowledge and technology transfer and funded by either the European Commission or the Norwegian Ministry of Education and Research. In general, the audience of these studies were policymakers with the aim to collect and monitor technology transfer activities and provide recommendations based on quantitative and qualitative data that was collected as part of these studies. This thesis, drawing on quantitative survey results, extends this work by conducting economic analysis aiming to contribute to the academic literature in this field to better guide policy on formal technology transfer in Europe.

Several studies have looked at the relationship of universities with their surrounding regions. Far fewer studies have examined how the national and regional environment influence the knowledge and technology transfer performance of universities and public research institutes. Chapter 2 analyses these issues and contributes to our understanding of the importance of the regional environment and other spatial levels for technology transfer. Chapter 2 examines how the national and regional economic structure as well as the institutional set-up of technology transfer influences the technology

transfer activities of universities and public research institutes. It analyses four classical technology or knowledge transfer outcomes: the number of patent applications, the number of research agreements, the number of license agreements and the number of start-ups. It recommends taking a multilevel perspective by controlling for hierarchical features when analysing the regional and national influence, to understand the role of the region and country on technology transfer outcomes. The results, drawing on data from a survey of more than 250 European institutions show that country differences are related to differences in the institutional set-up of technology transfer and to the (regional) economic environment which suggests multilevel analyses to properly take these interactions into account. Chapter 3 follows the recommendation of using a multilevel analysis, nesting university-level data (level 1) into regional-level data (level 2) into country-level ones (level 3). Universities in the same region and in the same country are likely more similar or related to each other in comparison to those selected randomly. Multilevel modelling accounts for these interdependencies by capturing residuals at different levels.

In the regional context, two key factors can influence knowledge transfer. First, the level of regional demand from firms for knowledge produced by universities located in the same region, and secondly the supply from universities of knowledge with potential commercial applications. Chapter 3 investigates these issues by continuing with the regional focus by examining the location of the university, quality-controlled competition and supply and demand factors on the technology transfer outcomes of universities. This chapter evaluates several aspects of the regional environment on the technology transfer outcomes of universities that have received little attention in the literature: the effect of regional employment in knowledge intensive services (KIS), quality weighted competition from other universities in the same region as the focal university, location in a metropolitan region, and interaction effects between the quality of the focal university and the quality of competition. Three types of commercialisation outcomes are examined: the number of research agreements, where the type of research is usually led by business partners; the number of start-ups, which are knowledge-led by university academics, and the number of licenses and license income. Licensing can be due to a mix of partner-led and knowledge-led research activities. The results using survey data for up to 292 universities in Europe show that competition from quality-weighted universities in the same region as the focal university decreases the number of research and licensing agreements, although the highest-ranked 13.4% of universities benefit from the regional co-location of other high quality universities for licensing.

A major characteristic of innovation diffusion is the ease of exchange of information and knowledge amongst countries, individuals, as well as organisations. The market for technology in which patents are traded or licensed, is however not very transparent and has been suffering from asymmetries of information and capacity barriers. Chapter 4 focusses on the business sector and examines the role of SMEs when operating on technology licensing markets and intends to improve the understanding of the factors affecting the licensing out, and licensing-in activities of SMEs. Chapter 4 examines the barriers faced by SMEs when operating on technology licensing markets and intends to improve our understanding of the factors affecting these barriers. Drawing on survey results of 332 SMEs this chapter shows that SMEs observe barriers differently after controlling for those with experience and without. The barriers are mostly observed with organisational costs and strategic related barriers where those with licensing-out experience are less likely to give a high importance to such barriers. From the licensing-in perspective the results show that those looking for licensing-in opportunities are less likely concerned with the quality of the technology compared to those with actual experience. Given the importance of policies promoting the increased diffusion of knowledge this chapter indicates the need to address barriers related to this policy objective. Future research could for instance explore if framework, organisational barriers, and negotiation barriers can be mitigated by assisting, in particularly SMEs without experience, with designing, drafting, and negotiating contractual agreements. Barriers in relation to the quality and development stage of the technology can be addressed through increased proof of concept funding and lowering the threshold criteria for such initiatives.

Thorough analysis on how technology is transferred amongst enterprises and from the public research sector to enterprises is of key importance to innovation policy. Chapter 5 analyses the determinants of technology transfer success. The chapter develops a conceptual framework to examine, using structural equation modelling, the importance of understanding the value of technology and the ability to identify the right partner on technology transfer successfulness. The chapter contributes to the literature by showing that the measure for the ability to identify licensees contributes to the successfulness of technology licensing but that the measure of better understanding the value of the technology has a negative relationship with technology licensing successfulness. Willingness to engage in technology transfer is confirmed in the model to have a positive relationship with licensing success. These results have implications for policies aiming to improve knowledge diffusion and open innovation as on the one hand removing asymmetric information to address market thickness can improve successful technology licensing. On the other hand, Chapter 5 shows that the value of the technology as perceived by their holders, i.e. SMEs, universities and other research institutes, reduces successfulness of technology licensing. This suggests that more valuable technology is not easily transferred.

Chapter 6 addresses several gaps in the academic literature on the influence of university policies on the knowledge transfer performance of KTOs. Using survey data for 247 European universities and 40 public research organisations, the chapter investigates the influence of institutional policies on four outcomes of transfer performance (R&D agreements with companies, patent applications, license agreements, and start-ups established). The analysis shows that the influence of policies to establish clear rules, improve transparency, and provide financial or non-financial incentives vary by outcome. The results suggest that universities and research institutes should carefully consider what rules their transfer policies include and what they publish, as the effects will vary between transfer performance measures. For instance, an institution that aims to increase its licence agreements should ensure that it is clear who owns the IP of R&D conducted at the institution. Furthermore, the institution should have written rules or protocols for licensing activities. However, the chapter also recommends keeping some flexibility when it comes to negotiating license contracts with outside parties. An institution that focuses on entrepreneurship and aims to create more start-ups should also clarify IP ownership, but at the same time avoid crushing entrepreneurial initiative by too much bureaucracy, i.e. regulations, restrictions and requirements which complicate the start-up process and demand time and resources which early entrepreneurs may lack.

Finally, Chapter 7 concludes this research with a reflection on the joint contribution of the chapters followed by a discussion on the limitations of this thesis. Chapter 7 ends with a general discussion on technology transfer by putting it in a broader perspective and presenting possible directions for future research.

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Chapter 1 Introduction

Economic development has typically involved increased production of not only goods and services but also of knowledge and technology. Technological change is widely accepted as essential for improving wellbeing and the standards of living. Research has shown that there is an increasing appreciation that in the long term the ability to generate and manage technological change is decisive in determining competitiveness and capacity to grow (Link and Siegel 2003, Haque 1995, Freeman 1982). As part of this technological change process, knowledge flows between and amongst different actors in society such as businesses, universities and research institutes. Knowledge can be produced, mediated, reproduced, acquired, and transformed, in and between forms through these different actors and channels. In the literature, including policy documents, this is referred to as knowledge transfer or technology transfer. These terms are often used interchangeably. However, knowledge transfer is a broader and more encompassing concept compared to technology transfer. Technology is for instance not the only field of knowledge for which transfer is considered important for technological advancements through commercialised products and services. The classic channels of knowledge transfer include publishing, teaching, conferencing and graduating. Knowledge flows can furthermore include social, cultural, and personal characteristics. These forms of knowledge transfer do not require intellectual property protection. In contrast, technology transfer often involves some sort of intellectual property protection. This technology transfer has gained increasing interest from policy. Technology transfer forms include patenting, licensing, spinouts or start-ups, consultancy and collaborative research and often is intended to lead to commercial beneficial results. This latter form is the focus of this thesis.

1.1 Background

Technology transfer can be conceptualised as a process that includes various stages and requires investment of time and effort by the transferee to access, learn, understand, adapt and use the technology. Technology transfer can take place through different channels, including market (or commercial) and non-market (non-commercial) ones. It may also be contractually based or not. The concept is therefore by its nature very broad, which can easily lead to confusion in discussing the issue of technology (and knowledge) transfer. In practical terms technology transfer most often consists of the transfer of components of technology from one actor to another. A wide variety of components can be transferred such as plants, machinery and equipment, production processes, software, manuals, publications, blueprints, patents and many more. For all possible technology transfer channels and directions, government policymakers have intervened to establish national or regional initiatives aimed at promoting technology transfer (Geuna and Rossi 2011; Grimaldi et al. 2011). Simultaneously, governments have implemented policies to increase domestic investment in building national science, technology and innovation (STI) capacity, at the firm level and at government bodies (Geuna and Rossi 2011).

In most cases formal agreements are involved in technology transfer transactions. These agreements are contracts typically entered into between two parties, by which one party (licensor) authorises another (licensee) to use its technology to produce goods and services. In general, the term "technology transfer agreement" refers to an agreement which licenses the use of patents, know-how, software copyrights or other types of intellectual property rights for the purposes of producing goods or services. Licensing is the most well-known form of technology transfer whereby an inventor allows another party to use the technology for commercial benefits in return for a fee.

Academics and policymakers framed these technology transfer activities as part of the push towards open and collaborative innovation (Lichtenthaler 2008; Chessborough 2017), where positive spillovers are welfare-enhancing (Blomström and Sjöholm 1999), and therefore promoted by public policy.

However, such agreements can also have welfare-reducing effects such as reductions of competition and it can impede developing countries (Müller and Schnitzer 2006; Choi 2001). In such agreements, smaller entities typically have a weaker position compared to larger counterparts, and this often results in the imposition of unwanted market inefficiencies such as contractual terms which allocate the risk on the weaker party (see also Chapter 4). However, such practices are not exclusively found in the field of technology transfer. These practices nevertheless become even more detrimental to societal welfare when they affect the transfer of intellectual property protected technologies that enhance standards of living (Link and Scott 2019).

Such practices may conflict with the traditional role of publicly funded research of advancing knowledge to benefit society. These issues are echoed in many studies that critique academic technology transfer dating back to the early 90s (Rosenberg and Nelson 1994). The argument then was that academic involvement might create unnecessary transaction costs by patenting knowledge that would otherwise flow freely to industry by traditional knowledge transfer channels such as publishing. Indeed, several studies have looked at the patenting activities of universities and the potential trade-off between publishing and patenting as the publication of a paper might, for example, limit the patentability of the same results and vice versa (Breschi 2008). Empirical work has however frequently found the relationship between patenting and publishing to be complementary and positive (e.g., Breschi et al. 2008; Meyer 2006; Crespi et al. 2011). One explanation is non-exclusivity between publishing and patenting because most research can lead to both publications and patents (Agrawal and Henderson 2002). Another explanation is that the prestige from publishing might serve as an indication of good research (Fabrizio and Di Minin 2008) that can lead to potential collaborations with industry and can stimulate both publishing and patenting (Fisch et al. 2015).

1.2 University-industry technology transfer

Universities serve the public interest by providing graduates with the opportunity to meet the needs of industry and businesses, and by contributing to the progress of science by conducting research. Research has shown that scientific research generated at universities and research institutes plays an important role in knowledge-economies (Fleming et al. 2019; Poege et al. 2019). The knowledge developed by universities and research institutes drives scientific and technological progress and spills over to the broader economy and society (Hausman, 2021; Stephan, 2015). Their current role has increasingly added interactions with industry, and with the society more generally often referred to as the third mission, next to the traditional missions of teaching and research (Kapetaniou and Lee 2017). This new role of universities has attracted considerable attention from scholars and policymakers (Hsu et al. 2015; Trune and Goslin 1998). Universities may address various objectives through these third mission activities, such as providing services to faculty, enhancing innovation and the practical use of research results, generating additional income streams, fostering local economic development, complying with national and institutional policies, and promoting public value (Bozeman et al. 2015).

In most developed countries, the business sector accounts for most investments in R&D, however the public sector accounts for a significant share of all R&D investments (Soete et al. 2020). Almost all R&D in the public sector is conducted either by government research institutes or by universities, such as general universities, technical universities, academic hospitals, government or non-profit research institutes, or research parks or incubators affiliated with these public organisations. Most of the R&D performed by universities is either basic research or humanities research with few short-term commercial applications. However, there are numerous examples of public research that led to commercial value. This includes a wide range of commercial applications, including, health applications, aerospace computerisation, energy, and new materials. Processes leading to these results often require legal and technical expertise.

To encourage and support these commercialisation activities many universities and research institutes have established Technology Transfer Offices (TTOs)[1] that can provide professional advice to assess the patentability of inventions, interact with firms, and provide licensing expertise. Although some universities have had TTOs for decades, the majority of European TTOs were established after 2000 (Arundel et al. 2013). Many started as industry liaison offices and developed services for university or research personnel to encourage commercialisation of research results. Over time, many of these TTOs employed specialised staff and developed services for assessing disclosed inventions, patenting, licensing, and developing and funding spin-offs and other start-ups, but also for actively approaching firms for contract-based arrangements (projects and transfer deals). Bayh-Dole type legislation, allowing public research to be commercialized, has been implemented in many countries (Mowery 2005), including in Europe. With the Lisbon-Agenda in 2002, universities were stimulated to exercise an intellectual property policy, focusing on patenting and licensing, and the number of TTOs grew (Audretsch, et al. 2012, Cosh and Hughes 2010).

Several studies examined technology transfer activities, including university–industry interactions, and have determined that technology flows through multiple channels. Technology transfer studies often comprise the exchange of codified academic research results in the form of publications, licensing and patents (e.g., Agrawal and Henderson 2002; Landry et al. 2006; Lach and Schankerman 2008). Other frequently cited proxies for university–industry cooperation are basic and applied R&D projects, meetings and conferences, student, graduate and researcher mobility, consultancy and training, joint supervision of final degree theses and informal contacts (Rynes et al. 2001; Cohen et al. 2002; Valentine 2002; Landry et al. 2006; D'Este and Patel 2007; Bekkers and Freitas 2008; Wright et al. 2008). Moreover, academic

1 These offices are also called Knowledge Transfer Offices (KTOs), Research Office, Research Commercialisation, Valorisation Office etc.. These offices can be part of a university or research institute. They can also be a separate business responsible for the technology transfer activities of a university or research institute. Some or all of the patenting, licensing, or other technology transfer activities of a university or research institute can fall under the responsibilities of such an office or business.

start-ups/spin-offs are becoming increasingly important as a transfer channel (Di Gregorio and Shane 2003; Landry et al. 2006; Guenther and Wagner 2008).

These science-industry interactions can also take place without the direct involvement of the university or research institute. For instance, Freitas et al. (2013) brought to light that personal contractual agreements between firms and individual academics amount to at least 50% of university–industry cooperation. Furthermore, D'Este and Patel (2007) found that informal relationships between businesspeople and academics are relevant aspects of university–industry interaction and, in many cases, underlie the establishment of more formal collaboration. Nevertheless, in many cases and particularly for formal transactions, these activities are handled by designated technology transfer offices set up by universities or research institutes.

The amount and quality of technology that is transferred either from universities to industry or from industry to industry is difficult to measure and value is not created directly (Bozeman 2015 and 2000). This is particularly true for informal channels or for methods that leave few traces, such as hiring or the use of publicly available knowledge by researchers in firms. In contrast, it is easier to measure formal transfer methods that leave traces in legal documents, such as licenses, patents, and research agreements, although it is still difficult to determine if the transferred knowledge has resulted in commercially viable goods and services. Nevertheless, technology transfer offices at universities and research institutes monitor their technology transfer activities which has led to an increasing interest of policy and academic researchers to monitor technology transfer activities of publicly funded universities and research institutes.

1.3 Aim of this thesis

The aim of this thesis is to contribute to a better understanding of formal technology transfer activities of universities, research institutes and firms in Europe. It analyses the interactions between these actors at different levels, the country, the region and the organisational level. Furthermore, the thesis analyses internal and external factors influencing the technology transfer activities of these actors. This thesis draws on surveys that have been conducted to collect information on formal technology transfer activities. These surveys were part of larger studies on knowledge and technology transfer and funded by either the European Commission or the Norwegian Ministry of Education and Research. In general, the audience of these studies were policymakers with the aim to collect and monitor technology transfer activities and provide recommendations based on quantitative and qualitative data that was collected as part of these studies. This thesis, drawing on quantitative survey results, extends this work by conducting economic analysis aiming to contribute to the academic literature in this field. The thesis aims to achieve this by conducting quantitative economic analysis of national, regional and sectoral differences in technology transfer activities across Europe. Moreover, the thesis contributes to the existing academic literature by investigating the challenges faced by universities, research institutes and firms when engaging in technology transfer to better guide policy on formal technology transfer in Europe.

The thesis consists of five main chapters. Several studies have looked at the relationship of universities with their surrounding regions. Far fewer studies have examined how the national and regional environment influence the knowledge and technology transfer (KTT) performance of universities and public research institutes. Chapter 2 examines how the national and regional economic structure as well as the institutional set-up of technology transfer influences the technology transfer performance of universities and public research institutes. It recommends a need to take a multilevel perspective and control for institutional features when analysing the regional and national influence on technology transfer outcomes. In the regional context, two key factors can influence knowledge transfer, the level of regional demand from firms for knowledge produced by universities located in the same region, and the supply from universities of knowledge with potential commercial applications. Chapter 3 examines these issues by using multilevel analysis, nesting university-level data (level 1) into regional-level data (level 2) into country-level data (level 3). Universities in the same region and in the same country are likely more similar or related to each other in comparison to those selected randomly. Multilevel modelling accounts for these interdependencies by capturing residuals at different levels. Chapter 3 adds on Chapter 2 by focussing on the competition effect of other universities in the same region to examine the location of the university, their quality-controlled competition and supply and demand factors and their influence on the technology transfer outcomes of universities.

A major characteristic of innovation diffusion is the ease of exchange of information and knowledge amongst countries, individuals, as well as organisations. The market for technology in which patents are traded or licensed, is however not very transparent and has been suffering from asymmetries of information and capacity barriers. Chapter 4 turns to the business sector by analysing the barriers faced by SMEs when operating on technology licensing markets and intends to improve the understanding of the factors affecting these barriers such as SME size, sector of activity, patenting activity and experience with licensing.

Thorough analysis on how technology is transferred amongst enterprises and from the public research sector to enterprises is of key importance to innovation policy. Chapter 5 aims to improve the understanding the role practices and methods used to assess the licensing value of technology and the ability to find licensees has on licensing success. Chapter 5 draws on data of SMEs, universities and research institutes resulting from the same survey data that was used in Chapter 4. Chapter 5 develops a conceptual framework to examine, using structural equation modelling, the importance of the value of the technology and the ability to identify the right partner on technology transfer successfulness.

Chapter 6 addresses several research gaps in the academic literature on the influence of university policies on the knowledge transfer performance of KTOs. Using survey data for 247 European universities and 40 public research organisations, the research investigates institutional policies on four outcomes of transfer performance (R&D agreements with companies, patent applications, license agreements, and start-ups established). The chapter examines the implementation of clear rules, transparency, and financial and non-financial incentives on university technology transfer.

The research is concluded in Chapter 7 with an elaborate reflection on the chapters' combined contribution in the concluding summary section. This is followed by a discussion on the limitations of this thesis. Chapter 7 ends with a general discussion on technology transfer by putting it in a broader perspective and presents possible directions for future research.

Chapters 2 and 6 draw on survey results that were part of a study funded by the European Commission, Directorate General for Research and Innovation (DG RTD), under contract RTD/DirC/C2/2010/SI2.569045. Chapters 4 and 5 draw on survey results of a study funded by the same directorate under contract RTD/PP-02821-2015. Lastly Chapter 3 draws on survey results that were part of a study funded by the Norwegian Ministry of Education and Research. Support from DG RTD of the European Commission and the Norwegian Ministry of Education and Research is gratefully acknowledged. The survey measurement tools used as part of these studies together with additional information on the data collection exercise is provided in the appendix at the end of this thesis.

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Chapter 2 Influences of the regional and national economic environment on the technology transfer performance of academic institutions in Europe

Abstract: Several studies have looked at the relationship of universities with their surrounding regions. Far fewer studies have examined how the national and regional environment influence the knowledge and technology transfer activities of universities and public research institutes. This chapter[2] analyses these issues and contributes to our understanding of the importance of the regional environment and other spatial levels for technology transfer. The chapter examines internal and external factors that influence university technology transfer such as region size, economic structure, per capita income, technology intensity, and R&D intensity. The role these factors play on four different technology transfer measures is examined empirically. We find that: 1) Country differences are related to differences in the institutional set-up of technology transfer and to the (regional) economic environment. 2) Institutions in a country usually excel in one performance measure which we take as a supporting argument for the development of transfer strategies. 3) Having manufacturing companies and a large share of governmental R&D expenditure in the region matter more than the technology intensity and R&D intensity of the regional economy. The latter result is counterintuitive and indicates that further research is needed to understand better where the clients of university technologies actually come from.

[2] This chapter is published in University Evolution, Entrepreneurial Activity and Regional Competitiveness (pp. 207-234), 2016). Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-17713-7_10. The chapter is written together with Franz Barjak of the School of Business, University of Applied Sciences and Arts Northwestern Switzerland (FHNW). Some additional analysis has been conducted after the publication. This has led to some changes in the text as compared to the publication.

1. Introduction

The amount of literature on the relationship of universities with their surrounding regions is sizeable and swiftly growing. Most theorizing and empirical research conducted by innovation economists, regional scientists and economic geographers has focused on the impact of universities on regional economies (for a review see Drucker and Goldstein 2007). Uyarra (2010) distinguishes five different roles which are ascribed to universities in this work: 1) knowledge factory, 2) relational university, 3) entrepreneurial university, 4) systemic university, and 5) engaged university. We have learned a lot from this body of research, for instance on the localised nature of knowledge spill overs from universities, the attractiveness of top universities and their star scientists to business enterprises, the multiple channels of interaction between academia and business, the importance of academic entrepreneurship, the role of universities in regional innovation systems and many other issues. However, this research has also been described as too much based on evidence from universities in Anglo-Saxon countries and to some extent ignoring the complexity and diversity of universities and their limited ability of collective action (Uyarra 2010).

A lot less work has looked at this relationship from the university perspective investigating the question: How does the socio-economic environment shape the abilities of universities to deliver their services of higher education, research and engagement with society? Research has mostly focused on the regional engagement and technology transfer part of this wider question and generally found an advantage for universities in wealthier and more technology-intensive regions. For instance, a recent study on Spanish universities looked at the effects of the regional stock of knowledge in the business sector (measured as accumulated R&D expenses per firm) on universities' licence agreements and spin-offs (González-Pernía, Kuechle, and Peña-Legazkue 2013). Though it did not find any significant effects for the variables of interest, regional dummy variables still raised the explanatory power of the estimations which led the authors to conclude: "This means that there are other regional characteristics, beyond the two that we used in our tests […], which can be useful to understand the behaviour and capacity of regions for technology transfer" (González-Pernía, et al. 2013, p. 14). Analysing data for universities from the UK, Chapple and her co-authors found strong influences for region-level variables, concluding that agglomeration effects might act upon the commercialisation of research (Chapple, Lockett, Siegel, and Wright 2005).

Of note, we do not want to suggest with this, that the regional environment is the most important let alone the only influence on transfer performance that is related to geography. To the contrary, we find a lot of truth in suggestions of a multilevel determination of university excellence – no matter whether in regard to teaching, research or transfer – and warnings of a too narrow focus of policies which try to raise the prominence of universities in regional innovation systems (Fromhold-Eisebith and Werker 2013; Power and Malmberg 2008). For this reason we find it highly desirable to keep an open eye on the role of other spatial levels as well, from local to national and even international.

This chapter analyses these issues and contributes to our understanding of the importance of the regional environment and other spatial levels for technology transfer. Thanks to a sufficiently large multinational dataset that we put together in 2011 and 2012 on behalf of the European Commission, we could include control variables for countries in regressions on transfer performance measures and discover interaction effects with institutional characteristics (of the universities and their transfer offices). The estimations use a wider set of regional socio-economic characteristics than previous studies and assess their relationship to knowledge transfer performance. For the latter we use four measures: two that are closer to research (the number of research agreements and patent applications) and two that are closer to the market (the number of license agreements and start-ups established).

We first give a short overview of the relevant literature, then describe the sample and data collection methods, present key results and close with a discussion and conclusions.

2. Research on knowledge transfer performance

Previous studies have evaluated the effect of a large number of factors that can affect knowledge transfer performance of universities and other public research organisations, including the characteristics and practices of the knowledge transfer office (KTO), the characteristics and policies of the affiliated institution, and of particular interest to this chapter the characteristics of the external environment.

2.1 Characteristics of the KTO and the institution

The establishment and design of a KTO, an office for knowledge and technology transfer, is often an institutional decision taken by the administration of the university or public research institute. Once established, many KTOs are able to make independent decisions in the area of IP management and knowledge transfer. This ability, combined with its age and experience, number and qualifications of its staff, degree of autonomy from the institution, organizational structure and degree of centralization of services can influence knowledge transfer performance (for reasons of brevity we omit references to the relevant literature, a review can be found in chapter 5).

Several institutional characteristics and policies can influence performance as well; previous work points to ownership (public-private), size, the existence of science departments or a medical faculty, research excellence and business orientation, institutional by-laws and policies for instance with regard to IP protection and management, licensing and the distribution of commercialization revenues (for supporting evidence see again Barjak, et al. 2014).

2.2 Regional characteristics

Several studies on the transfer performance of universities controlled for the regional market environment for university technologies. Mainly four issues have been investigated in this context (see also for an overview Table 1).[3]

[3] We abstract from a few other variables which also have been tested in individual studies, such as social capital (correlates positively with university spin-off numbers in Fini, Grimaldi, Santoni,

1) Technology intensity of the regional economy. Being located in a technology-intensive region has positive effects on the demand for technology from regional companies and a more entrepreneurial climate is to be expected. Moreover, hubs as defined as geographic concentration of patenting by firms in a specialized technical field facilitate the flow of academic science into industrial technologies (Bikard and Marx 2020). Empirical studies for US universities using the Milken Institute Tech-Pole Index indeed found positive effects of being located in a high-tech region on the numbers of licences (Friedman and Silberman 2003) and on licensing income (Belenzon and Schankerman 2009; Friedman and Silberman 2003; Lach and Schankerman 2008). The results for start-ups are inconclusive (Friedman and Silberman 2003; O'Shea, Allen, Chevalier, and Roche 2005). In addition, studies using other indicators for technology intensity could not reproduce this finding: the densities of high technology organisations and high technology employment have not been found to relate to the licences executed by a university in the AUTM survey (Sine, Shane, and Di Gregorio 2003). The number of patents held by regional firms does not contribute to explaining invention disclosures to German KTOs (Hülsbeck, et al. 2013); neither does the number of regional patent applications have an effect on licences in Europe and the US (Conti and Gaule 2011) - however there is a weak positive correlation with licence income (ibid.).

2) Research intensity of the regional economy. According to Link and Siegel (2005; 2003) industrial R&D in the state has a positive effect on the licensing productivity of universities. This finding could also be confirmed for UK universities using regional R&D intensity (Chapple, et al. 2005). A European multi-country study found no links between regional business R&D spending (BERD) and patent applications and contract research, but a positive correlation with the number of start-ups (Van Looy et al. 2011). The accumulated R&D expenses per firm in Spanish regions did not contribute to explaining licence agreements or spin-offs of regional universities in the study cited already above (González-Pernía, et al. 2013). Algieri et al. (2013)

& Sobrero 2011) or industry concentration (the lower the concentration the higher the number of invention disclosures to German universities in Hülsbeck, Lehmann, & Starnecker 2013).

found a positive coefficient for R&D staff at regional level with regard to university start-up numbers.
However, not only private sector R&D seems to matter, but also public sector activities, though it is not fully clear how. In studies with data for Italian universities, both, negative effects (Fini, et al. 2011) as well as positive effects (Algieri, et al. 2013) of regional governmental R&D expenses on university spin-off numbers have been found. Sine and his co-authors suggest that competition might explain the reduction of the number of licences executed by universities which are close to other licensing universities (Sine, et al. 2003).

3) Regional income. Previous studies tend to find that different regional income measures are unrelated to transfer performance. With data from a large scale survey of German professors at higher education institutions, Dornbusch, Kroll, and Schricke (2012) find a U-shaped influence of regional income (GDP per capita) on the frequency of professors' consultancy activities, but not on their involvement in R&D co-operations with local partners. They explain this with other factors than regional income that supposedly drive R&D co-operation. In the UK data set of Chapple et al. (2005) the regional GDP index raises the technical efficiency of KTOs with regard to licence income, but not with regard to the number of licences. In their estimations of licensing productivity of US universities, Link, Siegel and Atwater found that the average annual output growth in the state was not significantly related to productivity (2005; 2003). Hülsbeck, Lehmann, and Starnecker (2013) do not find a relationship between GDP per capita in German regions and invention disclosures at universities.

4) Venture Capital related activities. Local venture capital activity does not correlate with higher start-up rates in the US (Di Gregorio and Shane 2003). Along the same lines, an analysis based on Spanish RedOTRI data does not show a link between regional VC per firm and university spin-offs or university licence agreements (González-Pernía, et al. 2013). However, in a study with US AUTM data and an additional survey, the total operating costs of TTOs over total net licensing revenues are lower, the more VC is available within a 100 miles distance (Warren, Hanke, and Trotzer 2008). Taking Netval data from Italy Fini et al. (2011) show that the regional financial development index, measured as the probability that a household is shut off from the credit market, is positively related to the number of university spin-offs.

Table 1. Overview of findings on regional level variables and transfer performance

Dependent variables (KTO level)	Independent concepts (regional level)			
	Technology intensity	**Research in the private sector**	**Overall output**	**Venture capital**
# invention disclosures	/ Germany (Hülsbeck, Lehmann, and Starnecker 2013)		/ Germany (Hülsbeck et al. 2013)	
#patent applications		/ Europe (Van Looy et al. 2011)		
# R&D agreements		/ Europe (Van Looy et al. 2011)	/ Germany (Dornbusch, Kroll, and Schricke 2012)[a]	
# start-ups	+ US (Friedman and Silberman 2003) – US (O'Shea, Allen, Chevalier, and Roche 2005)	+ Europe (Van Looy et al. 2011) + Italy (Algieri, Aquino, and Succurro 2013) / Spain (González-Pernía, Kuechle, and Peña-Legazkue 2013)		/ US (Di Gregorio and Shane 2003) / Spain (González-Pernía et al. 2013) + Italy (Fini, Grimaldi, Santoni, and Sobrero 2011)
# licences	+ US (Friedman and Silberman 2003) – US (Sine, Shane, and Di Gregorio 2003) / Europe and US (Conti and Gaule 2011)	+ US (Link and Siegel 2005; Siegel, Waldman, and Link 2003) + UK (Chapple, Lockett, Siegel, and Wright 2005)	/ UK (Chapple et al. 2005) / US (Link and Siegel 2005; Siegel et al. 2003)[b]	/ Spain (González-Pernía et al. 2013)

Dependent variables (KTO level)	Independent concepts (regional level)			
	Technology intensity	**Research in the private sector**	**Overall output**	**Venture capital**
licensing income	+ US (Belenzon and Schankerman 2009; Friedman and Silberman 2003; Lach and Schankerman 2008) + Europe and US (Conti and Gaule 2011)	/ US (Siegel et al. 2003) + US (Link and Siegel 2005) / UK (Chapple et al. 2005) / Spain (González-Pernía et al. 2013)	+ UK (Chapple et al. 2005) / US (Link and Siegel 2005; Siegel et al. 2003)[b]	+ US (Warren, Hanke, and Trotzer 2008)

+ significant positive relationship, – significant negative relationship, / no significant relationship

a However, the study obtained a positive coefficient for consultancy activities.

b Average annual real output growth in the university's state.

2.3 National influences

Rather few empirical studies have investigated the mechanisms through which the national research and innovation system determines universities' abilities to commercialize knowledge (the innovation system literature frequently takes the opposite perspective and focuses on the contributions of universities and other elements of the system to corporate innovation activities).

The key issue of concern has been the ownership of academic intellectual property for which most European countries have a national default rule, except for Sweden and Italy. In most cases it is the employer (university or research institute) who owns the research. In Sweden and Italy however, researchers own the rights to their research as long as they have not agreed otherwise. This is referred to as the 'professors' privilege' regulation (Lissoni et al. 2013). Thus, in most other countries the employer owns the IP, however enforcement of the law varies by country and research and funding institutions may issue specific rules, or in some instances researchers by-pass the law (Geuna and Rossi 2011; Lissoni, Llerena, McKelvey, and Sanditov 2008). Research has shown that national IP regulations influence different formal channels of knowledge and technology transfer, such as research collaboration (Valentin and Jensen 2007) or licences (Conti and Gaule 2011).

Conti and Gaulé (2011) included several institutional characteristics, a control variable for regional technology demand and country dummies in their estimations on licensing performance of European and US universities. In 12 out of the 15 European countries universities had lower licence income than their US counterparts; only Denmark, Belgium and Switzerland had (insignificant) positive coefficients, i.e. slightly higher licence income; in the latter two countries universities even had a significantly higher number of licences than in the US.

3. Methodology

3.1 Data collection

Data on universities and public research institutes were collected through two separate surveys that were piloted in 2011 and repeated in 2012. Each survey pair referred to the preceding year (2010 and 2011). The European Knowledge Transfer Indicator Survey (EKTIS) collected data on the characteristics of KTOs, a few characteristics of the affiliated university or public research institute, who owns the intellectual property for discoveries, and data on technology transfer outcomes for 2010 and 2011. A copy of the survey questionnaire can be found in the appendix.

The survey focused on the leading research-intensive universities and research institutes in 39 countries including 27 EU member states and 12 countries associated to the European Framework Programmes for research, development, and innovation. The sample was weighted by each country's share of total European Government and Higher Education R&D expenditures (GOVERD), with data collected for approximately 500 universities and research institutes combined. The response rate for the EKTIS survey was 57.0% in 2011 and 55.9% in 2012. The second survey used a sub-sample of EKTIS respondents to collect information on institutional and national policies for knowledge transfer and attained a response rate of 50.0% in 2011 and 39.8% in 2012. Full details on the survey methodology plus copies of the two questionnaires are provided by Arundel et al. (2013).

The two sets of survey data were then linked to construct a cross-sectional database that includes data on the predictor variables for each university or research institute for one year. The number of cases for analysis is increased by including respondents for at least one of the two surveys. If a respondent replied to both surveys, the results for the most recent year (2011) are used. Since economic conditions, research funding and knowledge transfer policies in Europe did not change notably between 2010 and 2011, any biases due to combining years should be minor. Since it is a pooled cross-sectional data, country dummies are used to capture any clustering by subgroups that may exist between countries. This method is referred to in the literature as the dummy variable model (Steenbergen and Jones 2002). The country dummies absorb the unique variation among the different countries included in our data. The inclusion of the country dummies can capture the unobserved heterogeneity between the different countries beyond any country effects accounted for in the predictor variables such as ownership of IP. The linked dataset includes 170 cases for which 2011 data are available and 118 cases for which only 2010 data are available.

Regional-level data was then added to each institution taking data for NUTS2 regions of the classification of territorial units in Europe. In total, 316 NUTS2 regions, each having a population between 800'000 and 3 million inhabitants, have been assigned in the 27 EU Member States[4], the four EFTA countries Iceland, Liechtenstein, Norway, and Switzerland, and the five acceding and candidate countries Montenegro, Croatia, Macedonia, Serbia and Turkey (as of January 1st, 2013) (Eurostat 2013). The NUTS classification does not cover Albania, Bosnia-Herzegovina and Israel and consistent regional data could not be included which led to the exclusion of six universities from the analysis.

3.2 Variables

Dependent variables. We examine the correlation between the regional socio-economic environment, a set of control variables for countries and institutional characteristics and four dependent variables: the number of patent applications plus three variables that measure the potential for transferring commercially valuable knowledge from universities or public research institutes to private firms, i.e. the number of research agreements with firms, the number of licenses, and the number of start-ups established (see Table 2). Most studies, in particular those from the USA, focus on licences, licence income and/or start-ups (see Table 1 above). Although a patent is not required for technology transfer, the number of patent applications is included in the output variables because of previous research showing a strong link for European universities between licensing and

[4] EU Member States here refers to the status in 2012, i.e. including the UK and excluding Croatia.

patented inventions (Arundel and Bordoy 2009). Research agreements can be further from commercialisation than licensing or start-ups, but they can also involve solving specific problems with existing products or processes. In addition, patent applications and R&D agreements have rather been neglected in previous work (see Table 1 above). Of importance to note is that the survey questionnaire is not always fully completed by a respondent and often includes item non-responses. This explains the different number of observations for each technology transfer type in Table 2 and similarly in subsequent results.

Table 2. Key performance indicators for universities and public research institutes

	N[1]	Mean	Median	Standard deviation	Percent zero[2]
Universities					
Patent applications	230	14.4	6.0	24.1	18.7
Licenses executed	201	11.4	4.0	21.5	24.4
Start-ups formed	215	5.2	2.0	14.6	33.0
R&D agreements with companies	162	173.2	69.0	261.3	4.3
Research institutes					
Patent applications	37	13.6	6.0	21.8	10.8
Licenses executed	36	13.2	3.0	28.5	25.0
Start-ups formed	37	1.3	1.0	1.2	35.1
R&D agreements with companies	30	237.1	30.0	905.1	0.0

1: Number of KTOs reporting results for each performance measure (including zero outcomes).

2: Percent reporting 'zero' for each outcome. For example, 18.4% of 228 universities reported zero patent applications in 2010 and/or 2011.

Source: MERIT, European Knowledge Transfer Indicator Survey 2011 and 2012.

Independent variables. The control variables cover the key influences on transfer performance as assessed in the literature. Two KTO variables include the number of employees (KTO_SIZE) and its age and squared age to account for nonlinear effects of age (KTO_AGE, KTO_AGE2, see Table 3). The three institutional variables include the number of researchers NUMB_RES (research output is expected to be closely correlated with this variable), if the institution has a hospital (HOSP), coded as 1 when present and 0 otherwise, and the type of institution, coded as 1 when a university and 0 if a public research institute (UNIVERSITY). The variable for the presence of a hospital is included to capture activity in health sciences while the type of institution is an important factor in the use of licensing and start-ups. The full data set shows that the former is more common in public research institutes and the latter is more common in universities. We also include a control variable for ownership status (OWNERSHIP), coded as 1 when the institution or companies own the IP and 0 if the inventor or other parties own the IP. We furthermore include a set of country dummies for the eleven most frequent countries in the data set, to control for latent national specificities of the academic system and framework for knowledge and technology transfer.[5] These eleven countries contribute more than 80% of the observations, the remaining 20% of observations are contributed by 21 other European countries. Additional analysis was conducted to examine unobserved heterogeneity by including dummy variables for NUTS2 regions.

[5] These covers (number of observations in brackets): Germany (64), the UK (42), France (26), Spain (27), Italy (21), Switzerland (12), Ireland (10), Sweden (9), Austria (8), the Netherlands (8), and Denmark (8).

Table 3. Descriptive statistics of independent dummy variables

	Universities			Research institutes		
Characteristics of the KTO and institution	**N**	**Yes**	**Percent**	**N**	**Yes**	**Percent**
HOSP: Institution has a hospital	247	50	20.1%	39	0	0.0%
OWNERSHIP: IP is owned by institution or companies (Inventor or other=0)	245	131	53.5%	39	29	74.4%
Country dummies	**N**	**Yes**	**Percent**	**N**	**Yes**	**Percent**
AT: Austria	249	8	3.2%	39	0	0.0%
DE: Germany	249	49	19.7%	39	15	38.5%
DK: Denmark	249	6	2.4%	39	2	5.1%
FR: France	249	21	8.4%	39	5	12.8%
IE: Ireland	249	10	4.0%	39	0	0.0%
IT: Italy	249	18	7.2%	39	3	7.7%
NL: The Netherlands	249	6	2.4%	39	2	5.1%
ES: Spain	249	25	10.0%	39	2	5.1%
SE: Sweden	249	9	3.6%	39	0	0.0%
CH: Switzerland	249	8	3.2%	39	4	10.3%
UK: United Kingdom	249	40	16.1%	39	2	5.1%
SUBTOTAL	*249*	*200*	*80.3%*	*39*	*35*	*89.7%*
Other countries[1]	249	49	19.7%	39	4	10.3%
TOTAL	249	249	100%	39	39	100%

Note 1: Countries and number of observations (universities or otherwise mentioned) in brackets; Belgium (6), Bulgaria (1), Croatia (1), Czech Republic (4), Estonia (1), Finland (4), Greece (2 of which 1 research institute), Hungary(5), Iceland (1), Israel (5 of which 1 research institute), Latvia (2), Luxembourg (1), North-Macedonia (1), Malta (1), Norway (6), Poland (3), Portugal (2), Romania (2), Slovakia (1 research institute), Slovenia (1 research institute), Turkey (3).

The independent variables of interest include indicators to control for the regional market environment for technologies developed by public research organisations. The data have been extracted from Eurostat (see Table 4).

- GDP in billion PPS in 2010, was included to control for the size of the region. Two other independent variables reflect the region's industry structure, regional employment shares in industry and in services, both for the year 2011. Employment in industry is measured by aggregating NACE sectors B-F and employment in services is measured by aggregating NACE sectors G-L.
- Average regional GDP per capita over a three-year period (2008-2010) is used to measure regional income; squared regional GDP per capita serves to investigate whether regional income exerts a non-linear effect, as suggested by Dornbusch, Kroll, and Schricke (2012).
- The average EPO patent applications per million inhabitants in a region over a three-year period (2008-2010) capture the technological intensity of a region.
- Two additional variables are used to measure business sector research activities: The average share of business enterprise expenditure on R&D (BERD) in gross domestic expenditure on R&D (GERD) reflects whether a region has a strong business research sector (or governmentally funded R&D sector by taking the inverse); the average share of BERD in GDP measures regional R&D intensity. Both variables are calculated over a three-year period (2008-2010).

A suitable indicator for regional VC availability that has been found as important in previous national analyses of transfer performance (see above) could not be included due to a lack of comparable data.

A correlation table of the independent variables (Table 9) as well as descriptive statistics of the independent variables by country (Tables 10 and 11) are provided in the appendix. None of the correlations are above 0.6 thus any multicollinearity issues are not expected (Dormann et al. 2013). The descriptive statistics of the independent variables by country show various differences across countries. For the variables of interest notable differences are observed for regional gross domestic product which differs substantially between France and other countries, which is due to the construction of the geographical areas as NUTS 2 regions in France compared to other countries. Similarly, GDP per capita differs substantially between Ireland and other countries, explained by the presence of large multinational companies holding intellectual property. Results for these variables should therefore be interpreted with caution. Employment in industry differs as expected with higher share observed in Italy and Germany, and lower shares in the Netherlands, Switzerland and Denmark. Austria and Spain have higher shares of employment in services. High shares of business enterprise expenditure as a percent of GDP are observed in Denmark, Sweden, and Austria. High regional patenting is observed in Swiss regions and less in Spanish regions. As for the dummy independent variables, as explained, ownership of IP is usually held by the institution with notable exceptions in Italy (33.3% of the cases) and Sweden (22.2% of the cases). Few institutions in Italy and the United Kingdom in our sample have an affiliated hospital whereas this is more common in the Netherlands.

Table 4. Descriptive statistics of independent variables

	Universities				Research institutes			
	N	**Mean**	**Median**	**SD**	**N**	**Mean**	**Median**	**SD**
Characteristics of the KTO and institution								
NUMB_RES: Number of researchers	212	2,055.8	1,360	2,111	37	1,618.3	971.0	2,918.7
KTO_SIZE: KTO staff in FTE	249	9.3	5.0	11.2	39	9.0	5.0	10.8
KTO_AGE: age of KTO in years	221	12.0	9.0	9.3	38	18.97	13.5	18.6
Regional characteristics								
GDP_BIL_PPS: GDP in billion PPS	241	87.0	54.8	95.2	38	109.9	65.6	111.1
EMPL_INDUSTRY: Employment share in industry	245	22.4	22.6	7.5	39	20.5	20.0	6.8
EMPL_SERVICES: Employment share in services	245	30.8	30.7	6.1	39	31.1	30.9	6.3
GDP_CAP: GDP per capita (x 1'000 €)	245	41.3	28.0	55.8	38	46.6	32.6	51.8
BERD_GERD: Business enterprise R&D expenditures in percent of Gross R&D expenditures	244	55.4	58.5	19.5	38	53.4	54.6	18.3
BERD_GDP: Business enterprise R&D expenditures in per-cent of GDP	243	1.2	1.0	1.0	37	1.7	1.3	1.4
PATENTS_REG: EPO patent applications per million inhab.	244	132.9	101.6	123.4	38	207.5	167.6	166.1

3.3 Analytical methods

The independent variable in all regressions consists of the number of outcomes, using count data. As there are a significant number of zero responses (see Table 2), we use a negative binomial model appropriate for count data.
The regressions were first conducted using a dummy variable for the survey year (2011 versus 2010). The variable had no effect on any of the results except for the number of licenses, indicating that on average license activity declined in 2011. However, the dummy variable for the survey year had no effect on any of the variables of interest (regional variables) and is therefore not included in the final regressions given below.

The control variable for KTO age is the independent variable with the largest number of item missing values reducing the sample in the estimations by up to 23 cases. For this reason and to identify interactions between the experience of an institution with technology transfer and the other independent variables we estimated each model with and without the KTO_AGE variables. Each table includes the AIC value (Akaike Information Criterion), a goodness-of-fit measure in which smaller values are preferable.

4. Results

4.1 R&D agreements with companies

For R&D agreements with companies we have the highest percentage of item non-responses of the four dependent variables contributing to the exclusion of 39-53% of all cases (depending on missing values for independent variables). Hence, the estimations for this variable are the least precise among the four considered variables. As expected, the size of the institution (NUMB_RES) consistently contributes to explaining the variance of R&D agreements with companies across institutions (see Table 5). The older the knowledge transfer office (KTO_AGE) the more R&D agreements with companies were concluded; however, the effect is nonlinear. The relationship between the age of the KTO and the dependent variable is probably not causal, but an indication that more industry- and transfer-oriented universities established their transfer offices earlier. No consistent result is observed for ownership of IP (OWNERSHIP).

The national context is of considerable importance as the country dummy variables show. We observe consistently significant negative coefficients for Sweden and Germany, i.e. institutions in these countries conclude fewer R&D agreements compared to other countries in our data. The country dummies for Ireland and Italy are also negative and their impact increases in size in regressions that include control variables for the regional share of corporate R&D, corporate R&D intensity and technology intensity.

A consistent significant positive coefficient is observed for the Netherlands. Spanish institutions concluded significantly more R&D agreements compared to other countries but only in estimations that excluded the control variables for the KTO age. In other words, the observed results for Spain are mainly since KTOs are comparatively old (in fact almost 75% in our sample were established before the year 2000). This suggests that Spanish institutions placed a focus on tech transfer some decades ago and were able to built-up knowledge on how to collaborate with the corporate sector on R&D.

Among the regional level variables, we observe no effect for region size (GDP_MIL_PPS) and employment in services (EMPL_SERVICES). The share of employment in industry (EMPL_INDUSTRY) is strongly positive, suggesting that the primary corporate clients of universities and public research institutes for R&D agreements are manufacturing companies. GDP per capita is positive and significant. The negative sign of the squared GDP per capita variable points to an inverse U-shaped effect.

The share of corporate R&D expenditure to total regional R&D expenditure (BERD_GERD) is negative and significant. Conversely, the share of governmental R&D expenditure must have a positive effect on R&D agreements. We do not have a straightforward explanation for this, except that the BERD-GERD-share probably does not measure the absorptive capacity of companies – which is rather measured by the (non-significant) relationship of BERD to GDP – but whether a critical mass of non-corporate and predominantly public research exists in a region. If this is not the case, this is very likely the limiting factor and companies are unable to find academic research partners in this case. For patent applications per capita (PATENTS_REG) we observe a negative correlation. This indicates that in regions with a strong corporate technological basis firms work less with their regional academic partners.

Table 5. Regression results for R&D agreements

MODEL	1a	1b	2a	2b	3a	3b	4a	4b
N	159	180	159	180	152	173	151	172
AIC	1910.0	2139.6	1891.4	2121.9	1813.0	2041.0	1799.4	2026.2
CONSTANT	3.462**	3.891**	3.362**	3.845**	1.057	1.377	0.368	1.348
INSTITUTIONAL LEVEL VARIABLES								
NUMB_RES	0.366**	0.428**	0.342**	0.364**	0.305**	0.338**	0.285**	0.342**
KTO_SIZE	0.022*	0.006	0.002	-0.004	0.002	-0.004	0.006	-0.003
HOSP	-0.220	0.010	-0.195	-0.011	-0.127	0.106	-0.014	0.208
UNIVERSITY	-0.117	-0.044	0.161	0.302	0.038	0.164	0.178	0.269
OWNERSHIP	0.187	0.291+	0.046	0.147	0.284	0.395*	0.110	0.220
KTO_AGE	0.084**		0.102**		0.106**		0.097**	
KTO_AGE2	-0.002**		-0.002**		-0.002**		-0.002**	
COUNTRY DUMMY VARIABLES								
AT			0.647	0.517	0.024	-0.191	-0.170	-0.189
DE			-0.594*	-0.422+	-1.083**	-0.971**	-1.264**	-1.086**
DK			0.548	0.564	0.224	0.108	-0.618	-0.366
FR			0.046	0.300	-0.298	-0.132	-0.377	-0.282
IE			-0.635+	-0.787*	-0.493	-0.713	-0.855+	-1.103*
IT			0.037	0.122	-0.782+	-0.833+	-1.757**	-1.707**
NL			1.345**	1.548**	1.779**	1.789**	1.437*	1.384*
ES			0.252	0.653+	0.427	0.756+	0.218	0.386
SE			-2.567**	-2.527**	-2.851**	-2.939**	-2.865**	-2.929**
CH			0.151	-0.007	0.129	0.023	0.993+	1.187*
UK			-0.163	-0.127	0.213	0.231	0.211	0.137
REGION LEVEL VARIABLES								
GDP_BIL_PPS					0.001	0.001	0.002	0.002
EMPL_INDUSTRY					8.309**	7.970**	11.525**	9.621**
EMPL_SERVICES					-0.943	-1.218	-1.846	-3.147
GDP_CAP					0.030	0.055*	0.133**	0.139**
GDP_CAP2					0.000	-0.001*	-0.001**	-0.001**
BERD_GERD							-0.027**	-0.019**
BERD_GDP							0.137	0.124
PATENTS_REG							-0.002+	-0.003**

+= p <.10, * = p <.05, ** = p<.01, *** = p<.001.

4.2 Patent applications

Patent applications is the second dependent variable of transfer performance that is close to commercialisation. Among the included control variables the size of the institution (NUMB_RES) and of the transfer office (KTO_SIZE), and the age of the KTO are significant with the expected positive coefficients (see Table 6); the relationship for KTO_AGE is again nonlinear.

Most country dummies are insignificant, indicating that national differences are not a prominent influence on academic patenting in Europe – this might be surprising, but one should bear in mind that there has been a considerable homogenization regarding IP ownership in European academia between 2000 and 2010. Moreover, it can be argued that the countries in our sample have comparable patenting capabilities, Switzerland stands out as a country with several regions with high patenting compared to other countries.

Ownership still matters (see model 1b) and the two countries with deviant ownership regimes for academic inventions, Italy and Sweden, still stick out. The significant negative coefficient observed for these countries is likely a consequence of the fact that researchers may patent inventions outside of the institution. For France we also observe a negative significant coefficient for models that do not include regional level variables.

Employment in industry (EMPL_INDUSTRY) is again a significant regional level predictor. As for R&D agreements, we observe a negative coefficient for the share of corporate R&D to total regional R&D (BERD_GERD) which we would explain in the same way.

Table 6. Regression results for patent applications

MODEL	1a	1b	2a	2b	3a	3b	4a	4b
N	212	236	212	236	204	227	202	225
AIC	1487.5	1650.9	1493.6	1656.8	1431.5	1587.7	1425.2	1577.8
CONSTANT	1.299**	1.414**	1.610**	1.709**	0.153	0.406	-0.196	0.104
INSTITUTIONAL LEVEL VARIABLES								
NUMB_RES	0.258**	0.291**	0.275**	0.317***	0.311**	0.355**	0.303**	0.338**
KTO_SIZE	0.024**	0.025**	0.025**	0.021**	0.024**	0.019*	0.026**	0.020*
HOSP	0.024	-0.010	0.007	0.036	0.145	0.179	0.165	0.240
UNIVERSITY	-0.077	0.020	-0.153	-0.063	-0.173	-0.099	-0.161	-0.116
OWNERSHIP	0.226	0.271+	0.166	0.247	0.283	0.307+	0.203	0.218
KTO_AGE	0.043*		0.051*		0.033		0.031	
KTO_AGE2	-0.001*		-0.001**		-0.001*		-0.001*	
COUNTRY DUMMY VARIABLES								
AT			-0.135	-0.278	0.119	0.052	0.041	-0.029
DE			-0.275	-0.188	-0.023	0.018	-0.030	-0.019
DK			-0.245	-0.166	0.383	0.504	0.251	0.306
FR			-0.730*	-0.735*	-0.369	-0.337	-0.348	-0.354
IE			-0.110	0.017	0.507	0.620	0.460	0.531
IT			-0.633*	-0.588+	-0.776*	-0.740*	-1.049*	-1.130**
NL			-0.107	-0.148	0.686	0.603	0.618	0.431
ES			-0.644+	-0.437	-0.353	-0.225	-0.410	-0.333
SE			-1.443**	-1.430**	-0.850+	-0.843+	-0.771	-0.731
CH			-0.423	-0.448	0.436	0.472	0.788	0.904+
UK			-0.307	-0.083	0.328	0.453	0.322	0.402
REGION LEVEL VARIABLES								
GDP_BIL_PPS					0.001	0.001	0.001	0.001
EMPL_INDUSTRY					3.712*	3.321*	4.992*	4.880*
EMPL_SERVICES					2.883	2.504	3.536	3.065
GDP_CAP					-0.029	-0.030	-0.006	0.003
GDP_CAP2					0.000	0.000	0.000	0.000
BERD_GERD							-0.011	-0.014*
BERD_GDP							0.091	0.088
PATENTS_REG							-0.001	-0.001

+= p <.10, * = p <.05, ** = p<.01, *** = p<.001.

4.3 Licence agreements

For licence agreements which are closer to the market than the two previously discussed performance measures we obtain positive correlations for the control variables on size of the institution (NUMB_RES), size of the KTO (KTO_SIZE), age of the KTO (nonlinear, see KTO_AGE and KTO_AGE2), existence of a hospital (HOSP) and a negative correlation for universities, i.e. more licence agreements in non-university institutes (see Table 7).

Country dummies are consistently positive for Ireland and the UK; for Switzerland only if regional level variables are not included. In Sweden a significant negative coefficient is observed in all models, the dummy variable for Italy is negative but not significant in contrast to the results found for patent applications. Both results should not be surprising given the 'professors privilege' legislation in these countries. For Denmark, in the models with regional level variables, a significant negative coefficient is observed. Regarding, the regional level variables, we observe a non-linear relationship for GDP per capita similar as with R&D agreements. We also obtain a small positive effect for regional patent applications per capita (PATENTS_REG); in other words, the higher regional technology intensity, the more licence contracts were concluded by the academic institutions in the region.

Table 7. Regression results for licence agreements

MODEL	1a	1b	2a	2b	3a	3b	4a	4b
N	197	218	197	218	189	211	188	210
AIC	1245.1	1478.1	1196.2	1394.4	1153.5	1345.2	1138.6	1332.8
CONSTANT	1.263**	2.370**	1.246**	1.889**	0.985	1.906	0.540	1.736
INSTITUTIONAL LEVEL VARIABLES								
NUMB_RES	0.198**	0.196**	0.285**	0.295**	0.291**	0.302**	0.261**	0.281**
KTO_SIZE	0.040**	0.028**	0.025**	0.004	0.022*	0.002	0.018+	0.000
HOSP	0.204	0.172	0.570**	0.746**	0.369	0.548*	0.424+	0.558*
UNIVERSITY	-0.608**	-0.608**	-0.888**	-0.973**	-0.760**	-0.867**	-0.471+	-0.542*
OWNERSHIP	-0.050	-0.430**	-0.179	-0.243	-0.137	-0.205	-0.041	-0.114
KTO_AGE	0.083**		0.065**		0.048*		0.059*	
KTO_AGE2	-0.002**		-0.002**		-0.001**		-0.002**	
COUNTRY DUMMY VARIABLES								
AT			-0.398	-0.584	-0.667	-0.829	-0.984+	-1.036+
DE			0.448+	0.410+	0.256	0.103	-0.284	-0.307
DK			-0.519	-0.481	-0.990+	-1.018+	-1.520**	-1.311*
FR			-0.393	-0.427	-0.389	-0.499	-0.202	-0.239
IE			1.264**	1.167**	1.032*	0.957*	1.383**	1.357**
IT			-0.331	-0.342	-0.357	-0.413	-0.384	-0.299
NL			0.651	0.737+	0.354	0.297	0.253	0.330
ES			-0.171	0.173	0.147	0.408	0.330	0.672
SE			-3.773**	-3.723**	-4.028**	-4.172**	-4.339**	-4.460**
CH			0.694+	0.884*	0.488	0.740	-0.358	0.140
UK			1.441**	1.744**	1.552**	1.737**	1.758**	1.939**
REGION LEVEL VARIABLES								
GDP_BIL_PPS					-0.001	-0.001	-0.002	-0.002
EMPL_INDUSTRY					-0.172	-0.777	-0.100	-1.261
EMPL_SERVICES					-3.484	-4.665	-0.652	-2.269
GDP_CAP					0.085**	0.094**	0.074*	0.067*
GDP_CAP2					-0.001**	-0.001**	-0.001*	-0.001*
BERD_GERD							-0.016*	-0.012+
BERD_GDP							0.002	0.056
PATENTS_REG							0.004**	0.004**

+= p <.10, * = p <.05, ** = p<.01, *** = p<.001.

4.4 Start-ups established

The last dependent variable examined are the number of start-ups that were established by an institution which is also a transfer result that is close to the market. The size of the institution (NUMB_RES), size of the KTO (KTO_SIZE), and being a university correlate positively with the number of start-ups (see Table 8). The variable for KTO age slightly misses significance at the 10% level. Institutions in Germany, Ireland, and Sweden are particularly successful in establishing start-ups. At first sight, the same seems to be true for UK institutions. However, once we include the control variable for the age of the KTO, the dummy for the UK reverses the sign, and in models 2a and 3b we even observe significant negative coefficients for the UK. This suggests, that only due to their longer experience British universities are more successful regarding establishing start-ups. Other aspects of the national environment in the UK are less conducive for academic entrepreneurship – however, our survey does not reveal which factors might be particularly problematic in the UK.

Among the regional variables we observe a strong negative effect for the share of employees in services (EMPLY_SERVICES), if this is high, we find fewer start-ups *ceteris paribus*. We lack an explanation for this result. We also observe a negative coefficient for industry employment (EMPL_INDUSTRY) though this is usually insignificant. The inverse U-shaped relationship for GDP per capita that we have found for R&D agreements and licence agreements is also observed for start-ups in model 4b.

The share of corporate R&D to overall R&D (BERD_GERD) is again negative and significant, and the regional R&D intensity (BERD_GDP) is positive in one of the "full" models (without KTO_AGE) but slightly misses significance in the other one (with KTO_AGE). Regional technology intensity of the economy (PATENTS_REG) does not play a role for academic start-ups.

Table 8. Regression results for start-ups

MODEL	1a	1b	2a	2b	3a	3b	4a	4b
N	207	229	207	229	200	222	198	220
AIC	914.9	1146.4	878.3	1104.0	862.3	1082.3	855.0	1072.2
CONSTANT	-0.672*	-0.111	-1.097**	-0.861*	0.707	3.597	0.032	3.388+
INSTITUTIONAL LEVEL VARIABLES								
NUMB_RES	0.186**	0.166**	0.180**	0.199**	0.190**	0.191**	0.184**	0.182**
KTO_SIZE	0.015+	0.030**	0.038**	0.018*	0.036**	0.015+	0.037**	0.013
HOSP	-0.449*	-0.741**	-0.341	-0.342	-0.371	-0.379	-0.347	-0.352
UNIVERSITY	1.031**	1.379**	0.875**	1.072**	0.845**	1.021**	0.936**	1.137**
OWNERSHIP	0.308+	-0.404*	0.199	-0.103	0.294	-0.087	0.191	-0.174
KTO_AGE	0.035		0.036		0.040		0.033	
KTO_AGE2	-0.001+		-0.002*		-0.002*		-0.001*	
COUNTRY DUMMY VARIABLES								
AT			-0.130	-0.132	-0.265	0.047	-0.365	-0.001
DE			1.181**	1.068**	0.883**	0.933**	0.755*	0.801*
DK			-0.543	-0.300	-0.881	-0.556	-1.123	-0.638
FR			-0.532	-0.420	-0.893+	-0.954+	-0.818	-0.905+
IE			0.846+	0.730+	0.865+	0.895+	0.987+	1.035*
IT			0.388	0.364	0.138	0.185	-0.361	-0.187
NL			0.235	0.580	-0.349	-0.112	-0.424	-0.095
ES			0.074	0.221	0.017	0.372	0.006	0.356
SE			1.744**	1.722**	1.157*	1.019+	1.338*	1.095*
CH			0.592	0.772+	0.680	0.531	1.360*	1.330*
UK			-0.819*	1.665**	-0.742+	1.359**	-0.500	1.553**
REGION LEVEL VARIABLES								
GDP_BIL_PPS					0.000	0.001	0.001	0.002
EMPL_INDUSTRY					-1.888	-4.181+	1.059	-2.271
EMPL_SERVICES					-6.163	-10.948**	-4.943	-10.666*
GDP_CAP					0.042	-0.007	0.074*	0.014
GDP_CAP2					-0.001+	0.000	-0.001*	0.000
BERD_GERD							-0.020*	-0.017**
BERD_GDP							0.146	0.210+
PATENTS_REG							0.000	-0.001

+= p <.10, * = p <.05, ** = p<.01, *** = p<.001.

5. Discussion and Conclusions

We focus in this section on national and regional level influences on the performance of technology transfer offices of European universities and non-university research institutes.

5.1 Country results

It comes with little surprise that IP ownership differences matter. The effect is strongest for Sweden which sticks out for all four dependent variables, either positively (start-ups) or negatively (R&D agreements, patent applications and licence agreements). For research-related measures this is also observed for Italy. However, the findings still permit the interpretation, that institutions are just less involved in the commercialization of academic research results in Sweden and Italy, and that its overall level is not lower, but simply more often taking place in direct relations between faculty and companies, as others have suggested (Jacobsson, Lindholm-Dahlstrand, and Elg 2013; Lissoni, et al. 2008).
Ireland and the UK are the countries which stand out as those where institutions are most effective in licensing-out market-related outcomes of their inventions and technologies. German and Irish institutions concluded significantly fewer R&D agreements with companies compared to their peer institutions in most other countries. Institutions in Germany, Ireland, and Sweden generate more start-ups compared to their peers in other countries. Start-up creation of institutions in the UK is mostly due to the long existence of the transfer offices and (presumably, as we did not measure this directly) their bigger experience in the tech transfer business. Once we control for the founding date of the KTOs, the coefficient for the UK changes its sign.

Dutch institutions seem to put a clear focus on R&D agreements with companies: the coefficient for the Netherlands is consistently bigger than for all the other countries and significant. For none of the other three performance measures we observe a clear result for the Netherlands. Spanish universities and research institutes also perform better on R&D agreements than their peers in most other countries, but only if we *ex*clude the control variable for the founding date of the KTO. If we include this variable, the coefficient becomes smaller and insignificant. In other words, Spanish institutions perform better on R&D agreements mostly because of the age (and presumably experience) of their transfer offices.

For Austria, Denmark, France and Switzerland, no consistent effect is observed across all models. The results for these countries are not that different compared to the set of other countries, except for Denmark which concluded significantly fewer license agreements compared to other countries based on 4 out of 6 models.

5.2 Results for regional characteristics

Size of the region, measured through regional GDP, is not correlated to any of the four performance measures. However, sector structure contributes to explaining the transfer performance of the region's public research institutions:

- A strong base in manufacturing is positive for R&D agreements and patent applications; this could be an effect of a larger client base in industry for R&D agreements and academic patents which are frequently only applied for, if an industry partner shows interest in the invention.
- A large share of service employees in total regional employment is negative for start-ups.

For regional GDP per capita we observe inverse U-shaped effects for three of the four performance measures (R&D agreements, licence agreements, start-ups established). The top five regions in our dataset with the highest per capita income are London, Luxembourg, Oslo, Zurich and Hamburg - all five are characterised by financial and insurance activities, real estate activities, professional, scientific and technical services which are not the typical clients of academic R&D and licences. The coefficients for GDP tend to become larger the more other regional characteristics are included in the estimations. Above all the regressions on R&D agreements and start-ups indicate that a weak regional economic climate (low GDP) might be compensated by a dedicated focus on public R&D spending (the inverse of BERD_GERD which reflects the share of corporate R&D spending to total regional R&D spending). In other words: universities in economically weak regions may

raise their number of R&D agreements with companies (presumably from outside the region) and start-up numbers through R&D activities.
Including an indicator for the split of governmental/public and corporate R&D expenditures generates the interesting finding, that the larger the share of corporate expenditures, the smaller all four performance measures. We suggest that a large share of corporate R&D to total R&D in a region might indicate a lack of critical mass in public research which could reduce any of the transfer outcomes.

For regional technology intensity, measured as patent applications per capita, we observe a *negative* coefficient for R&D agreements and a *positive* coefficient for licence agreements. While the result for licences confirms some previous papers examining US universities (Belenzon and Schankerman 2009; Friedman and Silberman 2003; Lach and Schankerman 2008), the result for R&D agreements seems counterintuitive. Some additional analysis has been conducted to examine thus further by including squared patent applications per capita. The results for both license and research agreement indicate an inverse U-shaped effect. This suggests that at lower levels of patenting intensity in a region, collaboration with universities and research institutes is sought. However, in high patent intensity regions, fewer of such collaborations are predicted. This suggests competition effects in regions with higher patent intensities. It could also suggest that technology-intensive companies select their research partners more according to excellence. These issues are explored further in Chapter 3 of this thesis.

For regional research intensity (BERD_GDP), we only observe one significant positive coefficient in model 4a on start-ups. This essentially confirms Van Looy et al. (2011). For licence agreements, a positive result was only observed when we omitted several other regional variables from the estimations (GDP_CAP2, BERD_GERD, PATENTS_REG, result not shown). Our results cannot be compared to previous work on the US (Link and Siegel 2005; 2003) or on the UK (Chapple, et al. 2005) as those used different specifications.

The lack of a significant result for the employment share in services for several of the outcomes can to some extent be explained by other research. Results using Community Innovation Survey (CIS) data showed that universities and public research institutes are not a major source of information for service innovating enterprises. On average 4.4% of services innovators report using information from a higher education institute in the EU and just 3.2% use public research institutes as a source (Debackere and Veugelers 2005). Moreover, the same study showed that the share of service innovating enterprises that have collaborated with universities or public research institutes is very low in the EU (on average 6.4% and 7.0% respectively). Similarly in a more recent study, Carvalho et al. (2018), found that sources of innovation for innovation with universities or other higher education institutions, government or public research institutes differs between manufacturing and services. For innovative service firms, the sources of information are more diverse and the factor analysis showed a greater importance to sources such as conferences and fairs, competitors, and customers which is logical given the influence of the market and the importance of the external environment for service firms (Carvalho et al. 2018). These sources are of importance to service firms to introduce innovations as well as to learning in the innovation process (Trigo and Vence 2012; Jiménez-Zarco et al. 2011). Sources of information for manufacturing firms is however different as reported by Carvalho et al. (2018) who find sources as universities, research institutes, professional associations and labs more important.

Additional analysis was conducted to examine whether the inclusion of regional level dummy variables would improve fit compared to the inclusion of regional level variables (GDP_BIL_PPS, EMPL_INDUSTRY, EMPL_SERVICES, GDP_CAP, GDP_CAP2, BERD_GERD, BERD_GDP, PATENTS_REG). Including regional level dummies would moreover allow us to examine the unobserved heterogeneity between regions. In some cases, there is just one university in a NUTS2 region and therefore results of the regional dummy level models cannot be shared as anonymity was promised to survey participants. Instead, we report fit measures (AIC and R-squared) to examine model fit. Results are reported in Table 12 in the appendix of this chapter. The results, based on AIC values, show that regional level dummies are better able to capture regional differences compared to regional level variables when only institutional variables are included and no other independent variables. The results are mixed for the full model including country dummies. Regional level dummy regressions show a better fit for license agreements and are comparable for research agreements. For patent applications and start-ups, the inclusion of regional level variables shows a better fit based on lower AIC values. A likely reason for this is that the AIC measure includes a penalty that is an increasing function of the number of estimated parameters (degrees of freedom). With the inclusion of over a hundred regional level dummy variables, the AIC value might not be the best fit measure to compare a regional level variable model versus a regional dummy model. Using OLS regressions to calculate explained variance based on R-squared shows that the regional level dummy models always better explain the variance in the four technology transfer outcomes compared to the models including regional level variables.

Of interest, is to note that the results using regional level dummies show that for several technology transfer activities between region effects are observed with some European regions performing significantly better and others significantly worse compared to their peers. Results in addition show that regions within the same country perform significantly different compared to other regions in the same country. Moreover, in several instances it is found that some regions within a country correlate negatively with a particular type of transfer compared to other European regions. However, at the same time at the national level, the country performs better compared to other European countries. These results provide evidence of between region and between country effects, i.e. how mean characteristics of a group (country or region) affect the mean performance of a group (country or region). This further provides evidence to use multilevel analysis.

5.3 Conclusions

This chapter teaches us several lessons for assessing the performance of universities and public research institutes in the area of knowledge and technology transfer.

First, comparisons of transfer performance at the country level need to take a multilevel perspective and control for institutional features as well as regional characteristics, to understand the driving forces behind country differences. Closer analyses and comparisons of the estimation results show that some country differences originate in institutional differences (such as the ownership regime with regard to academic IP, or the older age of UK KTOs which contributes to their good start-up performance) or characteristics of the regional environment (R&D agreements and patent applications handled by Swiss KTOs becomes significant once we control for corporate/governmental R&D and patenting at regional level).

Second, in most countries the institutions are strong regarding one channel of formal knowledge and technology transfer: R&D collaboration (the Netherlands), licencing (Ireland and the UK), or establishing start-ups (Sweden and Germany). Even though in Switzerland institutions compare well for more than one performance measure – taking the most complete models 4a and 4b – this suggests that it is very challenging for universities and research institutes to maintain the necessary infrastructure and support system to excel in different transfer channels. In addition, the national institutional set-up affects which transfer channels work better. Developing transfer strategies which take the internal and external conditions into account seems as a very adequate reaction to this situation for universities and public research institutes (Breznitz, O'Shea, and Allen 2008; Wright, Clarysse, Lockett, and Knockaert 2008).

Third, the presence of a strong manufacturing sector in the region is important for universities' performance with regard to formal knowledge and technology transfer. A strong service sector has rather negative effects, and universities in service-oriented regions, like London, Luxembourg or Zurich, *ceteris paribus* perform worse than those in more industry-oriented regions like Stuttgart or the Basque country. This does not imply that the service sector is unimportant for universities or that there is no collaboration between universities and service companies; there is, of course. However, service companies usually do not take out patents and licences, and prefer other mechanisms than R&D contracts. In particular, informal channels are more important for service firms when acquiring knowledge from universities (see for instance Arvanitis, Ley, Seliger, Stucki, and Wörter 2013). In addition as explained above innovative service firms are more likely to collaborate with customers or even competitors as compared to innovative manufacturing firms who more often collaborate with unversities and research institutes (Carvalho et al. 2018). Still, it is surprising that a strong service sector also affects start-up numbers negatively. We can only speculate why this is the case, but our first pick would be, that the benefit packages of existing service companies, above all in the financial sector but possibly also in other advanced services and consulting for businesses, are more attractive than the potential gains from establishing a start-up. A developed service economy would then be too competitive and thus not a likely path for academic entrepreneurship.

From the consistent negative effect of the BERD-GERD ratio we can deduce, that governmental expenditure on R&D in a region plays a more important role than corporate expenditure for R&D. The rather weak results for regional R&D intensity and regional technology intensity fits into this reasoning. However, this does not mean that governments are the key clients of academic technology transfer. Governmental expenditure for R&D influences how much money universities and research institutes obtain for their research and for generating the results which later can be transferred. If regional corporate R&D and technology does not help to explain transfer performance, it must be corporate R&D and corporate technology demand from outside the region. In other words, we interpret this result as a pointer to the importance of non-regional relationships in the transfer business.

This is also where we would see one fruitful direction for further research: conducting similar analyses with other spatial levels as well, in Europe for instance at NUTS 1 and NUTS 3, to tease out the distinction between different region sizes. Spatial regression analyses could also be an appropriate way to relate performance to different geographical areas of universities. Another future research direction could be examining the role of the regional innovation system which could be measured by the Regional Innovation Scoreboard (RIS) (European Commission, 2021).

One of the limitations of this study is that unobserved heterogeneity between countries and between regions is only accounted for by using dummies (results for regions are not shown for confidentiality reasons, except for fit measures in Table 12). However, these dummy variables do not provide a substantive explanation of this heterogeneity. The dummy variables are only indicators of subgroup differences. They can address the statistical challenges but are limited in exploiting the theoretical opportunities multilevel modelling has. An important goal of multilevel analysis is to substantially account for causal heterogeneity and on this objective the dummy variable model is limited (Steenbergen and Jones 2002). Multilevel modelling permits the analysis of contextual effects, i.e. how characteristics of other individuals in the same context affect individual level outcomes. Simultaneously, it also allows for heterogeneity between individual units. This is an important improvement over the dummy variable model. Moreover, it allows controlling for multiple levels, as the pooled data used in this research are universities (level 1) nested within regions (level 2) which are further nested within countries (level 3). Another interesting aspect could be to control for the presence of other institutions involved in knowledge and technology transfers in the region, to evaluate whether the resulting competition drives transfer performance or rather reduces it. This aspect is explored in Chapter 3 using the recommended multilevel modelling approach.

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Appendix

Table 9. Correlation results for independent variables

	NUMB_ RES	KTO_SIZE	HOSP	UNIVERSITY	OWNERSHIP	KTO_AGE	GDP_BIL_ PPS	EMPL_ INDUSTRY	EMPL_ SERVICES	GDP_CAP	BERD_ GERD	BERD_GDP	PATENTS_ REG
NUMB_RES	1												
KTO_SIZE	0.343***	1											
HOSP	0.236***	0.167***	1										
UNIVERSITY	0.069	0.009	0.181***	1									
OWNERSHIP	0.162**	-0.041	0.112*	-0.147**	1								
KTO_AGE	0.107	0.041	0.093	-0.037	0.087	1							
GDP_BIL_PPS	0.170***	0.027	0.045	-0.081	0.026	-0.038	1						
EMPL_INDUSTRY	0.057	-0.144**	-0.042	0.088	-0.039	0.026	-0.257***	1					
EMPL_SERVICES	0.129**	0.090	-0.046	-0.019	-0.094	-0.026	0.38***	-0.002	1				
GDP_CAP	0.093	0.009	0.011	-0.033	-0.118**	-0.052	0.092	0.015	-0.024	1			
BERD_GERD	-0.052	0.001	0.054	0.035	-0.058	-0.073	0.066	0.175***	-0.079	0	1		
BERD_GDP	0.123*	-0.042	0.082	-0.147**	0.107*	0.005	0.087	0.069	-0.085	0.171***	0.552***	1	
PATENTS_REG	0.208***	-0.066	0.091	-0.193***	0.204***	0.013	0.176***	0.052	-0.070	0.230***	0.470***	0.594***	1

* = p <.10, ** = p <.05, *** = p<.01

Table 10. Descriptive statistics of independent variables by country

Country		NUMB_ RES	KTO_SIZE	KTO_AGE	GDP_BIL_ PPS	EMPL_ INDUSTRY	EMPL_ SERVICES	GDP_CAP	BERD_ GERD	BERD_ GDP	PATENTS_ REG
Austria	Mean	1806.5	3.2	8.7	44.1	23.0	34.0	37.2	62.2	2.0	174.2
	SD	1757.4	2.6	0.5	24.1	5.5	3.2	6.9	10.5	0.6	22.9
	Median	1350	2.5	9.0	32.6	25.7	32.0	38.6	55.8	2.2	167.1
Germany	Mean	2557.2	5.6	32.5	77.5	27.2	29.5	37.6	57.7	1.8	252.7
	SD	3132.9	6.2	71.0	46.9	5.3	2.6	44.1	17.8	1.4	153.8
	Median	1445	3.8	19.5	59.6	28.5	29.2	28.2	59.2	1.3	202.5
Denmark	Mean	1176	6.5	11.0	41.7	19.4	31.2	41.6	58.5	2.3	219.3
	SD	1282.6	5.6	6.6	20.6	5.1	2.4	7.9	22.0	1.7	93.9
	Median	350	6.0	9.5	35.8	22.3	30.2	38.8	71.6	3.0	206.1
France	Mean	1953.8	6.7	11.5	225.4	19.8	30.6	33.2	58.9	1.4	145.5
	SD	1883.7	7.1	7.2	221.5	4.8	4.2	11.7	14.4	0.7	91.3
	Median	1500	4.5	8.5	86.2	17.6	28.5	26.1	65.2	1.5	115.1
Ireland	Mean	680.7	5.5	8.8	88.9	19.0	35.6	36.6	66.3	1.1	66.7
	SD	776.9	3.2	6.4	44.0	2.1	2.9	7.9	2.7	0.0	5.4
	Median	400	5.0	7.0	116.2	17.7	37.4	41.5	64.6	1.1	63.3
Italy	Mean	2024.9	5.7	8.3	134.8	27.6	30.4	93.4	38.0	0.6	67.6
	SD	2080.1	7.3	4.3	107.3	5.4	0.6	113.2	24.3	0.3	48.7
	Median	1498	3.5	8.0	125.1	28.5	30.3	25.7	41.9	0.7	75.2
The Netherlands	Mean	2650.6	19.0	17.1	86.2	13.2	29.5	36.0	36.6	0.7	131.6
	SD	1468.6	17.8	20.7	29.4	2.1	1.6	4.5	5.6	0.1	14.5
	Median	2810.5	14.0	9.0	98.7	12.8	28.7	35.5	39.2	0.7	132.5
Spain	Mean	3176.5	12.3	17.8	141.4	20.6	35.7	25.1	47.9	0.7	33.6
	SD	3290.1	12.2	7.1	75.2	5.6	3.8	4.6	12.1	0.4	21.5
	Median	2535.1	7.0	19.0	200.9	17.2	35.1	26.9	55.6	1.0	44.7
Sweden	Mean	1163.8	5.1	10.6	32.5	23.4	25.7	30.5	73.4	2.2	215.5
	SD	1534.6	4.6	7.3	11.7	3.3	2.1	1.1	6.9	1.2	102.5
	Median	350	4.0	8.0	36.4	22.4	24.9	30.4	75.1	2.8	229.0
Switzerland	Mean	1477.7	5.3	10.4	59.6	17.8	33.6	53.6	73.5	1.2	391.3
	SD	1983.8	5.7	4.7	3.7	3.7	3.7	8.2	0.0	0.4	81.3
	Median	930	3.6	13.0	59.9	15.9	35.0	55.7	73.5	1.0	432.3
United Kingdom	Mean	1566.9	20.3	16.6	80.2	18.1	33.0	33.0	56.5	1.0	83.5
	SD	1341.0	15.4	11.8	72.5	5.1	3.1	20.2	22.4	0.8	51.7
	Median	1282.5	17.4	13.0	57.0	19.0	32.1	25.2	60.2	0.7	76.5

Note: Descriptives for the total sample can be found in Table 2.

Table 11. Descriptive statistics of independent dummy variables by country

		HOSP		OWNERSHIP	
		Institution has a hospital		IP is owned by institution or companies (inventor or other=0)	
Country	N	Yes	Percent	Yes	Percent
Austria	8	2	25.0%	8	100.0%
Germany	64	10	15.6%	49	76.6%
Denmark	8	2	25.0%	7	87.5%
France	26	9	34.6%	12	46.2%
Ireland	10	2	20.0%	5	50.0%
Italy	21	2	9.5%	7	33.3%
The Netherlands	8	4	50.0%	8	100.0%
Spain	27	3	11.1%	12	44.4%
Sweden	9	1	11.1%	2	22.2%
Switzerland	12	2	16.7%	10	83.3%
United Kingdom	42	2	4.8%	8	19.0%

Note: disaggregating by type of institution is not possible to protect confidentiality of the respondents.

Table 12. Inclusion of regional level dummy variables

		Baseline - no other independent variables		Including institutional variables[2]		Including country dummies (full model)		Relative likelihood comparison[3]
N	AIC	Regional variables[1]	Regional dummies	Regional variables[1]	Regional dummies	Regional variables[1]	Regional dummies	exp((AICmin – AICi)/2)
172	Research agreements	2130.6	2050.9	2059.2	2029.6	2029.0	2029.6	0.282
226	Patent applications	1709.9	1694.2	1577.9	1643.7	1583.4	1643.7	0.000
210	License agreements	1457.1	1358.1	1401.3	1334.3	1337.8	1334.3	0.015[4]
220	Start-ups	1169.4	1148.8	1102.0	1133.5	1069.6	1133.5	0.000
N	**R-squared[5]**							
172	Research agreements	0.0482	0.5107	0.1534	0.5525	0.2721	0.5525	
226	Patent applications	0.0289	0.4792	0.4517	0.7581	0.4681	0.7581	
210	License agreements	0.0507	0.7142	0.1782	0.7837	0.2668	0.7837	
220	Start-ups	0.0339	0.2784	0.1077	0.3003	0.1485	0.3003	

Notes: 1. Regional level variables: GDP_BIL_PPS, EMPL_INDUSTRY, EMPL_SERVICES, GDP_CAP, GDP_CAP2, BERD_GERD, BERD_GDP, PATENTS_REG. 2. Institutional level variables: NUMB_RES, KTO_SIZE, HOSP, UNIVERSITY, OWNERSHIP. 3. Based on Burnham and Anderson (2004) using the full model estimates. Interpretation for the value observed for research agreements; the regional dummy variable model is 0.282 times as probable to minimize information loss compared to the regional variable model. 4. AICmin is the AIC regional dummy value (for research agreements, patent applications and start-ups, AICmin is the AIC regional variables value). 5. Based on OLS regression.

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Chapter 3 The Influence of Regional Supply, Demand and Competition Factors on the Knowledge Transfer Outcomes of Universities

Abstract: In the regional context, two key factors can influence knowledge transfer. First, the level of regional demand from firms for knowledge produced by universities located in the same region, and secondly the supply from universities of knowledge with potential commercial applications. In this chapter[6] we examine these and other factors on three measures of university technology transfer outcomes. We contribute to the literature by examining if competition from high quality research produced by other universities affects all focal universities equally, or if the effect of competition is moderated by the research quality of the focal university. The results show that top-ranked universities perform significantly better compared to non-top-ranked universities on licensing. In addition, competition from quality-weighted universities in the same region as the focal university decreases the number of research and licensing agreements, although the highest-ranked 13.4% of universities benefit from the regional co-location of other high quality universities for licensing. These results suggest that universities compete with top-ranked universities for regional demand for knowledge particularly in regions with a high-density of highest-ranked universities.

[6] This chapter draws on a paper published in International Journal of Innovation Management, Vol. 25, No. 07, 2150078 (2021). DOI: https://doi.org/10.1142/S136391962150078X The paper is written together with Anthony Arundel of UNU-MERIT, Maastricht University. Some additional analysis has been conducted after the publication. This has led to some changes in the text of the results and discussion section and in the conclusions as compared to the publication.

1. Introduction

Universities can transfer knowledge to firms located anywhere within the world, but research has consistently established that many channels of knowledge transfer are influenced by the university's regional environment (Kempton 2019). This suggests that a significant proportion of university knowledge transfer is influenced by the benefits of proximity between universities and the potential users of university-produced knowledge (Mansfield 1998; Arundel and Geuna 2004). Proximity is often measured through the co-location of firms and universities in the same region.

In the regional context, two key factors can influence knowledge transfer. The first is the level of regional demand from firms for knowledge produced by universities located in the same region, which is often estimated from business expenditures on R&D or the share of economic activity in sectors with close links to science (Chapple et al. 2005). The second factor is the supply from universities of knowledge with potential commercial applications (Garcia-Alvarez-Coque et al. 2019). This quality characteristic of knowledge is likely to be an important supply factor (O'Shea et al. 2005; Sine et al. 2003), as well the effectiveness of knowledge transfer offices in raising firm awareness of the types of knowledge that are available (Colyvas et al. 2002).

Knowledge transfer takes place in different channels of interaction between universities and other actors. The classic channels of knowledge transfer include publishing, teaching, conferencing etc. (Holgersson and Aaboen 2019; Bradley et al. 2013). This chapter focusses on other transfer channels that have gained increasing interest from in particular policy such as patenting, licensing, start-ups, consultancy and collaborative research as it can lead to commercial beneficial results for universities (Miller et al. 2018).

We add to the existing literature on regional influences on knowledge transfer by extending research on demand and supply factors. First, in addition to using the share of employment in technology-intensive manufacturing industries as a measure of demand, as a contribution to the literature we include the regional employment share of knowledge intensive services (KIS). Firms active in KIS draw on knowledge from universities, although at a lower rate than manufacturing firms (Horváth and Berbegal-Mirabent 2020; Fernandes and Ferreira (2013).

Second, the importance of demand and supply at the regional level could create conditions where universities are in competition with other universities and with research institutes for business demand for their knowledge or expertise. In contrast to most research to date on knowledge transfer from research institutes, we evaluate the effect of competition from universities and research institutes separately, since they play different roles in knowledge production (Kergroach et al. 2018).

Third, we contribute to the literature by examining if competition from high quality research produced by other universities affects all focal universities equally, or if the influence of competition is moderated by the research quality of the focal university. Instead of reducing knowledge transfer, competition could have a positive influence on knowledge transfer if it leads to knowledge spillovers between top-ranked universities, or from signalling a cluster of regional expertise.

Fourth, we contribute to the literature by evaluating the moderating effect of location in a metropolitan region on the effect of the quality of the focal university on knowledge transfer outcomes.

We expect the influence of the regional supply of knowledge, regional demand, and competition to vary among three methods for transferring knowledge from universities to firms: research agreements between the university and firms, the licensing of knowledge, and the establishment of start-ups. For example, universities could face a high level of competition from other universities for research agreements with regional firms. Conversely, license income could be less affected by regional demand if derived from licenses for knowledge with a global market.

We evaluate the effect of regional demand, supply and competition on knowledge transfer by using data for up to 292 focal universities in selected European countries, plus data for all non-focal universities and research institutes located in the same region. The analyses use the ARWU international rankings for universities to control for the research quality of focal and non-focal universities.

The analyses find that the share of regional employment in KIS is only positively correlated with the number of start-ups. Quality-weighted competition from other universities in the same region has no effect on the number of start-ups, a negative effect on the number of research agreements and license agreements, and a positive effect on license income for top-ranked focal universities only. Competition from research institutes is only correlated with license income. Location in a metropolitan region has a large negative effect on the license income of top-ranked universities.

This chapter is structured as follows. Section 2 discusses the literature on regional supply and demand for university-industry transfers and the type of university knowledge transfer activities. Section 3 describes the methodology and the data used in our analysis which is followed by a discussion of the results in Section 4. Section 5 concludes the chapter.

2. Regional supply and demand

Research on the geography of university-industry relationships commonly finds that firms and production systems benefit from the regional concentration of university research and business innovation activities (Trippl et al. 2015; Brescia et al. 2014; Audretsch et al. 2012; Arundel and Guena 2004; Sine et al. 2003).

On the supply side, knowledge transfer is supported by the quality and commercial potential of knowledge produced by universities (Di Gregorio and Shane 2003; Grimpe and Fier 2010; Perkman et al. 2013, O'Shea et al. 2005). Public research institutes are an alternative source of knowledge that play an important role in many countries in the supply of applied and experimental development research, with universities tending to focus on basic research and to a lesser extent, compared to research institutes, on applied research (Bozeman 2000; Kergroach et al. 2018; Arundel et al. 2021).

It can be difficult for firms to assess the quality and relevance of knowledge produced by different organizations, particularly if much of the knowledge is tacit. Consequently, firms could partly rely on positive or negative perceptions of the university that act as a signal for the quality of its outputs (Podolny 1993; Shenkar and Yuchtman-Yaar 1997). A common signal of quality is a university's position on domestic or international rankings based on academic output (Dill and Soo 2005). Internationally comparable rankings are not available, however, for research institutes.

Regional demand for knowledge has been estimated through data on the industrial structure or technological intensity of the regional economy, the research intensity of the regional economy, and regional income. Several estimates for regional demand are positively correlated with the knowledge transfer outcomes of universities, such as the regional population size, per capita income, gross regional product (GRP), and the share of employment in high technology manufacturing sectors (Belenzon and Schankerman 2009; Friedman and Silberman 2003; González-Pernía et al. 2013; Lach and Schankerman 2008; Conti and Gaule 2011). American universities located in high-technology regions report more licenses and more license income compared to universities located in low technology regions. However, the effect of the regional technological intensity on the number of start-ups is inconclusive (Friedman and Silberman 2003; O'Shea et al. 2005).

A growing stream of research has begun to explore the innovation collaboration patterns of services firms, and knowledge intensive (business) service (KIS) firms in particular (Lee and Miozzo 2019). Services firms are nevertheless very diverse, and it is therefore difficult to generalize their collaboration patterns (Lee and Miozzo 2019). Barjak and Es-Sadki (2015) found that the regional employment share in all service sectors (NACE G – L) had no effect on the number of research or license agreements, but a significant negative effect on the number of start-ups. Some contributions focussing on knowledge intensive services argue that service firms regard universities as a less important source of innovation when compared to manufacturing firms (Rodriguez et al. 2017), yet others argue the contrary (Johnston and Huggins 2019 and Mina et al. 2014).

KIS is a subset of the service sector that could have greater demand for university knowledge than other service sectors. KIS rely on professional knowledge and provide support for the business processes of other organisations. As a result, the employment structures of KIS firms are heavily weighted towards scientists, engineers, and other experts. An important feature that distinguishes KIS from manufacturing is the type of product they supply. Whereas manufactured products and processes contain a high degree of codified knowledge, knowledge-intensive services are characterized by a high degree of tacit knowledge (Windrum and Tomlinson 1999) that requires little formal R&D, with knowledge derived from 'development on-the-job', skills and creativity (Schricke et al. 2012). Horváth and Berbegal-Mirabent (2020) find that the regional formation rate of new KIS firms is positively correlated with the regional concentration of universities, which could be due to KIS firms benefiting from access to the tacit knowledge of academics. Similarly, research has found that proximity has a positive influence on the probability of research collaboration between KIS firms and universities (Johnston and Huggins 2019, Fernandes and Ferreira 2013). Additionally other research (Lee and Miozzo 2019, Johnston and Huggins 2016) found that KIS firms are active collaborators with universities for innovation.

In addition to economic factors such as higher per capita incomes and a concentration of firms, metropolitan regions share other characteristics that differentiate them from other regions, such as regional or national government ministries, firm head offices, a diversity of cultural institutions, good travel links, and demographic diversity. These characteristics could improve both the supply and demand for high quality knowledge by helping to attract and retain leading researchers to both universities and businesses (Florida 2002).

In so far as knowledge transfer is influenced by the regional supply and demand for knowledge, universities in regions with a large number of other universities or research institutes could face a higher degree of competition for the supply of knowledge than universities located in regions with a small number of universities or research institutes. Sine et al. (2003) examined the effect of competition between universities located in the same region on knowledge transfer. They found that competition, measured by the number of AUTM universities in a region (a quality measure since AUTM universities are leading research universities), reduces the number of licenses obtained by each university.

Types of knowledge transfer

Universities can transfer knowledge through open science methods such as publishing research results (Cohen et al. 2000) and through contractual methods such as consulting, research agreements, licensing, and establishing start-ups (Kempton 2019), an excellent literature review on technology transfer methods is covered in Bradley et al. (2013). Which method to use could vary depending on regional factors such as the peripheral or metropolitan location of the university and the quality of research conducted by the university (Hewitt-Dundas 2012; Belenzon and Schankerman 2009).

Contractual knowledge transfer methods can be divided into two main classes: knowledge-driven, where knowledge is created by researchers with little or no input from firms, and partner-driven, where the requirements of business partners influences the type of knowledge that is created (Kempton 2019; Perkmann et al. 2013). Knowledge-led methods include start-ups, while partner-led methods include consulting and research agreements. Licensing can transfer knowledge created by either knowledge- or partner-led research activities.

The knowledge output of research agreements can be transferred through reports and prototypes, or through the assignment of intellectual property rights to the firm that funded the research. The number of research agreements within a region depends on the number of firms with sufficient funds and interest to enter into an agreement and the number of universities and research institutes with expertise in the types of knowledge sought by firms. At the regional level, this could result in inter-university competition, with an increase in the number of universities and research institutes with relevant expertise in a region reducing the average number of research agreements per university.

There is less reason to expect the number of start-ups to be influenced by competition from other universities in a focal university's region because start-ups usually result from knowledge-led research. The establishment of a start-up is therefore led by university staff and supported by university policies to provide seed capital or incubators and government policies to subsidise start-up creation, a common policy target in Europe (Muscio et al. 2015; Munari et al. 2015). Regional economic opportunities within a region, such as a high share of skilled employment and consumer or business markets could also influence start-up creation by providing a pool of talent and potential customers. Additionally, the (regional) availability of venture capital has found to be a positive predictor of university start-ups in several studies (Padilla-Meléndez et al. 2021; Huynh 2016; Powers and McDougall 2005).

The relationship between regional competition for university knowledge and licensing is likely to be more complicated in comparison to research agreements or start-ups because licensing can follow partner-led research agreements and therefore be negatively affected by regional competition or follow knowledge-led research that could face very few or no regional competitors. For example, the effect of regional competition would be mitigated if the university's intellectual property attracts the attention of firms located outside the region. Consequently, regional competition could have a smaller effect on the number of licenses than on the number of research agreements. In addition, license income could be largely unaffected by regional competition if skewed by a small number of very valuable licenses that earn income from geographically dispersed licensees (as for many enabling technologies) or attract interest from firms outside the region.

These expected effects could differ for leading research universities facing high quality competition. In this case, the effect of competition in reducing knowledge transfer could be eliminated if there are benefits due to knowledge spillovers from other leading universities located in the same region. Positive influence is more likely for the number of license agreements and license income. Similarly, leading universities located in a metropolitan region that attracts highly skilled labour and the head offices of firms could benefit from greater demand for advanced knowledge that requires additional research to develop into commercially viable products or processes. This type of knowledge is likely to be transferred through licenses, such that we would expect a positive effect on the number of licenses and license income. Conversely, researchers at universities in peripheral regions could be more active in research agreements (Zhang et al. 2016), resulting in a negative effect of location in a metropolitan region on this form of knowledge transfer.

Finally, we expect the effect of KIS firms on knowledge transfer to also vary by the type of knowledge transfer. The importance of tacit knowledge for KIS firms could create a positive demand for research agreements, where knowledge is often transferred in face-to-face meetings, but have no effect on licensing. The benefits to KIS firms of knowledge produced by universities could also have a positive effect on start-ups (Horváth and Berbegal-Mirabent 2020).

Table 1 summarizes the expected effect of regional inter-university competition, metropolitan location, and KIS firms on the three types of knowledge transfer outcomes.

Table 1. Predicted relationship with knowledge transfer outcomes

Variable of interest	Number of Research agreements	Licensing: Number of License agreements	Licensing: License income	Number of Start-ups
Quality measure of the focal university (UNI-TOP or UNI_RANK)	Positive	Positive	Positive	-[1]
Quality competition from other universities (QUALCOMP)	**Negative**	Negative	No effect	No effect
Location in a metropolitan region (METROP)	Negative	Positive	Positive	-[1]
KIS share of regional employment	Positive	No effect	No effect	Positive
Moderating effect of quality of the focal university on the effect of quality of competition from other universities (UNI_RANK by QUALCOMP)	Positive	**Positive**	**Positive**	No effect
Moderating effect of metropolitan area on the effect of quality of the focal university (METROP by UNI_TOP)	Negative	Positive	Positive	No effect

Bold: Stronger effect expected than for other knowledge transfer methods.
1: No prediction made.

3. Methodology

3.1 Data sources

Data for 2013 were obtained from three surveys of university Knowledge Transfer Offices (KTOs) conducted in 2014 by UNU-MERIT, ASTP, and HEFCE. All of the surveyed universities are research active and have a designated KTO for knowledge transfer activities. The UNU-MERIT survey covered universities in Austria, Denmark, Finland, the Netherlands, Norway and Sweden. The HEFCE (Higher Education Funding Council for England) survey provides data for the UK.[7] The survey of ten other European countries was a collaborative endeavour between UNU-MERIT and ASTP, a pan-European association for knowledge transfer professionals, with the ASTP-affiliated national associations RedOTRI and Netval collecting the data for Spain and Italy. Data collection methods vary between the three surveys due to minor differences in question sequences and wording, which could affect the comparability of the data.[8] However, this is likely to be a minor issue, since all of the universities collect similar data (usually by the KTO) for their internal use. Of note, no data are available for France and Germany.

The three surveys collected data on the characteristics of each KTO (number of employees, age, etc.), the KTO's affiliated university (number of researchers and presence of a hospital), and knowledge transfer activities and outcomes.

Forty-four universities with incomplete data for three control variables (number of research staff, number of KTO employees, and the KTO age) are excluded from all analyses. After exclusions, data are available for up to 292 universities in 17 countries. Table 2 provides the number of universities included in the analyses by country, with regional coverage best for the UK, Spain, Italy, the Nordic countries, the Netherlands and Belgium.

[7] The UK results are for the 2013/2014 fiscal year instead of the 2013 calendar year, but any bias from differences in the year should be minor.
[8] A copy of each survey can be provided on request.

Table 2. Distribution of universities included in the analyses by country, NUTS-2 region and ARWU status

	Universities in the analyses		NUTS-2 regions in the analyses		ARWU top 500 universities in the analyses	
Country	**Number**	**Percent total**	**Total NUTS-2 regions with a university**	**Percent covered**	**Total ARWU ranked universities**	**Percent included**
UK	98	33.6%	36	91.7%	37	97.3%
Spain	59	20.2%	17	100.0%	10	100.0%
Italy	57	19.5%	20	100.0%	19	89.5%
Sweden	13	4.5%	8	75.0%	11	72.7%
Austria	12	4.1%	6	83.3%	7	100%
Netherlands	10	3.4%	8	87.5%	12	83.3%
Norway	10	3.4%	5	100.0%	4	100.0%
Finland	8	2.7%	3	100.0%	5	60.0%
Denmark	7	2.4%	5	100.0%	4	100.0%
Belgium	6	2.1%	8	62.5%	7	57.1%
Ireland	4	1.4%	2	50.0%	3	33.3%
Switzerland	2	0.7%	7	14.3%	7	14.3%
Portugal	2	0.7%	7	28.6%	4	25.0%
Bulgaria	1	0.3%	6	16.7%	0	-
Estonia	1	0.3%	1	100.0%	0	-
Hungary	1	0.3%	7	14.3%	2	0.0%
Slovenia	1	0.3%	2	50.0%	1	0.0%
Total	**292**	**100%**	**164**	**77.7%**	**133**	**79.9%**

Note: Not all NUTS-2 regions have a university in their region.

Two types of data are available for universities. Survey and other data on KTO and university characteristics, university quality, and knowledge transfer outcomes are available for up to 292 *focal* universities. In addition, data on university quality are available from non-survey sources for *all* non-focal universities located in the same region as the focal university.

Regional-level data at the NUTS-2 (Nomenclature of Territorial Units for Statistics) level were added for all regions with one or more focal universities. Table 2 lists the number of NUTS-2 regions with a university in each country and the percentage included in our database. In total, the 17 countries have

148 NUTS-2 regions with a university, of which 115 regions (77.7%) are covered in this study. No data are available for the remaining 23% of NUTS-2 regions.

3.2 Dependent Variables

Four dependent variables measure outcomes from the transfer of knowledge to firms: the number of research agreements, the number of licenses, the amount of license income, and the number of start-ups established. Start-ups include spin-offs that are established by university staff and firms established by individuals that are not employed by the university. We do not use the number of patent applications or grants because they are measures of inventions instead of the transfer of knowledge from universities to firms.

The four outcomes are based on the awareness of KTO managers of the transfer of knowledge owned by the university and commercialised by their office. This will underestimate knowledge transfer if intellectual property rights are owned by the inventor and not handled by the university's KTO (Lissoni et al. 2008). Consequently, the results of this study only apply to knowledge transfer via the KTO. A sub-sample of our dataset, for 167 universities for which we have information on IP ownership, indicates that only 9% of respondents report that their university does not own the IP rights. Swedish universities account for 80% of these cases, due to a 'professors privilege law' (Tripp et al. 2015).

Table 3 provides the number of universities with data for each dependent variable. Data on the number of research agreements and the amount of licence income are available for 207 (70.9%) universities, while data on the number of start-ups and license agreements are available, respectively, for 284 (97.3%) and 267 (91.4%) of the 292 universities in our sample. The amount of license income is underreported because the KTO respondents are not always willing or allowed to share this information, even when full confidentiality is provided. Data on the number of research agreements are not available for all universities, possibly because these agreements are handled at the faculty level instead of by the KTO (Barjak et al. 2015).

Table 3. Descriptive statistics for dependent variables

	N[1]	Mean	Median	SD	Percent universities reporting outcome[1]
Number of research agreements	207	164.2	69	240.2	70.9%
Number of license agreements	267	14.5	3	34.1	91.4%
License income (million Euros)[2]	207	0.70	0.02	5.1	70.9%
Number of start-ups established	284	2.7	1	5.4	97.3%

Notes: 1. Includes zero outcomes. 2. In Euros for all countries, including countries that do not use the Euro.

3.3 Independent variables

To determine if the focal university faces competition for knowledge from other universities in the same region, it is essential to capture the quality of the research produced by both the focal university and by potential university competitors. Otherwise, an observed effect (or lack of an effect) from competition could be caused by differences in research quality.

We construct two variables for the quality of the focal university, UNI_TOP and UNI_RANK, using data from the Academic Ranking of World Universities (ARWU). ARWU data are also used to calculate a measure of quality competition for all other universities located in the same region as the focal university. The ARWU uses six indicators to rank research performance: 1) the number of alumni winning Nobel Prizes and Fields Medals, 2) the number of staff winning Nobel Prizes and Fields Medals, 3) the number of highly cited researchers, 4) the number of articles published in the journals *Nature* and *Science*, 5) the number of articles indexed in the Science Citation Index-expanded and the Social Sciences Citation Index, and 6) the per capita performance of an institution. The ARWU ranks more than 1,200 universities every year and publishes data for the best 500 (Liu and Cheng 2005).

There are several other global rankings of universities, including the Quacquarelli Symonds World University Ranking (QS) and the Times Higher Education World University Ranking (THE). All of these rankings are highly correlated (Shehatta and Mahmood 2016, Dill and Soo 2005). Aguillo et al. (2010) compared university rankings using similarity measures and found that each ranking is similar to other rankings. Aguillo et al. (2010) also find that similarities are increased when the comparison is limited to European universities. The ARWU is used here because it is a valid and realistic ranking system (Marginson and van der Wende 2007) and a good indicator of university excellence (Taylor and Braddock 2007).

The binary variable UNI_TOP determines if each focal university (see Table 4) is included in the top 500 universities in the 2013 ARWU rankings (coded as 1 if the university is in the top 500 ARWU and 0 otherwise). The ordinal variable UNI_RANK equals 3 if the university is in the top 200 in the ARWU ranking, 2 when the university receives an ARWU ranking of 201 to 300, 1 if the ARWU ranking is between 301 and 500, and zero otherwise (unranked by the ARWU). In total, there are 133 European universities in the ARWU top 500 in the 17 countries covered by this study, of which 101 (79.7%) are focal universities in our database (see Table 2).

Competition from other Universities and Research Institutes in the same region

Potential competition from other universities and research institutes is measured using data for research-active universities in the same NUTS-2 region as the focal university. With the exception of Denmark and a few universities in Belgium and Spain, relevant data on research-active universities in the same region as the focal university were obtained from the EUMIDA European University Data Collection database.[9] Data for universities that were not available from EUMIDA were collected manually.

The quality of university competition variable, QUALCOMP, is constructed in two steps. The first step counts the number of faculties, of the same type as the faculties of the focal university, in three fields where knowledge transfer is likely: sciences, engineering and health. Take for example university A in region R. University A has faculties in sciences and health. In region R there are two other universities, of which university B has a health faculty and university C has faculties in health, sciences and engineering. The number of competing faculties for university A equals three because there are two other health faculties and one other science faculty in the same region.

[9] This work is now continued in the RISER-ETER project.

The second step uses the ARWU rankings to weight the quality of the competing faculties in the same region as the focal university, using 5 ranks (5 = top 100, 4 = 101 to 200, 3 = 201 to 300, 2 = 301 to 400, 1 = 401 to 500). A hypothetical example is provided for university A. University B has an ARWU rank of 2 and university C has an ARWU rank of 5. University B's degree of quality competition is measured as two (one health faculty multiplied by the university ranking 2) and university C's degree of quality competition equals ten: two faculties (science and health) multiplied by 5. QUALCOMP for university A therefore equals 12. Seventy-five focal universities face zero ranked universities in the same region but face one or more comparable faculties in unranked universities. For these, QUALCOMP is assigned a value of 1. Finally, QUALCOMP is assigned a value of zero for 40 universities in regions with no other universities with comparable faculties.

The effect of QUALCOMP could vary by the quality of research conducted by the focal university. This is tested by an interaction term between QUALCOMP and UNI_RANK. For instance, the knowledge transfer activities of high quality focal universities could benefit from high quality competition due to either spillover effects for knowledge or a cluster of high quality universities attracting greater attention from firms, including firms located outside the region. Conversely, the knowledge transfer activities of lower quality focal universities could be reduced in the presence of high quality competitors in the same region.

Research institutes in each region with a focal university were identified from the EUMIDA database, national research councils, national academies of sciences, and organisations that fund or coordinate national research. Most of the research institutes are publicly funded, but we also included private research institutes that are likely to be active in knowledge transfer. As there is no internationally comparable ranking system for research institutes, the variable RICOMP equals the number of comparable science, health and engineering divisions within research institutes located in the same region as the focal university.

KIS and metropolitan region

Other regional variables of interest measure KIS activity and location in a metropolitan region. The variable EMPSHARE_KIS equals the share of employees in each region that are employed in knowledge intensive services.[10] The variable METROP equals 1 if the focal university's region has a population above 5 million people, or at least 20% of the country's total population, and zero otherwise. We use METROP instead of only relying on the regional population because METROP includes national urban centres in small countries and regional urban centres in large countries. An interaction term between the two binary variables METROP and UNI_TOP is used to determine if location in a metropolitan region moderates the effect of high quality focal universities on knowledge transfer.

3.4 Control variables

Control variables are included for the characteristics of the university, the university's KTO, and the region that could influence knowledge transfer outcomes.

Relevant characteristics of the university include the presence of a medical hospital (HOSP), and if the university is a technical university (TECH). The presence of a hospital has been found to increase knowledge transfer outcomes in Europe (Barjak and Es-Sadki 2015; Berbegal-Mirabent and Sabate 2015), although other research in Europe (Conti and Gaule 2011) and the US (Friedman and Silberman 2003) has found no effect. Technical universities focus on applied knowledge of commercial value and could therefore produce more knowledge transfer than non-technical universities. Both HOSP and TECH are dummy variables that equal 1 when the characteristic is present and 0 otherwise.

The control variables for the KTO are the number of employees (KTO_SIZE) and KTO age (KTO_AGE). KTO_SIZE increases the human resources available to identify and commercialize knowledge, while KTO_AGE is a measure of experience in knowledge transfer activities (Cesaroni and

[10] The relevant NACE Rev. 2 industry categories for KIS are provided by Eurostat: https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf

Piccaluga 2016; Conti and Gaule 2011; Curi et al. 2012). Both variables could increase the effectiveness of activities to promote university discoveries to firms (Friedman and Silberman 2003; Siegel et al. 2003).

Five of the six variables used to construct the ARWU rankings are affected by the size of the university, with larger universities with more research staff likely to out-perform smaller universities in the creation of knowledge. This size effect is controlled by a variable for the number of researchers at each university (NUMB_RES).

Variables to control for regional demand for university knowledge are the size of the regional population (POPULATION) and the per capita gross regional product (PER_CAP_GRP). Both are measures of potential demand for goods and services. Universities in wealthier regions are known to have more knowledge transfer outcomes than universities in poorer regions (Belenzon and Schankerman 2009; Friedman and Silberman 2003; González-Pernía et al. 2013; Lach and Schankerman 2008; Conti and Gaule 2011). We do not include a measure for venture capital for start-ups due to a lack of data at the regional level.

Common methods for measuring regional business demand use regional R&D, including regional R&D intensity (Chapple et al. 2005), the number of R&D staff in a region (Algieri et al. 2013), and regional business expenditures on R&D (Van Looy et al. 2011; Link and Siegel 2005). We do not use measures of R&D because of concerns that it underestimates regional R&D, as when R&D by a regional subsidiary is assigned to the head office. Instead, we use the share of regional employment in high and medium-high technology manufacturing (EMPSHARE_HMHT) (Belenzon and Schankerman 2009), which also matches our independent variable for the KIS sector. On average, 85% of R&D expenditure in EU manufacturing is accounted for by high and medium-high technology manufacturing industries. Data for these three variables at the NUTS 2 level are obtained from Eurostat.[11] Descriptive statistics for the independent and control variables are given in Table 4.

[11] Eurostat, Business enterprise R&D expenditure in high-tech sectors - NACE Rev. 2 [htec_sti_exp2].

Table 4. Descriptive statistics for independent variables

Control variables for the focal KTO and university	*Mean*	*Median*	*SD*
NUMB_RES*: Number of researchers in FTE	1,614.2	1,197.5	1,480.5
KTO_SIZE*: KTO staff in FTE	17.5	8.0	20.7
KTO_AGE*: age of KTO in years	15.0	13.0	8.6
HOSP: University has a hospital (1), other (0)	.223		
TECH: University is a technical university (1), other (0)	.086		
Control variables for the region	*Mean*	*Median*	*SD*
POPULATION*: Regional population (1,000,000)	3.2	2.1	2.6
PER_CAP_GRP*: Gross regional product per capita € (1,000)	29.1	28.2	8.8
EMPSHARE_HMHT: Employment share in high and medium high-technology manufacturing	4.2	3.7	2.2
Control variable for quality of the focal university	*Number*	*Percent*[1]	
UNI_TOP: University in top 500 (1), other (0)	101	34.6%	
UNI_RANK: Rank of university in top 500			
▪ Top 200 (UNI_RANK = 3)	39	13.4%	
▪ Top 201-300 (UNI_RANK = 2)	29	9.9%	
▪ Top 301- 500 (UNI_RANK = 1)	33	11.3%	
▪ Unranked (not in top 500) (UNI_RANK = 0)	191	65.4%	
Regional variables of interest	*Mean*	*Median*	*SD*
EMPSHARE_KIS: Employment share in Knowledge-intensive services	42.5	43.6	8.7
RICOMP: Number of competing research institutes in the same region as the focal university.	3.9	1.0	6.3
Quality of regional competition	*Mean*	*Median*	*SD*
QUALCOMP: Number of quality-weighted university science, engineering and health faculties of the same type and in the same region as the focal university	9.0	6.0	11.7
	Number	*Percent*[1]	
METROP: Focal university is located in a high population region (1), other (0)	96	32.9%	

* Statistics are before logarithmic transformation. 1: Percent of 292 universities.

3.5 Analytical Methods

Table 5 provides a correlation table for all independent variables. Variance Inflation Factors (VIF) were calculated for all models to test for multicollinearity. All VIFs are less than 4, below the cut-off point of 5 (O'Brien 2007). Each regression result includes the AIC value (Akaike Information Criterion), a goodness-of-fit measure in which smaller values are preferable.

Three of the four dependent variables are measured as counts: the number of license agreements, start-ups and research agreements. In line with other research, we use the negative binomial model for count data (Barjak et al. 2014; Sine et al. 2003). GLM (identity link) is used for the analyses of license income as it is a continuous variable.

As the data feature a hierarchical structure at multiple levels, the results in Tables 6 and 7 use a multilevel negative binomial model, nesting university-level data (level 1) into regional-level data (level 2) into country-level data (level 3). Universities in the same region and in the same country are likely more similar or related to each other in comparison to those selected randomly. Since there is unobserved heterogeneity amongst different regions or countries, running a normal regression would violate the independence of observations criteria as unobserved heterogeneity would go into the error term. Unobserved heterogeneity would make the error terms non-independent. For instance, predicted error terms for universities in the same region would be more similar to one another than error terms between two universities from different regions. In such cases the standard errors will be biased.

Multilevel modelling accounts for these interdependencies by capturing residuals at different levels. Baseline regressions without controlling for the multilevel were also conducted and provided in the appendix (Tables 8 and 9), key results do not differ with the multilevel regressions.

Tables 6 and 7 show the random intercept models. The random effect is necessary as the variance coefficients in all the models are non-zero for both the regional and country level variance components. This is evidence that there is variation across regions and countries above and beyond the difference in the fixed effects. The strongest evidence that supports this choice are the Likelihood Ratio tests. For all models these are significant compared to the baseline models (Tables 8 and 9) and hence support the choice of controlling for random effects. The results thus show that universities in the same region are significantly more homogeneous than universities in two different regions. The same analogy holds for countries; universities in the same country are significantly more homogeneous than universities in two different countries. As expected, the residual level variance component at the university level is also non-zero, thus individual characteristics of a university affects university level outcomes. This is also known as the within effect.

Additional statistical analysis has been performed to see if random slopes would improve model fit. Estimated variances of the random slopes tested for research agreements and license agreements are very small and close to zero. None of the models using random slopes has resulted in finding an improved fit based on the Likelihood Ratio test or AIC values. See Table 10 in the appendix for the results. The results show that there is no evidence found that region or country level heterogeneity varies across university level predictors.

The regressions use natural logarithmic transformations of the interval variables NUMB_RES, KTO_SIZE, KTO_AGE, POPULATION and PER_CAP_GRP to reduce the effects of outliers on the results. QUALCOMP is not transformed because it equals zero for some focal universities. License income, heavily skewed due to outliers has been transformed with a square root transformation and divided by 1,000 for reporting reasons.

Due to the cross-sectional nature of the data, it is not possible to identify cause and effect, for example if university quality drives knowledge transfer performance or if regional characteristics drives knowledge transfer performance. We therefore refer to correlations or relations in describing our results.

Table 5. Correlation results for independent variables

	NUMB_RES (log)	KTO_SIZE (log)	HOSP	TECH	KTO_AGE (log)	PER_CAP_ GRP (log)	POPULAT- ION (log)	EMPSHA- RE_HMHT	EMPSHA- RE_KIS	METROP	UNI_ TOP	UNI_ RANK	RI_ COMP	QUAL COMP
NUMB_RES (log)	1													
KTO_SIZE (log)	0.482***	1												
HOSP	0.314***	0.303***	1											
TECH	0.061	0.016	-0.134**	1										
KTO_AGE (log)	0.327***	0.480***	0.13**	-0.068	1									
PER_CAP_GRP (log)	0.116**	-0.071	0.156***	0.102*	-0.126**	1								
POPULATION (log)	0.030	0.059	-0.176***	-0.059	0.071	0.109*	1							
EMPSHARE_HMHT	-0.130**	-0.152***	-0.145**	0.032	-0.112*	-0.029	-0.040	1						
EMPSHARE_KIS	0.195***	0.271***	0.277***	0.042	0.027	0.534***	0.007	-0.438***	1					
METROP	0.024	-0.120**	-0.129**	0.072	-0.083	0.356***	0.572***	-0.102*	0.202***	1				
UNI_TOP	0.604***	0.248***	0.442***	0.061	0.065	0.244***	-0.033	0.037	0.147**	0.028	1			
UNI_RANK	0.614***	0.297***	0.547***	0.009	0.042	0.271***	-0.044	-0.037	0.227***	0.031	0.896***	1		
RICOMP	0.132**	0.033	-0.079	0.006	0.126**	0.345***	0.483***	-0.066	0.216***	0.574***	0.048	0.065	1	
QUALCOMP	0.023	0.118**	-0.050	-0.063	0.043	0.486***	0.485***	-0.148***	0.443***	0.399***	-0.091*	-0.068	0.418***	1

* = p <.10, ** = p <.05, *** = p<.01

4. Results and discussion

The regression results for each knowledge transfer outcome, with and without the interaction terms, are presented in two tables. Table 6 includes the variables METROP and UNI_TOP and their interaction term to analyse the influence of being top ranked and/or located in a metropolitan region. Table 7 includes UNI_RANK and QUALCOMP and their interaction term to analyse the effect of quality-weighted competition from other universities plus the moderating effect of UNI_RANK on QUALCOMP. It is not possible to include all variables in a single model because of the high correlation between UNI_TOP and UNI_RANK.

As discussed above non-zero variance of the intercepts for the different levels support the use of a multilevel model. To better understand the importance of the different levels of analysis we can examine the difference variance components for the country level, the regional level and the individual level.[12] We can consider the ratio of each variance component to the total variance (Snijders and Bosker 1999). Some interesting differences are observed depending on the technology transfer outcome. For research and license agreements, the variance component at the university level accounts for a major portion of the variance in the number of research and license agreements. For instance based on the results of Table 6 model *a* for research agreements the total variance at the university level explains 61.1% (0.876/(0.517+0.040+0.876) and the remaining 38.9% is explained at higher levels. Specifically, the country level accounts for 36.1% and the regional level for 2.8%. The country level accounts for a higher share in the estimated variance in license agreements compared to research agreements with 40.2% (based on model a). For license agreements, the university level still explains most with 57.5% and the regional level with 2.3%. The university level explains most for start-ups with 67.6%. For start-ups however the regional level variance component accounts for a larger variance compared to license

[12] In negative binomial models the residual variance in the dependent variable is the overdispersion beyond that expected from a simple Poisson process. The overdispersion is estimate as the log of the dispersion parameter (/lnalpha) after exponentiating the residual variance is obtained (alpha) following Osgood (2000).

and research agreements with 16.5 % (based on Table 6 model a). The country level accounts for 15.9% of the variation for start-ups.

Results are surprisingly different for license income with a contribution from the regional level of 53.8%, 29.4% at the country level and 16.9% at the university level. This suggests that there are strong contextual effects (how characteristics of other individuals in the same context affect individual level outcomes). In other words, universities in the same region (or country) show a significantly more homogeneous license income performance. This suggests that the characteristics of other universities in the same region (or country strongly affect university level outcomes. University (or within-effects) account for 16.9% of the variance. The GLM model with a normal distribution used for license income allows the calculation of the intraclass correlation coefficient (ICC1)[13], which is not possible for negative binomial regressions in Stata17, used for license and research agreements and start-ups. ICC1 can provide evidence for clustering in data. If ICC1 is zero, then there is no clustering, and all level variable units are independent of each other. The other extreme if ICC1 is one, then there is no variance within clusters. For license income the ICC at the country level is 0.29 and at the regional level nested within the country level 0.83. Thus, particularly for the regional level there is little variation within regions and evidence for strong clustering, showing the importance to take the hierarchical nature into account. Similar ratios for each variance components are observed in the *b* models in Table 6 and the models reports in Table 7.

[13] ICC1: [variance between groups/(variance between groups + variance within groups)]

Table 6. Multilevel negative binomial regressions without (a) and with (b) interaction term METRO by UNI_TOP

	Research agreements		License agreements		License income		Start-ups	
	a	b	a	b	a	b	a	b
Constant	-2.278	-2.486	-10.029***	-10.119***	-2.951**	-2.902**	-8.332**	-8.398**
Variance of intercept C	0.517 (0.337)	0.522 (0.324)	0.856 (0.528)	0.880 (0.620)	0.219 (0.180)	0.215 (0.176)	0.173 (0.119)	0.184 (0.121)
Variance of intercept R	0.040 (0.070)	0.023 (0.069)	0.050 (0.085)	0.041 (0.028)	0.401 (0.523)	0.400 (0.522)	0.180(0.057)	0.167 (0.064)
Residual variance (U)	0.876 (0.063)	0.884 (0.061)	1.225 (0.201)	1.229 (0.201)	0.126 (0.046)	0.126(0.046)	0.738 (0.172)	0.743 (0.173)
Characteristics of the KTO and the university								
NUMB_RES (log)	0.725***	0.719***	0.600***	0.593***	0.051*	0.053*	0.717***	0.707***
KTO_SIZE (log)	-0.030	-0.031	0.207**	0.202***	0.046	0.047	0.028	0.029
HOSP	0.669***	0.677***	0.947***	0.964***	0.438***	0.430***	0.290**	0.312**
TECH	0.284	0.277	0.499*	0.515*	0.163	0.153	0.841***	0.846***
KTO_AGE (log)	0.281*	0.285*	0.109	0.114	0.075	0.074	-0.272	-0.267
Regional characteristics								
PER_CAP_GRP (LOG)	-0.144	-0.101	1.189***	1.168***	0.449	0.443	-0.929*	-0.932*
POPULATION (LOG)	-0.123	-0.131	0.223	0.238	0.022	0.019	0.436**	0.446**
EMPSHARE_HMHT	0.078**	0.078**	0.063*	0.064**	0.017	0.017	0.059	0.060
EMPSHARE_KIS	-0.011	-0.010	-0.022	-0.022	0.019	0.018	0.028	0.029
METROP	0.072	-0.049	0.174	0.017	-0.176	-0.149	-0.338	-0.451
Quality characteristics of the focal university and competition from other faculties								
UNI_TOP	0.211	0.109	0.514**	0.434*	0.186***	0.209***	-0.109	-0.187
RICOMP	0.005	0.005	0.002	-0.003	-0.002	-0.002	-0.010	0.010
QUALCOMP	-0.014**	-0.014**	-0.026**	-0.026**	-0.003	-0.003	-0.007	-0.007
METROPxUNITOP		0.281		0.231		-0.062		0.210
N	207	207	267	267	207	207	284	284
Number of groups	81R, 15C	81R, 15C	108R,16C	108R,16C	85R, 16C	85R, 16C	113R,17C	113R,17C
Log likelihood	-1168.51	-1168.16	-772.68	-772.49	-170.02	-169.92	-542.94	-542.75
AIC	2365.0	2364.3	1575.4	1575.0	370.0	369.8	1117.9	1117.5
LR test vs. baseline[1]	21.15***	21.43***	22.55***	22.85***	53.93***	52.45***	14.28***	14.24***

Robust SE. *= p <.10, ** = p <.05, *** = p<.01. Note 1: vs. Negative binomial for research and license agreements and start-ups, vs. linear model for license income (see Table 8 and 9).

Table 7. Multilevel negative binomial regressions without (a) and with (b) interaction term QUALCOMP by UNI_RANK

	Research agreements		License agreements		License income		Start-ups	
	a	b	a	b	a	b	a	b
Constant	-1.399	-0.878	-9.020***	-8.749***	-1.589	-1.457	-8.587***	-8.681***
Variance of intercept C	0.479 (0.279)	0.505 (0.282)	0.865 (0.598)	0.882 (0.613)	0.221 (0.186)	0.228 (0.193)	0.174(0.118)	0.184(0.137)
Variance of intercept R	0.035 (0.051)	0.015 (0.038)	0.044 (0.034)	0.032 (0.029)	0.401 (0.472)	0.398 (0.468)	0.174(0.066)	0.173(0.061)
Residual variance (U)	0.868 (0.074)	0.863 (0.0830)	1.213 (0.211)	1.205 (0.209)	0.104 (0.040)	0.102 (0.102)	0.735 (0.171)	0.726 (0.166)
Characteristics of the KTO and the university								
NUMB_RES (log)	0.672***	0.678***	0.558***	0.566***	0.016	0.016	0.726***	0.727***
KTO_SIZE (log)	-0.036	-0.027	0.193**	0.186**	0.035	0.032	0.031	0.025
HOSP	0.436*	0.383*	0.858***	0.823***	0.342***	0.335***	0.354**	0.349**
TECH	0.240	0.202	0.522*	0.503*	0.224	0.228*	0.860***	0.845***
KTO_AGE (log)	0.340**	0.327	0.120	0.099	0.121*	0.121*	-0.286	-0.279
Regional characteristics								
PER_CAP_GRP (LOG)	-0.244	-0.266	1.093***	1.024***	0.352	0.364	-0.861	-0.865
POPULATION (LOG)	-0.102	-0.075	0.200	0.200	-0.035	-0.044	0.439***	0.447***
EMPSHARE_HMHT	0.074*	0.076**	0.063**	0.073**	0.012	0.011	0.057	0.056
EMPSHARE_KIS	-0.011	-0.011	-0.025	-0.025	0.015	0.015	0.027	0.027
METROP	0.057	0.039	-0.131	-0.116	-0.126	-0.118	-0.348	-0.358
Quality characteristics of the focal university and competition from other faculties								
UNI_RANK = 3 *(top 200)*	0.714	0.423	0.836**	0.652**	0.165**	0.162**	-0.190	-0.271
UNI_RANK = 2 *(top 201-300)*	0.338	0.061	0.432	0.166	-0.030	-0.154	-0.346	-0.216
UNI_RANK = 1 *(top 301-500)*	0.017	-0.028	0.472*	0.444*	0.608***	0.551***	0.028	0.022
RICOMP	0.006	0.008	-0.004	-0.005	-0.001	-0.001	0.014	0.015
QUALCOMP	-0.012**	-0.018***	-0.024**	-0.030***	-0.001	-0.002	-0.008	-0.009
UNIRANK=2*QUALCOMP		0.013***		0.014***		0.006***		-0.008
UNIRANK=3*QUALCOMP		0.009***		0.007***		0.002*		0.003
N	207	207	267	267	207	207	284	284
Number of groups	81R, 15C	81R, 15C	108R,16C	108R,16C	85R, 16C	85R, 16C	113R,17C	113R,17C
Log likelihood	-1166.79	-1164.67	-771.76	-770.59	-157.07	-155.93	-542.30	-541.94
AIC	2361.6	2357.3	1573.5	1571.2	344.2	341.9	1116.6	1115.9
LR test vs. baseline[1]	20.13***	20.75***	23.46***	24.27***	67.01***	68.00***	13.38***	13.86***

Robust SE. *= p <.10, ** = p <.05, *** = p<.01. Note 1: vs. Negative binomial for research and license agreements and start-ups, vs. linear model for license income (see Table 8 and 9).

Control variables

The results for the control variables for the university and KTO are similar to those of other studies. The number of researchers employed at a university (NUMB_RES) has a significant positive correlation with all knowledge transfer outcomes. KTO size (KTO_SIZE) has no effect on the number of research agreements, license income and start-ups, but KTO size has a significant positive correlation with the number of license agreements. This result is supported by other research (Conti and Gaule 2011; Barjak et al. 2014; Barjak and Es-Sadki 2015). As found in other research for Europe (Barjak and Es-Sadki 2015; Berbegal-Mirabent and Sabate 2015), the presence of a hospital (HOSP) has a significant positive correlation with all four knowledge transfer outcomes. Technical universities (TECH) have significantly more license agreements and start-ups.

The age of the knowledge transfer office (KTO_AGE) has a significant positive correlation with the number of research agreements in Table 6 and in model *a* in Table 7 as well as for license income in Table 7, as found in other studies (Carlsson and Fridh 2002; Conti 2009; Barjak et al. 2014).

Few of the regional control variables are correlated with the number of research agreements and licenses, but an increase in employment in high and medium-high technology manufacturing (EMPSHARE_HMHT) is significantly positively correlated with research and license agreements. The positive correlations for license agreements are in line with US (Belenzon and Schankerman 2009; Friedman and Silberman 2003; Lach and Schankerman 2008) and European research (Barjak and Es-Sadki 2015).

The regional per capita income (PER_CAP_GRP) has a positive correlation with license agreements, a result also found by Barjak and Es-Sadki (2015) and Chapple et al. (2005). Conversely, regional per capita income is negatively correlated with the number of start-ups in Table 6, as also found by Muscio et al. (2016). A possible explanation, in line with research by Bania et al. (1993) on start-up creation, is that wealthier regions could have higher costs for wages and capital expenditures which can be substantial barriers for university start-ups.

The log of the regional population (POPULATION) has a positive correlation in all models for university start-ups. This suggests that there is more potential for creating start-ups in larger populated regions with potentially more regional demand for the goods and services that these firms aim to produce.

KIS employment share

As predicted, with KIS being characterized by a high degree of tacit knowledge, the KIS employment share (EMPSHARE_KIS) in the region has no relationship with licensing which often involves formal R&D (Windrum and Tomlinson 1999; Schricke et al. 2012). In contrast with expectations and suggestions by Lee and Miozzo (2019) that proximity of KIS firms has a positive influence on research collaboration, there is no such evidence found. The expected positive relationship between the KIS employment share and the number of start-ups is also not found. These results suggest that KIS firms are not more likely than other service or low-tech manufacturing firms to use research agreements as a major method for accessing university knowledge or to benefit the creation of university start-ups. Unfortunately, we lack data on other methods of knowledge transfer that KIS firms might use to access more tacit knowledge of universities, such as consulting or informal contacts.

Location in a metropolitan region

The results for location in a metropolitan region and its interaction with UNI_TOP do not support the predictions in Table 1 concerning the type of technology transfer. No negative correlation with the number of research agreements is observed nor a positive relationship with licensing. It seems that firms' licensing decisions are unaffected by the location of universities in a metropolitan area when they are seeking commercially valuable intellectual property. Moreover, there is no evidence found for a moderating effect of a metropolitan area on the effect of quality of the focal university.

Quality of the focal university

The coefficient for UNI_TOP is significant and positive for license agreements and license income, indicating that top universities have more license agreements and subsequently more license income compared to non-top universities. Furthermore, the ordinal variable for the quality of the focal university (UNI_RANK) is significantly positively correlated with the number of license agreements, as observed by Sine et al. (2003), and license income (for the ARWU top 200 and top 301 – 500, see Table 7). As expected, there is no correlation with the number of start-ups.

Quality weighted competition from other universities in the same region

Table 7 provides results for the ordinal variable for the quality of the focal university (UNI_RANK) and the variable for quality-weighted competition (QUALCOMP) from other universities in the same region. Results are given with and without the interaction terms (UNI_RANK*QUALCOMP). For all models (Table 6 and 7), QUALCOMP has the predicted significant negative relationship with the number of research agreements and license agreements. These results suggest that there is indeed competition for the knowledge outputs of universities, such that an increase in the regional supply of knowledge is not matched by an equivalent increase in private sector demand. A possible reason for this may be that the private sector has different knowledge demands. This applies to both partner-led research agreements, and knowledge that can be either partner- or knowledge-led, as for license agreements. It also suggests that a significant share of demand must come from regional firms instead of from firms located in other regions or internationally.

The prediction for a positive interaction term between UNI_RANK and QUALCOMP for license agreements and research agreement is supported. For license income the interaction terms show the predicted significant positive correlation but the negative correlation of QUALCOMP is not significant. The predicted moderating effect of quality of the focal university on the effect of quality of competition from other universities is thus found for research and license agreements, and there is some support for this prediction for license income. A possible explanation is that the co-location of top-ranked universities and other quality universities could have either spill-over benefits for knowledge-led research or provide benefits from signalling a regional cluster of expertise to potential licensees.

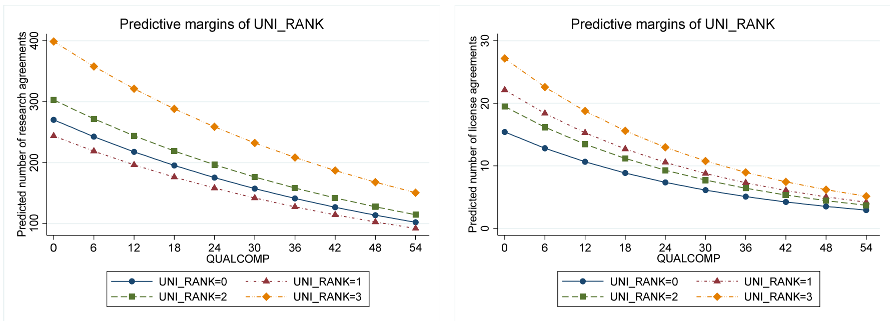
Cross-level interaction effect of UNI_RANK and QUALCOMP

To better elaborate the (moderating) cross-level interaction effect of regional quality competition and the four technology transfer outcomes we calculate margins after the estimations of model *b* in Table 7 for license agreements and research agreements. Margins are statistics calculated from predictions of a previously fit model at fixed values of covariates (QUALCOMP) and averaging or otherwise integrating over the remaining covariates. The curves depicted in Figure 1 show for each of the ordinal value of UNI_RANK the probability of the technology transfer outcomes (the predictive margins) at the specified values of QUALCOMP (zero to 54) conditional on that value of UNI_RANK.

The figures show that more quality competition reduces the number of technology transfer outcomes. Moreover, the moderating effect of top-ranked universities is shown as these types of universities are for all levels of QUALCOMP producing more technology transfer outcomes compared to other universities. The difference between the four groups, i.e. the gap between the four lines, is decreasing with increasing levels of quality competition. This result corroborates the results discussed earlier that there is limited demand for the knowledge outputs of universities, such that an increase in the regional supply of quality knowledge (QUALCOMP) is not matched by an equivalent increase in private sector demand which applies to both top-ranked universities and other universities. The results for license agreements show that universities in the third category (UNI_RANK=3, i.e. top 301-500) report on average more license agreements compared to universities in the second category (UNI_RANK=2, i.e. top 201-300). This result is also observable in Table 7 (model b) that presents larger and significant coefficients for UNI_RANK=3 compared to UNI_RANK=2 (0.444 vs 0.166). Similarly, for research agreements top-ranked universities (UNI_RANK=1, i.e. top 200) are predicted to perform worse compared to the baseline group of non-ranked universities (UNI_RANK=0) although this result is not significant. Although not reported in the Tables 6 or 7, the cross-level interaction effect of UNI_TOP and QUALCOMP is provided in the appendix for license agreements and license income. The figures show that more quality competition reduces the number of technology licensing outcomes. Top-ranked universities are always producing more technology licensing outcomes compared to other universities. Same as in Figure 1, the difference between the two groups, i.e. the gap between the two lines, is decreasing with increasing levels of quality competition for license agreements.

Figure 1. Cross-level effects of UNI_RANK and QUALCOMP on technology transfer outcomes

Research agreements **License agreements**



Competition from other research institutes in the same region

Competition from other research institutes in the same region with comparable science, health and engineering divisions as the focal university (RICOMP) has no significant effect in any of the models. The absence of an effect could be due to the lack of an adjustment for quality.

Additional analyses

We ran several additional analyses to explore the veracity of our results. First, we ran regressions to evaluate the effects of IP ownership on outcomes. As expected, ownership of IP by partners other than the university has a significant negative correlation for all four KT outcomes, a result in line with Barjak et al. (2014). The results for the control variables and the industrial sector (HMHT and KIS) remained consisted with the results presented. The results for QUALCOMP and METROP remained only significant in the models with research agreements but not in the models based on licensing. This result is not that surprising as IP ownership of partners other that the university is likely of more influence on commercially beneficial contracts such as licensing than for more collaboration types of contracts such as research agreements.

Additionally, the regressions were repeated using the count of comparable science faculties in universities in the same region as the focal university (FACCOMP) instead of the quality weighted variable QUALCOMP. FACCOMP for the number of research agreements and license agreements is no longer significant, while the interaction term (FACCOMP x UNI_RANK =3) for license income is negative and significant (-0.030, $p < .01$) instead of positive for QUALCOMP. These differences suggest that quality weighting is necessary to observe the effects of competition between universities. The negative effect for license income suggests that the absence of a quality adjustment masks the positive effect of top ranked universities through spill overs or signalling a regional cluster of expertise.

5. Conclusions

This chapter evaluates several aspects of the regional environment on the knowledge transfer outcomes of universities that have attracted little attention in the literature:

- the effect of regional employment in knowledge intensive services (KIS),
- quality weighted competition from other universities in the same region as the focal university,
- location in a metropolitan region, and
- interaction effects between the quality of the focal university and the quality of competition.

We look at three types of outcomes: the number of research agreements, where the type of research is usually led by business partners; the number of start-ups, which are knowledge-led by university academics; and the number of licenses and license income, which can be due to a mix of partner-led and knowledge-led research activities. We use ARWU university ranking data to measure the quality of both the focal university and competing universities.

The expected positive relationships between the KIS employment share and the number of research agreements and start-ups is not found. However, an increase in employment in high and medium-high technology manufacturing (EMPSHARE_HMHT) is significantly positively correlated with research and license agreements.

Quality-adjusted competition is shown to reduce the number of research and license agreements per university. The models with interaction effects show that all but the most elite universities in Europe experience crowding out effects for research and license agreements. However, the number of license agreements and the amount of license income reported by top 13.4% universities increases with quality of competition, possibly due to spill-over effects or signalling clusters of expertise. Competition from research institutes is unrelated to the knowledge transfer outcomes. This suggests that research institutes do not compete with universities, possibly due to focussing more on applied research (Arundel et al. 2013).

The European Union's regional policy aims at strengthening research, technological development and innovation in regional areas outside of the metropolitan centres (European Commission 2013). Location in a metropolitan area does not appear to be required for top-ranked universities, with the added effect of location in a metropolitan area being negative for these universities.

Start-up formation is correlated with different factors than those linked to the number of research and license agreements. The quality of the focal university, the quality of competition from other universities in the same region, metropolitan location, and the interaction terms have no effect on the number of start-ups. The lack of an effect for quality differs from results for the US, where university quality is positively correlated with start-up formation (Di Gregorio and Shane 2003). This is also found in a study drawing on the same data as used in Chapter 2 and 6, that showed that US universities that are included in the AUTM (Association of University and Technology Managers) survey in the United States created on average 3.7 start-ups in 2011 compared to 1.9 in Europe (Arundel et al 2013). Conversely in Europe, positive factors for start-ups are being a technical university and the size of the regional population, a measure of potential markets.

In respect to university policy, the transfer of commercially useful knowledge from the public research sector to private firms has become increasingly institutionalized and is supported by numerous reforms and initiatives at the national, regional and university levels (Munari et al. 2015). The results of this study suggest that the evaluation of university knowledge transfer outcomes by government funding bodies should consider the location of the university and the degree and quality of competition. For instance, expectations for the number of partner-led research agreements should be adjusted downwards for most universities, as regional demand, a major driver of research agreements, is limited. As said a possible reason for this may be that the private sector has different knowledge demands. Further research can explore if university supply of knowledge/technology and demand from firms is sufficiently matched. There is also an important regional context for research and license agreements, with top-ranked universities benefiting the most from spillovers or signalling effects from co-location in the same region as other top-ranked universities.

Limitations and Future Research

An important assumption in most research on regional influences on knowledge transfer is that a significant share of outcomes is with businesses in the same region as the university. However, this and other comparable studies rarely have data on the location of knowledge transfer recipients. Nevertheless, the observed correlations between regional variables and outcomes strongly suggest that regional knowledge transfer must be responsible for a significant share of all knowledge transfer outcomes. Further research could use longitudinal data to examine cause and effect relations of the regional environment on university knowledge transfer performance.

Another limitation of this study is that the results discussed in this chapter are largely driven by data availability and are not representative of all European countries. A third limitation is that this study could only evaluate a limited number of knowledge transfer mechanisms based on contractual arrangements. Many other mechanisms can lead to university-industry knowledge transfer such as student, graduate and researcher mobility, academic consulting, and training. Future research could investigate the share of knowledge that is transferred to proximate firms and if this varies by the type of knowledge, the type of knowledge transfer method, or the industrial structure of the region. Furthermore, future research could explore measures of venture capital as a predictor of university start-up creation in European regions. It would also be useful to develop a comparable measure for the quality of public research institutes and evaluate their effect on regional competition for university knowledge.

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Appendix

Table 8. Knowledge transfer outcomes without (a) and with (b) interaction term METRO by UNI_TOP

	Research agreements		License agreements		License income		Start-ups	
	a	b	a	b	a	b	a	b
Constant	0.450	0.482	-6.823***	-6.878***	-6.191**	-5.401**	-5.974**	-6.068**
Characteristics of the KTO and the university								
NUMB_RES (log)	0.705***	0.694***	0.447***	0.444***	0.568***	0.621***	0.695***	0.688***
KTO_SIZE (log)	0.024	0.026	0.342***	0.342***	0.141**	0.150**	-0.035	-0.035
HOSP	0.465**	0.480**	1.004***	1.014***	1.162***	1.015***	0.099	0.110
TECH	0.065	0.075	0.530**	0.537**	-0.288	-0.382	0.861***	0.871***
KTO_AGE (log)	0.166	0.171	0.528***	0.521***	0.817***	0.761***	-0.541***	-0.535***
Regional characteristics								
PER_CAP_GRP (LOG)	-0.170	-0.180	0.505	0.501	1.641***	1.593***	-1.076***	-1.060***
POPULATION (LOG)	-0.013	-0.011	0.031	0.036	-0.467***	-0.535***	0.345**	0.349**
EMPSHARE_HMHT	0.072	0.075*	0.092**	0.092**	0.187***	0.195***	0.072*	0.072*
EMPSHARE_KIS	-0.020	-0.019	0.016	0.017	0.016	0.014	0.034**	0.035**
METROP	0.451*	0.377	-0.042	-0.079	-0.193	0.511*	-0.351	-0.460
Quality characteristics of the focal university and competition from other faculties								
UNI_TOP	0.150	0.077	0.291	0.261	0.106	0.670***	0.142	0.070
RICOMP	0.008	0.009	0.015	0.015	0.003	-0.001	0.008	0.010
QUALCOMP	-0.021**	-0.022***	-0.016*	-0.016**	0.004	0.002	-0.008	-0.008
METROPxUNITOP		0.217		0.082		-1.594***		0.219
N	207	207	267	267	207	207	284	284
AIC	2386.8	2388.4	1614.1	1616.0	5360.1	5336.7	1128.4	1127.1

*= p <.10, ** = p <.05, *** = p<.01

Table 9. Knowledge transfer outcomes without (a) and with (b) interaction term QUALCOMP by UNI_RANK

	Research agreements		License agreements		License income		Start-ups	
	a	**b**	**a**	**b**	**a**	**b**	**a**	**b**
Constant	1.460	2.029	-6.099**	-5.936**	0.320	0.921	-6.592**	-6.622**
Characteristics of the KTO and the university								
NUMB_RES (log)	0.655***	0.654***	0.414***	0.417***	0.343***	0.342***	0.706***	0.707***
KTO_SIZE (log)	0.018	0.030	0.339***	0.341***	0.156**	0.155**	-0.026	-0.029
HOSP	0.133	0.103	0.964***	0.954***	0.890***	0.832***	0.212	0.202
TECH	0.039	-0.018	0.520**	0.509**	-0.145	-0.193	0.909***	0.900***
KTO_AGE (log)	0.209	0.177	0.550***	0.533***	1.044***	1.001***	-0.557***	-0.556***
Regional characteristics								
PER_CAP_GRP (LOG)	-0.351	-0.394	0.452	0.407	1.334***	1.267***	-0.961**	-0.963**
POPULATION (LOG)	-0.029	-0.056	0.006	-0.002	-0.761***	-0.785***	0.362**	0.365***
EMPSHARE_HMHT	0.077	0.083*	0.091**	0.100**	0.156***	0.160***	0.069	0.069
EMPSHARE_KIS	-0.020	-0.018	0.016	0.018	0.006	0.010	0.033**	0.033**
METROP	0.466*	0.469*	-0.012	0.000	-0.062	-0.093	-0.376	-0.381*
Quality characteristics of the focal university and competition from other faculties								
UNI_RANK = 3 *(top 200)*	0.714**	0.417	0.515*	0.367	1.933***	1.311***	-0.009	-0.042
UNI_RANK = 2 *(top 201-300)*	0.506*	0.360	0.169	-0.067	-1.373***	-1.500***	-0.169	-0.076
UNI_RANK = 1 *(top 301-500)*	-0.149	-0.165	0.290	0.275	0.125	0.103	-0.326	0.327
RICOMP	0.007	0.008	0.016	0.015	0.030**	0.031**	0.013	0.013
QUALCOMP	-0.018**	-0.025***	-0.015*	-0.021**	0.012	0.004	-0.010	-0.010
UNIRANK=2*QUALCOMP		0.007		0.013		0.008		-0.006
UNIRANK=3*QUALCOMP		0.009		0.005		0.025***		0.002
N	207	207	267	267	207	207	284	284
AIC	2386.1	2386.3	1616.5	1618.1	5340.4	5225.9	1130.1	1133.8

* = p <.10, ** = p <.05, *** = p<.01

Table 10. Tests for random slopes

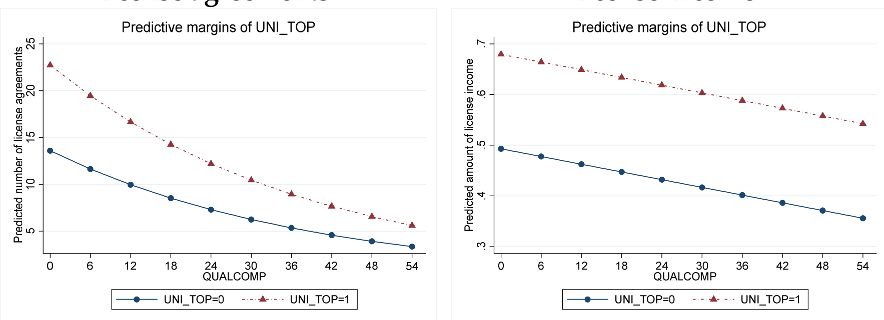
	Random slope	Coefficient	SE	LR test vs. model in Table 6 or 7	AIC	AIC model 6 or 7
Research agreements (Table 6a)	C: UNI_TOP	0.062	0.132	0.36	2372.6	2371
Research agreements (Table 6a)	R: UNI_TOP	0.000	0.000	NA	2371	2371
Research agreements (Table 7a)	C: UNI_RANK	0.019	0.037	0.41	2373.2	2371.6
Research agreements (Table 7a)	R: UNI_RANK	0.002	0.015	0.02	2373.6	2371.6
License agreements (Table 6a)	C: UNI_TOP	0.064	0.192	0.15	1581.2	1579.4
License agreements (Table 6a)	C: HOSP	0.144	0.290	0.33	1581	1579.4
License agreements (Table 6a)	R: UNI_TOP	0.000	0.000	0.00	1581.4	1579.4
License agreements (Table 6a)	R: TECH	0.34	0.562	0.51	1580.8	1579.4
License agreements (Table 7a)	C: UNI_RANK	0.012	0.034	0.14	1583.4	1581.5

Notes: Based on standard errors. For research agreements, additional random slopes were tested at the country level for the predictors: HOSP, TECH and QUALCOMP, and at the regional level for QUALCOMP. Similarly for license agreements, random slopes were tested at the country level for TECH and QUALCOMP and at the regional level for UNI_RANK. Stata 17 was not able to produce results for these models. Research agreements, N=207, license agreement N=267.

Figure 2. Cross-level effects of UNI_TOP and QUALCOMP on technology transfer outcomes

License agreements

License income



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Chapter 4 Barriers faced by SMEs when operating on technology licensing markets

Abstract: A major characteristic of technology diffusion is the ease of exchange of information and knowledge amongst countries, individuals, as well as organisations. The market for technology in which patents are traded or licensed, is however not very transparent and has been suffering from asymmetries of information and capacity barriers. This chapter examines the role of SMEs when operating on technology licensing markets and intends to improve the understanding of the factors affecting the licensing out and in activities of SMEs. Drawing on survey results of 332 SMEs this chapter shows that SMEs observe barriers differently after controlling for those with experience and those without. These perceived barriers are observed with organisational, costs and strategic related barriers where those with licensing-out experience are less likely to give a high importance to such barriers. From the licensing-in perspective the results show that those looking out for licensing-in opportunities are less likely concerned with the quality of the technology compared to those with actual experience. Spin-offs, either from the private or public sector, and smaller SMEs are more likely reporting high importance to costs, strategic, negotiation and credibility barriers. These results suggest that to improve technology diffusion, policies should be developed that help reduce the burden for smaller entities when it comes to designing, drafting, and negotiating contractual licensing agreements in order for them to actively participate in technology markets.

1. Introduction

A major characteristic of technology diffusion is the ease of exchange of information and knowledge amongst countries, individuals, as well as organisations. Information on how technology is transferred amongst enterprises is therefore of key importance to innovation policy. The market for technology in which patents are traded or licensed, is however not very transparent and has been suffering from asymmetries of information. Most technological sales and licenses are based on complex bilateral agreements in private law in a business-to-business setting of which much of the details are commercially sensitive (Anand and Khanna 2000; Bessy et al. 2002). Consequently, there is a lack of information on how these agreements are made, reasons why deals are not concluded and the extent to which barriers hamper mutually profitable agreements. From both the licensor and licensee side it is difficult to identify potential partners, to assess the technology upfront and the uncertainty of commercialization success. The complexity of licensing technology in terms of, asymmetric information, transparency, and absorptive capacity lead to market failures (Agrawal, et al. 2015; Cockburn and Verità 2007). Technology transfer can occur through several channels between enterprises, but this chapter focus is on licensing activities as this accounts for the largest share of transactions in these markets (Arora and Gambardella 2010) and plays a lead role in the diffusion of technology (Anand and Khanna 2000; Arora and Fosfuri 2003). Licenses are the leading mechanism in trading patents (Arora and Ceccagnoli 2006; Arora and Fosfuri 2003). The licensing deal market is not perfect however and characterised by several barriers. One of the major barriers is that the licensing deal is often based on the potential of the technology that is being licensed, but the technology itself is often underdeveloped and not yet ready for commercialisation. Commercialisation often requires further activities which must be dealt with by the licensee and in some instances with the help of the licensor (Cho and Shenkoya 2020). Trust, early involvement, and due diligence play an important role in meeting expectations (Geneste and Galvin 2013; Foos et al. 2006) and adequate management and organisation lead to success (Payumo et al. 2014; Bianchi et al. 2009). However, given the nature and the number of stakeholders involved, contractual mechanisms play a role to ensure commitment from both sides (Anand and Khanna 2000). Empirical research has studied these barriers but not for SMEs. Most of the research is on university-industry barriers for technology licensing (Barjak et al. 2015; O'Reilly and Cunningham 2017; Bekkers and Freitas 2008, Bruneel et al. 2010). Some studies have looked at barriers for inter-enterprises licensing (Sharma 2021; Agrawal et al. 2015; Jones and Jain 2002), large firms (Gilsing et al. 2011) and federal laboratories (Martyniuk 2003). This research focuses on SMEs as there are concerns that these have difficulty coping with the organisational and market inefficiencies associated with technology licensing. Complex agreements full of legal, technological, commercial and economics aspects require several competences which smaller enterprises do not always possess. Additionally, most of the literature has looked at the licensor's perspective. This chapter contributes to the literature by examining the barriers faced by SMEs from both the licensors perspective as well as the licensee's perspective using a unique dataset of SMEs in Europe. The aim of this chapter is to improve the understanding of these barriers and which factors such as SME size, sector of activity and patent activity affect the importance of these barriers. The chapter contributes to the literature by showing that barriers are perceived very differently amongst those SMEs with experience and those without. This has implications for policies aiming to improve knowledge diffusion and open innovation as SMEs without experiences require different interventions than those already operating on technology markets. The remainder of this chapter is structured as follows. Section 2 discusses the literature on licensing technology. Section 3 describes the methodology of the empirical analysis and Section 4 provides descriptive results. Section 5 presents the results of the regression analysis and Section 6 concludes with a discussion.

2. Literature on barriers to licensing technology

There are many reasons for firms to either license-out or license-in technology. Enterprises often grant licenses because they do not have the resources to achieve full commercial exploitation of their intellectual property by themselves (Gans and Stern 2010). The inventor, for instance, may lack complementary assets to fully appropriate the potential of the technology (Teece 1986) or may have insufficient financial resources to serve all geographic markets. In this case, licensing, can serve to broaden geographic and product markets and obtain additional revenue (Gambardella and Giarratana 2006).

One of the major barriers licensors and licensees face are difficulties in finding the right partner, also identified in the literature as market thickness (Roth 2008; Gans and Stern 2010). This search barrier is related to the time and other resources required to search for potential collaboration partners. The bargaining barrier is another early barrier associated with negotiation and coordination with potential partners. Patitt and Deeds (2021) looked at aspects of alliances and found that bigger firms usually have better bargaining position when it comes to terms such as access to facilities or non-solicitation clauses (poaching talent). Except for when the smaller firm has a larger number of patents or proprietary knowledge, in such cases the smaller firm had a strong position to protect that knowledge (Patitt and Deeds 2021). Information asymmetries and misaligned expectations on the value of the technology further negatively affect the deal-making process (Villani et al. 2017, Cockburn and Verità 2007). These barriers inevitably lead to transaction costs (Akcigit et al. 2016).

Next to search barriers, giving a correct value to the technology is maybe one the most difficult barriers to overcome for enterprises, particularly for smaller enterprises (Chiesa et al. 2007). Pricing of technology remains different from the traditional demand and supply mechanisms as the technology itself is not yet a commodity. The lack of transparency of how patent markets work makes it difficult to value technology with no real benchmarks (Lemley and Myhrvold 2008). The technology is not 'there' yet and this 'valley of death' is both the cause and consequence of difficulties in evaluating underdeveloped technologies (Frank et al. 1996; Ellwood et al. 2020). The "valley of death" is a metaphor often used to describe the gap between a technology and its commercial application in the marketplace.

Once a partner is found and a value is set, resources play a role in evaluating the technology from the licensee perspective as well as legal knowledge on drafting agreements for both parties. The costs associated with evaluating a technology as well as the organizational and legal work necessary to create a deal is a barrier for many enterprises, in particular smaller enterprises (Hall et al. 1999). SMEs with limited resources and no external (legal) support might find themselves at disadvantage compared with larger corporations. Yet, initial evaluation of the technology candidate to a deal and the preparation of the deal according to customary legal steps requires expertise and skills that are not always available to SMEs (Anand and Khanna 2000; Bessy et al. 2002). Legal barriers such as uncertainty on the applicable law, differences of regimes and jurisdictions represent concerns for contractual parties, especially SMEs that cannot invest financial resources in legal services aimed at assessing the risks associated with foreign jurisdictions (Mazurkiewicz and Poteralska 2015).

One of the main concerns in drafting a technology licensing agreement is to ensure that the licensee, in a principal-agent setting, aligns with licensor's interests. Granting a license, poses substantial risks for the inventor such as the risk of piracy, the loss of control over exploitation of the technology, and the dependence on others for revenue (Dratler 2021). This asks for an accurate draft of any agreement covering topics such as opportunistic behaviour (Agrawal et.al. 2015), 'best effort' clauses (Fernández-Molina 2004) milestones (Dechenauxex et al. 2011) and 'warranties' related to sharing risks (Dratler 2021) which are particularly relevant for the ICT sector (Rustad and Kavusturan 2019; San and Peng 2016).

Another barrier affecting both licensors and licensees are perceptions of an organisation (Podolny 1993). The assumptions, based on economic research, are that these perceptions emerge from past performance and influence exchange transactions by providing signals of quality. Positive external perceptions about the general organisation influence external perceptions of its goods (Shenkar and Yuchtman-Yaar 1997). Es-Sadki and Arundel (2021) showed that university rankings as a proxy for research quality has a positive influence on technology transfer activities of universities. Scandura and Iammarino (2022) reported a positive relationship between academic engagement and departments in applied sciences. They furthermore note that the role of research quality for academic engagement strictly depends on the level of the department's previous experience in university-industry partnerships, where this is a moderating factor in basic science departments. Grimpe and Fier (2010) have argued that faculty quality as measured by being a research group leader, publications, and patent applications, serves as a signal to potential commercialisation partners in industry for public research organisations. McCarthy and Ruckman (2017) found that licensor prominence, licensor knowledge structuration and patent quality increases royalty rates and results in a strong licensing-out position for licensors. Furthermore Prokop et al. (2019) showed in their study the importance of credibility for spin-offs next to early investments and an entrepreneurial mindset (Prokop et al. 2019). The above-described barriers apply in some way or another to both the licensor as well as the licensee. There are however a few specific barriers that only apply to licensors or licensees.

Barriers to licensing-out

Licensing creates competition by giving away proprietary know-how to potential rival enterprises. One of the major risks involved with creating a competitor is that the licensing enterprise may lose its technological or competitive ''edge'' by setting up its future competitor in innovation markets (Choi 2002). In particular, granting others the right to use its intellectual property may enable them to develop new products, which makes the licensed technology obsolete and leaves the licensor in backwater of technology—the so-called 'boomerang' effect (Choi 2002). This effect is particularly present in evolving technologies where there is a risk that licensees downstream further develop the technology and appropriate the improvements, thus leaving behind the licensor (Leone and Reichstein 2012). It is therefore not surprising that enterprises are often reluctant to license their cutting-edge technologies since they may be giving their rivals the knowledge necessary to develop a better technology (Roberts and Mizouchi 1989; Davies 1977).

Barriers to licensing-in

Dealing with the technology, which is developed by someone else and hence leads to difficulties in understanding, is a major barrier for licensees. These absorptive capacity barriers have been studied by several authors (Szulanski 1996; Cohen and Levinthal 1990; Xie et al. 2018) with several suggestions to mitigate this barrier such as consulting provisions where the licensee receives access to skill and competences of inventors (Arundel and Geuna 2004). Another mitigating factor as discussed in (Schartinger et al. 2001; Arundel and Geuna 2004) is R&D activity. Enterprises that invest heavily in R&D are likely to possess a high technological capability that also allows them to absorb the knowledge developed outside the firm. If 'absorptive capacity' (Cohen and Levinthal 1990) has a major role we would expect that the higher the firm's R&D intensity (or investment) the lower the barriers to engage in licensing-in.

3. Methodology

The data used in this study is from a survey on technology licensing activities of SMEs funded by the European Commission, DG Research and Innovation (DG RTD). The survey was conducted in 2017, a copy of the survey questionnaire can be found in the appendix. The survey sample were SMEs that received financing under Horizon 2020. In most cases the questionnaire was answered by the director or head of R&D or similar positions within the enterprise. All the SMEs are research active, however not all SMEs (57.8%) have a patent (yet) and not all SMEs are active in licensing activities, see Table 1. However, since all of the SMEs are research active it is fair to assume that the SMEs have a good understanding of the pro's and con's to licensing technology. The survey, which used both printed copies of the survey as well the possibility to answer online, led in total to 384 responses, with a response rate of 26.9%. Several responses were invalid for various reasons such as: not reporting any technology transfer activities, not completing the questionnaire, or item non-responses for independent variables of interest such as the sector (scientific focus) they are mainly operating in, or the number of research employees or patent portfolio. These incomplete or invalid responses were excluded from this analysis and only enterprises that answered all the variables of interest are included. This left 332 eligible enterprises for analysis. Table 1 provides basic characteristics of the SMEs in the dataset.

The independent variables used in the regression analysis all come from the same questionnaire. Enterprises are categorised in three size classes: micro-enterprises (1 to 9 employees), small enterprises (10 to 49 employees) and medium-sized (50 to 249 employees). A dummy variable for spin-offs is included as well as the research intensity of the enterprise measured by the share of research personnel. Another dummy variable is included for those enterprises with a written licensing strategy. Respondents were asked to report on their licensing activities. Two questions of interest are used to construct variables used in the analysis. The first (binary) variable is looking out for licensing opportunities and a second (binary) variable for licensing experience. Note that these two variables are not mutually exclusive as some enterprise have no experience and are (currently) not looking for licensing opportunities, while other SMEs have licensing experience but are (currently) not looking out for licensing opportunities. Some have no experience but are looking out for licensing opportunities and lastly some enterprises have both experience and are looking out for licensing opportunities. Patenting activity is included as a categorical variable with enterprises grouped into those with no patents, one patent in their portfolio, two to five, and six or more. Categorising the patent portfolio is done to reduce the effect of outliers and to control for the large group of enterprise with just one patent (15.1%). The scientific focus of the enterprise is included to see if barriers differ depending on the sector. Lastly, the geographical area of the SMEs is included as a control variable to account for regional differences. Due to a small number of observations, it was not possible to include country dummies for each country and instead regional geographical areas are used except for countries for which enough observations are available.

Table 1. Basis characteristics of the SMEs

Variable	Mean	Std. Deviation
Number of employees (FTE)	29.33	44.66
Number of research personnel (FTE)	10.58	19.07
Research intensity (share of research personnel)	0.53	0.33
Patent applications	0.98	4.82
Patent portfolio	5.71	20.48
License out agreements	1.98	13.63
License in agreements	0.32	1.53
Variables included in the regression analysis[1]		
Dummy variables	**N**	**Percent**
Spin-offs (both private sector and university or research institute)	110	33.1
Written license strategy	62	18.7
Looking out for licensing-out opportunities	160	48.2
Looking out for licensing-in opportunities	76	22.9
Licensing-out experience	95	28.6
Licensing-in experience	97	29.2
Categorical variables	**N**	**Percent**
Enterprise size		
Micro (1 to 9)	154	46.4
Small (10 to 49)	121	36.4
Medium-sized (50 to 249)	57	17.2
Patent portfolio size		
Zero	192	57.8
One	50	15.1
2 to 5	42	12.7
6 or more	48	14.5
Scientific focus (sector)		
Biomedical	61	18.4
ICT	70	21.1
Material Science	32	9.6
Energy and Sustainability (low carbon)	53	16.0
Engineering	43	13.0
Electronics	27	8.1
Other	46	13.9

Categorical variables

	N	Percent
***Geographical area*[2]**		
Western Europe	79	23.8
Northern Europe	29	8.7
Southern Europe	36	10.8
Eastern Europe	24	7.2
Germany	41	12.3
UK	36	10.8
Italy	48	14.5
Spain	39	11.7

Source: Own calculation based on survey results. N=332 1: Research intensity is also included in the regressions 2: Subregions as defined by the UN Geoscheme. SMEs from Germany, UK, Italy and Spain are excluded from Western and Southern Europe.

The objective of this chapter is to examine the factors affecting the relative importance of a variety of barriers to technology licensing, either for those SMEs licensing-out technology or for SMEs licensing-in technology. There are two survey questions on the importance of barriers that can be used for this purpose, one on licensing-out and the second one on licensing-in technology. Respondents were asked to assess the level of importance of barriers (none, low, medium and high) to licensing-out their own technology and barriers to licensing-in technology developed by others. These questions were asked to all SMEs, regardless of their experience with licensing activities or not.

Using the data obtained from the two questions on licensing-out and licensing-in and other basis characteristics from the enterprise collected with the survey, this study proceeds in three steps to address the research objective of this chapter. The first step, as reported in Section 4, starts by analysing the differences in the importance of barriers to licensing-out on the one hand and licensing-in on the other, using descriptive statistics. The results are provided in Tables 2 and 3. After this step a hierarchical cluster analysis is carried out to categorise the different barriers into groups. It is important to note that this technique is used to cluster variables i.e. the barriers to technology licensing and not to group cases. This approach follows a similar methodology as Bekkers and Freitas (2008). Five clusters of barriers were identified for licensing-out activities. These clusters bring together barriers that often are given similar ratings from individual respondents. The barriers 'underdeveloped technology' and 'potential loss of technological or competitive edge' are combined in the 'strategic' cluster but also included separately as these barriers are distinctively different as identified by Choi (2002). Six clusters of barriers were identified for licensing-in activities. Cluster analysis is used instead of factor analysis as the objective is not to reduce the number of variables (barriers) but to group them based on closeness to each other. The clustering of barriers avoids neglecting barriers as at least one-third of the respondents finds each barrier for both licensing-out and licensing-out of medium or high-importance, except for credibility of licensor as part of the licensing-in barriers which is just below one-third (31.8%, see Table 3).

Table 2. Importance rating for the barriers to technology licensing out (Step 1)

Barriers to licensing-out	Average importance	Share of medium or high importance (%)	Most important barrier (%)
A. Unknown regulatory framework	2.6	56.3	7.2
B. Fear of litigation	2.4	45.1	0.9
C. Lack of skilled employees within your enterprise	2.5	52.1	7.8
D. Underdeveloped technology	2.5	52.7	10.2
E. Potential loss of technological/competitive edge	2.8	62.7	13.3
F. Lack of experience in drafting agreements	2.5	51.3	3.3
G. Costs for external support to evaluate the commercial potential of your technology	2.8	62.0	5.1
H. Costs for external support to prepare patent applications and other legal matters involving IP rights	2.8	61.8	7.8
I. Costs for external support to prepare licensing contracts	2.7	59.3	2.1
J. Costs for external support to market or advertise your technology	2.7	57.8	9.9
K. Difficulties in identifying the right licensees	2.7	60.1	7.8
L. Lack of information to price the license	2.6	58.3	4.2
M. Difficulties in reaching agreements on terms other than price	2.4	47.6	4.5
N. Difficulties to monitor or enforce a license agreement	2.6	56.9	6.0
O. Credibility of your enterprise	2.3	59.0	2.7
P. Credibility of potential licensee	2.3	39.6	0.6
Other	1.6	19.8	6.3
Total average	*2.5*	*53.1*	-

N=332

Table 3. Importance rating for the barriers to technology licensing in (Step 1)

Barriers to licensing-in	Average importance	Share of medium or high importance (%)	Most important barrier (%)
A. Unknown regulatory framework	2.4	48.2	5.7
B. Fear of litigation	2.3	43.7	1.2
C. Lack of skilled employees within your enterprise	2.3	42.4	3.6
D. Technology offered is underdeveloped	2.6	54.4	8.7
E. Technology offered is of low quality	2.6	51.1	5.1
F. Lack of experience in drafting agreements	2.3	39.9	1.8
G. Costs associated with drafting and managing licensing agreements	2.5	51.2	5.7
H. Difficulties in identifying the right licensor	2.4	49.8	3.0
I. Lack of information on value of technology	2.6	55.7	3.6
J. Too high prices charged by licensor	3.0	73.6	16.6
K. Difficulties in reaching agreements on terms other than price	2.5	55.0	4.5
L. Refusal of licensor to grant license	2.2	39.7	0.9
M. Risk of exposing your technology strategy	2.4	49.5	5.7
N. Credibility of your enterprise	2.1	31.8	3.0
O. Credibility of licensor	2.4	44.1	2.1
P. No need or interest to licensing-in technology	2.5	58.2	18.7
Q. Other	1.5	19.0	9.9
Total average	*2.4*	*47.5*	-

N=332

The third step, as reported in Section 5, addresses the sources of the variation in each of the identified clusters of barriers to technology licensing. The dummies for each cluster take the value '1' if the average score for that cluster was equal to 3 or above, which means that the group of barriers is at least considered important. Respondents were asked to rate the importance of each barrier (both licensing-in and out) to technology licensing, using the following categories: 1: 'Not important', 2: 'Low importance' 3: 'Medium importance', 4: 'High importance'.

In Section 5, the estimates of the binary logistic models are analysed for the importance of each of the clusters of barriers to technology licensing (in or out) on the independent variables. The Wald chi-square values are highly significant in all the regression estimations indicating that the estimated models fit the data significantly better than a null model.

4. Importance of barriers to technology licensing

In the questionnaire respondents were asked to indicate the importance of barriers to licensing-out their technology and barriers to licensing-in technology. Table 2 reports the average rated importance of 16 barriers to licensing-out as well as the percent for each barrier rated as most important amongst the 332 SMEs. The highest rated average importance is observed for the barrier 'potential loss of competitive edge' and two costs barriers, 'for external support to evaluate commercial potential' and 'for external support to prepare IP documentation'. Followed by two other costs barriers as well as 'lack of information to price the license'. The potential loss of a competitive edge is most frequently reported as the most important barrier followed by 'underdeveloped technology' and 'costs for external support to market or advertise the technology'.

In a following section of the questionnaire the respondents were asked to report on the importance of 15 barriers to licensing-in technology. Table 3 reports the average rated importance of the licensing-in barriers as well as the percent for each barrier rated as most important. 'Too high prices charged by licensor' stands out as the most important barrier both in terms of highest average importance and most frequently reported as the most important barrier to licensing-in. Other important barriers relate to the technology itself such as its development stage, quality, and information on value.

Both lists of barriers for licensing-out and licensing-in are similar, but the perspective differs and there are distinct barriers depending on the perspective, for instance ‘potential loss of competitive edge’ is not relevant for the licensee (licensing-in) whereas ‘too high prices charged’ is not applicable for licensors (licensing-out). The different perspectives also explain why some barriers are part of one group in the licensing-out cluster and not part in the same group in the licensing-in clusters and vice versa. Of note, responses to the ‘other’ category are not used due to insufficient written text to add or reclassify these responses.

To better understand the pattern of the importance of these different barriers to technology licensing a hierarchical cluster analysis on the pooled response data (332 SMEs) is performed. This exercise brings together barriers that often receive similar ratings of importance among the respondents (note that the barriers are clustered and not the respondents). It is important to note that the barriers are grouped based on correlated responding patterns using the full dataset, but the heterogeneity of the SMEs is not lost in the regression analysis as variables such as size, sector and patenting activity are included to account for these differences. The grouping of barriers is studied by allowing for any number of clusters between 2 and 8. Tables 4 and 5 shows how the different barriers are clustered together for licensing-out barriers and licensing-in barriers respectively. The clusters chosen all include at least two barriers. Ideally clusters with one single barrier should be avoided but out of research interest following Choi (2002) results for the strategic cluster, the grouping of the barriers ‘Underdeveloped technology (d)’ and ‘Potential loss of competitive edge (e)’ are also analysed separately in Section 5. Following the outcome of the cluster analysis the subsequent grouping emerged which are according to the literature discussion above plausible clusters of barriers to technology licensing:

Licensing-out clusters:

- Framework and Organisational (A, B, C and F)
- Costs (G, H, I and J)
- Asymmetric information (K, L, M and N)
- Strategic (D and E) *and separately:*
    - Underdeveloped technology (D)
    - Potential loss of competitive edge (E)
- Credibility (O and P)

Licensing-in clusters:

- Framework and Organisational (A, B and C)
- Quality (D and E)
- Experience and Costs (F, G, H and I)
- Negotiation (J and K)
- Strategic (L and M)
- Credibility (N and O)

Table 4. Clusters of barriers to technology licensing-out (step 1)

	Number of allowed clusters						
Barriers to licensing-out	**8**	**7**	**6**	**5**	**4**	**3**	**2**
A. Unknown regulatory framework	1	1	1	1	1	1	1
B. Fear of litigation	1	1	1	1	1	1	1
C. Lack of skilled employees within your enterprise	2	2	2	1	1	1	1
D. Underdeveloped technology	3	3	3	2	2	2	2
E. Potential loss of technological/competitive edge	4	4	3	2	2	2	2
F. Lack of experience in drafting agreements	2	2	2	1	1	1	1
G. Costs for external support to evaluate the commercial potential of your technology	5	5	4	3	3	3	1
H. Costs for external support to prepare patent applications and other legal matters involving IP rights	5	5	4	3	3	3	1
I. Costs for external support to prepare licensing contracts	5	5	4	3	3	3	1
J. Costs for external support to market or advertise your technology	5	5	4	3	3	3	1
K. Difficulties in identifying the right licensees	6	6	5	4	4	1	1
L. Lack of information to price the license	6	6	5	4	4	1	1
M. Difficulties in reaching agreements on terms other than price	7	6	5	4	4	1	1
N. Difficulties to monitor or enforce a license agreement	7	6	5	4	4	1	1
O. Credibility of your enterprise	8	7	6	5	2	2	2
P. Credibility of potential licensee	8	7	6	5	2	2	2

N=332

Table 5. Clusters of barriers to technology licensing-in (step 1)

Barriers to licensing-in	Number of allowed clusters						
	8	**7**	**6**	**5**	**4**	**3**	**2**
A. Unknown regulatory framework	1	1	1	1	1	1	1
B. Fear of litigation	1	1	1	1	1	1	1
C. Lack of skilled employees within your enterprise	2	2	1	1	1	1	1
D. Technology offered is underdeveloped	3	3	2	2	2	2	2
E. Technology offered is of low quality	3	3	2	2	2	2	2
F. Lack of experience in drafting agreements	4	4	3	3	1	1	1
G. Costs associated with drafting and managing licensing agreements	4	4	3	3	1	1	1
H. Difficulties in identifying the right licensor	5	4	3	3	1	1	1
I. Lack of information on value of technology	5	4	3	3	1	1	1
J. Too high prices charged by licensor	6	5	4	4	3	2	2
K. Difficulties in reaching agreements on terms other than price	6	5	4	4	3	2	2
L. Refusal of licensor to grant license	7	6	5	5	4	3	1
M. Risk of exposing your technology strategy	7	6	5	5	4	3	1
N. Credibility of your enterprise	8	7	6	5	4	3	1
O. Credibility of potential licensor	8	7	6	5	4	3	1

N=332

5. Explaining the different barriers to technology licensing

As shown in Tables 2 and 3 there are several barriers to technology licensing activities. The following section aims to explain the variance in importance of different clusters of barriers by drawing on the insights of the literature review. For this purpose, binary logistic regressions are conducted to analyse the influence of characteristics of the SMEs, their scientific focus, their experience with licensing and their patenting activities. All the models presented in Tables 6 and 7 are indicating that the model fits the data significantly better than a null model. In Section 5.1, using the results from Table 6, the barriers to licensing-out are analysed by examining the importance of the six identified clusters of barriers to licensing-out. Similarly, in Section 5.2, using the results from Table 7, the clusters of barriers to licensing-in are analysed by examining the importance of six identified clusters.

5.1 Barriers to licensing-out technology

In this section the objective is to understand how the variables of interest, such as SME size, sector of activity, patent activity and other characteristics influence the importance of each group of barriers to technology licensing-out. The significant results are summarised below (see Table 6):

- The 'Framework and Organisational' barriers are more important the more the enterprise is 'looking out for licensing-out opportunities' but less important for SMEs with actual experience with licensing-out. This suggests the presence of revealed barriers (D'Este et al. (2012). SMEs with ICT as scientific focus find this barrier more important whereas SMEs in Italy find these barriers less important.
- The 'Costs' barriers are more important for small SMEs (10 to 49 employees) and spin-offs. This cluster is less important for SMEs which have experience with licensing-out technology. Also, SMEs in the ICT sector find these barriers more important.
- Asymmetric information barriers, such as difficulty identifying the right licensee or lack of information to price the license, are more important for spin-offs. The results also show significant results for the

different sectors included in the analysis. The magnitude as measured by the size of the coefficient is different across sectors with stronger results observed amongst SMEs in the Biomedical, Engineering and Electronics sector. On the other hand, SMEs with experience are less likely reporting barriers related to asymmetric information.

- Strategic barriers which are identified in the hierarchical cluster analysis as the combination of 'Underdeveloped technology' and 'Loss of competitive edge' is more important for spin-offs and SMEs looking out for licensing-out activities. It is also found more important for SMEs with a large patent portfolio (6 or more). SMEs in Western Europe (excluding the UK and Germany) also find these barriers more important.
- Looking at the individual barrier 'Underdeveloped technology' (part of the 'strategic' cluster) shows that small SMEs and spin-offs more often report this as an important barrier. On the other hand, SMEs with a high research intensity (share of R&D personnel) are less likely reporting this as an important barrier. Enterprise looking out for licensing-out opportunities find this barrier more important. No sectoral or geographical correlations are found to be significant.
- The barrier most frequently reported as the most important barrier, 'Loss of competitive edge' (part of the 'strategic' cluster) is more important for spin-offs but remarkably less important for micro-enterprises (1 to 9 employees). Of interest are the results for the patent portfolio categories: showing, for all categories, a higher importance of this barrier amongst SMEs with patenting activities. SMEs operating in the Material Science, Energy and Sustainability, Engineering and Electronic sector also find this barrier more important. Geographical differences are observed with SMEs in Western and Eastern Europe and the UK finding this barrier more important. Enterprises who are 'looking out for licensing opportunities', find this barrier more important. Whereas on the other hand, SMEs with licensing experience find this barrier less important.

- Lastly the 'Credibility' barriers are found to be more important for micro-enterprises and spin-offs, SMEs in the Engineering sector and SMEs in Eastern Europe.

5.2 Barriers to licensing-in technology

In this section the objective is to understand how the variables of interest influence the importance of each group of barriers to technology licensing-in. All the models presented include the same independent variables as for licensing-out except for the variable 'looking out for licensing-out opportunities' which is replaced with its counterpart 'looking out for licensing-in opportunities'. The significant results indicating where the barriers are more important are summarised below (see Table 7):

- The 'Framework and Organisational' barriers are less important amongst enterprises looking out for licensing-in opportunities. Actual experience has no significant effect. SMEs with ICT as scientific focus find this barrier more important whereas SMEs in Italy find these barriers less important. These results are in line with the results found for licensing-out.
- The 'quality' barriers are found to be of less importance for SMEs looking for licensing-in opportunities but of more importance for those enterprise with actual experience with licensing-in. None of the different sectors show any significant result suggesting that in terms of technological quality, all the sectoral results are induced by other factors. SMEs in Italy find these barriers less important.
- Experience barriers such as a lack of experience and costs associated with drafting agreements as well as identifying technologies and their value is more important for spin-offs, and remarkably for those SMEs which have a written licensing strategy. The latter could be explained by having such a strategy it is more difficult to meet the criteria set out for a good licensor and value determination. These barriers are furthermore found to be of less importance for SMEs looking for licensing-in opportunities but of more importance for those enterprise with actual experience with licensing-in. SMEs in the ICT sector and in Southern Europe find these barriers more important.

- Negotiation barriers which are identified in the hierarchical cluster analysis as the combination of 'Too high prices charged by licensor' and 'Difficulties in reaching agreements on terms other than price' is more important for spin-offs but less important for SMEs looking out for licensing-in opportunities. Several sectoral influences are observed, SMEs in the Biomedical, ICT, Material Science, Energy and Sustainability and Engineering sector find these negotiation barriers more important. The magnitude as measured by the size of the coefficient is stronger for SMEs in the ICT and Material Science sectors. SMEs in Western Europe (excluding Germany and the UK) find these barriers more important.
- Strategic barriers such as 'Refusal of licensor to grant technology' and 'Risk of exposing your technology strategy' are more important for small SMEs, but less for SMEs looking out for licensing-in opportunities. SMEs in the UK find these barriers less important.
- Lastly the 'Credibility' cluster is found to be more important for small-enterprises, spin-offs, and SMEs in the ICT sector, but less for SMEs looking out for licensing-in opportunities.

Table 6. Estimates of the binary logistic model on the medium and high average importance of each cluster of barriers to licensing-out technology (step 2)

	Cluster A Organisational	Cluster B Costs	Cluster C Asymmetric information	Cluster D Strategic	Cluster E Underdeveloped technology	Cluster F Loss of competitive edge	Cluster G Credibility
SME characteristics							
Enterprise size							
- Micro enterprise	-0.267	0.484	0.385	-0.154	0.448	-0.976**	0.760*
	(0.413)	(0.39)	(0.393)	(0.386)	(0.385)	(0.423)	(0.433)
- Small enterprise	0.137	0.633*	0.255	0.483	0.703**	0.129	0.478
	(0.383)	(0.361)	(0.360)	(0.354)	(0.356)	(0.387)	(0.403)
Spin-off	0.148	0.353	0.491*	0.698**	0.695**	0.485*	0.725**
	(0.291)	(0.269)	(0.274)	(0.273)	(0.276)	(0.293)	(0.288)
Research intensity	0.213	0.137	-0.250	-0.305	-0.948**	-0.081	-0.471
	(0.445)	(0.410)	(0.418)	(0.411)	(0.416)	(0.441)	(0.441)
Written licensing strategy	0.074	0.176	0.123	-0.550	-0.293	-0.297	0.388
	(0.375)	(0.357)	(0.364)	(0.358)	(0.361)	(0.384)	(0.371)
Looking out for licensing opportunities	0.640**	0.365	0.245	0.572*	0.855***	0.707**	0.344
	(0.324)	(0.298)	(0.300)	(0.299)	(0.303)	(0.323)	(0.318)
Licensing-out experience	-0.995***	-0.962***	-0.833**	-0.354	-0.215	-0.758**	-0.467
	(0.352)	(0.316)	(0.322)	(0.311)	(0.313)	(0.334)	(0.336)
Patent portfolio							
Zero (reference category)							
- One	0.366	0.463	-0.207	0.433	0.524	0.805*	0.086
	(0.443)	(0.400)	(0.399)	(0.397)	(0.398)	(0.425)	(0.441)
- Two to five	0.688	0.115	-0.824	0.811	0.422	1.391**	0.915
	(0.586)	(0.544)	(0.559)	(0.553)	(0.552)	(0.609)	(0.570)
- Six or more	0.374	0.469	-0.113	0.881**	0.099	1.541***	0.500
	(0.488)	(0.441)	(0.441)	(0.443)	(0.441)	(0.499)	(0.473)

	Cluster A Organisational	Cluster B Costs	Cluster C Asymmetric information	Cluster D Strategic	Cluster E Underdeveloped technology	Cluster F Loss of competitive edge	Cluster G Credibility
Sector							
Other (reference category)							
Biomedical	-0.235	0.425	1.205**	0.609	0.335	0.451	0.414
	(0.491)	(0.438)	(0.471)	(0.441)	(0.444)	(0.454)	(0.489)
ICT	0.931**	1.206***	1.001**	0.374	-0.139	0.712	0.619
	(0.442)	(0.422)	(0.451)	(0.42)	(0.414)	(0.435)	(0.467)
Material Science	0.091	0.611	0.962*	-0.052	-0.527	1.091*	0.347
	(0.569)	(0.523)	(0.555)	(0.53)	(0.527)	(0.598)	(0.585)
Energy and Sustainability	0.361	0.419	0.822*	0.323	-0.165	0.868*	0.319
	(0.472)	(0.439)	(0.473)	(0.446)	(0.44)	(0.472)	(0.497)
Engineering	-0.194	0.667	1.083**	0.631	-0.202	0.842*	0.998**
	(0.525)	(0.461)	(0.494)	(0.463)	(0.457)	(0.484)	(0.507)
Electronics	0.293	0.798	1.670***	0.495	-0.165	1.357**	-0.358
	(0.579)	(0.528)	(0.567)	(0.535)	(0.534)	(0.587)	(0.656)
Geography							
Spain (reference category)							
Western Europe	-0.033	-0.127	0.123	0.709*	-0.293	1.142**	0.553
	(0.432)	(0.421)	(0.430)	(0.428)	(0.426)	(0.454)	(0.471)
Northern Europe	-0.055	0.208	0.813	0.465	-0.145	0.609	0.456
	(0.539)	(0.527)	(0.537)	(0.527)	(0.534)	(0.548)	(0.565)
Southern Europe	0.168	0.556	0.507	0.588	-0.431	0.742	0.483
	(0.520)	(0.526)	(0.509)	(0.510)	(0.508)	(0.533)	(0.554)
Eastern Europe	-0.096	0.385	0.342	0.839	0.157	2.014***	1.172**
	(0.575)	(0.547)	(0.558)	(0.556)	(0.556)	(0.679)	(0.590)

	Cluster A Organisational	**Cluster B Costs**	**Cluster C Asymmetric information**	**Cluster D Strategic**	**Cluster E Underdeveloped technology**	**Cluster F Loss of competitive edge**	**Cluster G Credibility**
Germany	-0.782	-0.170	-0.493	0.047	-0.611	0.420	-0.026
	(0.547)	(0.490)	(0.511)	(0.494)	(0.496)	(0.511)	(0.556)
UK	-0.665	-0.158	0.178	0.682	0.028	1.133**	0.325
	(0.550)	(0.499)	(0.511)	(0.514)	(0.519)	(0.540)	(0.550)
Italy	-0.805*	-0.363	-0.575	-0.308	-0.749	0.030	-0.215
	(0.487)	(0.456)	(0.478)	(0.468)	(0.466)	(0.479)	(0.519)
Constant	-1.213*	-1.527**	-1.308**	-1.489**	-0.339	-1.462**	-2.393***
	(0.683)	(0.637)	(0.660)	(0.644)	(0.637)	(0.673)	(0.735)
Country fixed effects	yes	yes	yes	yes	yes	yes	yes
Observations	332	332	332	332	332	332	332
Log likelihood	383.6	427.3	417.4	426.6	425.4	380.4	380.8
LR chi-square	35.3**	32.9*	35.9*	33.6*	33.8*	58.3***	35.1*
Pseudo R-Square	0.14	0.13	0.14	0.13	0.13	0.22	0.14

* = p <.10, ** = p <.05, *** = p<.01

Table 7. Estimates of the binary logistic model on the medium and high average importance of each cluster of barriers to licensing-in technology (step 2)

	Cluster A Organisational	**Cluster B Quality**	**Cluster C Experience**	**Cluster D Negotiation**	**Cluster E Strategic**	**Cluster F Credibility**
SME characteristics						
Enterprise size						
- Micro enterprise	0.153	0.213	0.414	-0.120	0.472	0.659
	(0.414)	(0.393)	(0.419)	(0.406)	(0.419)	(0.473)
- Small enterprise	0.167	0.169	0.109	0.478	0.785**	0.845*
	(0.377)	(0.361)	(0.392)	(0.374)	(0.388)	(0.435)
Spin-off	0.166	0.321	0.553*	0.810***	0.465	0.646**
	(0.296)	(0.277)	(0.29)	(0.291)	(0.295)	(0.305)
Research intensity	-0.719	0.449	0.137	0.166	-0.321	0.478
	(0.439)	(0.414)	(0.436)	(0.427)	(0.438)	(0.472)
Written licensing strategy	0.184	0.060	0.664*	-0.250	0.089	0.247
	(0.350)	(0.333)	(0.347)	(0.344)	(0.354)	(0.352)
Looking out for licensing-in opportunities	-0.847**	-1.408***	-1.249***	-1.357***	-1.521***	-1.156***
	(0.345)	(0.318)	(0.363)	(0.308)	(0.372)	(0.383)
Licensing-in experience	-0.460	0.582**	-0.592*	0.276	-0.058	0.175
	(0.303)	(0.283)	(0.304)	(0.295)	(0.298)	(0.306)
Patent portfolio						
Zero (reference)						
- One	0.494	-0.382	-0.231	0.081	0.396	-0.637
	(0.436)	(0.401)	(0.428)	(0.418)	(0.434)	(0.435)
- Two to five	0.135	-0.682	-0.296	-0.074	-0.369	-0.343
	(0.605)	(0.554)	(0.585)	(0.563)	(0.636)	(0.597)
- Six or more	0.489	0.011	0.384	0.240	0.762	0.181
	(0.475)	(0.441)	(0.462)	(0.459)	(0.468)	(0.462)

	Cluster A Organisational	Cluster B Quality	Cluster C Experience	Cluster D Negotiation	Cluster E Strategic	Cluster F Credibility
Sector						
Other (reference)						
Biomedical	0.765	0.287	-0.155	1.142**	0.471	0.373
	(0.493)	(0.444)	(0.489)	(0.463)	(0.496)	(0.52)
ICT	1.178**	0.506	0.829*	1.294***	0.752	1.095**
	(0.464)	(0.426)	(0.45)	(0.444)	(0.460)	(0.494)
Material Science	0.498	-0.078	-0.045	1.278**	-0.574	-0.297
	(0.593)	(0.535)	(0.587)	(0.57)	(0.638)	(0.632)
Energy and	0.227	-0.200	0.392	1.129**	0.776	-0.086
Sustainability	(0.512)	(0.456)	(0.485)	(0.468)	(0.487)	(0.557)
Engineering	0.516	0.041	0.411	1.028**	0.809	0.303
	(0.520)	(0.476)	(0.512)	(0.49)	(0.512)	(0.562)
Electronics	0.946	0.471	0.288	0.773	0.505	-0.636
	(0.586)	(0.546)	(0.582)	(0.556)	(0.593)	(0.710)
Geography						
Spain (reference)						
Western Europe	-0.281	0.029	0.281	0.856*	0.002	0.653
	(0.442)	(0.431)	(0.458)	(0.450)	(0.451)	(0.503)
Northern Europe	-0.928	0.039	-0.401	0.280	-0.441	0.503
	(0.576)	(0.534)	(0.577)	(0.554)	(0.569)	(0.611)
Southern Europe	0.212	0.363	1.099**	0.476	0.088	0.578
	(0.522)	(0.516)	(0.531)	(0.521)	(0.528)	(0.571)
Eastern Europe	0.099	0.118	0.113	0.606	0.509	0.310
	(0.562)	(0.563)	(0.581)	(0.592)	(0.573)	(0.631)
Germany	-0.075	0.092	-0.316	0.145	-0.117	0.237
	(0.510)	(0.513)	(0.564)	(0.522)	(0.530)	(0.589)
UK	-0.775	-0.118	0.013	0.298	-1.062*	0.242
	(0.55)	(0.512)	(0.551)	(0.530)	(0.584)	(0.600)

	Cluster A Organisational	**Cluster B Quality**	**Cluster C Experience**	**Cluster D Negotiation**	**Cluster E Strategic**	**Cluster F Credibility**
Italy	-1.085**	-0.858*	0.150	-0.057	-0.336	-0.455
	(0.511)	(0.482)	(0.492)	(0.475)	(0.488)	(0.571)
Constant	-0.998	-0.261	-1.239*	-1.343**	-1.532**	-2.220***
	(0.685)	(0.649)	(0.695)	(0.679)	(0.696)	(0.783)
Country fixed effects	yes	yes	yes	yes	yes	yes
Observations	332	332	332	332	332	332
Log likelihood	381.1	411.2	379.7	395.3	378.5	342.6
LR chi-square	36.2**	48.8**	49.9***	59.1***	52.4***	49.3***
Pseudo R-Square	0.15	0.18	0.19	0.22	0.20	0.20

* = p <.10, ** = p <.05, *** = p<.01

6. Discussion and conclusion

This chapter intends to explore the factors affecting the relative importance of a variety of barriers to technology licensing, either for those SMEs licensing-out technology or for SMEs licensing-in technology. The evidence has shown that experience and looking out for licensing opportunities are the determining factors that explain the variance in how barriers are perceived.

Barriers to licensing-out

Enterprises which have experience with licensing-out technology are less likely to report barriers related to framework and organisational conditions, costs, asymmetric information, and loss of competitive edge. Of specific interest are the results found for the organisational and loss of competitive edge barriers. In these cases, enterprises who are looking out for licensing opportunities (these may include those with experience) are more likely giving a high importance to these barriers. This result suggests that there are revealed barriers as discussed by D'Este et al. (2012) who refer in their study to SMEs engaging in the innovation process. For instance, the results for framework and organisational and loss of competitive edge barriers show that there are learning experiences when the enterprise stats engaging in licensing activities. The smaller set of experienced SMEs (28.6% see Table 1) which have learned by engaging in the licensing process are less likely reporting framework and organisational or loss of competitive edge barriers compared to the bigger set of SMEs (48.2% see Table 1) that are looking out for licensing-out opportunities. These results suggest that learning-by-doing can reduce the perceived importance of these barriers and gives room for policy supporting training or other activities for SMEs with no experience yet.

Smaller SMEs and spin-offs are more likely reporting barriers such as asymmetric information, underdeveloped technology, and issues with credibility. A result in line with the literature findings from Hall et al. (1999) and can be explained given their limited capacity for engaging in licensing activities. SMEs with patenting activities, moreover those with more patents, are more likely giving a high important to the barrier potential loss of competitive edge. This result is in line with the literature discussed in section

2 such as Choi (2002). A major risk of licensing-out is the creation of a competitor and thereby losing your competitive edge. The results for those SMEs with a patent portfolio should therefore not be surprising as these SMEs invested substantial time and resources in their technology. On the other hand, micro enterprises report less likely a competitive loss as a barrier. A reason for this is likely having limited staff to further develop the technology or not well established yet and hence having less competitive edge to lose. Additionally, the potential financial gain from licensing technology for these very small enterprises is likely of more importance than a loss of competitive edge. There are just a few significant results found for sectoral differences except for SMEs operating in the ICT sector. These SMEs report more often framework and organisational and costs barriers. A reason for this might be the extensive use of warranties in licensing agreements to share risks in this sector (Rustad and Kavusturan 2019; San and Peng 2016). Some geographical influences are observed. SMEs in Italy are less likely reporting framework and organisational barriers, a reason for that could be the support of the Italian government with respect to technology transfer in the last decade (Grimaldi et al. 2021). SMEs in Western Europe (excluding Germany and the UK) are more likely reporting strategic barriers and countries in Eastern Europe are more reporting loss of competitive edge and credibility barriers.

Barriers to licensing-in

The revealed barriers work very differently when changing the perspective to licensing-in. In all the models in Table 7 the variable looking out for licensing-in opportunities shows a significant negative relationship with the clusters of barriers to licensing-in. On the other hand, SMEs with licensing-in experience report that quality issues are of relevance, something which can only be determined after the fact. This suggests that there are SMEs who find such barriers of less importance and consider obtaining the technology itself superior to any risks involved in the transaction. Similarly, as for licensing-out barriers, in particular smaller SMEs and spin-offs are more likely reporting barriers related to experience, negotiation, strategic and credibility. Sectoral differences are mostly observed amongst ICT SMEs, particularly for framework and organisational, experience and credibility related barriers. SMEs in Italy are less likely reporting framework and organisational and quality barriers, SMEs in Southern Europe (except Italy) are more likely reporting experience barriers and lastly SMEs in the UK are less likely reporting strategic barriers.

Absorptive capacity to conduct licensing activities, measured through the inclusion of research intensity (share of R&D personnel) has, apart from one model shown no significant results, neither for licensing-out nor licensing-in. This result suggests a lack of a mitigating effect of R&D intensity when reporting barriers to technology licensing. Interestingly however SMEs with a higher research intensity are less likely reporting the 'underdeveloped technology' barrier.

Given the importance of policies supporting the increased diffusion of knowledge this chapter indicates the need to address barriers to this policy objective (EC 2007 and 2020. Future research could for instance explore if framework and organisational, cost and negotiation barriers can be mitigated by assisting, in particularly SMEs without experience, with designing, drafting and negotiating contractual agreements. Barriers in relation to the quality and development stage of the technology can be addressed through increased proof of concept funding and lowering the threshold criteria for such initiatives. Policies targeting competition, such as a potential loss of competitive or technologic edge issues might be more challenging but framework and organisational, costs and search barriers can be alleviated through better communication and assistance on how technology markets work.

This study is not without limitations. Firstly, there might be a bias induced by the selected sample of research active SMEs receiving H2020 funding. In determining the variables of interest great care has been given to gather sufficient data for each of the variables that are seen exemplary for the characteristics of the SMEs in this dataset. Secondly, contract law remains mostly a national issue, even if licensor and licensee are in different countries a decision needs to be made in which country the contract shall be put into force. Given the small sample for several countries in the dataset, these differences could not be accounted for. Instead, geographical differences are controlled for by subregions and to the extent possible dummies for individual countries were included for which enough observations were available.

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Chapter 5 The role of technology value and finding the right partner on licensing success

Abstract: Thorough analysis on how technology is transferred amongst enterprises and from the public research sector to enterprises is of key importance to innovation policy. This chapter aims to improve the understanding the role practices and methods used to assess the licensing value of technology and the ability to find licensees has on licensing success. This chapter develops a conceptual framework to examine using structural equation modelling the importance of determining the licensing value of the technology and the ability to identify the right partner on technology transfer successfulness. The chapter contributes to the literature by showing that the measure for identifying licensees contributes to the successfulness of technology licensing but that the measure of value of the technology has a negative relationship with technology licensing successfulness. Willingness to engage in technology transfer is confirmed in the model to have a positive relationship with licensing success. These results have implications for policies aiming to improve knowledge diffusion and open innovation. On the one hand improving market thickness by using practices to identify potential licensees can improve successful technology licensing. On the other hand, this chapter shows that a better understanding of the value of the technology as perceived by their holders, i.e. SMEs, universities and other research institutes, reduces successfulness of technology licensing. A stronger effect is found for enterprises which suggest that potentially more valuable technology is not easily transferred.

1. Introduction

The knowledge produced by Small and Medium sized Enterprises (SMEs) and the public research sector (universities and public research organizations (PROs)) is a key factor in the ability of enterprises to innovate and consequently to improve living standards. Thorough analysis on how technology is transferred amongst enterprises and from the public research sector to enterprises is therefore of key importance to innovation policy. As discussed in Chapter 4 of this thesis, a major characteristic of innovation diffusion is the ease of exchange of information and knowledge amongst countries, individuals, as well as organisations. Information on how technology is diffused among technology actors is therefore of interest for research and policy.

In the current technology-driven world, SMEs, start-ups, as well as many universities and research institutions, are constantly developing new and more innovative products, services, and other types of technologies. The intellectual property rights arising from these inventions are often some of the most important resources for these entities. For many enterprises and particularly SMEs involved in technology markets, the ability to license out their technology, is often an important strategy for their commercial activities. For universities and other research institutions, licensing out inventions can be an important milestone in their third pillar activities aiming to commercialise technology. Hence, technology licensing is essential for all these technology-based organisations. Technology transfer can occur through several channels, but this chapter focus is on licensing activities as this accounts for the largest share of transactions in these markets (Arora and Gambardella 2010) and plays a lead role in the diffusion of technology (Anand and Khanna 2000; Arora and Fosfuri 2003). Licenses are the leading mechanism in trading patents (Arora and Ceccagnoli 2006; Arora and Fosfuri 2003). Even though licensing activities have increased over time, with estimates of producing billions of dollars in annual revenue (Caviggioli and Ughetto 2013; Alvarez and López 2015) the market is still considered to lack efficiency and operate 'in near total darkness' as noted by Love et al. (2018). Efficient market operation depends on three outcomes as defined by Roth

(2008), market thickness, lack of congestion and market safety. A market is "thick" if there are ample opportunities for buyers and sellers to trade. Lack of congestion implies that the transaction speed is at such a level that allows seeking alternatives on the one hand but also ensures market clearing and a market is "safe" if actors do not have incentives for distortion or strategic behaviour that disrupts the ability to evaluate potential transactions. When these three outcomes arise, market participants can take part in trading with full access and information of potential alternative transactions. This should lead to efficient markets (Gans and Stern 2010). The market for technology in which patents are traded or licensed, is however not very transparent and has been suffering from asymmetries of information that might hinder successfulness of licensing. Most technological sales and licenses are based on complex bilateral agreements in private law in a business-to-business setting of which much of the details are commercially sensitive (Anand and Khanna 2000; Bessy et al. 2002). As a consequence, there is a lack of information on how these agreements are made, reasons why deals are not concluded, and which factors contribute to successful outcomes. One of the major factors of successful technology licensing is the potential of the technology that is being licensed. However, the technology itself is often underdeveloped and not yet ready for commercialisation which may lead to a buyer's reluctance to commit to underdeveloped technologies (Dushnitsky 2010). With limited information regarding the market potential of a technology, buyers (licensees) wish to invest as little as possible, whereas sellers (inventors) seek as much as possible upfront to minimize the risks associated with developing the technology further (Gans and Stern 2010). Another important factor of the successfulness of a licensing deal is identifying the right partner. Moreover, the ability to identify potential buyers of a technology is a major issue as discussed in Chapter 4 of this thesis. Most exchanges of technologies occur under conditions that are best described as a bilateral monopoly (Gans and Stern 2010). There are limited alternative exchanges and buyer and seller engage in negotiations bilaterally. This limits competition and reduces the ability to achieve stable markets as actors are often unable to leverage alternative options to their advantage and obtain gains from trade. This is particularly the case in technology markets

(De Rassenfosse and Higham 2021; Love et al. 2018; Lemley and Myrvhold 2008; and Troy and Werle 2008).

To overcome the lack of information in technology markets and to improve the understanding on the complexities behind technology deals, this chapter examines the role of identifying licensees and technology value plays on the successfulness of technology transfer activities of SMEs, universities, and research institutes. This chapter draws on a survey that was funded by the European Commission DG Research and Innovation. It uses the same survey data as in Chapter 4. The questionnaire collected information on the technology transfer activities of these SMEs, universities, and research institutes. This chapter focusses on smaller entities as there are concerns that these, on either the buyer or the seller side, have difficulty coping with the market inefficiencies associated with concluding a technology transfer deal. Willingness to engage in technology transfer activities is an important pre-requisite for success. This aspect is also covered in the survey questionnaire and in the model framework. In addition, there are also concerns that smaller entities have difficulties coping with framework conditions including national policies and regulations. The latter has been investigated and discussed in Chapter 4 of this thesis. This chapter uses exploratory analysis to examine the role of potential licensing value and the ability to identify licensees plays in the market of technology licensing. The model proposed is tested empirically using Structural Equation Modelling (SEM). SEM is a multivariate statistical analysis framework that allows simultaneous estimation of a system of equations. SEM can be used to fit a range of models, including those involving measurement error and latent constructs. Moreover, SEM allows each item in the model to have its own unique variance (Acock 2013).

The aim of this chapter is to improve the understanding the role the value of technology and the ability to find licensees has on licensing success. The chapter contributes to the literature by showing that the measure for the ability to identify licensees contributes to the successfulness of technology licensing but that better understanding the value of the technology to be licensed has a negative relationship with technology transfer successfulness.

Willingness to engage in technology transfer is confirmed in the model to have a positive relationship with licensing success. These results have implications for policies aiming to improve knowledge diffusion and open innovation as on the one hand removing asymmetric information to address market thickness can improve successful technology licensing. On the other hand, this study shows that a better understanding of the value of the technology as perceived by their holders, i.e. SMEs, universities and other research institutes reduces successfulness of technology licensing. This might suggest that potentially more valuable technology is not easily transferred through licensing deals. The remainder of this chapter is structured as follows. Section 2 discusses the literature on the importance of the value of the technology and the ability to identify licenses for licensing. Section 3 describes the methodology of the research and Section 4 discusses the results. Section 5 concludes with a discussion.

2. Literature on finding the right partner and determining the value of the technology

The successful commercialization of new findings often depends on bringing several parties together. Firms desire innovative products to stay competitive but are not always eager to solely take risks when conducting basic research that requires substantial investment but with no clear return on investment (Kotha et al. 2018; Teece 1986). On the other hand, inventors, universities, and research institutes push the frontiers of science, but often lack the skills, willingness and resources needed to bring their discoveries to market. Given these complementary interests, opportunities to collaborate should appeal to both sides. However, potentially beneficial collaborations are often hindered through several factors as discussed in Chapter 4. The existing literature on the benefits of collaborations is large, particularly for inter-firm relations (Gnyawali et al. 2016; Mazzarol and Reboud 2008; Lavie 2006). Objectives to collaborate in relation to technology transfer include performance enhancements, cost containment, risk reduction, efficiency in innovation, interchange of knowledge as well as know-how, reduction of ambiguity and the identification of opportunities (Caloghirou et al. 2021; Talmar et al. 2020;

Hernández-Espallardo 2011; Belderbos et al. 2004; Cannon and Perreault 1999; Teece 1992).

This section reviews relevant literature on the importance of the ability to identify licensees and the importance of practices to better understand the value of the technology in the market of technology licensing.

2.1 The importance of the ability to identify licensees for licensing

One of the major factors in the successfulness of a technology deal is finding the right partner, also identified in the literature as market thickness (Roth 2008; Gans and Stern 2010). One of the main obstacles to licensing agreements is indeed misalignment of the licensee and licensor and their objectives as discussed in research from Razgaitis (2004) and Cockburn and Verità (2007). Technology developed, particularly from smaller actors often target niche markets and communicating the features of such technologies leads to higher transaction costs (Cockburn and Verità 2007). The ability to identify licensees in searching for partners and negotiations represents a significant source of transaction costs. This search ability is related to the time and other resources required to search for potential collaboration partners. Dealing with the technology, which is developed by someone else and hence leads to difficulties in understanding, is a major impediment for licensees. These absorptive capacity barriers have been studied by several authors (Szulanski 1996; Cohen and Levinthal 1990; Xie et al. 2018). Moreover, when universities or research institutes are seeking to licensing out technology, there might be differences in culture that make the identification of potential licensees more complex, since most universities and research institutes are publicly funded institutions and are in general not driven by profit and revenue (Schoppe 2014). Important practices which constitute the ability to identify potential collaboration partners include current clients or customers, informal networks and conferences and trade fares (Freitas et al. 2013; Hoffman et al. 2012; Buganza and Verganti 2009; Bekkers and Freitas 2008), scientific publications (Bekkers and Freitas 2008; Fabrizio 2006), patent databases (Kim and Lee 2015; Baglieri and Cesaroni 2013; Bekkers and Freitas 2008) and professional or industry associations (Iacopino et al. 2018; Pittaway et al. 2004; Swan and Newell 1995).

2.2 Methods to better understand the potential value of technology

In general, sellers have more information on the technology (Hotz and Xiao 2013; Sun 2011; Guo and Zhao 2009) than customers. This leads to information asymmetry between sellers and customers. This information asymmetry can influence consumer's willingness to pay and the seller's willingness to sell, possibly resulting in failure of the transaction (Akerlof 1970). The costs of trying to commercialize the wrong technology or the right technology at the wrong time can be substantial (Heslop et al. 2009) particularly for smaller actors in technology markets which likely have fewer buffers for risky endeavours. In addition, this information asymmetry also influences consumers' ability to assess technological quality and its value (Ghosh and Galbreth 2013; Fishman and Hagerty 2003). Giving a correct value to the technology is maybe one of the most important factors to successful technology licensing for organisations seeking to license out their technology in particular for smaller enterprises (Chiesa et al. 2007). Several researchers have investigated these issues (Guan et al. 2020; Clottey and Benton 2019; Arya et al. 2014; Grossman and Hart 1980) with Heslop et al. (2009) developing a readiness assessment measure (Heslop 2001) that can guide decisions about where to invest commercialization efforts. Pricing of technology remains different from the traditional demand and supply mechanisms as the technology itself is not yet a commodity. The lack of transparency of how patent markets work makes it difficult to value technology with no real benchmarks (Lemley and Myhrvold 2008). The technology is not 'there' yet and this 'valley of death' is both the cause and consequence of difficulties in evaluating underdeveloped technologies (Ellwood et al. 2020; Zemlickienė et al. 2017). An important factor determining the technology capabilities of an organisation is R&D activity (Arundel and Geuna 2004; Schartinger et al. 2001). Enterprises that invest heavily in R&D likely possess a high technological capability and are able to develop technologies with substantial value. Moreover, these types of enterprises should be well able to determine the value of a technology. External experts are often brought in, particularly amongst universities and research institutes to determine the technological quality and its value (Arundel et al. 2013; Bandarian 2007).

Licensing creates competition by giving away proprietary know-how to potential rival enterprises. One of the major aspects involved in technology licensing is that the licensing enterprise may lose its technological or competitive ‘‘edge’’ (Choi 2002). Granting another organisation the right to use its intellectual property may enable them to develop new products, which makes the licensed technology obsolete and leaves the licensor in backwater of technology—the so-called ‘boomerang’ effect (Choi 2002). This effect is particularly present in evolving technologies, such as basic research conducted by universities, where there is a risk that licensees downstream further develop the technology and appropriate the improvements, thus leaving behind the licensor (Leone and Reichstein 2012). It is therefore not surprising that enterprises are often reluctant to license their cutting-edge technologies since they may be giving their rivals the knowledge necessary to develop a better technology (Roberts and Mizouchi 1989; Davies 1977). Hence following this view, a better understanding of the potential commercial value of cutting-edge technologies can be an obstacle in successful technology licensing.

2.3 Hypothesis

This chapter focuses on two factors of the successfulness of technology licensing: the ability to identify licensees and the value of the technology.

Based on the literature review, two hypotheses are tested:

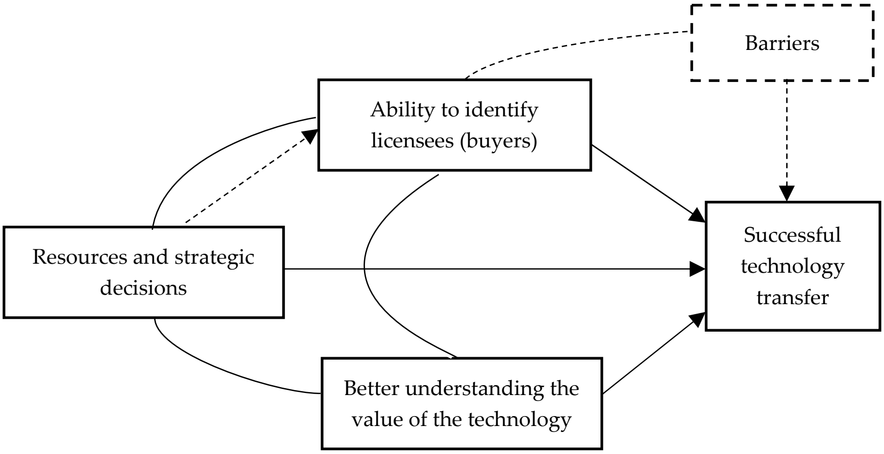
> *H1. Ability to identify licensees: Improving market thickness by using practices to identify licensees positively influences technology transfer successfulness*
>
> *H2. Value of the technology: A better understanding of the value of the technology to be licensed negatively influences technology transfer successfulness*

H1 is suggested by previous research in that the ability to reduce asymmetries and transaction costs improves technology licensing. The hypothesis is empirically tested with the expectation that organisations that are better able to identify licensees have greater success in technology licensing. H2 is also empirically tested. Based on the literature we know that the potential commercial value is an important factor in determining the value of the technology to be licensed. Hence it is expected that the better understanding of the value of the technology the more difficult it will become to part with the technology and agree on the necessary elements for a successful technology deal. Furthermore, resources and strategic decisions to participate in technology transfer activities is also included in the model and expected to positively influence technology transfer successfulness (H3). It is also expected to positively influence the ability to identify licensees, but this is not tested directly in this study.

> *H3. Resources and strategic decisions devoted to technology transfer positively influences technology transfer successfulness*

Barriers, as discussed in this chapter but also in Chapter 4 negatively influence technology transfer successfulness but are not tested in this study. Figure 1 shows the conceptual framework.

Figure 1. Conceptual framework



Note: Dashed lines and barriers not tested in this study. Curved lines are covariances.

3. Methodology

3.1 Data

The data used in this study is from a survey (funded by the European Commission, DG Research and Innovation (DG RTD)) on technology licensing activities of SMEs, universities and research institutes. The survey was conducted in 2017. The enterprise survey sample were SMEs that received financing under Horizon 2020 and is the same dataset used in Chapter 4 of this thesis. As discussed in the introduction of this thesis, to encourage and support knowledge transfer activities, particularly those that require legal and technical expertise, many European universities and research institutes have established Technology Transfer Offices (TTOs) that can provide professional advice to assess the patentability of inventions, interact with enterprises, and provide licensing expertise.[14] In total the university and research institute surveys led to 215 responses with a response rate of 35.1% and the enterprise survey to 440 responses with a response rate of 26.9%. Several responses were invalid for various reasons such as not reporting any technology transfer activities, not completing the questionnaire or item non-responses for independent variables of interest. These incomplete or invalid responses were excluded from this analysis. The questionnaire included several questions related to the technology transfer activities of the organisations. This chapter only includes those organisations that had experience with technology licensing or were planning to license-out technology in the near future. These respondents answered questions on their technology transfer resources and strategies, methods to determine the license value of a technology, methods to identify licensees (buyers) and patent activity. This left in total 371 eligible units for analysis, 183 enterprises, 145 universities and 43 research institutes.

3.2 Statistical analysis

The respondents to the survey answered two sections of interest for the construction of the latent variables 'ability to identify licensees' and 'value of the technology' (See Table 1, the appendix of this thesis includes a copy of the survey questionnaire). The data sample is considered adequate for factor analysis, as the responses to variables ratio exceeds 5:1 (Hair et al. 1998). Factor analysis is conduced to check if the selected measures group together to describe the structural configuration. The value for the Kaiser-Meyeer-Olkin (KMO) measure of sampling adequacy was 0.603 for the ability to identify licensees, and 0.658 for the value of the technology which exceeds the recommended threshold level of 0.50 (Hair et al. 1998).

The reliability of the final constructs measures was estimated by the Cronbach's alpha parameters. The alpha values obtained did not pass the

[14] These offices are also called Knowledge Transfer Offices (KTOs), Research Office, Research Commercialisation, Valorisation Office etc.. These offices can be part of a university or research institute, or it can be a separate business responsible for the technology transfer activities of a university or research institute. Some or all of the patenting, licensing, or other technology transfer activities of a university or research institute can fall under the responsibilities of such an office or business. For ease of understanding all such offices are referred to as TTOs.

usual 0.700 for both final constructs based on the six items. However, the Cronbach alpha estimated using the full set of questions passed was close to the threshold (0.722 for the ability to identify licensees, and 0.652 for the value of the technology). These results suggest that the questionnaire sections had adequate internal consistency. A likely reason for the lower alpha values observed for the final construct is because the alpha coefficient is a direct function of the number of items, with only 6 items for each construct. In addition, using SEM as a methodology is sensitive to the survey questionnaire design but a similar approach as used in this chapter has been done in previous research (e.g. Sánchez-Barrioluengo and Benneworth 2019; Guerrero et al. 2015). Some factor loadings are for instance below 0.5 but included nevertheless given the average importance given by the respondents and based on the literature review. The final variables for inclusion in each construct are presented in Table 1 based on the literature review and statistical analysis. Table 1 lists in the first part practices or methods to identify licensees, followed by practices or methods to better understand the value of the technology, resources and strategic decisions in relation to technology licensing and the variables used to measure a successful technology transfer. Table 5 in the appendix provides the results from the factor analysis for the latent variables of interest: ability to identify licensees and value of the technology. The appendix also includes descriptive statistics (Table 3) and correlation results (Table 4) of all the variables included in the SEM model. None of the correlations are above 0.6 thus any multicollinearity issues are not expected (Dormann et al. 2013).

Table 1. Constructs of the model

Ability: Practices or methods to identify licensees (independent variable)

Variable name	**Description**	**Variable calculation**	**Motivation**
A_CC	Current clients or customers	Likert scale. Degree of importance 1(none)-4(high)	Important practice (Freitas et al. 2013; Hoffman et al. 2012; Buganza and Verganti 2009; Bekkers and Freitas 2008).
A_INF	Informal networks	Likert scale. Degree of importance 1(none)-4(high)	Important practice (Freitas et al. 2013; Hoffman et al. 2012; Buganza and Verganti 2009; Bekkers and Freitas 2008).
A_ASSOC	Professional or industry association	Likert scale. Degree of importance 1(none)-4(high)	Important practice (Iacopino et al. 2018; Pittaway et al. 2004; Swan and Newell 1995)
A_JOURN	Scientific/technical journals or trade publications	Likert scale. Degree of importance 1(none)-4(high)	Important practice (Bekkers and Freitas 2008; Fabrizio 2006).
A_PDATA	Research in patent databases	Likert scale. Degree of importance 1(none)-4(high)	Important practice (Freitas et al. 2013; Hoffman et al. 2012; Buganza and Verganti 2009; Bekkers and Freitas 2008).
A_CONF	Conferences, trade fairs, exhibitions	Likert scale. Degree of importance 1(none)-4(high)	Important practice (Freitas et al. 2013; Hoffman et al. 2012; Buganza and Verganti 2009; Bekkers and Freitas 2008).

Value: Practices or methods to better understand the value of the technology (independent variable)			
Variable name	**Description**	**Variable calculation**	**Motivation**
Q_RD	Costs of R&D activities carried out	Likert scale. Degree of importance 1(none)-4(high)	R&D investment (Schartinger et al. 2001; Arundel and Geuna 2004).
Q_REV	Potential revenue for the licensee	Likert scale. Degree of importance 1(none)-4(high)	Technology that is more mature has more value (Ellwood et al. 2020; Zemlickienė et al. 2017; Dushnitsky 2010). More demand leads to a higher value.
Q_LRATE	Licensing rates according to industry norms (of similar technologies)	Likert scale. Degree of importance 1(none)-4(high)	Improves understanding of the value of the technology by reducing information asymmetries (Love et al. 2018; Akerlof 1970). Can provide benchmark (Lemley and Myhrvold 2008)
Q_INT	Potential number of clients interested	Likert scale. Degree of importance 1(none)-4(high)	More demand leads to a higher value.
Q_MRES	Market research on similar technologies	Likert scale. Degree of importance 1(none)-4(high)	Improves understanding of the potential value of the technology and reduces information asymmetries (Love et al. 2018; Akerlof 1970)
Q_EVAL	Evaluating the commercial potential by an external expert	Likert scale. Degree of importance 1(none)-4(high).	Improves understanding of the potential value of the technology. Important practice (Arundel et al. 2013; Bandarian 2007)

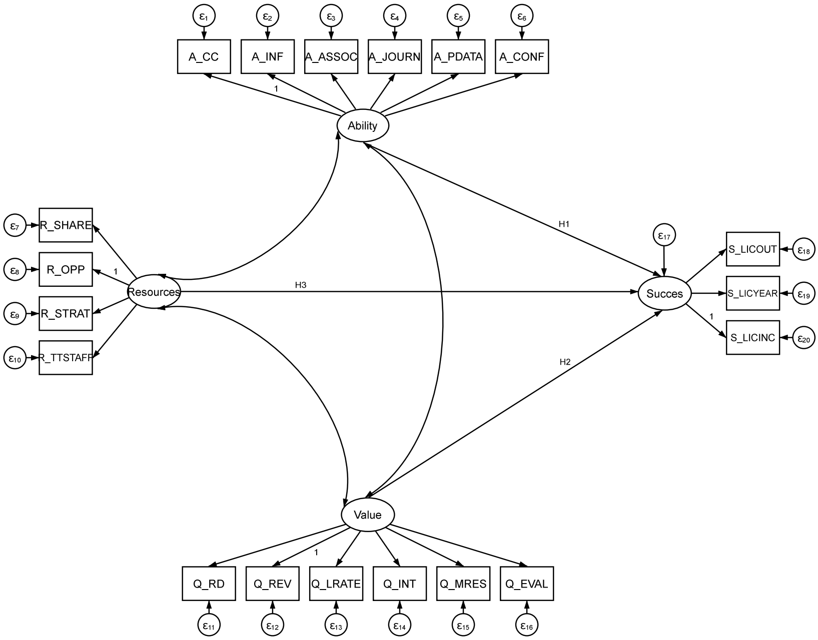
Resources and strategic decisions (control variable)			
Variable name	**Description**	**Variable calculation**	**Motivation**
R_OPP	Does the organisation actively look for opportunities to license out technology?	Yes (1)/No (0)	The organisation devotes time and efforts to license out technology.
R_STRAT	Does the organisation have a written strategy for licensing out technology?	Yes (1)/No (0)	A written strategy shows the organisation has a protocol for technology transfer. Additionally, it is shown in Chapter 6 of this thesis that it is beneficial for TT outcomes.
R_TTSTAFF	Does the organisation have dedicated technology transfer staff?	Categorical (1 if >0 and <=2, 2 if >2 and <=5, 3 if >5, zero otherwise, in FTE)	The organisation devotes time and efforts to license out technology.
R_SHARE	The share of the organisation's patent portfolio that they are willing to license out.	Percentage of patent portfolio willing to license out.	Indicator of willingness to license out technology.

Successful technology transfer (dependent variable)			
Variable name	**Description**	**Variable calculation**	**Motivation**
S_LICOUT	Did the organisation license out technology in the previous 5 years?	Yes (1)/No (0)	Indicator to identify organisations that have license-out experience.
Variable name	**Description**	**Variable calculation**	**Motivation**
S_LICYEAR	Did the organisation made any license-out agreement in 2016?	Yes (1)/No (0)	Measure of recent licensing activity.
S_LICINC	Did the organisation have any license income in 2016?	Yes (1)/No (0)	Measure of recent licensing success.

3.3 Structural model

Economic literature on technology transfer activities of universities has used structural equation modelling to analyse relationships between latent constructs that integrate a model of observed factors (e.g. Sánchez-Barrioluengo and Benneworth 2019; Sánchez-Barrioluengo 2014; Guerrero et al. 2015; Purushotham et al. 2013 and Guerrero and Urbano 2012). The advantage of SEM is that it allows for simultaneous analysis of all the variables in the model instead of investigating each construct separately using regression or factor analysis, moreover measurement errors are not aggregated in a single residual error term but are estimated for each variable in the model separately (Acock 2013). The structural equation path diagram of this study is shown in Figure 2. The path diagram follows the conceptual model presented in Figure 1 with the addition of the observed variables used to construct the latent constructs. In this model technology transfer successfulness is the dependant variable, the constructs' ability to identify licensees and technological quality are the independent variables of interest and the resources and strategic decisions are included as control variables.

Figure 2. Structural equation model



The structural path is first evaluated based on model fit tests using the full model, the fit indices for the three sub-groups (enterprises, universities, and research institutes) are provided in Appendix 3. The goodness of fit is determined mainly by the χ^2 statistic, with cut-off values for χ^2 normalised to be less than 2 (Ullman 2001) or less than 5 (Suchmacker and Lomax 2004). Other measures are proposed in the literature to evaluate model fit such as the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root Mean Square Residual (SRMR), which are good measures to evaluate a SEM model (Acock 2013; Sharma et al. 2005, Hu and Bentler 1999; Bentler 1995). Guidelines suggest a CFI and TLI close to 1, χ^2 normalised (χ^2/df), RMSEA and SRMR less than 0.10 (Hu and Bentler 1999; Bentler 1995). The models present significant coefficients and adequate parameters [χ^2 normalised 1.652; RMSEA 0.057; SRMR 0.075; CFI 0.819; TLI 0.790].

In terms of empirical results (see Table 2), all the variables selected to measure the constructs present a positive and significant value which can be interpreted as the adequacy and robustness of these items to capture the content of the conceptual framework. Moreover, the results for the structural paths, i.e. the hypothesis tested, show the expected signs and are significant. According to the evidence obtained, the results indicate a positive and significant effect of the ability to identify licensees on successful technology transfer [0.341; $p<0.05$] and a negative and significant effect of a better understanding of the value of the technology on successful technology transfer [-0.622; $p<0.01$]. Additionally, the results for the control variables resources dedicated to technology transfer and strategic decisions indicate a positive and significant effect [0.656; $p<0.01$]. Most important factors for the construct ability to identify licensees are conferences, trade fairs and exhibitions [0.508; $p<0.01$] followed by professional or industry associations [0.491; $p<0.01$] and research in patent databases [0.483; $p<0.01$]. For the construct value of the technology, the most important factors are market research [0.455; $p<0.01$], the potential number of clients interested [0.391; $p<0.01$] and evaluating the commercial potential [0.390; $p<0.01$]. Of interest, are the results for the covariances between the constructs ability to identify licensees and a better understanding of the value of the technology [0.926; $p<0.01$]. This suggests that those holders of technology that have a good understanding of its value are also well able to identify potential licensees. As expected, the covariance between resources and strategic decisions together with the ability to identify licensees is positive and significant [0.344; $p<0.01$], with more resources you are able to identify licensees better, which leads to successful technology transfer (hypothesis 1) and reinforces incentives to invest in resources and develop strategies for technology transfer activities. Covariance between resources and strategic decisions together with better understanding the value of the technology shows no significance which suggests that these two constructs are treated as separate activities within the organisations included in this analysis.

The model has also been tested by subgroups, i.e. enterprises, universities and research institutes and are correspondingly presented in Tables 6, 7 and 8 in the appendix. It should be noted that the results by subgroups should be interpreted with caution, particularly those for the 43 research institutes, as implementing SEM would require at least 100 subjects (Williams et al. 2004). Sub-group analysis will therefore only discuss results for enterprises and universities. Results for the first two hypothesis hold and are robust for both enterprises and universities. The results of the control variables resources and strategies are positive but not significant for universities. This is likely due to a lack of variation for this group as most of the universities have dedicated resources and strategies for their third mission activities. Comparing the structural path coefficients in terms of importance on technology transfer success shows an interesting difference as the negative effect of the construct better understanding the value of the technology is significantly more critical in enterprises versus universities [-1.139 vs. -0.773; $p<0.001$]. This suggests that enterprises are less willing to license out technology with high value as it may lose their technological or competitive ''edge'' (Choi 2002) which is of lower importance to universities. A second striking result comparing the structural path coefficients is the importance of the ability to identify licensees as this is significantly more critical in universities versus enterprises [1.034 vs. 0.517; $p<0.05$]. Universities have a third mission in terms of engaging with industry, this mandate requires universities to explore opportunities to collaborate and make knowledge developed in universities available to society. The most critical factor for the construct ability to identify licensees in enterprises is research in patent databases [0.473; $p<0.01$] followed by professional or industry associations [0.469; $p<0.01$] and conferences, trade fairs and exhibitions [0.428; $p<0.01$]. For universities the most critical factors for the construct ability are informal networks [0.614; $p<0.01$] and conferences, trade fairs and exhibitions [0.420; $p<0.01$]. The most critical factor for the construct value of the technology in enterprises is evaluating the commercial potential [0.492; $p<0.01$] followed by market research [0.429; $p<0.01$]. For universities the most critical factors are the potential number of clients interested [0.539; $p<0.01$] followed by market research [0.512; $p<0.01$].

Table 2. SEM results full sample

Structural configuration				Estim-ate	S.E.	*P*
H1	TT successfulness	←	Ability to identify licensees	0.341	0.149	**
H2	TT successfulness	←	Value of the technology	-0.622	0.170	***
Control variables						
H3	TT successfulness	←	Resources and strategic decisions	0.656	0.132	***
Components of each construct						
Ability to identify licensees		←	Current clients or customers	0.198	0.084	**
Ability to identify licensees		←	Informal networks	0.392	0.078	***
Ability to identify licensees		←	Professional or industry association	0.491	0.073	***
Ability to identify licensees		←	Scientific/technical journals	0.397	0.079	***
Ability to identify licensees		←	Research in patent databases	0.483	0.074	***
Ability to identify licensees		←	Conferences, trade fairs, exhibitions	0.508	0.073	***
Value of the technology		←	Costs of R&D activities carried out	0.250	0.084	***
Value of the technology		←	Potential revenue for the licensee	0.157	0.085	*
Value of the technology		←	Licensing rates	0.213	0.087	**
Value of the technology		←	Potential number of clients interested	0.391	0.079	***
Value of the technology		←	Market research	0.455	0.078	***
Value of the technology		←	Evaluating the commercial potential	0.390	0.083	***
Resources/strategic decisions		←	Looking out to license	0.505	0.077	***
Resources/strategic decisions		←	Written strategy for licensing	0.357	0.080	***
Resources/strategic decisions		←	Share portfolio willing to license out.	0.297	0.081	***
Resources/strategic decisions		←	Dedicated technology transfer staff	0.530	0.071	***
TT successfulness		←	License out technology experience	0.832	0.037	***
TT successfulness		←	License-out agreement in 2016	0.774	0.040	***
TT successfulness		←	License income in 2016	0.680	0.046	***
Covariances						
Ability to identify licensees		↔	Value of the technology	0.926	0.077	***
Resources/strategic decisions		↔	Ability to identify licensees	0.344	0.133	***
Resources/strategic decisions		↔	Value of the technology	0.044	0.161	

Note: ***p<0.01; ** p<0.05; p<0.010. Standardized coefficients are presented. N=371

4. Discussion and conclusion

Technology transfer is increasingly seen as a method to diffuse knowledge and create more efficient markets. It is an important mechanism for the commercialization of research and forms a central element in the overall contribution of technology producers to technological advancement and economic growth. Institutional actors are developing framework conditions that are conductive to technology transfer activities for several decades but there is limited analysis of the influences of the value of the technology and its implications for competitiveness on the extent of technology transfer successfulness. Additionally, asymmetric information is a persistent barrier to technology transfer successfulness although the results in this study suggest that several methods and practices to identify licensees can positively influence technology transfer. This chapter adds to the so far limited analyses of these influences and suggests paths for further analysis and implications for policy developments.

4.1 Findings and contribution

This chapter uses a SEM model to test a framework of two latent constructs: the ability to identify licensees and better understanding the value of technology. It shows that the value of the technology has a negative relationship with technology transfer successfulness and that the ability to identify licensees has a positive relationship. Additionally, devoting resources and developing specific strategies for technology transfer activities are beneficial for organisations to identify potential licensing partners and are beneficial to technology transfer success. Moreover, the covariance results show that the value of the technology and the ability to identify licensees go hand in hand. Technology producers that are well able to determine the potential value of the technology are also well able to identify potential licensees.

Protecting technology and knowledge with a patent is an indication that the producer of that knowledge or technology does not have an incentive to share this knowledge freely. Moreover, enterprises as producer of valuable technology, with profit maximisation and staying competitive as main goals, are less willing (as measured by successful technology transfer) to license out technology as it may lose their technological or competitive edge. This is particularly relevant for the SMEs included in this study. SMEs have a need to position themselves in new markets and are therefore less willing to license out their technologies if it has commercial potential. Similar results are found for universities, although to a lesser extent, which should not be that surprising as their mission is to generate and share knowledge. However, with the surge in third mission activities and resources devoted to these activities, universities have an incentive to obtain good returns on their investments. For example, in terms of financing R&D and technology transfer activities. Additionally, why should universities freely or easily share technology that it has developed if they know it has commercial potential? On the other hand, license income cannot serve as a viable source of income for universities (Arundel et al. 2013) but it can finance research or infrastructure without relying too much on basic (governmental) funding.

4.2 Implications

This chapter contributes to the literature of the multi-faceted phenomena of technology transfer and has several implications for practice and policy. Institutional developments and policies aimed to increase technology transfer activities should keep in mind that valuable technology is not easily transferred. As the results in this chapter have suggested, a better understanding of the value of the technology is less likely leading to successful technology transfer. The results therefore provide an indication that policy supporting knowledge diffusion and technology transfer activities may not necessarily lead to transfer of valuable technology. Rather it seems more important for enterprises to hold on to valuable technology. An obvious reason for this is to remain competitive. In this regard developing capabilities within their organisation to develop promising technology further is likely more relevant. Easier access to proof-of-concept funding can help in this instance together with creating a system for SMEs to track the results of funding activities of the European Commission by following up on the status of the enterprise and by identifying their needs after the funding/project has ended. Another implication of this study is related to the finding that for universities the importance of the ability to identify licensees is significantly more important compared to enterprises. Many universities have dedicated staff for their third mission activities of knowledge and technology transfer which leads to higher success in terms of finding licensees as shown in this research. However, the value of these higher success rates in technology transfer might not meet initial expectations or intended outcomes as a better understanding of valuable technology is less likely leading to successful technology transfer. License income, particularly royalty rates, is directly linked to the commercial success of products, where in this regard value of the technology transfer activity itself is a predictor of success once the product is on the market. Devoting efforts and resources in technology transfer deals which turn out to be less successful than intended can challenge the support for technology transfer activities, particularly for universities. This finding suggests that future technology transfer policies should enable actors involved in technology transfer to not only focus on the quantity of technology transfer activities. Decision makers should consider devoting more efforts to the technology transfer process that leads to more beneficial outcomes.

4.3 Limitations

This chapter has limitations that opens avenues for future research. First, a larger number of observations would enable better structural equation modelling (Williams et al. 2004). As a result, the sub-group findings should be interpretated with some caution even though enterprises and university cases meet the threshold for analysis (>100). Second, this study does not control for scientific disciplines. Research in Chapter 4 of this thesis and in Arundel et al. (2013) showed that certain scientific disciplines are more successful in technology transfer activities, e.g. biomedical research in terms of license income. Future research could take this difference into account to understand whether differences in scientific disciplines affect the relationships between the ability to identify licensees, value of the technology and technology transfer successfulness. Further, there might be a bias induced by the selected sample of research active SMEs receiving H2020 funding. Lastly, structural equation modelling is sensitive to the design of the questionnaire, which is not something which has been considered in the design of the survey of which the data has been used in this chapter. For instance, some of the SEM goodness of fit indicators and Cronbach's alpha are known to improve when longer Likert scales are used (Hair et al. 1998). However, the study followed similar methodological approaches as in other literature such as (Sánchez-Barrioluengo and Benneworth 2019; Sánchez-Barrioluengo 2014 and Guerrero et al. 2015)

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Appendix

Table 3. Descriptive statistics

Variable name	Description	Enterprises (N=183)		Universities (N=145)		Research Institutes (N=43)		Total (N=371)	
Ability to identify licensees		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
A_CC	Current clients or customers	3.588	0.665	3.451	0.730	3.512	0.768	3.526	0.704
A_INF	Informal networks	3.094	0.758	3.154	0.725	3.279	0.630	3.139	0.732
A_ASSOC	Professional or industry association	2.879	0.877	2.979	0.758	2.837	0.785	2.913	0.822
A_JOURN	Scientific/technical journals or trade publications	2.901	0.855	2.640	0.885	2.698	0.803	2.777	0.867
A_PDATA	Research in patent databases	2.577	1.009	2.965	0.867	2.651	0.842	2.736	0.953
A_CONF	Conferences, trade fairs, exhibitions	3.148	0.831	2.958	0.780	3.163	0.814	3.076	0.813
Value of the technology		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Q_RD	Costs of R&D activities carried out	3.105	0.860	2.826	0.996	2.714	0.918	2.953	0.931
Q_REV	Potential revenue for the licensee	3.542	0.705	3.446	0.724	3.548	0.593	3.506	0.700
Q_LRATE	Licensing rates according to industry norms (of similar technologies)	2.925	0.867	3.138	0.839	3.184	0.730	3.037	0.847
Q_INT	Potential number of clients interested	3.302	0.813	3.210	0.739	3.167	0.762	3.223	0.820
Q_MRES	Market research on similar technologies	3.079	0.829	3.139	0.842	3.205	0.894	3.144	0.803
Q_EVAL	Evaluating the commercial potential by an external expert	2.713	0.942	2.962	0.898	2.707	0.782	2.806	0.914

Variable name	Description	Enterprises (N=183)		Universities (N=145)		Research Institutes (N=43)		Total (N=371)	
Resources and strategic decisions		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
R_OPP	Does the organisation actively look for opportunities to license out technology?	0.776	0.418	0.931	0.255	0.837	0.374	0.843	0.364
R_STRAT	Does the organisation have a written strategy for licensing out technology?	0.361	0.482	0.566	0.497	0.512	0.506	0.458	0.498
R_SHARE	The share of the organisation's patent portfolio that they are willing to license out.	32.9	36.4	60.7	28.8	50.0	30.0	46.5	35.1
R_TTSTAFF	Does the organisation have dedicated technology transfer staff?	1.486	0.876	2.344	0.776	2.280	0.766	1.910	0.926
Technology transfer successfulness		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
S_LICOUT	Did the organisation license out technology in the previous 5 years?	0.486	0.501	0.772	0.421	0.721	0.454	0.625	0.484
S_LICYEAR	Did the organisation made any license-out agreement in 2016?	0.459	0.500	0.828	0.379	0.860	0.351	0.650	0.478
S_LICINC	Did the organisation have any license income in 2016?	0.552	0.499	0.897	0.306	0.837	0.374	0.720	0.450

Table 4. Correlation results

	A_CC	A_INF	A_ASSOC	A_JOURN	A_PDATA	A_CONF	Q_RD	Q_REV	Q_LRATE	Q_INT	Q_MRES	Q_EVAL	R_OPP	R_STRAT	R_TTSTAFF	R_SHARE	S_LICOUT	S_LICYEAR	S_LICINC
A_CC	1																		
A_INF	0.105**	1																	
A_ASSOC	0.014	0.229***	1																
A_JOURN	0.073	0.031	0.115**	1															
A_PDATA	0.037	0.040	0.152***	0.361***	1														
A_CONF	0.147***	0.171***	0.229***	0.228***	0.128**	1													
Q_RD	0.071	-0.059	0.123**	0.13**	0.067	0.108**	1												
Q_REV	0.101*	0.05	-0.036	0.036	0.045	0.178***	0.125**	1											
Q_LRATE	0.136**	0.12**	0.143***	0.191***	0.166***	0.233***	0.132**	0.201***	1										
Q_INT	-0.034	0.255***	0.226***	0.169***	0.278***	0.162***	0.059	0.201***	0.229***	1									
Q_MRES	-0.034	0.255***	0.226***	0.169***	0.278***	0.162***	0.059	0.201***	0.229***	0.295***	1								
Q_EVAL	0.042	0.024	0.283***	0.071	0.258***	0.167***	0.152***	0.132**	0.091*	0.163***	0.292***	1							
R_OPP	0.065	0.205***	0.064	0.037	0.134**	0.077	0.006	0.070	0.102*	0.000	0.154***	0.042	1						
R_STRAT	0.053	0.025	0.209***	-0.046	0.063	0.053	0.030	-0.056	0.047	0.014	0.051	0.109**	0.233***	1					
R_TTSTAFF	-0.009	0.025	0.094*	-0.113**	0.179***	-0.021	-0.095*	-0.008	0.037	-0.064	0.040	0.016	0.138***	0.193***	1				
R_SHARE	-0.002	0.101	0.109*	-0.013	0.221***	-0.044	-0.057	0.004	0.045	-0.119*	0.009	0.108*	0.29***	0.110*	0.174***	1			
S_LICOUT	0.114**	0.035	-0.059	-0.125**	-0.007	-0.083	-0.124**	-0.013	0.088	-0.157***	-0.061	-0.174***	0.177***	0.189***	0.325***	0.153**	1		
S_LICYEAR	0.040	0.107**	0.028	-0.028	0.082	0.052	-0.162***	0.092*	0.174***	-0.022	0.065	-0.106**	0.172***	0.154***	0.325***	0.153**	0.496***	1	
S_LICINC	0.064	0.023	0.033	-0.123**	0.036	0.006	-0.175***	-0.007	0.145***	-0.067	0.019	-0.09*	0.259***	0.200***	0.286***	0.197***	0.586***	0.505***	1

* = p <.10, ** = p <.05, *** = p<.01

Table 5. Results of the factor analysis of the constructs of the latent variables

Variables	Description	Factor analysis			Reliability
Ability to identify licensees				*Loadings*	*Cronbach / item to total*
A					0.495
A_CC	Current clients or customers	*KMO*	0.603	0.288	0.505
			133.60		
A_INF	Informal networks	X^2	Sig. ***	0.429	0.475
A_ASSOC	Professional or industry association	*Eigen value*	1.728	0.560	0.441
A_JOURN	Scientific/technical journals or trade publications	*Variance explained*	28.81	0.625	0.413
A_PDATA	Research in patent databases			0.580	0.439
A_CONF	Conferences, trade fairs, exhibitions			0.649	0.407
Value of the technology					
Q					0.526
Q_RD	Costs of R&D activities carried out	*KMO*	0.658	0.324	0.547
			115.54		
Q_REV	Potential revenue for the licensee	X^2	Sig. ***	0.527	0.469
Q_LRATE	Licensing rates according to industry norms	*Eigen value*	1.820	0.546	0.504
Q_INT	Potential number of clients interested	*Variance explained*	30.34	0.615	0.453
Q_MRES	Market research on similar technologies			0.680	0.430
Q_EVAL	Evaluating the commercial potential by an external expert			0.545	0.474

* = p <.10, ** = p <.05, *** = p<.01

Table 6. SEM results enterprises (n=183)

	Structural configuration			Estim-ate	S.E.	*P*
H1	TT successfulness	←	Ability to identify licensees	0.517	0.107	***
H2	TT successfulness	←	Value of the technology	-1.139	0.147	***
	Control variables					
H3	TT successfulness	←	Resources and strategic decisions	0.449	0.196	**
	Components of each construct					
	Ability to identify licensees	←	Current clients or customers	0.340	0.058	***
	Ability to identify licensees	←	Informal networks	0.454	0.089	***
	Ability to identify licensees	←	Professional or industry association	0.469	0.082	***
	Ability to identify licensees	←	Scientific/technical journals	0.318	0.094	***
	Ability to identify licensees	←	Research in patent databases	0.473	0.088	***
	Ability to identify licensees	←	Conferences, trade fairs, exhibitions	0.428	0.089	***
	Value of the technology	←	Costs of R&D activities carried out	0.093	0.086	
	Value of the technology	←	Potential revenue for the licensee	0.093	0.110	
	Value of the technology	←	Licensing rates	0.246	0.108	**
	Value of the technology	←	Potential number of clients interested	0.346	0.096	***
	Value of the technology	←	Market research	0.429	0.091	***
	Value of the technology	←	Evaluating the commercial potential	0.492	0.081	***
	Resources/strategic decisions	←	Looking out to license	0.362	0.078	***
	Resources/strategic decisions	←	Written strategy for licensing	0.230	0.107	**
	Resources/strategic decisions	←	Share portfolio willing to license out.	0.111	0.096	
	Resources/strategic decisions	←	Dedicated technology transfer staff	0.234	0.094	**
	TT successfulness	←	License out technology experience	0.893	0.037	***
	TT successfulness	←	License-out agreement in 2016	0.618	0.073	***
	TT successfulness	←	License income in 2016	0.714	0.061	***

Notes: * = p <.10, ** = p <.05, *** = p<.01. Standardized coefficients are presented. Covariances are kept constant in sub-group analysis.

Table 7. SEM results universities (n=145)

Structural configuration				Estim-ate	S.E.	*P*
H1	TT successfulness	←	Ability to identify licensees	1.034	0.236	***
H2	TT successfulness	←	Value of the technology	-0.773	0.258	***
Control variables						
H3	TT successfulness	←	Resources and strategic decisions	0.110	0.277	
Components of each construct						
	Ability to identify licensees	←	Current clients or customers	0.339	0.058	**
	Ability to identify licensees	←	Informal networks	0.614	0.091	***
	Ability to identify licensees	←	Professional or industry association	0.108	0.157	***
	Ability to identify licensees	←	Scientific/technical journals	0.283	0.158	***
	Ability to identify licensees	←	Research in patent databases	0.355	0.130	***
	Ability to identify licensees	←	Conferences, trade fairs, exhibitions	0.420	0.135	***
	Value of the technology	←	Costs of R&D activities carried out	0.093	0.086	
	Value of the technology	←	Potential revenue for the licensee	0.280	0.142	**
	Value of the technology	←	Licensing rates	0.210	0.139	
	Value of the technology	←	Potential number of clients interested	0.539	0.110	***
	Value of the technology	←	Market research	0.512	0.113	***
	Value of the technology	←	Evaluating the commercial potential	-0.107	0.167	
	Resources/strategic decisions	←	Looking out to license	0.362	0.078	***
	Resources/strategic decisions	←	Written strategy for licensing	-0.092	0.103	***
	Resources/strategic decisions	←	Share portfolio willing to license out.	0.038	0.106	***
	Resources/strategic decisions	←	Dedicated technology transfer staff	0.198	0.117	***
	TT successfulness	←	License out technology experience	0.704	0.098	***
	TT successfulness	←	License-out agreement in 2016	0.582	0.085	***
	TT successfulness	←	License income in 2016	0.601	0.087	***

Notes: * = p <.10, ** = p <.05, *** = p<.01. Standardized coefficients are presented. Covariances are kept constant in sub-group analysis.

Table 8. SEM results research institutes (n=43)

Structural configuration				Estimate	S.E.	*P*
H1	TT successfulness	←	Ability to identify licensees	1.442	0.491	***
H2	TT successfulness	←	Value of the technology	-0.649	0.568	
Control variables						
H3	TT successfulness	←	Resources and strategic decisions	-0.377	0.470	
Components of each construct						
	Ability to identify licensees	←	Current clients or customers	0.339	0.058	***
	Ability to identify licensees	←	Informal networks	0.390	0.201	*
	Ability to identify licensees	←	Professional or industry association	0.626	0.138	***
	Ability to identify licensees	←	Scientific/technical journals	0.091	0.256	
	Ability to identify licensees	←	Research in patent databases	0.730	0.096	***
	Ability to identify licensees	←	Conferences, trade fairs, exhibitions	0.522	0.162	***
	Value of the technology	←	Costs of R&D activities carried out	0.093	0.086	
	Value of the technology	←	Potential revenue for the licensee	0.442	0.183	**
	Value of the technology	←	Licensing rates	0.236	0.223	
	Value of the technology	←	Potential number of clients interested	0.281	0.220	
	Value of the technology	←	Market research	0.710	0.108	***
	Value of the technology	←	Evaluating the commercial potential	0.522	0.159	***
	Resources/strategic decisions	←	Looking out to license	0.362	0.078	***
	Resources/strategic decisions	←	Written strategy for licensing	0.575	0.121	***
	Resources/strategic decisions	←	Share portfolio willing to license out.	0.006	0.189	
	Resources/strategic decisions	←	Dedicated technology transfer staff	0.310	0.249	
	TT successfulness	←	License out technology experience	0.580	0.173	***
	TT successfulness	←	License-out agreement in 2016	0.658	0.106	***
	TT successfulness	←	License income in 2016	0.647	0.114	***

Notes: * = p <.10, ** = p <.05, *** = p<.01. Standardized coefficients are presented. Covariances are kept constant in sub-group analysis. Interpret cautiously due to low number of observations for this sub-group.

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Chapter 6 The effectiveness of institutional policies on technology transfer outcomes

Abstract: This chapter[15] addresses several gaps in the academic literature on the relationship of university policies on the knowledge transfer performance of KTOs. We examine the influence of a broader range of policies than available in other studies, with data on policies for IP, licensing and start-up activities. Furthermore, we distinguish between internal policies that affect mainly faculty and staff and published policies; publishing a policy and communicating its content to potential transfer clients potentially reduces the opportunities for negotiation of terms, with consequences for licensing agreements. Lastly, we include incentives for non-financial benefits. Currently, financial incentives dominate the literature. We find that the influence of policies to establish clear rules, improve transparency, and provide financial or non-financial incentives vary by outcome. Improving transparency by publishing the policies for licensing or IP are often negatively correlated with outcomes, particularly for license agreements. Out of three non-financial incentives, only social rewards have a rather positive influence (on start-ups), but financial incentives are positively correlated with several outcomes. A higher salary is positively linked to the number of research agreements and patent applications, while giving inventors a share of revenue is positively correlated with licensing and start-ups. The results suggest that the type of incentive as well as the degree of transparency of transfer policies should be chosen to complement the main transfer channels and strategy of the institution.

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1. Introduction

Since the early 1990s an increasing stream of publications has investigated the knowledge and technology transfer performance of universities and public research institutions and the influence of different policies on performance. Awareness among university administrators and policy makers about the importance of regulations governing knowledge transfer activities has also risen. Yet there is little evidence on the effectiveness of policies for specific outcomes.

This is of particular concern for Europe, where national laws and institutional regulations on the ownership and transfer of academic research results are subject to change (Geuna and Rossi 2011). To encourage good practice, in 2008 the European Commission (EC) issued recommendations for a Code of Practice (COP) containing eighteen guidelines (referred to as principles in the document) for the management of intellectual property (IP) and knowledge transfer activities by universities and public research institutes. The COP includes seven principles for IP, seven principles for knowledge transfer, and four principles for collaborative and contract research. The goal of the principles is to "better convert knowledge into socio-economic benefits" through a more effective exploitation of publicly funded research results (European Commission 2008, p. 5). Several principles advance publishing IP and other policies to improve transparency. The EC suggested that EU member states adopt the COP principles in their national guidelines and regulations and encourage their universities and public research organisations to also adopt practices compatible with the COP. Compliance with principles 1 and 2 are required as part of the funding conditions for R&D under the Framework Programme "Horizon 2020" (European Commission 2013, pp. 53-54). The mandatory principles (1 and 2) cover the publication of IP policies and the provision of clear rules for staff and students regarding the disclosure of new ideas with potential commercial interest, the ownership of research results, record keeping, the management of conflicts of interest and engagement with third parties.

This chapter uses the results of two surveys conducted in 2011 and 2012 of European Knowledge Transfer Offices (KTOs) to examine the influence of several recommended principles on knowledge transfer outcomes. Responses were obtained from 247 leading research universities and 40 public research institutes located in 32 European countries. The results permit an evaluation of a greater range of policies than possible for single country studies. Most previous research is based on a single country, such as research using the US Association of University Technology Managers (AUTM) dataset (see for instance Friedman and Silberman 2003; Lach and Schankerman 2004, 2008), Caldera and Debande’s (2010) study of Spanish universities and Okamuro and Nishimura's (2013) Japanese study). One of the few exceptions using a multi-country dataset is Conti and Gaule (2011), but this study does not include policy variables.

The analyses presented below address several gaps in the academic literature on the relationship of university policies on the knowledge transfer performance of KTOs. First, we examine the influence of a broader range of policies than available in other studies, with data on policies for IP, licensing and start-up activities. Second, we distinguish between internal policies that affect mainly faculty and staff and published policies; publishing a policy and communicating its content to potential transfer clients potentially reduces the opportunities for negotiation of terms, with consequences for licensing agreements. Third, we include incentives for non-financial benefits. Currently, financial incentives dominate the literature. For brevity, the multivariate analyses focus on four outcomes: two that are closer to research (the number of research agreements and patent applications) and two that are closer to the market (the number of license agreements and start-ups established).

2. Research on knowledge transfer performance

Previous studies have evaluated a range of factors that can affect knowledge transfer performance, including the characteristics of the KTO, the characteristics of the affiliated institution, market characteristics, and of particular interest to this chapter, policies that can affect knowledge transfer outcomes.

2.1 Characteristics of the KTO

Several KTO features such as its age, size and experience of its staff can influence knowledge transfer performance. Previous research has established that older KTOs with presumably more experienced staff perform better (e.g. Conti and Gaule 2011; Curi et al. 2012; Link and Siegel 2005; Siegel et al. 2003a). In addition, the number of KTO employees has been found to increase performance (e.g. Conti and Gaule 2011; Owen-Smith and Powell 2001; Rogers et al. 2000; Siegel et al. 2003a; Thursby and Kemp 2002), with some exceptions. Chapple et al. (2005) found a negative relationship between KTO size and transfer efficiency in UK universities and Van Looy et al. (2011) found no correlation between KTO size and patent applications and contract research. Using the British HEFCE dataset, Hewitt-Dundas (2012) argues that it is not the size of the KTO, but the alignment of organisational support and strategic priorities that influences success. A related factor is the characteristics of KTO staff, with low turnover (conducive to greater experience) and business and marketing expertise improving transfer success (Conti and Gaule 2011; Siegel et al. 2003b).

Researchers have examined several organisational characteristics and strategies used by KTOs, including: the autonomy of KTOs in respect to the institution that they serve (Conti and Gaule 2011; Markman et al. 2009; Siegel et al. 2003a), their organizational structure and degree of centralization of services (Bercovitz et al. 2001; Debackere and Veugelers 2005; Schoen et al. in print), and transfer strategies (Belenzon and Schankerman 2009; Caldera and Debande 2010; Friedman and Silberman 2003; Litan et al. 2007). Whereas organisational autonomy seems to improve outcomes, the influence of organisational structure and transfer strategies on performance are ambiguous.

2.2 Institutional characteristics

Several characteristics of universities or public research institutes can influence performance. These include ownership (public-private), size, the presence of science or medical faculties, research excellence and business orientation (Baldini 2009; Belenzon and Schankerman 2009; Caldera and

Debande 2010; Curi et al. 2012; Sapsalis et al. 2006; Schartinger et al. 2001; Thursby et al. 2001; Thursby and Kemp 2002; Van Looy et al. 2011).

2.3 Institutional policies

Research on the influence of policies on performance outcomes is quite heterogeneous, looking at entire strategies or sets of institutional rules and practices, as well as at specific rules. Prominent topics in the literature are 1) incentives for faculty and staff, 2) IP policies, and 3) start-up strategies, support infrastructure and rules.

1) Incentives for faculty and staff. Several studies have found a lack of financial incentives to be an important barrier for knowledge transfer (Siegel et al. 2003a; Siegel et al. 2004; Woolgar 2007) while the provision of financial incentives has a positive influence on transfer performance in many countries: the US (e.g. Lach and Schankerman 2004; Lach and Schankerman 2008; Link and Siegel 2005), Italy (Baldini 2010), Spain (Caldera and Debande 2010), or Japan (Woolgar 2007). Providing a share of revenues to the inventor's department is positively related to licence income (Markman et al. 2009), unrelated to start-ups (Markman et al. 2004) and negatively related to licences executed (Friedman and Silberman 2003).

Other types of financial incentives, as well as non-financial benefits which do not consist of direct and personal payments to the inventor, such as social rewards, additional R&D funds, or the inclusion of transfer successes in promotion and career decisions have not been examined.

2) IP policies. In some countries, IP ownership rules and other relevant regulations are determined nationally and can influence the performance of individual universities or public research institutes (Colyvas et al. 2002; Conti and Gaule 2011; Geuna and Rossi 2011; Goldfarb and Henrekson 2003; Valentin and Jensen 2007). University by-laws on IP can act as a stimulus to promote patenting (Baldini et al. 2006; Baldini 2010), whereas these by-laws have not been found to affect licensing agreements (González-Pernía et al. 2013). Wright et al. (2008) find that the use of identical patent policies across institutions can help to attract the R&D activities of larger companies. Conversely, Okamuro and Nishimura (2013), in a study of Japanese

companies, find that university IP policies which flexibly meet firms' needs have a positive influence on the number of patents and new products produced by university-industry collaborations.

Little research has been conducted on the influence of rules that complement knowledge transfer. A study of Spanish universities found that rules on conflicts of interest are correlated with a higher number of university-industry R&D contracts, income from such contracts, licences executed, income from licences and the number of start-ups (Caldera and Debande 2010). Conversely, the same study finds that rules on R&D contracts that stipulate the participation of the institution in any benefits from commercialisation reduce the number of contracts.

3) Start-up strategies, support infrastructure and rules. The literature on institutional start-up policies covers a wide number of issues. The existence of a start-up program, not surprisingly, correlates with a higher number of start-ups (Caldera and Debande 2010). Other research finds that different institutional start-up models generate different numbers and types of start-ups (Clarysse et al. 2005). The "low selective model" creates internally an entrepreneurial climate and reduces institutional barriers, but it offers little support and survival is left to market forces. The "supportive model" gives extensive support to academic entrepreneurs in the pre-start-up phase; while in the "incubator model" companies are spun off in a late stage after receiving support from the institution to prepare them for this step. Such spin-off policies have been found to affect the growth potential of ventures (Clarysse et al. 2005; Degroof and Roberts 2004).

A few studies examined the influence of supporting infrastructure and rules. The presence of an incubator did not raise the number of start-ups from American universities (Di Gregorio and Shane 2003), but it correlated positively with spin-offs in a Spanish study (González-Pernía et al. 2013). Rules on spin-off involvement that grant temporary leave to academics are positively correlated with the number of spin-offs (Caldera and Debande 2010). Lerner (2004) argues that too vigorous conflict-of-interest regulations can have a chilling influence on entrepreneurial activity. The possibility to take equity stakes can increase start-up rates (Di Gregorio and Shane 2003).

2.4 Main focus of this research

This chapter focuses on the influence of three sets of policies: financial and non-financial incentives to faculty and staff to become involved in knowledge transfer, codifying policies by developing written documents and streamlining IP management and transfer practice, and the influence of publishing policies and raising transparency.

Based on the literature review, we test five hypotheses:

H1. Financial incentives have a positive influence on transfer outcomes.

H2. Non-financial incentives have a positive influence on transfer outcomes.

H3. Codified transfer policies for internal staff and faculty have a positive influence on transfer outcomes.

H4. Publishing transfer policies so that they are available to businesses has a positive influence on transfer outcomes which are close to research.

H5. Publishing transfer policies has a negative influence on transfer outcomes which are close to the market.

H1 is strongly suggested by previous research. H2 is open to discussion, but we would expect that non-financial incentives could also increase commitment to knowledge transfer. The latter could have a stronger impact on transfer outcomes that are closer to research, as non-financial incentives are more closely related to the Mertonian norms of science (Merton 1996) than to commercialization. For other reasons we might get a similar result for H3: codifying policies will raise internal awareness of IP and transfer issues and ensure greater efficiency through the development of consistent practices. H4 follows from H3 by improving client expectations. With regard to H5, we point to Okamuro and Nishimura (2013): publishing policies might limit the flexibility in dealing with external clients.

3. Methodology

3.1 Data collection

Data were collected through two separate surveys in 2011 and 2012. Each survey referred to the preceding year (2010 and 2011). The European Knowledge Transfer Indicator Survey (EKTIS) collected data on the characteristics of KTOs (number of employees, age, etc), a few characteristics of the affiliated university or public research institute, who owns the intellectual property for discoveries, and data on performance outcomes for 2010 and 2011.

The surveys focused on the leading research-intensive universities and research institutes in 39 countries including the 27 EU member states and 12 associate countries. The response rate for the EKTIS survey was 57.0% in 2011 and 55.9% in 2012. The second survey used a sub-sample of EKTIS respondents to collect information on institutional and national policies for knowledge transfer and attained a response rate of 50.0% in 2011 and 39.8% in 2012. Full details on the survey methodology plus copies of the two questionnaires are provided by Arundel et al. (2013).

The two sets of survey data were then linked. The number of cases for analysis is increased by including all respondents for at least one of the two surveys. If a respondent replied to both surveys, the results for the most recent year (2011) are used. Since economic conditions, research funding and knowledge transfer policies in Europe did not change notably between 2010 and 2011, any biases due to combining years should be minor. The linked dataset includes 170 cases for which 2011 data are available and 118 cases for which only 2010 data are available.

3.2 Variables

There are four dependent variables for performance: the number of patent applications and three variables that measure the potential for transferring commercially valuable knowledge to private firms, the number of research agreements with firms, the number of licenses, and the number of start-ups established. These performance measures have been widely used in previous research. Although a patent is not required for knowledge transfer, the number of patent applications is included in the output variables because of previous research showing a strong link for European universities between licensing and patented inventions (Arundel and Bordoy 2009). Research agreements can be further from commercialisation than licensing or start-ups, but they can also involve solving specific problems with existing products or processes and they have been neglected in previous work (with the exception of Caldera and Debande 2010; Van Looy et al. 2011).

The data are based on the awareness of KTO managers of the transfer of knowledge owned and commercialized by their office. As some organisations or countries permit the assignment of IP rights to inventors, this will underestimate the total knowledge transfer output of a university or research institute to the extent that some inventor-owned IP is commercialised through the assistance of organisations other than the responsible KTO (Lissoni et al. 2008). Consequently, the results of this study only apply to institutional knowledge transfer via the KTO. In our database, 61.5% report that only the institution or "companies that fund research conducted by your institution" owns the IP, 9% report that only the inventor or 'others' own the IP, and 29.5% report that IP can be owned by either the inventor, the institution, companies or others. We use this information to control for the possibility that inventors or others own the IP generated at the institution. The variable ownership equals 1 if only the institution or funders own the IP and 0 if inventors/others have the right to IP as well or exclusively. Company ownership is combined with institutional ownership because the KTO is highly likely to be aware of the research outputs of company funded research, since KTOs normally draw up the governing legal agreements.

Although data are available for license income, we do not provide regression results for this variable because of a lack of data over a sufficiently long time period. The amount of income earned in 2010 or 2011 can depend on inventions that were made long before the survey reference year, when the values of the independent policy variables may have been very different from their values in 2010 or 2011.

The independent variables of interest include four types of COP policy variables.

The first policy variable consists of who owns the intellectual property from a discovery made at the institution. The variable 'IPR owned by the inventor' equals 1 when the inventor owns the intellectual property and 0 otherwise.

The second type of policy variable concerns the availability of written rules to prevent potential conflicts. The variable 'Rules on IP ownership' equals 1 when the institution has rules for who owns the intellectual property and 0 otherwise. The second variable, 'rules for conflicts of interest' equals 1 when there are rules to manage conflicts of interest and 0 otherwise.

The third type of policy variable concerns the availability of written and published rules on intellectual property, licensing policy, and start-up policies. The variables for a 'Written Policy' equal 1 when the institution has a written document for the relevant policy, but it is only available to staff of the institution. The variables for a 'Published policy' equal 1 when there is a written policy that is available both to internal staff and externally to the public. The reference category of 0 occurs when no written policy is available. Separate written and published policy variables are provided for IP, license, and start-up policies.

The final type of policy variable is for incentives for the protection of IP or its exploitation. Four variables cover direct financial benefits to the inventor: 'Percent of revenues', 'Lump sum payment' and 'Higher salary' (for each 1 if the inventor receives the incentive and 0 otherwise). In addition, the 'Inventor share' is the percentage of revenue from licencing given to the inventor. Three variables cover non-financial benefits to the inventor: 'Promotion decisions', referring to taking success in protecting or exploiting IP in promotion and career decisions into account; 'Social rewards' in case of awards or publicity; 'Funding for research', if additional funds for the inventors' R&D are provided. Finally, one variable covers a financial benefit to the inventor's department: 'Departmental share' is the percentage of revenue that is given to the department, institute, or other unit with which the inventor is affiliated.

In addition to IP ownership (see above) we include further control variables which cover the key influences on transfer performance as assessed in the literature. Two KTO variables include the number of employees and KTO age (equal to 1 if the KTO was established before January 2000 and 0 otherwise). The three institutional variables include the number of researchers (research output is expected to be closely correlated with this variable), if the institution has a hospital, (1 when present and 0 otherwise), and the type of institution (1 when a university and 0 if a public research institute). The variable for the presence of a hospital is included to capture activity in health sciences while the type of institution is an important factor in the use of licensing and start-ups. The full data set shows that the former is more common in public research institutes and the latter is more common in universities. We do not include a control variable for university ownership status (private or public) as almost all universities in our sample are publicly owned.

3.3 Analytical methods

All independent variables are measured as counts. We tested for overdispersion, i.e. whether the conditional variance equals the conditional mean of the dependent variable, as described in Cameron and Trivedi (1998: 77-79) and found significant overdispersion for all four dependent variables. This rules out the use of a Poisson model and consequently we chose the Negative Binomial model instead.

As there are large numbers of zero responses for patent applications, license agreements and start-ups (see Table 1), we also estimated zero-inflated negative binomial models (ZINB) as part of the sensitivity analysis. The ZINB model assumes that the zero outcomes are due to two different processes (Long et al. 2006). For instance, in our data, the two processes could be that a) an institution has not participated in one type of formal knowledge transfer activities (and consequently reports 0 output) or b) that it participated but without success. The two parts of a zero-inflated model are a binary model, in this case a logit model to model which of the two processes the zero outcome is associated with, and a (negative binomial) count model to model the count process. To differentiate between the two processes an inflation variable is needed which we lack in our cross-sectional dataset. We approximated it with invention disclosures (for patent applications) and patent applications (for license agreements and start-ups) of the same year. The results of the ZINB models do not differ in any meaningful way from the Negative Binomial results provided below, indicating that these results are reasonably robust.

Due to the cross-sectional nature of the data, it is not possible to unambiguously identify cause and effect, for example whether policies drive performance or if institutions alter their policies as a result of performance outcomes. However, the latter is more likely to occur in response to poor performance, which would reduce the ability to identify policies with a positive effect on outcomes.

The regressions were first conducted using a dummy variable for the survey year (2011 versus 2010). The variable had no effect on any of the results except for the number of licenses, indicating that license activity declined in 2011. However, the variable for year had no effect on any of the policy variables and is consequently not included in the final regressions given below.

As we included up to 18 variables in the estimations, we also checked for multicollinearity and calculated the variance inflation factors and condition numbers. These tests indicated that multicollinearity is not a problem for our estimations. A correlation table of the independent variables can be found in the appendix.

In order to identify the influence of the key variables of interest on our dependent variables, we entered them stepwise into the models. For each dependent variable, the model 1 regressions are limited to the control variables with subsequent models including additional variables. Model 2 adds the policy codification variables, model 3 the transparency rules, models 4 and 5 financial incentives, and model 6 financial and non-financial incentives for the inventor. For the regressions for the number of start-ups, the control variable for KTO age is not included (with one exception) because it was never statistically significant and excluding this variable increased the sample by 18 cases that had not provided this information. Each table includes the AIC value (Akaike Information Criterion), a goodness-of-fit measure in which smaller values are preferable.

4. Descriptive results

On average, the universities in our sample reported 14.3 patent applications, 11.3 executed licenses, 5.2 start-ups and 170.5 research agreements (see Table 1). The performance of research institutes is comparable, except for a lower average for start-ups and a higher average for research agreements. A large percentage of institutions report zero values for each outcome, particularly for the number of start-ups, with 33.2% of universities reporting no start-ups in the reference year. The median values are considerably lower than the arithmetic means for most indicators, indicating a few institutions with high values, particularly for research agreements.

Table 1. Key performance indicators for universities and public research institutes

	Universities				Research institutes			
	N	Mean	Median	Percent zero[1]	N	Mean	Median	Percent zero[1]
Patent applications	228	14.3	6	18.4	38	14.6	6.5	10.5
Licenses executed	200	11.3	3.5	24.5	37	13.7	3	24.3
Start-ups formed	214	5.2	2	33.2	38	1.3	1	34.2
R&D agreements with companies	161	170.5	68	4.3	31	249	30	0.0

1: Percent reporting 'zero' for each outcome. For example, 18.4% of 228 universities reported zero patent applications in 2010 and/or 2011.
Source: MERIT, European Knowledge Transfer Indicator Survey 2011 and 2012.

Tables 2, 3 and 4 provide the number and percentage of universities and other research institutes that reported specific types of policies. Table provides results for policies to make university knowledge transfer activities clear and transparent to staff or firms. The most common policy consists of rules on who owns the IP, reported by 86.1% of universities. Of interest, far fewer universities and research institutes make their policies publicly available. For example, 69.4% of universities have a written IP policy available for internal staff, compared to only 29.3% who made this policy publicly available. The lowest level of codification is for licensing policies, with only 26.9% of universities providing a written license policy and only 7.2% making their license policy publicly available. Start-up policies are written down in almost four out of ten institutions, but only published by 17.1%.

Table 2. Codification and transparency of knowledge transfer policies of the affiliated institution

	Universities			Research institutes		
	N	Yes	Percent	N	Yes	Percent
IP policy includes rules on IP ownership	245	211	86.1	40	36	90.0
IP policy includes rules for conflict management	245	123	50.2	40	20	50.0
Institution has a written IP policy	232	161	69.4	38	22	57.9
Institution has published the IP policy	232	68	29.3	38	4	10.5
Institution has a written licence policy	223	60	26.9	36	9	25.0
Institution has published the licence policy	223	16	7.2	36	1	2.8
Institution has a written start-up policy	228	89	39.0	37	22	59.5
Institution has published the start-up policy	228	39	17.1	37	4	10.8

Source: FHNW, European Knowledge Transfer Practice Surveys 2011 and 2012. Written policies are only available for internal staff, while published policies are publicly available.

Table 3 provides the percentage of universities and research institutes that provide incentives for researchers and students to protect and exploit IP, while Table 4 gives the average distribution of license revenues. As shown in Table 3, the most common incentive, reported by 82.5% of universities, is to provide researchers with a percentage of the revenues. Salary upgrades are reported by only 6.7% of universities.

Table 3. Provision of incentives for researchers and students to protect and exploit IP

	Universities			Research institutes		
	N	Yes	Percent	N	Yes	Percent
Percentage of revenues	223	184	82.5	37	31	83.8
Social rewards (e.g. awards, publicity)	224	125	55.8	37	15	40.5
Additional funds for R&D	224	76	33.6	37	12	32.4
Inclusion in promotion and career decisions	224	56	25.0	37	12	32.4
Lump-sum payments	223	52	23.3	37	14	37.8
Salary upgrades	224	15	6.7	37	2	5.4

Source: FHNW, European Knowledge Transfer Practice Surveys 2011 and 2012.

Table 4 provides the average distribution of knowledge transfer revenues by the type of recipient. On average, the inventor and other researchers at universities obtain 42.8% of the revenues, with the KTO receiving slightly below 7%.

Table 4. Average shares of revenues from IP by recipient

	Universities		Research institutes	
	N	Percent	N	Percent
Inventors or researchers from the institution	184	42.8	36	26.3
Institution	184	28.5	36	48.1
Department, institute, or other institutional subunits	184	19.0	36	21.5
KTO or other intermediaries[1]	157	6.8	33	3.6
Other beneficiaries	184	2.9	36	0.5
Total		100.0		100.0

1: KTO shares were collected separately only in 2012.

Source: FHNW, European Knowledge Transfer Practice Surveys 2011 and 2012.

5. Regression results

5.1 Research agreements

Table 5 gives regression results for the number of research agreements. The variation in the number of cases is due to missing responses, which is greatest for the interval level variables for revenue sharing. The control variables show significantly strong positive correlations with the number of researchers and founding date of the KTO, a small influence of KTO size. No significance is found for the presence of a hospital, ownership by the inventor, and type of institution (university or research institute).

Several methods to increase the transparency of IP and licensing policies have no significance, including rules for IP ownership and conflicts of interest and a published license policy. A written IP policy and a written licensing policy have a significant positive relationship; however, they are no longer significant once the incentive variables are added in the regressions. Conversely, publishing the IP policy is positive and weakly significant only when incentives are included (models 4-6).

The only incentive that always increases the number of research agreements is to provide a higher salary to inventors that protect or exploit IP. A higher departmental share of revenues also improves performance, but the inventor share has no significance. Of note, these incentives refer to license income. Only a minority of research agreements are likely to lead to license income in the future, which may explain why the security of higher staff salaries is the most effective incentive for inventors. Of the non-financial incentives, funding for the inventor's research is negative – possibly because it reduces the need to enter into research agreements (model 6).

Table 5. Number of research agreements in the previous year

Model	1	2	3	4	5	6
N	159	148	148	123	123	141
AIC	1909.98	1780.34	1783.91	1496.65	1496.74	1699.98
Number of researchers	.375***	.384***	.377***	.268***	.289***	.319***
Number of KTO employees	.019**	-.001	-.002	.023*	.020*	.007
Presence of Hospital[1]	-.200	-.221	-.208	-.306	-.347	-.272
University[2]	.000	.036	.026	.312	.254	.147
IPR Owned by inventor[3]	.243	.204	.214	.180	.215	.173
KTO age[4]	.421**	.437**	.446***	.310	.345*	.423**
Policy codification and transparency						
Written IP policy		.592***	.594***	.051	.081	.304
Published IP policy		.260	.245	.574**	.544**	.415*
Written licence policy		.451**	.444**	.134	.147	.338
Published licence policy		-.368	-.381	-.623	-.585	-.187
IP ownership rules			.163	.078	-.006	.641
Conflict of interest rules			.053	-.161	-.155	-.134
Inventor incentives						
Percent of revenues[5]				.230		.096
Lump-sum payment[5]				.339	.383*	.322
Higher salary[5]				.998**	.818**	.947***
Revenue sharing						
Departmental share				.014***	.015***	
Inventor share					.005	
Non-financial inventor incentives						
Promotion decisions[5]						.300
Funding for research[5]						-.415**
Social rewards[5]						-.078

* = p <.10, ** = p <.05, *** = p<.01

1: Reference category is no hospital; 2: Reference category is a research institute, 3: Reference category is IP owned by the institute or by firms; 4: Reference category is establishment after 2000; 5: binary variables where 1 = use of incentive.

5.2 Number of patent applications

Table 6 gives results for the number of patent applications. The number of researchers has a consistent significant positive correlation. The number of KTO employees is also positive and significant (except in model 3). When the IP is owned by the inventor the coefficient is positive but only significant when we include variables on incentives as well. The founding date is positive, indicating more applications by older KTOs, but only significant in two models. The existence of a hospital and the type of institution are insignificant.

Policy codification and transparency tends to increase the number of patent applications. The variable for a written IP policy is positive and statistically significant in models 2 and 3. Publishing the IP policy is positive and statistically significant in models 4 and 5. Rules for IP ownership and conflicts of interest are consistently positive, but rarely significant.

Similar to the results for research agreements, a higher salary to inventors consistently increases the number of patent applications. A lump sum payment for inventors is significant in models 4 and 5. Giving the inventor a share of the revenues is positive in model 6, but the actual size of the inventor share (measured as continuous variable) has no influence (see model 5). There are no significant results for the departmental share of license income and all non-financial incentives.

Table 6. Number of patent applications in the previous year

Model	**1**	**2**	**3**	**4**	**5**	**6**
N	213	203	202	158	158	191
AIC	1494.15	1419.63	1409.69	1101.42	1101.53	1345.64
Number of researchers	.255***	.277***	.291***	.163***	.170**	.245***
Number of KTO employees	.023***	.017**	.013	.024***	.023**	.014*
Presence of Hospital[1]	.045	-.010	.084	.278	.317	.123
University[2]	.031	.065	.057	.133	.074	.088
IPR Owned by inventor[3]	.238	.243	.259	.326*	.350*	.306*
KTO age[4]	.245	.270*	.224	.299	.377**	.233
Policy codification and transparency						
Written IP policy		.581***	.451**	.176	.234	.166
Published IP policy		.086	.090	.424**	.397*	.276
IP ownership rules			.244	.303	.356	.173
Conflict of interest rules			.333**	.266	.266	.231
Inventor incentives						
Percent of revenues[5]				.255		.500**
Lump-sum payment[5]				.429**	.479**	.244
Higher salary[5]				1.346***	1.189***	.737**
Revenue sharing						
Departmental share				-.002	-.001	
Inventor share					.005	
Non-financial inventor incentives						
Promotion decisions[5]						.101
Funding for research[5]						.096
Social rewards[5]						.184

* = p <.10, ** = p <.05, *** = p<.01

1: Reference category is no hospital; 2: Reference category is a research institute, 3: Reference category is IP owned by the institute or by firms; 4: Reference category is establishment after 2000; 5: binary variables where 1 = use of incentive.

5.3 Number of licenses

Table 7 gives results for the number of licenses. The variables for the number of researchers and the size of the KTO are positive and statistically significant. Universities have significantly fewer licenses than the reference category of research institutes. The ownership of IP has no significant correlation, but the age of the KTO and the presence of a hospital have a significant and positive correlation in several models.

The variable for IP ownership rules is positive and significant in models 4 and 5 which also include variables for financial incentives. A written or published IP policy has no influence in any of the models, but a written licence policy has a significantly strong positive correlation in all models. Of interest, making the license policy publicly available has a negative correlation in several estimations, particularly in model 6, which includes non-financial incentives. The greater importance of an internally transparent versus an externally transparent licensing policy could reflect the need for flexibility in negotiations with firms. A published licence policy could indicate less flexibility in licensing negotiations, leading to fewer licence contracts. Semi-structured interviews with companies and transfer offices suggest that companies back off if universities' ideas in licence contract negotiations are incompatible with their own views (Arundel et al. 2013).

In contrast to the results for the number of research agreements and patent applications, a higher inventor salary has no significant relationship with the number of licenses while a lump-sum payment has a significant negative correlation, but only in model 6 when non-monetary incentives are included. The existence of a rule that reserves a percentage of the revenues for the inventor is strongly positive, but the actual size of the inventor share (measured as a continuous variable) has no influence (see model 5). Conversely, the departmental share is positive and statistically significant. For the non-financial incentives, we only find a weak negative correlation for giving more research funds to the inventors as a premium for being involved in transfers (model 6).

Table 7. Number of licenses in the previous year

Model	1	2	3	4	5	6
N	197	184	183	146	146	173
AIC	1262.16	1149.93	1145.30	925.55	935.25	1094.18
Number of researchers	.172***	.232***	.235***	.084**	.129***	.189***
Number of KTO employees	.034***	.018**	.017**	.029***	.024***	.017*
Presence of Hospital[1]	.287	.411*	.374	.388	.424*	.446*
University[2]	-.469**	-.463**	-.455**	-.530**	-.506*	-.673***
IPR owned by inventor[3]	-.083	-.112	-.108	-.229	-.242	-.095
KTO age[4]	.355**	.215	.198	.389**	.520***	.152
Policy codification and transparency						
Written IP policy		.266	.178	-.069	.203	-.106
Published IP policy		.282	.286	.034	-.023	.253
Written licence policy		.948***	.927***	.674***	.741***	.928***
Published licence policy		-.648*	-.666*	-.481	-.403	-.855**
IP ownership rules			.217	.974**	.982**	.184
Conflict of interest rules			.083	-.066	-.036	.005
Inventor incentives						
Percent of revenues[5]				1.187***		1.165***
Lump-sum payment[5]				-.279	-.204	-.401**
Higher salary[5]				.347	-.157	.445
Revenue sharing						
Departmental share				.017***	.015**	
Inventors share					.006	
Non-financial inventor incentives						
Promotion decisions[5]						.119
Funding for research[5]						-.334*
Social rewards[5]						.354*

* = p <.10, ** = p <.05, *** = p<.01

1: Reference category is no hospital; 2: Reference category is a research institute, 3: Reference category is IP owned by the institute or by firms; 4: Reference category is establishment after 2000; 5: binary variables where 1 = use of incentive.

5.4 Number of start-ups established

Table 8 gives the results for the number of start-ups established in the previous year. The variables for the number of researchers and KTO employees are positive and significant. The variable for university is positive, indicating that universities produce more start-ups than research institutes (5.2 compared to 1.3, see Table 1). When the IP is owned by the inventor, the coefficient is consistently negative and significant in several models. This could suggest that inventors that own the IP are less interested in establishing start-ups, and perhaps prefer to license inventions. While there is no significant relationship found for this variable with the number of licenses in Table 7, this explanation is still possible, as Table 7 covers licence agreements of the institution, whereas we would have to look at licence contracts of inventors (not available) to properly evaluate the argument. However, another explanation could be that our survey respondents (the KTOs) are not fully aware of all start-ups, particularly if inventors own the IP and establish start-ups outside the purview of the KTO.

With the exception of IP ownership rules, policy codification and transparency reduce the number of start-ups. The variable for a published IP policy is consistently negative and statistically significant. Neither a written nor published start-up policy has any influence. Rules for conflicts of interest are consistently negative, suggesting that these dampen the interest of university staff in participating in start-ups.

A higher salary has a significantly strong negative correlation in models 4 and 5, possibly because an increase in salary reduces inventor interest in supporting a start-up. Giving the inventors a share of the revenue raises the number of start-ups as well (model 6) and the size of this share also seems to matter (model 5). The departmental share is not significantly correlated with the number of start-ups. Similar to the results for license agreements, social rewards to the inventors have a statistically significant and positive effect on the number of start-ups. The social award effect could be due to the prestige of establishing a company. However, funding for the inventor's research has a significant negative correlation, suggesting that it reduces the incentives for inventors to establish a start-up or provide support for an independent start-up that uses the inventor's IP.

Table 8. Number of start-ups established in the previous year

Model	1	2	3	4	5	6
N	207	211	211	161	161	198
AIC	918.22	1062.93	1057.40	813.11	801.37	993.91
Number of researchers	.173***	.158***	.176***	.146***	.202***	.190***
Number of KTO employees	.011	.025***	.026***	.030***	.019*	.027***
Presence of Hospital[1]	-.394*	-.540**	-.644***	-.596**	-.474*	-.724**
University[2]	1.102***	1.493***	1.474***	1.287***	1.040***	1.450***
IPR owned by inventor[3]	.291	-.310*	-.302*	-.350*	-.211	-.157
KTO age[4]	.094					
Policy codification and transparency						
Written IP policy		.112	.058	.165	.503*	-.348
Published IP policy		-.605***	-.604***	-.593**	-.816***	-.426*
Written start-up policy		.202	.168	-.090	-.030	.073
Published start-up policy		-.181	-.121	-.067	-.090	-.072
IP ownership rules			.752**	.956**	1.038**	.694*
Rules for conflict of interest			-.414**	-.385**	-.204	-.559***
Inventor incentives						
Percent of revenues[5]				.198		.895***
Lump-sum payment[5]				.085	.210	.033
Higher salary[5]				-.745*	-1.103**	.196
Revenue sharing						
Departmental share				-.005	.003	
Inventors share					.023***	
Non-financial incentives						
Promotion decisions[5]						.093
Funding for research[5]						-.510***
Social rewards[5]						.763***

* = p <.10, ** = p <.05, *** = p<.01

1: Reference category is no hospital; 2: Reference category is a research institute, 3: Reference category is IP owned by the institute or by firms; 4: Reference category is establishment after 2000; 5: binary variables where 1 = use of incentive.

5.5 Does policy drive performance or vice versa?

For both licenses and start-ups, publishing the license and start-up policies either reduces the number of outcomes (as for licenses) or has no significance (for start-up policies). A possible explanation for these results is that poorly performing KTOs try to improve their performance by implementing publication policies, perhaps as part of marketing transfer opportunities. This hypothesis is difficult to test with the available cross-sectional data. One option is to conduct separate regressions for KTOs that perform below and above the median in terms of the number of licenses or start-ups per 1,000 researchers. If publishing a policy reduces outcomes for both groups, then it is unlikely that the cause is due to a change in policy by poor performers to improve their performance. However, if publishing a policy has a negative statistical relationship in the poor performing group and a positive relationship in the high performing group, then the poor performers could be implementing publication policies to improve their performance.

Table 9 provides summary results for a test of this hypothesis (the estimations include the control variables, but for simplicity they are excluded in Table 9). The results in the first half of Table 9 show that publishing the license policy has a significant negative correlation with the number of licenses for both the poor and good performing groups, while the coefficients for publishing the IP policy are consistently positive, but only statistically significant for the below median group. The second half of Table 9 gives the results for KTOs that perform below and above the median for start-ups. The results show that publishing the IP policy is significantly negative for the group above the median but not for the group below the median. Publishing the start-up policy is not statistically significant in both groups, but the relationship is negative in all but one model. These results do not suggest that poor performing KTOs publish their policies to improve their performance.

Table 9. Number of licenses and start-ups in the previous year by group performance

	Above median performance		Below median performance	
Model	**1a**	**2a**	**1b**	**2b**
		Number of license agreements		
Written IP policy	.088	.106	-.758*	-.718
Published IP policy	.433	.433	.694*	.674
Written licence policy	.675***	.658**	.854**	.843**
Published licence policy	-.859*	-.851*	-2.710**	-2.627**
IP ownership rules		-.111		.273
Conflict of interest rules		.037		-.121
N	92	91	92	92
		Number of start-ups		
Written IP policy	.217	.177	.194	.325
Published IP policy	-.608**	-.625**	-.085	.047
Written start-up policy	.107	.031	.982**	1.160**
Published start-up policy	-.436	-.280	.133	-.115
IP ownership rules		.713*		1.521
Conflict of interest rules		-.548**		-.543
N	109	109	102	102

* = p <.10, ** = p <.05, *** = p<.01.

Note: The median is 2.5 per 1,000 researchers for license agreements and 0.96 per 1,000 researchers for start-ups. The drop in cases is due to unreported values for the independent variables.

6. Discussion and Conclusions

This chapter uses survey data to examine the correlation between policies that are expected to support knowledge transfer and four knowledge transfer outcomes for leading European universities and public research institutes. The four outcomes are the number of patent applications, research agreements, licenses, and start-ups established in the year preceding the survey. The patent application outcome is the furthest from the market, but is a key goal for many universities and research institutes because of the positive link between patenting activity and license income. Research agreements can produce discoveries that can be quickly commercialised, or they may produce results that will take a long time, if ever, to be commercially valuable. In contrast, licenses and start-ups are much closer to the market. Firms will not license a discovery without an expectation of future commercial opportunities and private investors will similarly expect a future return from start-ups, even though many start-ups will fail.

6.1 Codifying and publishing IP and transfer policies

The European Commission's (2008) principles for knowledge transfer policies stress the value of specific policies, examined in this study, for supporting knowledge transfer outcomes that lead to commercialisation. These include clear IP ownership and conflict of interest rules to minimize disputes, the codification and publication of policies for IP, licensing and start-ups; and incentives that encourage inventors to protect IP and support its exploitation by firms. After controlling for several characteristics of the KTO and the number of researchers in the university or research institute, we find that none of these policies have a consistently positive correlation with all four outcomes. A few policies tend to show more negative than positive correlations, while the benefits of other policies vary by the type of outcome. The fact that we are unable to detect generalizable (across all outcomes) and positive correlations suggests that 1) more research is needed on institutional policies and their influence and 2) that the COP should be implemented carefully until we have better understanding of how policies affect performance.

Clear rules on IP ownership have positive benefits for the two outcomes that are closest to commercialisation, possibly because they make it easier to determine who is to receive a share of future revenue from licensing or start-ups. In contrast, conflict of interest rules have no significant relationship with licensing but a strong negative correlation with the number of start-ups (as suggested by Lerner 2004). We do not know the reasons behind this, but possibly such rules discourage engagement in start-ups or are a proxy for an unfavourable institutional environment for academic entrepreneurship. This result conflicts with Caldera and Debande (2010), who find that rules for conflicts of interest have a positive correlation with both the number of licenses and the number of start-ups. The difference in results could be due to the smaller sample size in the Caldera and Debande study, which limited the analyses to one policy variable per regression, whereas our analyses simultaneously control for the influence of multiple policies.

The goal of providing codified, written policies on IP, licensing, and start-ups to the staff of university or research institutes is to ensure that all staff understand the potential benefits of commercialisation and to contribute to consistent management of different projects. Yet the influence of written policies is inconsistent, such that hypothesis H3 is only partly confirmed. Written IP policies only have a significant positive correlation with early-stage outcomes (research agreements and patent applications), but this correlation is lost once policies for incentives are included in the models. Inventors that respond to incentives may not need a written IP policy, but the implication is that the policy has little influence on researchers that have not yet participated in protecting or exploiting their IP. A written start-up policy has no correlation with the number of start-ups. The only consistent and positive written policy is for licensing, which generally has a positive correlation with the number of research agreements and a large and positive correlation with the number of licenses.

The next step is to publish policies to make them available to potential transfer clients. The results show that publishing the IP policy has a significant positive correlation on the number of research agreements and patent applications once incentives are also included in the model but has no correlation with the number of licenses and tends to have a negative correlation with the number of start-ups. In respect to publishing the license policy, there is no influence for research agreements, but a strong correlation for licenses, while a published start-up policy has no correlation with the number of start-ups. These results confirm H5 and partially H4 and point to a complex relationship between policy content, transparency, and transfer success. A possible explanation for the negative correlation with published policies is that they reduce room for negotiations between universities or research institutes and private firms, or at worst scare away potential private sector investors. This supports Okamuro and Nishimura's (2013) findings that companies appreciate flexible IP policies; at least to some extent. The alternative explanation that poorly performing KTOs introduce publication policies in order to improve their performance is unlikely, given the results of Table 9 that show that publication policies do not improve the performance of institutions with above average performance for licensing and start-ups.

In sum, these results suggest that universities and research institutes should carefully consider what rules their transfer policies include and what they publish, as the results will vary between transfer performance measures. For instance, an institution that aims to raise its licence agreements should ensure that it is clear who owns the IP of R&D conducted at the institution and lay down the rules for licensing in writing; but it should keep some flexibility regarding negotiating license contracts with outside parties. An institution that focuses on entrepreneurship and aims to create more start-ups should also clarify IP ownership, but at the same time avoid crushing entrepreneurial initiative by too much bureaucracy, i.e. regulations, restrictions and requirements which complicate the start-up process and demand time and resources which early entrepreneurs may lack.

6.2 Providing financial and non-financial incentives to faculty and staff

The European Commission’s 2008 guidelines stress the provision of incentives, including non-monetary incentives such as considering transfer activities in promotion decisions.

The results for non-financial incentives vary by outcome measure. Using the IP and exploitation achievements of staff in promotion decisions has no effect on any of the outcomes. A possible reason for this could be a consequence of traditionally focussing on other research outcomes such as publications as a driver for the promotion of staff.

Rewarding transfer commitment and success with additional funding for the inventor's research has a significant negative relationship with research agreements, licence agreements, and start-ups. Such funding is seemingly not suitable to keep alive scholars' commitment to technology transfer and their interest in cooperation with the private sector. The provision of social rewards has a significant positive correlation with the number of licence agreements and a significantly strong positive correlation with the number of start-ups, possibly because of the prestige involved with participating in or setting up a business. In general, hypothesis H2 is rejected, except for social rewards regarding licences and start-ups which are therefore the only non-financial incentive supported by the results of this study as improving transfer performance. The impact of a research premium for transfer contributions is even negative. The COP recommendation to support these types of rewards and in particular to include IP and knowledge transfer aspects in appraisal procedures does not seem to be justified.

Financial incentives have contrasting influences depending on the outcomes. First, a higher salary has a significant positive correlation with the number of research agreements and patent applications, no correlation with the number of licenses, and some indication of a negative correlation with the number of start-ups. This result could be linked to a preference among researchers to continue working within a university or research institute environment if there is adequate financial compensation. Conversely, earning a share of revenues has a significant positive correlation with the number of licenses and on the number of start-ups. In contrast to Link and Siegel's (2005) results for the US, using the actual share instead of a binary variable for an undefined share in the regressions, is not significant for licensing, although it is positive and significant for start-ups. This could be because the actual income earned from a license is not correlated with the share, since the income will depend on the size of the potential market for the invention. In this case, the existence of a revenue sharing agreement could be positive, while the actual share could have no effect.

Third, the negative influence of a lump sum payment for license agreements also suggests a strong preference for revenue sharing agreements. We also find that lump-sum payments interact with non-monetary incentives for three out of four outcome measures. Lump-sum payments raise the number of R&D agreements and patent applications when non-monetary incentives are excluded, and they do not significantly affect licence agreements. When non-monetary incentives are included, there is no significant relationship found with R&D agreements and patent applications, but a negative and highly significant correlation with licence agreements. This indicates that lump-sum payments, like higher salaries, are only effective for raising engagement in research and IP protection, but do not raise commitment to their subsequent commercialization. In addition, even though it is a monetary incentive, it seems to have above all a symbolic value that is less effective if non-financial incentives are also in place.

The results tend to confirm hypothesis H1. A focus on monetary rewards might be adequate, with benefits in terms of higher salaries more effective when there is no immediate prospect of license income and a revenue-sharing agreement more effective for licensing and start-ups.

Of interest, the departmental share of license income correlates positively with the number of research agreements and licenses but not the other outcome measures. The departmental share is the only incentive included in this analysis that does not focus on benefits to the individual, but to a collective. The result could suggest that stressing collective benefits of involvement in knowledge transfer strengthens transfer channels that require collective transfer commitment (like R&D or licence contracts) but is not effective for channels requiring (mainly) individual involvement (such as setting up a start-up company).

6.3 Limitations

Our results show that institutional by-laws and practices can affect transfer performance. However, to pin down cause and effect conclusively, longitudinal data are required that can track the effect of a change in policy over time; qualitative data from different stakeholders of knowledge and technology transfer on how and why policies and incentives have an impact would contribute to drawing the right conclusions. European professional knowledge transfer organisations would be in a good position to collect such data over time from a panel of academic organisations in Europe. Professional knowledge transfer associations should also ensure that academic organisations know about good practices in IP management and transfer and that they are aware of the effects that different rules and practices will have on different steps of the transfer process.

In addition to the limitations due to the cross-sectional nature of the data, another limitation of this study is that it does not cover the full range of knowledge transfer activities between universities or public research institutes and private firms. Informal channels such as personal communications between scientists and engineers, gleaning knowledge from academic publications, or the participation of people from industry in academic events are not covered as this would require surveying university researchers or companies. This leads to a bias in our results against research areas where knowledge transfer occurs without the use of formal channels such as patenting, licensing, or start-ups. Research areas that are likely to be underrepresented include the social sciences, humanities, and some fields within natural sciences and engineering, such as mathematics, which makes little use of formal intellectual property mechanisms such as patents. In addition, asking faculty about their transfer performance and assessment of institutional transfer regulations would have the benefit of learning directly about the impact of such regulations. However, the sampling for such a survey is certainly demanding, as we would expect a self-selection bias and limited knowledge of the regulatory details from faculty not involved in the transfer business.

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Appendix

Table 10. Correlation results for independent variables

	Numb_ res	Kto_size	Hosp	UNI	OWN	AGE	IP_ written	IP_publ.	Lic_pol_ written	Lic_pol_ publ.	SU_pol_ written	SU_pol_ publ.	IP own rules	Conflict of int.	INC_ rev	INC_ lump sum	INC_ salary	REV_ depart.	REV_ inventor	INC_ promotion	INC_RD funds	INC_ social
Numb_res	1																					
Kto_size	0.343***	1																				
Hosp	0.236***	0.167***	1																			
UNI	0.069	0.009	0.181***	1																		
OWN	0.162**	-0.041	0.112*	-0.147**	1																	
Kto_age	0.149**	0.147**	-0.052	-0.128**	0.061	1																
IP_written	0.035	0.240***	-0.022	0.083	0.107*	-0.081	1															
IP_publ.	0.023	-0.004	-0.005	0.147**	0.056	-0.119*	0.421***	1														
Lic_pol_written	0.076	0.212***	0.044	0.014	0.054	0.010	0.318***	0.123**	1													
Lic_pol_publ.	-0.075	0.030	0.011	0.061	0.036	-0.087	0.153***	0.403***	0.425***	1												
SU_pol_written	0.139**	0.198***	0.010	-0.141**	0.126**	0.076	0.248***	0.181***	0.278***	0.215***	1											
SU_pol_publ.	0.011	-0.013	-0.062	0.062	-0.001	0.044	0.130**	0.405***	0.041	0.304***	0.529***	1										
IP own rules	0.097	0.177***	0.018	-0.039	0.110*	-0.001	0.339***	0.178***	0.174***	0.061	0.213***	0.123**	1									
Conflict of int.	-0.012	0.204***	0.009	-0.010	0.007	-0.046	0.270***	0.084	0.345***	0.179***	0.214***	0.042	0.351***	1								
INC_rev	0.184***	0.146**	0.128**	-0.006	-0.001	0.108*	0.270***	0.192***	0.113*	0.049	0.201***	0.167***	0.318***	0.143**	1							
INC_lumpsum	-0.026	0.008	0.014	-0.125**	0.052	-0.004	0.049	-0.141**	0.108*	-0.055	0.037	-0.114*	0.01	0.082	0.069	1						
INC_salary	0.092	0.076	0.003	0.016	-0.025	0.062	0.060	-0.133**	0.098	-0.070	0.049	0.007	-0.007	0.148**	-0.085	0.032	1					
REV_depart.	0.155**	0.087	0.095	-0.065	0.176**	-0.090	0.153**	0.071	0.147**	0.070	0.092	-0.057	-0.012	0.104	-0.092	0.019	0.106	1				
REV_inventor	-0.084	0.075	-0.028	0.312***	-0.281***	-0.127*	0.025	0.178***	-0.037	0.022	0.024	0.205***	0.115*	-0.024	0.125*	-0.076	0.016	-0.304***	1			
INC_promotion	-0.071	0.138**	-0.063	-0.066	-0.083	-0.006	0.153**	-0.024	0.166***	0.076	0.189***	0.056	0.103*	0.187***	-0.004	0.038	0.202***	-0.003	0.063	1		
INC_RDfunds	0.142**	0.108*	0.018	0.003	-0.013	0.024	0.011	-0.063	0.025	-0.058	-0.032	0.015	0.085	0.007	0.031	0.12**	0.105*	0.066	-0.049	0.095	1	
INC_social	-0.108	0.211***	-0.084	0.118*	-0.19***	-0.044	0.198***	0.013	0.249***	0.127**	0.122**	0.048	0.114*	0.221***	-0.033	0.028	0.054	0.026	0.069	0.292***	0.177***	1

* = p <.10, ** = p <.05, *** = p<.01

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Chapter 7 Conclusions

7.1 Concluding summary

The aim of this thesis is to contribute to a better understanding of formal technology transfer activities of universities, research institutes and firms in Europe. The thesis comprises five interlinked chapters investigating formal technology transfer activities. The five main chapters aim to build on existing research and contribute to the literature on the determinants and factors that influence formal technology transfer activities. All five chapters use quantitative survey data that was collected as part of studies funded by either the European Commission or the Norwegian Ministry of Education and Research. The thesis addresses several research questions and uses different quantitative approaches to advance the understanding of formal technology transfer and to provide insights for policy.

In Chapter 1, the introduction, the thesis positions the research by first discussing the background of the study and the motivation of national governments and international organisations such as the European Commission to support science-industry linkages and engagement. As discussed in Chapter 1, knowledge transfer is a broader and more encompassing concept compared to technology transfer. This thesis refers to both knowledge transfer and technology transfer but focusses on activities which are in some way recorded at universities, research institutes or firms, and often involve some form of intellectual property. Chapter 2 examines how the national and regional economic structure as well as the institutional set-up of technology transfer influences the technology transfer activities of universities and public research institutes. Chapter 2 teaches us several lessons when assessing universities and public research institutes technology transfer activities. First, comparisons of transfer performance at the country or regional level need to take a multilevel perspective and control for institutional features as well as regional characteristics, to understand the driving forces behind national or regional differences. Second, in most countries the institutions are strong in one formal technology transfer channel: R&D collaboration (the Netherlands), licencing (Ireland and the UK), or establishing start-ups (Sweden and Germany). This suggests that it is very challenging for universities and research institutes to maintain the necessary infrastructure and support system to excel in different transfer channels. In addition, the national institutional set-up affects which transfer channels work better. Developing transfer strategies which consider both internal and external conditions is recommended for universities and public research institutes.

Chapter 3 continues with the regional focus by examining the location of the university, quality-controlled competition from universities in the same region and supply and demand factors on the technology transfer outcomes of universities. This chapter analyses several aspects of the regional environment on the technology transfer outcomes of universities that have received little attention in the literature: the effect of regional employment in knowledge intensive services (KIS), quality weighted competition from other universities in the same region as the focal university, location in a metropolitan region, and interaction effects between the quality of the focal university and the quality of competition. Chapter 3 uses a multilevel analysis, nesting university-level data (level 1) into regional-level data (level 2) into country-level ones (level 3). Universities in the same region and in the same country are likely more similar or related to each other in comparison to those selected randomly. Multilevel modelling accounts for these interdependencies by capturing residuals at different levels. The results show that quality-adjusted competition is shown to reduce the number of research and license agreements for universities. The models with interaction effects show that all but the most elite universities in Europe experience crowding out effects. These findings support the insights resulting from Chapter 2 as both internal factors, such as research excellence, and external factors, such as co-location of other universities in the same region, influence the technology transfer activities of universities. The results of Chapter 2 and 3 suggest that the evaluation of university technology transfer outcomes by government funding bodies should consider the location of the university and the degree and quality of competition. For instance, expectations for the number of research agreements should be adjusted downwards for most universities, as regional demand, a major driver of research agreements, is limited. A possible reason for this might be a limited alignment between the knowledge or technology demands from industry and the supply of knowledge of universities. There is also an important regional context for research and license agreements, with top-ranked universities benefiting the most from spillovers or signalling effects from co-location in the same region as other top-ranked universities.

Chapter 4 focusses on technology transfer activities of the business sector by examining the barriers faced by Small and Medium sized Enterprises (SMEs) when operating on technology licensing markets. An important insight resulting from the analysis in Chapter 4 is that SMEs observe barriers differently after controlling for those with experience and without. SMEs most often report barriers related to organisational costs and strategic decisions where those with licensing-out experience are less likely to give a high importance to such barriers. Analysing barriers to technology licensing-in shows that SMEs looking for licensing-in opportunities are less likely concerned with the quality of the technology compared to SMEs with actual experience. Given the importance of policies promoting the increased diffusion of knowledge Chapter 4 indicates the need to address barriers related to this policy objective. Chapter 5 aims to provide more insights on this. The chapter focusses on all three actors analysed in this thesis: universities, research institutes and firms. Chapter 5 uses structural equation modelling to investigate the determinants of licensing success by examining the role of better understanding the value of the technology and the ability to find licensees. The results of Chapter 5 show that the measure for the ability to identify licensees contributes to the successfulness of technology licensing but that the measure of better understanding the value of the technology has a negative relationship with technology licensing successfulness. Willingness to engage in technology transfer is confirmed to have a positive relationship with licensing success. The results found in Chapter 4 and 5 have several implications for policies aiming to improve knowledge diffusion and open innovation as removing asymmetric information to stimulate market transparency can improve successful technology licensing. Thus, addressing several of the barriers found in Chapter 4 should benefit technology transfer and knowledge diffusion. Framework and organisational barriers, and negotiation barriers can be mitigated by assisting, in particularly SMEs without experience, with designing, drafting, and negotiating contractual agreements. On the other hand, Chapter 5 shows that the value of the technology as perceived by their holders, i.e. SMEs, universities and other research institutes, reduces successfulness of technology licensing. This suggests that more valuable technology is not easily transferred. Consequently, barriers in relation to the quality and development stage of the technology which are often addressed through increased proof of concept funding, may not necessarily lead to improved technology transfer. This is particularly the case for firm-to-firm licensing. Policies targeting the increased diffusion of knowledge and technology should therefore focus on increasing the transfer of publicly funded research as universities and research institutes have a different role in the knowledge economy compared to firms. Firms inherently want to remain competitive and thus it is logical that they want to hold on to valuable technology. Increasing competitiveness of SMEs is another important policy objective of the European Commission (2022). In this regard SMEs that are developing promising technologies should be supported with capacity building and resources that allow them to commercialise technologies.

Lastly, Chapter 6 examines the effectiveness of policies on technology transfer outcomes. As discussed above and of particular concern to the European Commission is to encourage good practice on the ownership and transfer of academic research results. In 2008 the European Commission issued recommendations for a Code of Practice (COP) containing eighteen principles for the management of intellectual property and knowledge transfer activities by universities and public research institutes. The goal of the principles is to "better convert knowledge into socio-economic benefits" through a more effective exploitation of publicly funded research results (European Commission 2008). These include clear IP ownership and conflict of interest rules to minimize disputes, the codification and publication of policies for IP, licensing and start-ups; and incentives that encourage inventors to protect IP and support its exploitation by firms. Chapter 6 shows that none of these policies have a consistent positive correlation with technology transfer activities of universities and research institutes. The fact that no generalizable (across all outcomes) conclusion can be made suggests that more research is needed on institutional policies and their effects. At the time of the data collection, policies may not have yet been in full effect as universities and research institutes likely needed time to adapt. However more recent results as discussed in Chapter 4 show that several barriers that hamper technology transfer are persistent. In the spring of 2023, the European Commission started a process to update the COP. In a co-creation process: "Community of practice on industry-academia collaboration for knowledge valorisation" practitioners, academics, and policymakers come together to provide input to the new COP. Several of the implications of this thesis are relevant in this regard.[16] In addition it is crucial that European professional technology transfer organisations such as ASTP[17] participate in these exercises as they are in the best position to share practical experiences with the Code of Practice and other national policies on technology transfer.

7.2 Limitations

This study does not come without limitations. One of its main limitations is the cross-sectional nature of the data used in this thesis which does not allow the identification of cause and effect. Longitudinal data are required for this purpose that for example can track the effect of a change in policy over time, institutional learning though gaining experience with technology transfer or regional influences on the technology transfer activities of individual universities, research institutes or firms. Qualitative data from different stakeholders of knowledge and technology transfer on these issues would furthermore support gaining insight into how and why certain factors or policies have an impact and others not.

Another limitation of this study is that it does not cover the full range of knowledge transfer activities between universities or public research

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[16] I, Nordine Es-Sadki, have participated in this community and brought forth several of the findings in this thesis as input into the discussions with practitioners and policy makers, particularly on the issue of measuring technology transfer.

[17] ASTP is a non-profit member's organisation committed to knowledge transfer among universities and industry.

institutes and private firms. Informal channels such as personal communications between scientists and engineers, gleaning knowledge from academic publications, or the participation of people from industry in academic events are not covered as this would require surveying university researchers or companies. This leads to a bias in the results against research areas where knowledge transfer occurs without the use of formal channels such as patenting, licensing, or start-ups. Research areas that are likely to be underrepresented include the social sciences, humanities, and some fields within natural sciences and engineering, such as mathematics, which makes little use of formal intellectual property mechanisms such as patents. Furthermore, several other mechanisms can lead to university-industry knowledge transfer such as student, graduate and researcher mobility, academic consulting, and training. Future research could investigate the share of knowledge that is transferred to proximate firms and if this varies by the type of knowledge, the type of knowledge transfer method, or the industrial structure of the region.

An important assumption in most research on regional influences on knowledge or technology transfer is that a significant share of outcomes is with businesses in the same region as the university (as in Chapters 2 and 3). However, this and other comparable studies rarely have data on the location of transfer recipients. Nevertheless, the observed correlations between regional variables and outcomes strongly suggest that regional knowledge transfer must be responsible for a significant share of all technology transfer outcomes.

7.3 General discussion

Putting formal technology transfer in perspective

The current era of globalisation with linkages and interconnections in a global system of production, distribution and consumption stimulates worldwide competition. Competition pressures producers to continually innovate by improving the quality of existing products, introducing new products and improve the effectiveness of production. Firms however, particularly SMEs as discussed in Chapter 4, cannot acquire (due to lack of capabilities) nor afford (due to resource constraints) all the technological and human resources they need. This requires firms to foster relationships with other firms, and more importantly, institutions, like universities. Given large investments in public research, policy makers and firm managers seek greater returns through spill overs and technology transfer to improve competitive advantages in the global world. This technology transfer process begins with the identification of discoveries that can improve lives and drive growth. Knowledge has made tremendous contributions in advancing medicine, technology, agriculture, and public health, thereby improving quality of life globally by transforming research into innovation. Moving a cutting-edge idea from a laboratory to the real world is however not easy and requires collaborations with different actors (Roessner et al. 2013).

Technology transfer requires this process of which ideas, proofs-of-concept, and prototypes move from research-related to production-related phases of product development. In practice, however, information is often not that easy to transfer to firms as there are several barriers as discussed in Chapter 4. Moreover, licensing frequently involves the services of the licensor's personnel to install and train the licensee's personnel. In a similar vein, for licensee firms, it is insufficient to expose them to the relevant knowledge without their own efforts to internalize such knowledge (Cohen and Levinthal 1989). This is particularly true when knowledge is less explicit and less codified. In the case of international technology transfer, it may further entail adaptation of the technology to a local market. As discussed in Chapter 5, finding the right partner is not straightforward and may demand substantial resources. For instance, Teece (1977) reports that the costs of transferring a production process averaged 19% of the total costs of the project. Moreover, Soares et al. (2020) have shown that university policies supporting technology transfer may not necessarily provide enough incentives that outweigh the opportunity costs of academics to engage in technology transfer nor the transaction costs related to pursuing technology transfer activities.

As technology transfer has become increasingly recognized for the role it plays in the knowledge-based economy (Hausman 2020; Link and Scott 2019) it also has become more integrated into many universities, research institutes and the public debate (Perkmann et al. 2021). Along with that change, the role of the technology transfer office (TTO) also has evolved. Academic research on the economic contribution of publicly funded basic research has shown that it is positive and substantial (Salter and Martin 2001), but it is a challenge to link specific transfer channels to outcomes. Research using patent citation data has found positive benefits from academic research on the number of corporate patents in technology-based sectors (Verspagen and De Loo 1999). This thesis has contributed to this literature by showing that collaboration between government, academia and industry is considered to be of critical importance in enhancing regional economic activities as discussed in Chapters 2 and 3. The effectiveness of this multilateral collaboration has, however, been questioned, as many regions have failed to obtain expected benefits from knowledge transfer in terms of innovation, GDP and employment (Asheim and Coenen 2005; McAdam et al. 2012).

One of the main concerns with most technology transfer research is that it gives disproportionate attention to what is referred to as the "out-the-door" technology transfer effectiveness criterion by Bozeman and Boardman (2014). This criterion is most often used by policy, scholars and practitioners. It is also driving the collection of metrics on technology transfer. A major reason for this is that they have the merit of practical utility and convenience of measurement and allow comparative analysis. This thesis largely draws on these metrics, but they do have drawbacks. The out-the-door criterion characterises technology transfer as successful once the technology has been converted into a transfer mechanism and another party has acquired or licensed the technology. However, the organisation acquiring the technology may or may not have put the technology into use. No motive behind the technology transfer is considered in the "out-the-door" criterion.

There are obvious disadvantages to the "out-the-door" criterion but so far it has the most compelling logic. For instance, most of the published technology transfer studies, including this research, focusses on university technology transfer and IP activity, largely due to the availability of data. This data is provided by knowledge/technology transfer offices. These offices and their managers may have some capabilities and control of strategic choice among the options available to transfer the technology but there are many factors over which the TTO officer has no control. For instance, the university or research institutes has no control over the ability of firms to effectively develop and market technology. To some extent this explains the appeal of the "out-the-door" criterion from the perspective of universities as a concluded deal is a result. Nevertheless, if one only uses the "out-the-door" criterion, we will have no knowledge of any economic or social impact beyond the established collaboration or transfer of technology between two parties.

Measuring economic and social benefits require data from a range of economic actors such as firms, non-profits, and government organizations on the uptake, application and economic value of knowledge produced by universities. This is very difficult to estimate because many innovations are built upon multiple sources of knowledge. For all technology transfer channels, estimates need to obtain data from surveys of managers, but managers are unlikely to be able to estimate the diffuse effects of science on their organisation and often may not know or recognize the role of science on key products (Mazzucato 2015). So, despite its critical limitations, the "out-the-door" criterion is the most used criterion and the basis for most metrics employed for technology transfer. They are particularly good indicators of technology transfer activity but as discussed, they do not provide information on downstream impacts and outcomes.

Recent developments in science-industry collaboration

In recent decades, universities and public research organisations have undergone fundamental changes aiming to broadening their activities next to research and teaching. This process has largely been the addition of market oriented and knowledge transfer activities, known as the third mission. In their communication most universities and public research organisations note that the main goal of knowledge and technology transfer is to support the economic and social benefits of knowledge transferred to firms, individuals and governments and the subsequent effects to the economy (Cheah and Ho 2020). Both industry and university researchers report that the most important forms of knowledge transfer are publications, patents and, university graduates as employees (Bekkers and Freitas 2008). Except for research agreements with firms, the technology transfer activities part of the 'out-the-door' criterion such as licensing are found to be of lessor importance as reported by the same study. The complex relations between universities and industry does not make progress on this easier as universities and industries have different goals. Universities provide education and conduct research as an end in itself and are characterized by open dissemination of knowledge (Ivascu et al. 2016; Perkmann and Walsh 2007). Industry on the other hand, seeks knowledge for market application for their products and processes, and thus ultimately seeks to secure a financial return.

Research discussing these different goals have argued that this is at odds with the traditional mission of universities and public research institutes of sharing knowledge and advancing science. Universities and public research institute's main role has been educating, conducting research and publishing results to make them available to society (Sánchez-Barrioluengo 2014; Florida and Cohen 1999; Hughes and Kitson 2012). It is difficult to argue that patenting and licensing, which inherently involve some form of secrecy and private ownership, aligns with this traditional mission. This debate however remains open as universities continue with technology transfer activities such as setting up new technology transfer offices and implementing policies to increase business engagement, as discussed in Chapter 6. Since 2014, and further continued in the 2022 'Framework for State aid for research and development and innovation' the European Commission has through provisions enabled public support for technology infrastructures (EC 2014 and 2022). This policy action incentivises universities and research organisations to invest in infrastructures such as facilities, technical equipment, capabilities, and support services. This infrastructure, such as testing labs often found in university science parks, is intended to develop, test and upscale technology. The aim of such activities is enabling the swift development of innovative technologies especially by small and medium sized enterprises (SMEs) and facilitating the green and digital transition of the EU economy (EC 2022). For firms, the European Commission has several funding schemes such as the 'SME instrument' and ‘Fast Track to Innovation’ (EC 2022; 2013). These aim to fund innovation from the demonstration stage through to market uptake and increase commercialisation of research results and often include academic partners or research institutes. Such activities are continued by the European Innovation Council (EIC) in several of their actions that aim to identify, develop, and scale up breakthrough technologies (EC 2022).

Academic research is divided on this new role of universities. On one side of the debate, researchers argue that engagement in university-industry relations produces high quality research output (Thursby and Thursby 2011; Van Looy et al. 2004; Etzkowitz and Leydesdorff 2000). Whereas others show the negative aspects of interactions with business for universities (Gold 2021; Geuna and Nesta 2006; Slaughter and Rhoades 1996. The concerns of the latter group are mainly related to problems of secrecy and skewing (Florida and Cohen 1999). The secrecy problem is particularly persistent in cases of increasing degree of collaboration with industry that is associated with restrictions on the disclosure of research findings and, more importantly on the dissemination of research results. This constitutes a threat to the norms of open science (Sánchez-Barrioluengo 2014). The skewing problem arises when greater emphasis on collaboration with industry disrupts a curiosity driven research agenda. Universities are known to play a different role in the accumulation of knowledge compared to research institutes which are for instance more oriented to practical applications (Arundel et al. 2013). Enterprises are more interested in commercial applications whereas many universities perform basic research with often no clear practical or commercial potential. The skewing problem highlights the threat that university’s research agenda shifts towards a profile characterized by more practical applications and short-term research at the expense of addressing societal challenges or curiosity driven, basic and long-term research. The general trend is that closer to market support for innovation has increased driven by policy support for innovation (Jugend et al. 2020). Higher technology readiness levels are necessary for innovation to take place. This policy focus is not only aimed at increasing jobs or economic growth, but more importantly to direct technological change and the uptake of addressing societal challenges (green, social and health) (Klofsten et al. 2019).

The role of patenting by universities and research institutes

Patents held by universities or other public research institutes play a crucial role in the debate on open science. Patents are in essence secretive and contribute to the secrecy problem. Nevertheless, universities patent and ideally this should lead to increased interaction with industry to generate social and private returns from publicly funded research. Surprisingly however, there has been little systematic empirical analysis conducted on how patents are used by universities. There are a few studies that have investigated the use of patents by enterprises showing that between 36% and 38% of patents are never used (Giuri et al. 2007, Walsh et al. 2016). Results from the dataset used for the analysis in Chapter 4 show that on average 49% of the patent portfolio of enterprises is intentionally not licensed out. Universities are on average not willing to license-out 13.3% of their patent portfolio. For research institutes this share is much higher (29.7%). Patents may remain unused amongst enterprises for strategic reasons such as to prevent the entry of competitors (Gilbert and Newbery 1982) or to serve as bargaining power in cross-licensing negotiations or infringement suits until an agreement is reached (Shapiro 2001, Hall and Ziedonis 2001; Heller and Eisenberg 1998). For universities and research institutes it is however unclear why certain patents are intentionally unused.

The PatVal study showed that universities and research institutes (both public and private) license a large fraction of their technologies and rarely use them internally (Giuri et al. 2007). However, the same study showed that 27.5% of patents from inventors employed at universities are unused. At public research institutes the reported share is even larger with 34.1%. Other research has looked at the role that universities play in the technology for market as owners of patents. Valdivia (2013) showed that universities are increasingly pressurised to increase and improve their linkages with industry. This can lead to adverse effects. For instance, Lemley (2008) documents complaints about university patents and provides some interesting examples of how in some instances industry sees universities as patent trolls. Technology transfer offices that are responsible for these activities are seen from the outside as being primarily interested in generating revenue, which has led to industry's regular complaint about universities being too aggressive in negotiating patent licenses (Clarysse et al. 2007), particularly on price as discussed in Chapter 4 of this study. Moreover, interviews with firms and university technology transfer offices suggest that firms are reluctant to engage in negotiations with universities when universities' ideas of how agreements should be made are incompatible with the view of the firm (Arundel et al. 2013).

National patent offices and the European Patent Office (EPO) have an important role to play in this regard. EPO's mission is to provide high quality patent protection for innovation in Europe (EPO, 2020). As the foundation of licensing or R&D agreements, patents play a crucial role in commercialising inventions and attracting investors. A recent study by the EPO (2020) assessed whether Europe is fulfilling its innovation potential. The results found are similar as described above, universities and research institutes commercialise one third of their inventions, while other patented inventions are still not advanced enough to bring to the market. The challenges as reported by the EPO related to this are similar as those researched in Chapter 4 and 5 of this thesis. These include; the technology being underdeveloped, still prospecting and failure to identify the right partner. In a European Commission funded study[18] on patent licensing Renda et al. (2018) proposed to address these issues. The recommendations included updating the 2008 COP on knowledge valorisation by universities and public research institutes, and also develop one for SMEs, provide more transparency of licensing deals by for instance publishing royalty rates as is more common in the US, and provide support for smaller organisations. The EPO European Patent Academy is addressing several of these issues by increasing awareness, providing training and supporting businesses to better understand how to co-operate with research partners. However, the large

[18] Study on Technology Transfer agreements. DG RTD/PP-02821-2015. Chapters 4 and 5 draw on survey results of the same study.

share of underused inventions of universities and research institutes shows that there are still challenges ahead.

Another important recommendation as reported in the study by Renda et al. (2018) is to streamline and promote proof of concept funding. The European Innovation Council (EIC) has recently started several initiatives such as the EIC Transition that funds innovation activities that go beyond the experimental proof of principle to support the maturation and validation of technology and the development of a business case for commercialisation (EIC 2022).

Alternative measures of technology transfer

The demand for accountability and effectiveness is unlikely to be deterred by the challenge of developing more appropriate valid measures of technology transfer. For instance, many university technology transfer offices fail to bring in enough funding through licensing or other activities to cover their own costs (Hall 2014), but the offices are still being funded. Only a handful of universities appear to make substantial amounts of revenue and license income is highly concentrated. Survey results have shown that the top 10% universities generating license income in Europe account for 86.5% of the total license income (Arundel et al. 2013). Furthermore, total license income of European PROs accounted for 0.9% of research expenditures by universities and 3.0% of research expenditures by other research organisations (Arundel and Es-Sadki 2012). Similarly in the US, license income accounted for 4.1% of total research expenditures. From the survey data used in Chapter 4, results show that on average €14,920 license income per TTO staff member was generated amongst universities with less than 3,000 researchers. For larger universities the average is €156,049 license income per TTO staff member. This number is however highly skewed because of six universities that earn more than €5 million euro of license income. It is exactly those few large earners that distort the "out-the-door" measures and incentivises university boards to keep on investing in TTO offices even though the overwhelming majority is hardly able to cover the office salary expenses. By this, I am not implying that universities should stop with third pillar or technology transfer activities, but accountability and effectiveness should be based on other measures than just the most commonly "out-the-door" criterion.

One of such measures is the public value criterion for technology transfer effectiveness (Bozeman et al. 2015, Benington and Moore 2010) this criterion aligns well with the more recent emphasis on "Responsible Research and Innovation (RRI)" (Owen et al. 2021; Burget et al. 2017). This is particularly relevant in the European Union, and specifically European Commission policy context where more policy attention has been given to the Triple Helix model (Leydesdorff and Etzkowitz 1998; Freitas et al. 2013; Grotenbreg and van Buuren 2018). Moreover, several EU policies aim to increase civil society interactions as for example in the European Commission research programme 'Science with and for Society' (SwafS) (EC 2020). The overall aim of SwafS is to build effective cooperation between science and society, recruit new talent for science and to pair scientific excellence with social awareness and responsibility. An earlier framework programme of that policy led to the Responsible Research and Innovation approach.[19]

In terms of technology transfer, particularly university technology transfer, this approach can be thought of as focussing not only on organisational achievements but also on the provision of beneficial public outcomes. In recent years the social and business engagement activities of universities has shifted to societal challenges such as open science and addressing social development goals. Metrics of third pillar or technology transfer activities have however only scarcely been developed for these newly focussed engagement activities. On an administrative level, surveys of technology and knowledge transfer activities of universities and public research institutes can easily achieve this by including and developing metrics related to the "responsible research and innovation" concepts such as engagement with society and science education. Another approach is to focus more on processes. This would require the further development of indicators beyond

[19] Under the 6th Framework Programme, the SwafS initiative was called 'Science and Society', and under the 7th Framework Programme for Research and Technological Development (FP7), it became 'Science in Society (SiS)' which led to the Responsible Research and Innovation approach (EC 2020).

the traditional measures used to measure technology or knowledge transfer. For example, it is often at least as valuable to enhance the capacities of organisations or knowledge producing communities as to provide direct beneficial outputs. There is some evidence for this capacity focus as shown by Ponomariov and Boardman (2010). It should be easier to develop metrics of the impact of technology transfer activities on scientific and human capital than valid measures of economic and social impact. If for instance a small firm develops the capacity to use artificial intelligence, then that capacity may provide a stream of benefits extending out for many years and likely beyond the individual firm. Another approach is the UK Research Excellence Framework (REF) (Donovan 2019). REF is used to inform the allocation of £2 billion in public research funding. REF provides a framework of accountability by assessing publicly funded higher education institutes in the UK. Traditional measures, such as publications, account for 60% of the overall result. Research environment measures, such as strategy, resources and infrastructure accounts for 15%. Research impact measures are of relevance for this discussion, they account for 25%. Research impact is defined as ‘an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia’ (REF, 2021). Evidence of impact is presented through an impact statement and impact case study narratives where quantitative and qualitative indicators may be provided in support, along with testimony from end users. The assessment is conducted by peer review panels, comprised of academic peers and research users. A quick search in the online impact case study database shows that many case studies include examples of impact resulting from the technology transfer activities discussed in this thesis such as start-ups, patents, and license or research agreements.[20] REF is not a one size fits all type of measure as there is sensitivity to the requirements of different research fields. Several other countries use similar frameworks to assess publicly funded research such as Ireland, the Netherlands, and Norway (Donovan 2019). Measurement frameworks such as the impact case studies included in the REF are better suited to assess knowledge or technology transfer activities of universities and research institutes. Case study narratives make the

[20] REF 2021 Impact case study database: https://results2021.ref.ac.uk/impact

complexities of the impact of research on society more tangible. It is certainly an improvement over the out-the-door criterion as it allows making broader impacts of publicly funded research become more visible to society.

Future research

Technology transfer remains a popular topic among not only researchers and policy makers, but also among managers and entrepreneurs going through the scientific literature to find usable knowledge (Bozeman et al. 2014). To advance studies of technology transfer irrespective of level of focus, researchers should use a broad range of methodological and data collection approaches and be more experimental in their research design of studies of technology transfer by moving away from classical measures of direct output, such as the out-the-door criterion. Researchers should consider developing "responsible research" measures that are of more societal relevance. Some measures are already discussed above but they are not yet widely adopted. Measures that go beyond the out-the-door criterion can provide further evidence for policy makers, recipients of technology transfer and potentially enhance their understanding and decision making as to where to direct resources and support. Opportunities exist to be more inclusive and open thereby expanding the context of studies in terms of institutional and domain settings. Most studies have focused on technology transfer in university-industry settings, but as other types of organisations are getting more involved in the technology transfer process these should also be included in future studies. While the predominant domain focus of empirical studies of technology transfer have been science, engineering, and technology there is a need to expand the domain focus to arts, humanities and social sciences. The narrative of the 'third mission' role universities have in society is shifting to a 'service-to-society' (Reichert 2019) and having more social responsibility (Cai and Ahmed 2021; Jones et al. 2021). In addition, more funding for research and innovation is being channelled to address societal challenges where for instance the European Commission sees a key role for universities and research organisations (EC 2022). Finally, future studies of technology transfer irrespective of level of analysis should consider the recipient organisation perspectives of technology transfer as well as situations where technology transfer has failed. Failure of technology transfer, as discussed above with the many unused patents being held by universities and public research organisations, is another potential and fruitful research avenue for future research which has largely remained under explored.

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Appendix

Survey questionnaire - Chapter 2, 3 and 6

The survey questionnaire below resulted in data used in Chapter 2 and 6. A similar survey except for different reference years and sent to a different sample of universities and research institutes resulted in data for Chapter 3.

European Knowledge Transfer Indicators Survey (EKTIS)

The EKTIS was administered by the United Nation University's Maastricht Economic Research Institute on Innovation and Technology (UNU-MERIT) on behalf of the European Commission's DG for Research & Innovation.

The EKTIS questionnaire contains questions addressing research activities, intellectual property rights, invention disclosures, patenting, licensing, start-ups, and other related knowledge transfer activities, as well as office staff.

The purpose of the survey is to obtain internationally comparable indicators of knowledge transfer activities by the leading European public research organisations (universities and public research institutes) within the 27 EU Member States and twelve associated countries. The data needed to be comparable across individual institutions, at the national level, and with non-European countries that collect similar data. Two surveys have been conducted, each of them during the spring of 2011 and 2012. The questionnaire was sent to the managers of knowledge or technology transfer offices that handle the patenting, licensing and commercialisation activities of each university or research institute.

The EKTIS 2011 survey has been sent to a total of 705 leading universities and research institutes in the target countries. The EKTIS 2012 has been sent to 805 public research organisations. The number of selected organisations in each country is weighted by the national share of the total government R&D expenditures in the 39 countries, although there is a minimum of one institute or university per country.

The EKTIS surveys in 2011 and 2012 created both in their respective years the largest available dataset of the knowledge transfer activities of European PROs. The full dataset for 2010 consists of 430 PROs and the full data set for

2011 consists of 498 PROs. The EKTIS surveys in 2011 and 2012 had both the broadest coverage of any survey to date, with responses from 27 of the 27 EU member states and from 9 out of 12 Associated States.

European Knowledge and Technology Transfer Practice Survey

Result from the European Knowledge and Technology Transfer Practice Survey were also used for Chapter 6. That survey was also part of the European Knowledge Transfer Study 2010-2012 realised by Empirica, UNU-MERIT and the University of Applied Sciences Northwestern Switzerland (FHNW). The survey was administered by FHNW. A copy of the survey can be sent upon request by sending an email to Nordine Es-Sadki at n.es-sadki@maastrichtuniversity.nl. It is also included in Arundel et al. (2013) DOI: doi.org/10.2777/31336.

European Knowledge Transfer Indicators Survey (EKTIS)

1.	**Is your office responsible for some or all of the patenting, licensing, or other knowledge transfer activities of the following institutions?** *(Check **all** that apply.)*
☐	General university (both humanities and sciences)
☐	Technical university (mostly science and technology)
☐	Hospital (linked to a university or an independent hospital)
☐	Government or non-profit research institute
☐	Research park or incubator affiliated with a university, hospital, or research institute
☐	None of the above *(Please go to the comments on page 4)*

2.	**Is your office responsible for the knowledge transfer activities of two or more *independent* institutions?** *(For instance two or more separate universities. A hospital or research park affiliated with a university is not a separate institution.)*
☐	Yes If yes, how many separate institutions does your office serve? __________
☐	No

3.	**Is your office responsible for all patenting and licensing by the institution(s) checked in question 1?** *(Hereafter referred to as 'your institution'.)*
☐	Yes *(go to question 4)*
☐	No Approximately what percentage of all patent applications by your institution was handled by your office in 2011? __________%

4. Office staff	
4.1 In what year was your office established?	__________
4.2 In 2011, how many office employees (in Full-Time Equivalents) were responsible for knowledge transfer services (include professional, administrative and support staff)?	__________FTE
4.2a How many of your office's employees were professionals directly involved in knowledge transfer activities?	_________ FTE
4.3 In 2011, did any of your office staff have university qualifications in:	*Check all that apply*
Engineering or natural sciences	☐
Biomedical	☐
Law	☐
Finance	☐
Management or business administration	☐
None of the above	☐

5.	**Does your office use external experts to assist with the following tasks?** *(Check* ***all*** *that apply.)*
☐	Evaluating the commercial potential of invention disclosures
☐	Patent applications and other legal matters involving intellectual property rights
☐	Preparing contracts for research agreements, licensing, etc
☐	Marketing or advertising your intellectual property
☐	None of the above

6.	**Who has the rights to the intellectual property created at your institution?** *(Check* ***all*** *that apply if ownership can vary)*		
☐	The institution	☐	Companies that fund research conducted by your institution
☐	The inventor within your institution	☐	Other

The remaining questions ask for 2011 data on your 'institution'. This includes all institutions for which your office manages knowledge transfer activities.

First, please note if your answers refer to a calendar or fiscal year.

☐ Calendar year (January 1st to December 31st)

☐ Fiscal year 2010-2011 starting ____________ day _________________________ month

Please insert '0' where relevant, or 'NA' if the answer is not available.

7.	**Invention disclosures and patenting in 2011**	
7.1	How many invention disclosures *(inventions subject to an evaluation by technology experts)* were reported by your institution to your office?	__________
7.2	How many new patent applications (priority filings) did you file for your institution?	__________
7.3	How many **technically unique** patents were granted to your institution? *A* ***technically unique*** *patent grant is for one invention only. Count a patent for the same invention in two or more countries as* ***one*** *technically unique patent.*	__________
7.4	How many USPTO (United States Patent and Trademark Office) patents were granted to your institution?	__________

8.	**Were any of your 2011 patent applications in the following subject areas?** *(Please check **all** that apply.)*	
A	Biomedical (diagnostics, medical devices, pharmaceuticals, etc) for human & animal health	☐
B	Computers, communication equipment and software	☐
C	Nanotechnology and new materials	☐
D	Low or zero carbon energy technologies	☐
E	Other subject areas not listed above	☐
Which of the above was the **most frequent subject area** for patent applications?_____ (insert letter)		

9.	**Start-up companies** *(A company **specifically** established to exploit technology or know-how created by your institution. Exclude student-established companies.)*	
9.1	How many start-ups were formed in 2011?	_________
9.2	How many of your start-ups, established in the last five years, have developed your institution's licensed technology or knowledge into products or processes that are sold in the market?	_________

10.	**Licensing activities and income in 2011**	
10.1	How many licenses (include assignments) or option agreements were made between your institution and companies?	__________
10.2	How many of these licenses and option agreements were granted to:	_________
	Start-up companies	_________
	Other firms with less than 250 employees	_________
	Other firms with more than 250 employees	
10.3	What was the **total** amount of license income earned by your institution from its intellectual property (patents, software, material transfer agreements, confidentiality agreements, etc)? ***Include** license issue fees, annual fees, option fees, etc., plus milestone, termination & cash-in payments. **Exclude** license income forwarded to other companies and patent reimbursement fees.*	_________€
10.4	In total, how many licenses earned income in 2011? *Count multiple licenses for the same invention only once.*	__________

11.	Approximately what share of your total 2011 license revenue was from licensed technology in each of the following subject areas?	
	Biomedical	_______%
	Computers, communication equipment and software	_______%
	Nanotechnology and new materials	_______%
	Low or zero carbon energy technologies	_______%
	Other subject areas not listed above	_______%
		100 %

12. In the last three years, has any of your institution's licensed technology or knowledge resulted in commercially profitable products or processes?

☐ Yes ☐ No ☐ Don't know

13. Research activities in 2011	
13.1 How many research and development agreements were made between your institution and companies? *(Exclude consultancy contracts and cases where a firm funds a research chair or research of no expected commercial value to the firm)*	_____________
13.2 What is the total number of research personnel at your institution *(include researchers, technicians and administrative support)*?	_________FTEs
13.3 What were the total research expenditures of your institution?	____________€
13.4 Approximately what percentage of your institution's total research expenditures was funded by private companies?	____________%

In order to protect confidentiality, only aggregated results of this survey will be disclosed, unless you agree otherwise:

I give permission to disclose results for my institution ☐ Yes ☐ No

Comments (*If you only answered question 1, please give a brief description of the activities of your office*)

Technology Transfer Survey questionnaire - Chapter 4 and 5

The survey questionnaire below resulted in data used in Chapter 4 and 5. The version below was sent to enterprises. The survey sent to universities and research institutes is identical except for changes in wording (university or research institute instead of enterprise) and the exclusion of questions 1.6, 1.7 and the section on licensing-in. The survey sent to universities and research institutes included in addition a question that asked for the number of invention disclosures reported in 2016.

TECHNOLOGY TRANSFER SURVEY

1. Organisational information		
Please insert '0' where relevant, or 'NA' if the answer is not available.		
1.1 What is the total number of employees at your enterprise?		_________ FTE[1]
1.2 What is the total number of research personnel at your enterprise (include researchers, technicians and administrative support)?		_________ FTE[1]
1.3 How many office employees in your enterprise are responsible for technology transfer services (include professional, administrative and support staff)?		_________ FTE[1]
1.4 What were the total research expenditures of your enterprise in 2016?		________€(x1000)
1.5 What is your enterprise's main industry sector or technological field of activity?		_________
1.6 What was your enterprise's total turnover for 2016? *Turnover is defined as the market sales of goods and services (include all taxes except VAT)*		________€(x1000)
1.7 Was your enterprise originally established as a spin-off[2]?		
	Yes, as a spin-off from a university or public research institute	☐
	Yes, as a spin-off from a private sector enterprise	☐
	No	☐
1.8 Does your enterprise have a **written** strategy for licensing out your technology? *For instance specified guidance principles for decision-making.*		
	Yes	☐
	No	☐
1.9 Does your enterprise actively look for opportunities to license out technology?		
	Yes	☐
	No	☐

1. Organisational information	
1.10 Has your enterprise licensed out any technology after 2012?	
Yes	☐
No, but we plan to license out a technology in the next two years	☐
No ***(go to question 4)***	☐

Notes: 1. Full-Time Equivalents 2. Spin-off, an enterprise established for the purpose of exploiting Intellectual Property originating from either a university or public research institute or from a private sector enterprise.

2. Principles for decision making

2.1 How important are the following methods or practices for determining the license value of your enterprise's technologies?

	Degree of importance				
Internal	**High**	**Medium**	**Low**	**Not important**	**Not available**
A. Cost of R&D activities carried out	☐	☐	☐	☐	☐
B. Potential revenue for the licensee	☐	☐	☐	☐	☐
C. Licensing rates according to industry norms	☐	☐	☐	☐	☐
D. Potential number of clients interested	☐	☐	☐	☐	☐
E. Market research on similar technologies in the market	☐	☐	☐	☐	☐
F. Proprietary model used, i.e. patent, copyright or other. *Please use comment box to elaborate if importance is high.*	☐	☐	☐	☐	☐
G. Other, please describe…………………………	☐	☐	☐	☐	☐
External					
H. Consult universities or higher education institutes	☐	☐	☐	☐	☐
I. Consult research institutes	☐	☐	☐	☐	☐
J. Evaluating the commercial potential by an external expert	☐	☐	☐	☐	☐
K. If your enterprise is part of a group, consult other enterprises within your enterprise group	☐	☐	☐	☐	☐
L. Other, please describe…………………………….	☐	☐	☐	☐	☐

2.2 Which of the above is the most useful method or practice to determine the license value of a technology?	_________(insert letter)

3. Process of marketing				
3.1 How important are the following information sources or methods for identifying licensees for your enterprise's technology?				
	Degree of importance			
	High	**Medium**	**Low**	**Not important**
A. Current clients or customers	☐	☐	☐	☐
B. Participation in standards organisations	☐	☐	☐	☐
C. Participation in patent pools	☐	☐	☐	☐
D. Informal networks	☐	☐	☐	☐
E. Professional or industry associations	☐	☐	☐	☐
F. Marketing technology on the web	☐	☐	☐	☐
G. Scientific/technical journals or trade publications	☐	☐	☐	☐
H. Research in patent databases	☐	☐	☐	☐
I. Use of technology/licensing exchange platforms	☐	☐	☐	☐
J. Use of intermediaries	☐	☐	☐	☐
K. Conferences, trade fairs, exhibitions	☐	☐	☐	☐
L. Other, please describe……………………………………… …	☐	☐	☐	☐

3.2 Which of the above is the most useful information source or method to identify potential licensees?	_________(insert letter)

4. Barriers				
4.1 How important are the following barriers to licensing out your enterprise's technology?				
	Degree of importance			
	High	**Medium**	**Low**	**Not important**
A. Unknown regulatory framework	☐	☐	☐	☐
B. Fear of litigation	☐	☐	☐	☐
C. Lack of skilled employees within your enterprise	☐	☐	☐	☐
D. Underdeveloped technology	☐	☐	☐	☐
E. Potential loss of technological/competitive edge	☐	☐	☐	☐
F. Lack of experience in drafting agreements	☐	☐	☐	☐
G. Costs for external support to evaluate the commercial potential of your technology	☐	☐	☐	☐
H. Costs for external support to prepare patent applications and other legal matters involving IP rights	☐	☐	☐	☐
I. Costs for external support to prepare licensing contracts	☐	☐	☐	☐
J. Costs for external support to market or advertise your technology	☐	☐	☐	☐
K. Difficulties in identifying the right licensees	☐	☐	☐	☐
L. Lack of information to price the license	☐	☐	☐	☐
M. Difficulties in reaching agreements on terms other than price	☐	☐	☐	☐
N. Difficulties to monitor or enforce a license agreement	☐	☐	☐	☐
O. Credibility of your enterprise	☐	☐	☐	☐
P. Credibility of potential licensee	☐	☐	☐	☐
Q. Other, please describe………	☐	☐	☐	☐
4.2 Which of the above is the most important barrier to licensing your enterprise's technology?	_________(insert letter)			

5. Licensing-in				
5.1 Has your enterprise licensed in any technology after 2012? *(Exclude the acquisition of licenses for common software for desktop and laptop computers such as operating systems, word processing, spreadsheets, etc.)*				
Yes				☐
No, but we plan to **license in** a technology in the next two years				☐
No *(go to question 5.4)*				☐
5.2 How important are the following factors in determining licensing in conditions?				
	Degree of importance			
	High	**Medium**	**Low**	**Not important**
A. Ensuring freedom-to-operate[21]	☐	☐	☐	☐
B. Exclusive licensing	☐	☐	☐	☐
C. Need to close technological gaps for core technologies	☐	☐	☐	☐
D. Enabling rapid time-to-market	☐	☐	☐	☐
E. Sufficient rights included in grant provision for an optimal exploitation	☐	☐	☐	☐
F. Right to sublicense	☐	☐	☐	☐
G. Geographical scope of the license	☐	☐	☐	☐
H. Limits of the rights granted to a concretely defined field of use[22]	☐	☐	☐	☐
I. Type of payment scheme, (for example lump-sum or royalties)	☐	☐	☐	☐
J. Calculation of royalties	☐	☐	☐	☐
K. Clauses in agreement that deal with a potential future dispute	☐	☐	☐	☐
L. Other, please describe………………………………………..	☐	☐	☐	☐
5.3 Which of the above is the most important factor in determining licensing in conditions?				_________(insert letter)

[21] To ensure that the commercial production, marketing and use of new product, process or service does not infringe the IP rights of others.
[22] The licensee is only able to use the IP in a subset of the potential commercial uses and therefore the licensor has the right to directly exploit or license the same intellectual property for a different field.

5.4 How important are the following barriers to licensing in technology?

	Degree of importance			
	High	**Medium**	**Low**	**Not important**
A. Unknown regulatory framework	☐	☐	☐	☐
B. Fear of litigation	☐	☐	☐	☐
C. Lack of skilled employees within your enterprise	☐	☐	☐	☐
D. Technology offered is underdeveloped	☐	☐	☐	☐
E. Technology offered is of low quality	☐	☐	☐	☐
F. Lack of experience in drafting agreements	☐	☐	☐	☐
G. Costs associated with drafting and managing licensing agreements	☐	☐	☐	☐
H. Difficulties in identifying the right licensor	☐	☐	☐	☐
I. Lack of information on value of technology	☐	☐	☐	☐
J. Too high prices charged by licensor	☐	☐	☐	☐
K. Difficulties in reaching agreements on terms other than price	☐	☐	☐	☐
L. Refusal of licensor to grant license	☐	☐	☐	☐
M. Risk of exposing your technology strategy	☐	☐	☐	☐
N. Credibility of your enterprise	☐	☐	☐	☐
O. Credibility of licensor	☐	☐	☐	☐
P. No need or interest in licensing-in technologies	☐	☐	☐	☐
Q. Other, please describe………………………………………..	☐	☐	☐	☐

5.5 Which of the above is the most important barrier to license in technology? __________(insert letter)

If you have not licenced in or out any technology (no to question 1.10 and no to question 5.1) go to question 7.

Otherwise go to question 6.

6. Successful deals

6.1 How important are the following factors in concluding a technology license agreement?

	Degree of importance			
	High	**Medium**	**Low**	**Not important**
A. Quality of licensed technology	☐	☐	☐	☐
B. Quality of the protection of the technology	☐	☐	☐	☐
C. Accessibility to complementary know-how	☐	☐	☐	☐
D. The potential value of the technology	☐	☐	☐	☐
E. Ability to identify good licensees	☐	☐	☐	☐
F. Reaching agreement on the value of the technology	☐	☐	☐	☐
G. Diligence obligations, such as minimum royalties or milestones to be achieved at determined dates	☐	☐	☐	☐
H. Granting mirror rights on future improvements of the technology	☐	☐	☐	☐
I. Other, please describe………………………………………..	☐	☐	☐	☐

6.2 Which of the above is the most important factor in concluding a technology licensing deal? _________(insert letter)

Please share any additional comments you may have on important factors to conclude a licensing agreement

7. Technology transfer and licensing activities in 2016

Please insert '0' where relevant, or 'NA' if the answer is not available.

7.1 How many new patent applications (priority filings) were filed by your enterprise in 2016?	___________
7.2 How many **license out** agreements were made between your enterprise and other enterprises in 2016? *(Include assignments and option agreements)*	___________
7.3 How many **license in** agreements were made between your enterprise and other enterprises in 2016? *(Include assignments and option agreements)*	___________
7.4 What is the total number of patents in your enterprise's patent portfolio?	___________
7.5 Approximately, what share of your patent portfolio is:	
a. Currently licensed out	_________%
b. Not licensed, but your enterprise would be willing to license out	_________%
c. Not licensed and no intention to license out	_________%
7.6 What was the **total** amount of license income earned by your enterprise from its intellectual property in 2016?	_________€

8. Were any of your 2016 patent applications in the following subject areas?

(Please check ***all*** *that apply.)*

A	Biomedical (diagnostics, medical devices, pharmaceuticals, etc) for human & animal health	☐
B	Computers, communication equipment and software	☐
C	Nanotechnology and new materials	☐
D	Low or zero carbon energy technologies	☐
E	Other subject areas not listed above	☐

8.1 Which of the above was the **most frequent subject area** for patent applications? _____ (insert letter)

Please comment if you have anything to share on the topic of licensing technology that you consider important

Impact paragraph

This thesis empirically examines the technology transfer activities of universities, research institutes and firms. All the chapters include discussions aimed at policy makers. Chapter 2 recommends that comparisons of transfer performance at a national or regional level need to take a multilevel perspective and control for institutional features as well as regional characteristics. The results of Chapter 3 suggest that the evaluation of university knowledge transfer outcomes by government funding bodies should consider the location of the university and the degree and quality of competition. For instance, expectations for the number of partner-led research agreements should be adjusted downwards for most universities, as regional demand, a major driver of research agreements, is limited.

Given the importance of policies targeting the diffusion of knowledge Chapter 4 indicates the need to address barriers to this policy objective. Future research could for instance explore if barriers related to framework and organisational, cost and negotiation can be mitigated by assisting, in particularly SMEs without experience, with designing, drafting, and negotiating contractual agreements. Barriers in relation to the quality and development stage of the technology can be addressed through increased proof of concept funding and lowering the threshold criteria for such initiatives. Closer to market support for innovation has however increased where the focus has shifted to policy support for innovation which requires higher technology readiness. This focus is not only on increasing jobs or economic growth, but more importantly to direct technological change and uptake towards societal challenges. Policies targeting barriers related to a reluctance to transfer technology for fears of losing competitive or technological edge might be more challenging as enterprises are competitive in nature. On the other hand, barriers related to framework and organisational, costs and search barriers can be alleviated through better communication and assistance on how technology markets work.

The European Commission's principles for knowledge transfer policies stress the value of specific policies, examined in Chapter 6, for supporting knowledge transfer outcomes that lead to commercialisation. These include clear IP ownership and conflict of interest rules to minimize disputes, the codification and publication of policies for IP, licensing, and start-ups; and incentives that encourage inventors to protect IP and support its exploitation by firms.

Most of the research in this dissertation was presented in international conferences or published in peer-reviewed journals or book chapters. Chapter 2 was presented at the T2S conference in Bergamo, Italy in 2013 and a later version was published as a book chapter in University Evolution, Entrepreneurial Activity and Regional Competitiveness in 2016. Research from Chapter 3 was presented at two conferences, the first time at the FINKT conference in Rimini, Italy in 2015 and an updated version in 2019 at the UNU-MERIT internal conference in Maastricht, The Netherlands. The chapter, with some modifications, is based on the paper that is published in *International Journal of Innovation Management* in 2021. Chapter 4 and elements of Chapter 7 have been presented at the ASTP PROTON conference "Options for Technology Transfer Policy in EU Context" in 2018. Chapter 6 is published in *Research Evaluation* in 2015.

Biography

Nordine Es-Sadki was born in Maastricht in 1984. He obtained his bachelor's degree in economics from Maastricht University in 2009. In 2010 he obtained his master's degree in economics from the Erasmus University in Rotterdam with distinction. He joined UNU-MERIT as a researcher in January 2011. At UNU-MERIT he has mostly been working on contract research projects for the European Commission on topics of innovation indicators, survey design and methodology.

His research interests include, the analysis of Science, Technology & Innovation, public sector innovation and social innovation, knowledge flows from public research to firms, and survey questionnaire design and methodology.

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