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THIAGO JOSÉ CYSNEIROS CAVALCANTI SOARES

Três ensaios sobre a difusão do conhecimento da pesquisa acadêmica

SÃO CARLOS
2019

UNIVERSITY OF SÃO PAULO
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RESUMO

SOARES, T. J. C. C. **Três ensaios sobre a difusão do conhecimento da pesquisa acadêmica**. 2019. 109 f. Tese (Doutorado em Engenharia de Produção) – Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos, 2019.

Universidades ao redor do mundo estão cada vez mais envolvidas em atividades de transferência de tecnologia, intensificando os fluxos de conhecimento da pesquisa acadêmica para empresas. Espera-se que essas instituições desempenhem um papel ativo no desenvolvimento da economia local. De fato, houve um crescimento significativo nas atividades de patenteamento por parte de universidades nos últimos anos. Além disso, as universidades têm utilizado diversos mecanismos para apoiar atividades de transferência de tecnologia, tais como a implementação de regulamentações e a criação de organizações internas destinadas a facilitar as interações com empresas. Embora estudos passados tenham ampliado de forma abrangente a nossa compreensão sobre a disseminação do conhecimento acadêmico, várias questões fundamentais permanecem em aberto. Desse modo, o objetivo desta tese é investigar como tecnologias acadêmicas são disseminadas para empresas, examinando também a relação entre atributos idiossincráticos das universidades, seu contexto regional e atividades de transferência de tecnologia. Os capítulos que seguem se baseiam nas literaturas de spillovers de conhecimento e transferência de tecnologia, abordando diferentes dimensões da difusão do conhecimento acadêmico. Esta tese consiste em uma introdução geral, três capítulos e uma conclusão. O primeiro capítulo baseia-se em dados de bases de patentes americanas, enquanto o segundo e terceiro usam dados no contexto de universidades brasileiras. Cada capítulo, de uma perspectiva diferente, explora dimensões que ainda não foram abordadas pela literatura. A investigação dos padrões de disseminação do conhecimento tecnológico embutido em invenções acadêmicas é fundamental para o entendimento de como e sob quais circunstâncias a pesquisa científica é disseminada e utilizada por empresas. Desse modo, esta tese contribui para o campo da inovação e gestão da tecnologia de diversas maneiras.

Palavras-chave: Difusão do conhecimento acadêmico. Transferência de tecnologia – mecanismos de suporte. Comercialização de pesquisa acadêmica. Spillovers de conhecimento. Escritórios de transferência de tecnologia. Desenvolvimento regional.

ABSTRACT

SOARES, T. J. C. C. **Three essays on knowledge diffusion from academic-based research**. 2019. 109 f. Tese (Doutorado em Engenharia de Produção) – Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos, 2019.

Universities around the world are increasingly engaging in activities of technology transfer, intensifying knowledge flows of academic-based research to firms. It is expected that these institutions play an active role in the development of the local economy. In fact, there was a sharp rise in patenting activities by universities over the last years. Moreover, universities have used different mechanisms to support university-industry technology transfer, as for example the implementation of regulatory frameworks and the creation of internal organizations aimed at facilitating interactions with firms. Although prior studies have comprehensively increased our understanding of the ways in which academic knowledge is disseminated, several important questions remain open. In this sense, the purpose of this dissertation is to investigate how university technologies are disseminated to firms, also examining the relationship between idiosyncratic attributes of universities, their regional context and university-industry technology transfer. The essays in this dissertation build on the knowledge spillover and technology transfer literatures, addressing different dimensions of the diffusion of academic knowledge. The dissertation consists of a general introduction, three essays, and a conclusion. The first essay relies on US patent databases, whereas the second and third use data in the context of Brazilian universities. Each essay, from a different perspective, explores dimensions that have not yet been addressed by prior literature. Investigating the dissemination patterns of technological knowledge embedded in university inventions is critical to understanding how and under circumstances scientific research disseminates and is deployed by firms. Along this line, this dissertation contributes to the field of innovation and technology management in several ways.

Keywords: Diffusion of academic knowledge. Technology transfer – support mechanisms. University research commercialization. Knowledge spillovers. Technology transfer offices. Regional development.

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LIST OF ACRONYMS

AUTM	Association of University Technology Managers
EFA	Exploratory Factor Analysis
FORTEC	Brazilian Innovation and Technology Transfer Managers National Forum (Fórum Nacional de Gestores de Inovação e Transferência de Tecnologia)
FTE	Full-time equivalent employees
FY	Fiscal year
INPI	Brazilian Patent and Trademark Office (Instituto Nacional de Propriedade Industrial)
IP	Intellectual property
KMO	Kaiser-Meyer-Olkin measure of sampling adequacy
MBA	Master of Business Administration
R&D	Research and Development
STPs	Science and technology parks
PCT	Patent cooperation treaty
PhD	Doctor of Philosophy
TT	Technology transfer
TTO	Technology transfer office
UBIs	University business incubators
US	United States
VIF	Variance inflation factor

CONTENTS

1 INTRODUCTION

Universities around the world are being reshaped as they engage in activities of technology transfer. This process represents the still ongoing second academic revolution (ETZKOWITZ, 2001, 2003; ETZKOWITZ; LEYDESDORFF, 2000), characterized by the creation of the entrepreneurial university and integration of economic and social development to the university's mission. In addition to the roles of teaching and developing knowledge, these institutions are expected to play an active role in turning scientific developments into innovations (DEBACKERE; VEUGELERS, 2005). In fact, universities are increasingly relying on patents to claim intellectual property (IP) rights for its inventions, leading to a sharp expansion in academic patenting over the years. The rise of universities as economic actors has taken place in a scenario of decreasing research budgets and an increasing pressure on academic institutions to return public investments (KOLYMPIRIS; KLEIN, 2017; ZAHRINGER; KOLYMPIRIS; KALAITZANDONAKES, 2017). In this context, universities have used an array of mechanisms to support TT-related activities, as for example the implementation of TT-related regulations (BALDINI, 2010; BALDINI; GRIMALDI; SOBRERO, 2006; GEUNA; ROSSI, 2011); and the creation of intermediary organizations such as technology transfer offices (TTOs) (BATTAGLIA; LANDONI; RIZZITELLI, 2017; CHAPPLE et al., 2005; GOBLE; BERCOVITZ; FELDMAN, 2017; SIEGEL; WALDMAN; LINK, 2003), university business incubators (UBIs) (PHAN; SIEGEL; WRIGHT, 2005; ROTHAERMEL; THURSBY, 2005; VILLANI; RASMUSSEN; GRIMALDI, 2017), and science and technology parks (STPs) (MCCARTHY et al., 2018; RAMÍREZ-ALESÓN; FERNÁNDEZ-OLMOS, 2018; RATINHO; HENRIQUES, 2010), aimed at facilitating knowledge flows from universities to firms.

Given the ascension of academic institutions as active economic actors in recent years (GRIMALDI et al., 2011), as well as the pressures on universities to return public investments (KOLYMPIRIS; KLEIN, 2017; ZAHRINGER; KOLYMPIRIS; KALAITZANDONAKES, 2017), it is important to understand the dissemination of knowledge from the academia to the private sector. Although previous studies have shed light in important dimensions of the diffusion of academic knowledge, several questions concerning how university research affects the world beyond academia and also the circumstances under which it diffuses to the private sector remain unaddressed. Looking at some of those questions, I examine in this dissertation three main points related to the dissemination of university research:

a) to which extent academic technology-based knowledge crosses university boundaries and is deployed by firms;
b) how TTO human resources, in terms of experience and educational background, affect TT outcomes; and
c) how internal support mechanisms and the regional context of universities affect TT outcomes.

To investigate these issues, I organize this work into three essays, each of them addressing one of the research questions. The first essay focuses on non-market spillovers from academic patents, and builds on the knowledge spillover literature to examine whether or not academic knowledge is disseminated and used in the innovative processes of the industrial sector. The second essay focuses on TTO employees, building on the university technology transfer literature to understand how the industry experience and educational background of TTO staff affect different stages of the TT process. Finally, the third essay focuses on universities and their local context, and builds on the technology transfer literature to examine how university support mechanisms and regional development affect TT outcomes.

In order to approach the different research questions empirically, the essays in this dissertation rely on three main datasets. The first essay collects data from two sources: the New NBER Patent Data Project (BESSEN, 2009; HALL; JAFFE; TRAJTENBERG, 2001) and the Harvard Patent Network Dataverse. These databases contain detailed information about US utility patents and have been vastly used in the literature to measure university knowledge flows (e.g., BELENZON; SCHANKERMAN, 2013; DRIVAS et al., 2014; HENDERSON; JAFFE; TRAJTENBERG, 1998; SORENSON; FLEMING, 2004). As to the second and third essays, they rely on data from the latest annual survey of the Brazilian Innovation and Technology Transfer Managers National Forum (FORTEC Innovation Survey), regarding fiscal year 2017 (FY2017). This dataset represents the second edition of the FORTEC Innovation Survey, being the first with publicly available data. This Survey resembles the Association of University Technology Managers (AUTM) Licensing Survey, and contains information about the activities of Brazilian universities and research institutes associated with the protection and commercialization of academic-based research.

1.1 Essays on Knowledge Diffusion of Academic-Based Research

The connecting point of the three essays in this dissertation is that they all examine the diffusion of academic inventions that are protected by IP rights. While the first essay investigates the diffusion of university inventions through non-market spillovers (i.e., citations to academic patents), the second and third essays examine the dissemination of those inventions through market-mediated transactions (i.e., technology transfer agreements).

The following sections provide a brief description of each of the essays in this dissertation.

1.1.1 Essay 1: Academic spill-ins or spill-outs? Examining knowledge spillovers of university patents

The first essay of this dissertation examines whether academic technology-based knowledge crosses university boundaries or remains trapped inside the ivory tower. Although academic knowledge has been suggested to improve the innovative capabilities of firms (BISHOP; D'ESTE; NEELY, 2011; CASSIMAN; VEUGELERS; ZUNIGA, 2008; ZAHRINGER; KOLYMPIRIS; KALAITZANDONAKES, 2017), research on the extent to which academic research spills over to the private sector or remains confined within universities is relatively limited. To address this issue, I compare the spillovers generated by academic and firm patents using measures that take into account knowledge spilling-in and knowledge spilling-out of academia (i.e., knowledge flows from one university to another and knowledge flows from universities to firms). While it is true that knowledge exchanges among universities may inflate the overall spillovers of university patents vis-à-vis firm patents, the results indicate that university patents generate more spillovers than corporate patents, even when knowledge flows among universities are not regarded as spillovers. This suggests that firm technologies more frequently rely on academic patents than on technologies from other corporations. In addition, I find that the gap between university and industry spillovers is smaller in industries where patents are important for appropriating returns from R&D (i.e., more economically valuable), such as chemical and drugs, and larger in industries with complex technologies (where firms have strong incentives to patent aggressively), such as computers and electronics. Finally, I show that industry patents generate more spillovers locally and that academic knowledge spillovers are less geographically localized than those of corporate research.

1.1.2 Essay 2: TTO's human capital and technology transfer outcomes: Examining technology transfer officers' experience and educational background

The second essay in this dissertation introduces and tests a framework to understand how the human capital of TTOs affects the early and late stages of TT activities. Despite the attention TTOs have received in previous studies, the question of how they should recruit the appropriate mix of employees remains unanswered (CUNNINGHAM; O'REILLY, 2018; GRIMALDI et al., 2011). This study helps to fill this gap by exploring the relationship between the backgrounds of TTO staff and technology transfer outcomes. The findings suggest that TTO professionals with different backgrounds affect the early and late stages of the technology transfer process differently. Employees with a doctoral degree are positively associated with new invention disclosures, but have no effect on new licensing agreements. On the other hand, professionals with an MBA have a positive and significant impact on new licensing agreements, but appear to have no (or only little) influence on new invention disclosures. Interestingly, employees with industry experience appear to negatively affect new licensing agreements. It is possible that the focus of these individuals is on obtaining licensing revenues rather than on maximizing the number of licensing agreements. Finally, the results indicate that outsourcing IP-related tasks has a negative effect on new invention disclosures, but a positive impact on the number of new licenses concluded. In addition to contributing to the incipient literature on TTO human resources, these findings have the potential to help university managers strategically develop TTO staff aiming at specific outcomes.

1.1.3 Essay 3: University support mechanisms, regional development and technology transfer

The third essay investigates how the quality of TT-related regulations, the availability of UBIs, STPs, and regional development impact new patent applications and licensing agreements in the context of Brazilian universities. The findings indicate that the quality of TT-related regulations has a positive impact on both patenting and licensing activities, whereas only the availability of regulations has no (or only little) effect on TT outcomes. This suggests that analyses based solely on the existence of regulations may lead to confounding results, especially considering that low-quality regulations may ultimately hinder technology transfer activities instead of promoting them. I find no relationship between the availability of UBIs and STPs and patenting and licensing outcomes. It is possible that the diffusion of university technologies to UBIs and STPs takes place through alternative channels, such as R&D contracts, consultancy or even informal non-market spillovers. Finally, the results suggest that regional economic development has a negative impact on patenting activities. Although puzzling, this finding may reflect the lack of patenting experience of universities in underdeveloped regions. These universities may be less selective in the technologies they choose to protect, leading to larger patent portfolios of lower quality. On the other hand, universities located in regions with higher levels of economic activity generate more licensing agreements.

1.2 Contributions

This dissertation as a whole contributes to the literature in different respects. First, it provides empirical and theoretical insights into how academic inventions are disseminated to the private sector and used in the innovative processes of firms. Second, it gives an overview of how the different backgrounds of TTO employees affect the different stages of the technology transfer process. Third, it contributes to the understanding of which university support mechanisms are more effective in promoting TT activities. Finally, it also generates insights into how idiosyncratic attributes of the regions in which universities are settled affect the dissemination of academic inventions.

2 ACADEMIC SPILL-INS OR SPILL-OUTS? EXAMINING KNOWLEDGE SPILLOVERS OF UNIVERSITY PATENTS

Is academic knowledge trapped inside the ivory tower or is it disseminated and used in the innovative processes of the industrial sector? The diffusion of university-based research to the industry takes place through a variety of channels including consultancy and collaborative research with firms (BANAL-ESTAÑOL; JOFRE-BONET; LAWSON, 2015; D'ESTE; PATEL, 2007; FUDICKAR; HOTTENROTT; LAWSON, 2018; LAWSON, 2013). Prior studies have found that firms drawing from universities "… nurture their absorptive capacity by enhancing their explorative and exploitative learning capabilities" (BISHOP; D'ESTE; NEELY, 2011, p.37). Moreover, further evidence suggests that scientific knowledge improves the quality and impact of subsequent firm innovations (CASSIMAN; VEUGELERS; ZUNIGA, 2008; ZAHRINGER; KOLYMPIRIS; KALAITZANDONAKES, 2017). Nevertheless, research on the extent to which scientific knowledge spills over into the private sector or remains confined within academia is relatively limited. In this essay, we examine the impact and dissemination of academic inventions by classifying knowledge spillovers into knowledge spilling–in and knowledge spilling-out of academia. Using this approach, we examine knowledge spillovers generated by university inventions vis-à-vis inventions sharing similar characteristics to those that were generated by firms. Employing a comparative perspective allows us to determine if the dissemination trajectory of academic inventions deviates from what one should expect to observe in inventions originating from the private sector. Particularly, we aim at examining the amount and the dissemination patterns of knowledge spillovers generated by academic inventions relatively those generated by comparable inventions produced in the private sector.

We develop our analysis by focusing on university patents as an indicator of relevant inventions. Although patents may not always be the most common form of output for scientific knowledge, they reflect inventions that universities expect to have more direct commercial applications (HENDERSON; JAFFE; TRAJTENBERG, 1998). Therefore, studying the dissemination patterns of technological knowledge embedded in university patents represents an important step towards understanding the contribution of scientific research to more applied work developed by the industrial sector. Furthermore, universities are increasingly relying on patents to claim intellectual IP rights for its inventions, leading to an increase in the number of academic patents over the years. Indeed, the number of patents issued annually to American universities increased by 744% between 1980 and 2000, whereas the number of patents issued to American firms increased by only 178% in the same period.

A variety of factors have been responsible for the sharp rise in patenting activities by universities. Among these is the enactment of Bayh-Dole (GRIMALDI et al., 2011; MOWERY; ZIEDONIS, 2002); the dissemination of technology transfer offices (HENDERSON; JAFFE; TRAJTENBERG, 1998; OWEN-SMITH; POWELL, 2001; SIEGEL et al., 2004); the emergence of the biotechnology industry (MOWERY et al., 2001; OWEN-SMITH; POWELL, 2003); and the intensification of industry funding for university research (HENDERSON; JAFFE; TRAJTENBERG, 1998). This sharp expansion in academic patenting has taken place in a scenario of decreasing research budgets and increasing pressure on universities to return public investments (KOLYMPIRIS; KLEIN, 2017; ZAHRINGER; KOLYMPIRIS; KALAITZANDONAKES, 2017), sparking debates on the economic and strategic importance of academic patents as well as on the diffusion of academic knowledge.

Comparing the value of American university patents relative to non-university patents, Henderson, Jaffe and Trajtenberg (1998) find that academic patents, although on average more important than other patents, had been losing value over time. The authors suggest that this effect was likely caused by the lack of experience of entrant academic patenters. These entrant universities, encouraged to commercialize their inventions in the wake of the Bayh-Dole Act, may have filed patents less strategically, leading to a disproportionate increase in the volume of academic patents with lower value. Subsequent studies have compared patents assigned to both experienced and inexperienced universities, pre- and post-Bayh-Dole. Mowery and Ziedonis (2002) find that the decline in the value of overall US academic patents is associated with increased patenting activities by universities with less experience and expertise, whereas Mowery, Sampat, and Ziedonis (2002) find that the importance of the patents assigned to entrant academic patenters improved during the late 1980s and early 1990s. These findings suggest that universities learned to identify valuable IP and, over time, also became more selective in their patenting activity.

Despite the large number of studies examining knowledge flows of university patents (e.g., BACCHIOCCHI; MONTOBBIO, 2009; ROSELL; AGRAWAL, 2009), we are unaware of any that investigated whether the spillovers generated by academic patents were the result of academic knowledge being deployed within academia or by firms in the private sector. To address this issue and determine whether academic knowledge crosses university boundaries, we differentiate the spillovers of university patents based on their subsequent use as an input into future innovations. If a subsequent innovation building on an academic patent has been generated by another university patent, we classify it as knowledge spilling-in academia. Alternatively, if a patent building on a university patent as an input comes from industry, we consider it as knowledge spilling-out academia. This is an important distinction with which to understand the broad impact of academic knowledge beyond academia. Academic spill-ins may lead to an overestimation of the overall spillovers of university patents when compared to those of firms. For example, academic knowledge spillovers may be actually knowledge spilling-in among university scientists, indicating that scientific knowledge might be trapped inside the ivory tower and remain unused by the private sector. Examining this issue, our study distinguishes between knowledge spilling-in and knowledge spilling-out of academia with the goal of comparing the relative knowledge spillovers of university patents vis-à-vis firm patents.

Another important aspect of knowledge spillovers concerns the geographic patterns of knowledge dissemination. To the best of our knowledge, with the exception of Jaffe, Trajtenberg and Henderson (1993), the geographic comparison of knowledge spillovers from universities to those of firms has been largely overlooked. Recent literature examining the geography of academic knowledge flows has focused on comparisons among universities, such as the degree of localization of citations to academic patents vs. scientific publications (BELENZON; SCHANKERMAN, 2013) and the extent of localization of citations to academic patents vs. licensing agreements (MOWERY; ZIEDONIS, 2015). In general, the results of these studies suggest that the spillovers of academic knowledge tend to be geographically localized. For example, Belenzon and Schankerman (2013) find that citations to academic patents decline sharply with distance and are strongly constrained by state borders. However, the question of whether academic spillovers are more or less geographically localized compared to those of firms remains open. In order to address these questions, we investigate intra- and inter-state knowledge flows from universities and firms located in the US. Since state borders represent institutional delimitations that may confine and constrain knowledge flows (BELENZON; SCHANKERMAN, 2013), we consider them as a criterion in the investigation of the geography of academic and corporate knowledge dissemination.

Using patent forward citations as a measure of knowledge spillovers[1] (JAFFE; TRAJTENBERG; HENDERSON, 1993; MOWERY; ZIEDONIS, 2015), we examine

[1] In the empirical part of the chapter, we discuss the advantages and potential limitations in the use of forward citations as a proxy for knowledge spillovers.

citations to patents with application years between 1990 and 2000. This choice of period is due to the fact that it was only in the late 1980s and early 1990s that the importance of entrant-university and incumbent-university patents converged (MOWERY; SAMPAT; ZIEDONIS, 2002). This period also overlaps the research design employed in the literature (e.g., BACCHIOCCHI; MONTOBBIO, 2009; MOWERY; SAMPAT; ZIEDONIS, 2002; MOWERY; ZIEDONIS, 2002), allowing us to build on and extend those findings.

One empirical challenge in comparing university patents to those generated by firms concerns the heterogeneity in several observable and unobservable characteristics between these two groups. Previous studies (MOWERY; SAMPAT; ZIEDONIS, 2002; MOWERY; ZIEDONIS, 2002) have dealt with this potential issue using matching techniques to create treatment and control groups based on technological classes and the years that patents have been generated. We expand this approach and apply a more stringent matching criteria using coarsened exact matching (CEM) (IACUS; KING; PORRO, 2012). The use of stringent procedures reduces concerns related to endogeneity and also the sensitivity of post-matching-regression-based estimations on specific functional form assumptions (MOFFITT, 2004). To create treatment and control groups, we use additional matching criteria based on the patent's citations to scientific literature and to other patents, the number of individual inventors behind a patent, and the lag between the patent's application and its grant year. Therefore, we also extend the literature on academic knowledge and patents empirically by employing a more stringent matching procedure to create a comparable control group (counterfactual) to university patents.

Our main findings indicate that universities generate more spillovers than firms when academic spill-ins are not regarded as spillovers. This suggests that firm technologies rely more often on academic inventions than on those from other firms. Thus, we find no evidence that, relative to industry technologies, academic technologies sit unused on the shelves of university laboratories. Furthermore, our results indicate that the gap between academic and industry spillovers is smaller (but still significant) in industries where the economic value of patents is higher, such as chemicals and drugs. Finally, we find that universities generate fewer spillovers than firms locally and that academic knowledge spillovers are less geographically localized than those of corporate research.

2.1 Incentives and Strategies in University and Industry Patenting

Based on their own idiosyncratic attributes and goals, patent applicants may choose different strategies to maximize benefits and diminish their risks. Firms may patent aggressively for defensive purposes, aiming at leveraging patents in potential cross-licensing agreements and avoiding costly litigation (LAMPE, 2012; SAMPAT, 2010). Indeed, having a large patent portfolio increases the chances that a defendant will successfully countersue based on one or more of its own patents (PARCHOMOVSKY; WAGNER, 2005). In addition, it decreases the probability of being involved in a suit on any individual patent (LANJOUW; SCHANKERMAN, 2004). Therefore, firms may prioritize strategies such that the quality of individual patents is less important than obtaining a large patent stock (HALL; ZIEDONIS, 2001).

Universities, on the other hand, are less likely to benefit from strategies aiming at maximizing patent portfolios. While most firms tend to profit from their investments in R&D by embedding and commercializing their own technology in downstream product markets, the traditional route for universities to profit from innovation is through the upstream commercialization of academic patents through licensing contracts (ALCÁCER; GITTELMAN; SAMPAT, 2009). This may increase the incentives of universities to screen inventions and only patent those more likely to raise interest from potential licensees. Since patenting inventions with low potential for licensing would only imply unnecessary transaction costs and expenses, we expect that universities prioritize the quality of individual patents relative to the size of their patent portfolio. This assumption is supported by the fact that academic institutions have significantly higher shares of applicant-added citations than other types of assignees, even after controlling for technological fields (ALCÁCER; GITTELMAN; SAMPAT, 2009). Reporting relevant citations guarantees the enforceability of the issued patent over the cited art, making the patent stronger against potential litigation. Also, conducting thorough prior art searches and reporting relevant citations ensure that the boundaries between adjacent patents are more clearly defined, which increases the quality of the patent (LAMPE, 2012).

We do not expect that all university patents will be economically relevant, especially considering the heterogeneity in capabilities and resources of academic institutions. However, given the different incentives and strategies for commercialization, we expect universities to be in general more meticulous in their invention screening and patent application processes than are firms. In addition, due to their basic nature, university technologies are more likely to serve as fundamental inputs for later work across a broad range of fields and industries (TRAJTENBERG; HENDERSON; JAFFE, 1997). Finally, the expanding share of industry sponsored research (LAWSON, 2013) may lead to an increase in academic patents that solve practical research problems of firms. In this sense, we expect that spillovers of academic patents will be larger than those of corporate patents, even when knowledge spilling-in academia is not considered to be a spillover.

Dependent on different technology fields (e.g., drugs, chemicals, electronics, etc.), patenting strategies also vary considerably. Firms in industries with fragmented intellectual property are likely to prioritize a vast patent portfolio over the quality of individual patents, whereas the quality of IP is pivotal for firms in fields where patents are important for appropriating returns from R&D (ALCÁCER; GITTELMAN; SAMPAT, 2009; LAMPE, 2012; SAMPAT, 2010). For universities, in turn, differences in patenting incentives and strategies across fields are expected to be less salient. We argue that these diminished differences across technological fields for universities are also due to the differences in the patenting approaches of universities and firms. Consequently, the relative quality of individual academic patents is expected to be similar across fields (considering field specificities), which is not the case for corporate patents. Thus, assuming that university patents generate more spillovers than do firms, we expect that the differences between academic and industry spillovers will be smaller in technology fields where the economic value of patents is high, as for example drugs and chemicals.

2.2 Geographic Dimensions of University and Industry Knowledge Spillovers

The geographic proximity of firms with similar specializations provides them with advantageous, non-market knowledge externalities (AHARONSON; BAUM; FELDMAN, 2007; KOLYMPIRIS; KALAITZANDONAKES, 2013; WALLSTEN, 2001). As a consequence, firms are likely to be concentrated in certain states and locate close to one another (WALLSTEN, 2001). The increasing returns to existing concentrations of specialized R&D foster dense clustering of specialized firms (AHARONSON; BAUM; FELDMAN, 2007), which may contribute to the localization of the spillovers generated by corporate patents. Additionally, D’Este, Guy, & Iammarino (2013) find evidence that when firms located in dense technology clusters collaborate in research projects with universities, they do so regardless of the location of the university. Therefore, we expect that the impact of clusters of specialized firms on the localization of spillovers will be stronger for firm inventions than for academic patents.

In addition to the informal knowledge exchanges promoted by agglomerations of specialized R&D, formal channels through which inventions are disseminated may also influence the geography of academic and corporate patent spillovers. University inventions are likely to be disseminated through non-localized mechanisms such as conferences and journal publications (CZARNITZKI; HUSSINGER; SCHNEIDER, 2011; JAFFE; TRAJTENBERG; HENDERSON, 1993; MOWERY; ZIEDONIS, 2015). In fact, the diffusion of academic knowledge through distinct and widespread channels is essential for universities to accomplish their mission of promoting social and economic growth (ETZKOWITZ, 2003). As stated by Henderson, Jaffe and Trajtenberg (1998, p.119), "universities are in principle dedicated to the widespread dissemination of the results of their research". Firms, on the other hand, usually treat their inventions with secrecy and do not unveil their research results as do universities. Thus, considering the differences in both formal and informal dissemination mechanisms of university and firm inventions, as well as the fact that the basic nature of academic patents is likely to make them more suitable as inputs in a broad range of industries (TRAJTENBERG; HENDERSON; JAFFE, 1997), we expect that spillovers of academic patents will be less concentrated than those of corporate patents.

The question of whether academic spillovers are more or less concentrated than are those of firms remains relatively unexplored in the innovation literature. Also, it is not clear whether academic patents locally generate more or fewer spillovers than firms. Nevertheless, studies examining the geography of university knowledge flows suggest that spillovers of academic patents tend to be localized. For example, Jaffe, Trajtenberg and Henderson (1993) utilized two patent cohorts (1975 and 1980) to compare the geographic location of the citations to patents from universities, large firms and other firms. They found a strong pattern of localization of citations at the country, state and standard metropolitan statistical area (SMSA) levels, but no significant differences in localization between the citations to university and firm patents. Subsequent studies have shifted their focus to comparisons among different kinds of university spillovers. Belenzon and Schankerman (2013) use data on citations to academic patents and scientific publications to show that academic spillovers are strongly localized. Their findings indicate that citations to patents are very sensitive to distances up to 150 miles, but essentially constant beyond that. In addition, the authors report the existence of strong state border effects for citations to university patents, even after controlling for the distance between the citing/cited patent pair assignees.

Since the study of Jaffe, Trajtenberg and Henderson (1993), comparisons of the geography of knowledge flows from universities to those of firms have received little attention. We help to extend this research agenda by investigating intra- and inter-state knowledge flows from universities and firms located in the US. In addition, by comparing the fraction of local citations at the state level received by academic and corporate patents, we shed light on the debate as to whether academic spillovers are more or less geographically localized than to those of firms. Following Belenzon and Schankerman (2013), we consider state borders as a criterion with which to compare the geographic dissemination of knowledge from universities and firms. Indeed, state borders represent differences in local institutional settings that may influence knowledge spillovers beyond the state borders.

2.3 Data

To create our sample and variables, we collect data from two sources. First, we use information from the New NBER Patent Data Project. This database contains information about all US utility patents applied from 1976 to 2006 (BESSEN, 2009; HALL; JAFFE; TRAJTENBERG, 2001). Considering that the intensity with which universities commercialize their technologies experienced a sharp increase in the 80s, we opted to start our data collection from the 90s, 10 years after the passage of the Bayh-Dole Act. In our sample, we include all utility patents issued by the United States Patent and Trademark Office (USPTO) until 2000. We stop in 2000 to allow us to calculate forward citation within a 5-year moving window and avoid censoring issues. Using this window, we have sufficient time to observe the number of citations received by a patent overtime (HALL; JAFFE; TRAJTENBERG, 2001). Second, we use the Harvard Patent Network Dataverse to connect information on the nature of the backward citations in each patent (total number of scientific and non-scientific references) with the number of individual inventors of the patent.

Patents with multiple assignees were excluded from our sample.[2] The evaluation of knowledge spillovers in those cases could become very challenging, especially if co-assignees are located in different states or if a focal patent is simultaneously assigned to both a university and a firm. We restricted our sample to US Corporation and US University patents for which we could access all relevant information used in our empirical analysis. Our initial

[2] These patents represent roughly only 4% of all of the NBER database patents.

sampling procedure results in 559,328 patents with application years between 1990 and 2000, 20,067 belonging to universities and 539,261 to firms.

The next step was to employ CEM to find an adequate control group to assign each university patent in our sample. Specifically, we construct a sample that matches academic to industry patents based on the three-digit technology class, application year, grant year, number of individual inventors that created the patent (the team of inventors) and the technological uncertainty regarding the future development of a given technology.

By including the grant year as part of our matching criteria, we are able to account for the possibility that the gap between the application and the grant year might itself reflect non-trivial heterogeneity related to specific patent characteristics. Furthermore, we also take into consideration the start of a patent's "citation clock", which only occurs after a patent is issued (MEHTA; RYSMAN; SIMCOE, 2010). Matching on the number of inventors, we account for possible team size effects. Larger teams may have more connections to a network of inventors, increasing the chances of knowledge spillovers. Finally, matching on technological uncertainty, we allow for instances in which the stage of development of a technology might impact its relevance as an input to other technologies (LAURSEN et al., 2017). This variable is measured as the rate of scientific references in the backward citations of the focal patents in a sample. The idea behind this measure is that the uncertainty associated with "early stage" technologies has a greater chance of being higher (ZIEDONIS, 2007) and that these technologies are more likely to be based on scientific knowledge (LAURSEN et al., 2017), whereas mature technologies (closer to market) will more often rely on other patented inventions. We employ exact matching for application year, grant year and technological class, whereas, for the number of inventors, we use three buckets (1 or 2, 3, and 4 or more) and twenty for technological uncertainty (equally distributed in 0.05 intervals from 0 to 1).

With this set of criteria, we are able to find industry matches for 12,871 out of 20,067 academic patents, resulting in a final sample of 25,742 patents, 12,781 observations pertaining university patents and the same number for corresponding industry patents. Post-matching T-tests indicate no significant difference for any of the matching variables between both groups. In addition, the Multivariate Imbalance Measure (MIB) $\mathcal{L}_1$ decreases from 0.620 pre-matching to 0.145 post-matching, suggesting a significant improvement in the overall level of imbalance between university and firm patents (IACUS; KING; PORRO, 2012).

2.4 Methodology

2.4.1 Dependent variable

The inventive process is primarily cumulative as inventions build on previous knowledge and also serve as input for other inventions that come after (JAFFE; DE RASSENFOSSE, 2017). Thus, the citations that appear in a patent, known as backward citations, contain information on the technological antecedents of the invention. In contrast, the citations that a patent receives from subsequent patents, known as forward citations, contain information on its technological descendants. We use forward citations as a proxy to quantify the amount of knowledge spillover generated by a patent (JAFFE; TRAJTENBERG; HENDERSON, 1993). Knowledge spillovers have been defined as the use of previous inventions as input for the development of new inventions without the existence of a contractual agreement and where, in many cases, no monetary compensation exists (MOWERY; ZIEDONIS, 2015). Since the pioneering study of Jaffe, Trajtenberg and Henderson (1993), patent forward citations have been used in the literature as a proxy for knowledge spillovers (HENDERSON; JAFFE; TRAJTENBERG, 1998; MOWERY; ZIEDONIS, 2015; ROSELL; AGRAWAL, 2009; SINGH; AGRAWAL, 2011). In this study, we operationalize our dependent variable by computing the number of forward citations that university and firm patents received within a five-year moving window, starting with its application year. Given that self-citations do not represent knowledge flows (BELENZON; SCHANKERMAN, 2013; ROSELL; AGRAWAL, 2009), we exclude those citations from the computation of our dependent variable. However, excluding self-citations does not allow one to determine whether academic knowledge flows are spilling-in or spilling-out academia. It is possible, for example, that the greater percentage of citations academic patents receive are from peer universities, implying that academic knowledge stays mostly within the confines of universities. Therefore, we also use as dependent variable a measure that computes only forward citations made by firms. By doing this, we are able to assess the impact of academic knowledge on the private sector and to shed light on the debate of whether academic technology-based knowledge is or is not confined within the ivory tower. In a nutshell, we estimate our main analysis using two different dependent variables: (1) total number forward citations received by a focal patent; (2) total number forward citations received by a focal patent only from industry patents. To evaluate the geography of knowledge spillovers of universities and firms, we compute these variables for two subsets of the total forward citations generated in the US: citations received within the same state as the focal patent, and citations received in different states than the focal patent. With these criteria, we are able to determine if universities generate more (or less) spillovers than firms, both locally and non-locally. Finally, to investigate whether academic spillovers are more or less localized than those of firms, we use the fraction of local US citations (at the state level) received by the focal patents as our last dependent variable.

2.4.2 Control variables

Technology and patentee attributes not included in our matching approach may also influence the count of forward citations received by the focal patents in our sample. By using CEM, we are able to eliminate a large portion of undesirable heterogeneity between university and firm patents, making both groups more comparable. To further strengthen our econometric approach, we use several control variables to account for any remaining undesirable heterogeneity related to the focal patent in our sample. At the patent level, we control for the backward citation's age and patent scope. A backward citation's age is measured as the average age in years of all the backward patent citations of a focal patent. Patents based on current technologies are expected to cite recent patents, whereas patents with an older technology base are more likely to cite older patents. Following previous studies (CZARNITZKI; HUSSINGER; SCHNEIDER, 2011; LERNER, 1994), we use the number of technology classes to which a patent is assigned as a measure of patent scope. Patents with a broader scope are expected to receive more citations from other patents (LERNER, 1994). At the patent-organization dyad level, we employ the focal index proposed by Ziedonis (2007) to control for the proximity between a focal patent and the technological portfolio of the patentee organization. The idea behind this variable is to measure how close a patent i is to the core technological capabilities of the patentee organization j (which, in this case, can be either a university or a firm). We expect that the closer a patent is to the core technological areas of the organization that created it, the more likely it is that this patent will be more valuable. This measure ranges between 0 and 1, with values closer to 1 meaning that the organization's core patent portfolio corresponds closely to the focal patent's technology class. The index is calculated as follows:

$$Core\ Technology = \left[\frac{\left(\sum_{t-6}^{t}\sum_{j}\tilde{C}_i.\, p_i\right)_c}{\left(\sum_{t-6}^{t}\sum_{j}\tilde{C}_i.\, p_i\right)}\right],$$

where t represents the focal patent's application year, $\left(\sum_{t-6}^{t}\sum_{j}\tilde{C}_{i}.p_{i}\right)_{c}$ the citation-weighted sum of university/firm i's issued patents that were applied for within 6 years at the time of the focal patent application t and that belong to the same primary class of the patent under consideration, and $\left(\sum_{t-6}^{t}\sum_{j}\tilde{C}_{i}.p_{i}\right)$ is the sum of all citation-weighted patents issued to the university/firm j that were applied for by date t. We expect that patents belonging to the focal organization's core technology are more likely to be cited by other patents.

Additionally, we control for the stock of patents of a focal organization by using the total number of patents assigned to the university/firm during the five years prior to the application year of the focal patent. Given that unobserved characteristics of the focal patent's geographic location (e.g., the existence of high technology clusters or local laws) might also impact forward citations, we incorporate state-fixed effects in our analysis. Finally, we use period-fixed effects based on the application year of the focal patent to account for period effects that could drive forward citation patterns.

2.4.3 Estimation technique

We employ negative binomial regressions to compare the number of citations to academic patents with the citations to industry patents. In addition, we use tobit regressions to compare the fraction of local citations received by academic and corporate patents. We estimate the following specification using data at the patent level:

$$Y_i = \alpha Univ_i + \beta X_{ij} + \eta_{state} + \eta_{year} + \varepsilon$$

where Y_i is either the number of citations received by patent i, for the negative binomial models, or the fraction of local citations received by patent i, for the tobit models; $Univ_i$ is a dummy that takes a value of one if patent i is assigned to a university and zero otherwise; X_{ij} is a set of control variables that include measures at the focal patent level as well as at the level of the patentee organization j[3]; η_{state} represents state-fixed effects; η_{year} represents application year- fixed effects; and ε is the error term.

The sign and significance of α offers insight into the relationship between the type of patentee organization (university or firm) and the patterns of knowledge spillovers. When the

[3] We refer to the patentee organization as the organization, either university or firm, that has developed the patent in question.

dependent variable is the number of citations received by the focal patent, a positive and statistically significant α can be interpreted as evidence that academic patents generate more spillovers than corporate patents, while a negative and significant coefficient indicates the opposite. When the dependent variable is the fraction of local citations received by the focal patent, a positive and statistically significant α can be interpreted as suggestive evidence that the spillovers of academic patents are more concentrated than those of firm patents.

2.5 Results

2.5.1 Summary statistics and correlations

Table 2.1 reports the mean, standard deviation, minimum and maximum values, and the Pearson correlation for the variables considered in the regression analysis. None of the correlations raise concern about multicollinearity, which we confirmed with a variance inflation factor (VIF) analysis. The highest VIF for any of our independent/control variables is 1.31 (mean VIF=1.15).

Table 2.1 – Descriptive statistics and correlations post-matching (N= 25,742)

	Variable	Mean	S.D.	Min.	Max.	1	2	3	4	5
1	University dummy	0.50	0.50	0	1	1.000				
2	Average BPC's age	7.15	3.77	0	25	-0.027	1.000			
3	Patent scope	1.62	0.71	1	4	0.018	-0.015	1.000		
4	Core Technology	0.28	0.33	0	1	-0.373	0.049	-0.058	1.000	
5	Stock of patents	661.0	1,579.9	1	21,196	-0.137	-0.078	-0.003	-0.258	1.000

Source: elaborated by the authors

2.5.2 General results

The general results of academic and industry spillovers can be seen on Table 2.2. The goal of the regression analysis is to investigate to what extent knowledge spilling-in academia may lead to an overestimation of the spillovers generated by university patents. In Model 1, we regress our explanatory variables on the total number of forward citations that the focal patents receive. The results are in line with previous findings (BACCHIOCCHI; MONTOBBIO, 2009; HENDERSON; JAFFE; TRAJTENBERG, 1998; MOWERY; SAMPAT; ZIEDONIS, 2002; ROSELL; AGRAWAL, 2009), indicating that, on average, university patents generate a greater number of spillovers than do firms. The predicted citations count for university patents, holding all other variables at their means, is 19.5 percent higher than it is for firms (Universities = 4.83 vs. Firms = 4.04). One possible explanation for this gap is that the relatively greater importance of academic patents is caused by university spill-ins (i.e., knowledge flows from one university to another). If the greater number of shares of inter-university patent citations are driving this finding, it is reasonable to assume that a good portion of university technological knowledge may remain confined within the academia, being far less useful for the industry than the results suggest.

To investigate if that is the case, we estimate Models 2 to 8 using the total number of forward citations that the focal patents receive exclusively from firms as a dependent variable. The results of Model 2 extend the findings of previous studies and indicate that, although the relative importance of academic patents decreases when only corporate spillovers are considered, they still generate more spillovers than their industry counterparts. The predicted citations count for university patents, holding all other variables at their means, is 11.4 percent higher than it is for firms (Universities = 4.12 vs. Firms = 3.70). Interestingly, when we employ fixed effects for state and application year (results are reported on the lower section of Table 2.2), the relative importance of university patents increases across the models. The predicted citations count for universities becomes 25.6 percent higher than it is for firms in Model 1 (Universities = 4.56 vs. Firms = 3.63) and 17.1 percent higher in Model 2 (Universities = 3.90 vs. Firms = 3.33). Thus, we find no evidence that, in comparison to industry patents, academic patents containing scientific knowledge sit unused on the shelves of university labs. Further, our findings also indicate that academic patents are more likely to be cited, even by corporate patents, when contrasted with patents from firms.

Table 2.2 – Negative binomial models estimating forward citations *

Variables	Total forward citations (1) All cat.	Only corporate citations (2) All cat.	(3) Chem.	(4) Comp.	(5) Drugs	(6) Elec.	(7) Mech.	(8) Others
University dummy	0.178***	0.108***	0.162*	0.237***	0.064	0.194***	0.095	-0.194+
	(0.025)	(0.027)	(0.064)	(0.062)	(0.044)	(0.052)	(0.099)	(0.113)
Average BPC's age	-0.049***	-0.050***	-0.033***	-0.048***	-0.015**	-0.054***	-0.051***	-0.065***
	(0.003)	(0.003)	(0.009)	(0.008)	(0.005)	(0.006)	(0.013)	(0.012)
Patent scope	0.090***	0.085***	0.092*	-0.029	0.122***	0.163***	0.149*	0.194***
	(0.015)	(0.016)	(0.037)	(0.034)	(0.031)	(0.033)	(0.065)	(0.057)
Core technology	0.253***	0.220***	0.573***	0.501***	0.496***	0.387***	0.479**	-0.183
	(0.038)	(0.040)	(0.094)	(0.101)	(0.069)	(0.084)	(0.170)	(0.127)
Stock of patents (/1000)	0.039***	0.044***	0.026	-0.010	0.056*	-0.002	0.030	0.045+
	(0.007)	(0.007)	(0.017)	(0.011)	(0.025)	(0.011)	(0.029)	(0.026)
Constant	1.508***	1.440***	0.956***	2.254***	0.719***	1.588***	1.443***	1.478***
	(0.041)	(0.044)	(0.117)	(0.091)	(0.081)	(0.080)	(0.167)	(0.174)
Log-likelihood	-64,805.1	-61,227.4	-8,886.2	-8,733.8	-24,671.8	-11,524.1	-3,408.1	-2,502.0
Pseudo R^2	0.004	0.004	0.004	0.006	0.002	0.008	0.007	0.015
N	25,742	25,742	4,170	2,746	12,130	4,248	1,346	1,102
Equations with application year and state fixed effects								
University dummy	0.228***	0.158***	0.153*	0.282***	0.144**	0.194***	0.038	-0.266**
	(0.026)	(0.027)	(0.060)	(0.058)	(0.047)	(0.053)	(0.087)	(0.101)
Average BPC's age	-0.043***	-0.044***	-0.029***	-0.035***	-0.014**	-0.044***	-0.048***	-0.059***
	(0.003)	(0.003)	(0.008)	(0.008)	(0.005)	(0.006)	(0.010)	(0.010)
Patent scope	0.073***	0.069***	0.086*	-0.008	0.081**	0.164***	0.152**	0.181***
	(0.015)	(0.016)	(0.035)	(0.032)	(0.028)	(0.031)	(0.049)	(0.051)
Core technology	0.294***	0.263***	0.666***	0.574***	0.569***	0.377***	0.522***	-0.091
	(0.037)	(0.039)	(0.100)	(0.087)	(0.067)	(0.078)	(0.140)	(0.123)
Stock of patents (/1000)	0.054***	0.058***	0.036*	0.003	0.099***	-0.014	0.033	0.050*
	(0.007)	(0.007)	(0.017)	(0.012)	(0.024)	(0.011)	(0.027)	(0.024)
Constant	-0.694	-0.632	-0.794***	1.085***	-0.034	0.162	0.506	-0.982
	(0.569)	(0.567)	(0.144)	(0.304)	(1.101)	(0.356)	(0.422)	(0.674)
Log-likelihood	-63,808.5	-60,361.4	-8,716.7	-8,488.4	-24,089.1	-11,370.7	-3,289.5	-2,418.6
Pseudo R^2	0.019	0.018	0.023	0.034	0.026	0.021	0.041	0.048
N	25,742	25,742	4,170	2,746	12,130	4,248	1,346	1,102

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

*All forward citation counts are represented in a five-years moving window and exclude self-citations. These models consider both citations from the US and from outside the US. The regressions on the lower half of the table account for application year and state fixed effects. Robust standard errors are reported in parenthesis. Model 1 accounts for citations of both universities and corporations, whereas Models 2 to 8 account only for corporate citations. Models 3 to 8 represent the 6 technology categories in the US patenting system. These are, respectively, Chemical, Computers & Communications, Drugs & Medical, Electrical & Electronics, Mechanical, and Others.

Source: elaborated by the authors

Next, Models 3 to 8 report the results for each of the 6 technology categories in the US patenting system – Chemical, Computers and Communications, Drugs and Medical, Electrical and Electronics, Mechanical, and Others. Our findings show that, across most of the technological categories, academic patents appear to generate more spillovers than their corporate counterparts. The differences in citation counts are smaller in drugs and chemical (industries in which patents are traditionally of economic value) and larger in computers and electronics (industries with complex technologies, where firms have strong incentives to aggressively patent). Model 5 shows that, for drugs, the differences between academic and industry spillovers only become significant once state and application year-fixed effects are accounted for. A possible interpretation of this finding is that industry spillovers are more localized than are university spillovers. Alternatively, the drugs industry may be concentrated in just a few states, whereas universities active in this field may be spread across the entire US.[4]

2.5.3 Geography of knowledge spillovers

Our analysis concerning the geography of academic and corporate knowledge spillovers is presented on Table 2.3. Models 9 and 11 show the negative binomial regressions for citations received within the same state as the focal organization. While Model 9 still considers academic spill-ins (i.e., knowledge flows from one university to another) for the assessment of knowledge flows, Model 11 only considers corporate citations as a proxy for spillovers. We observe that the university dummy has a negative and significant effect in both models, suggesting that spillovers of firms are locally stronger than those of universities. As expected, the negative effect of the university dummy becomes more significant when only corporate citations are considered (Model 11). In Model 11, the predicted citations count for firm patents is 25.6 percent higher than it is for universities (Universities = 0.51 vs. Firms = 0.64). Once we include state and application year-fixed effects, the predicted citation count for universities and firms becomes very similar (Universities = 0.27 vs. Firms = 0.28) and the difference between academic and industry spillovers becomes insignificant. These results are consistent with the idea that US high-tech firms are concentrated in certain states, as suggested by Wallsten (2001). In addition, these findings indicate that patterns of geographic concentration of specialized R&D may be responsible for the apparent localization of the spillovers generated by corporate patents.

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[4] We also estimated the models employing fixed effects in a step-wise fashion. When we consider only state fixed effects the coefficient for the university dummy in Model 5 is higher (and also significant at $p<0.01$) than it is when we consider both state and application year effects.

Next, in Models 10 and 12, we analyze non-localized knowledge flows, i.e., citations received in states different from that of the focal organization. The positive and significant coefficients of the university dummy in Models 10 and 12 indicate that academic patents are more relevant than corporate patents in different states. Further, the results of Model 12 – considering that university spill-ins are excluded in this model – suggest that corporate patents more often rely on non-local academic technologies than on non-local corporate patents. In Model 12, the predicted citations count for university patents is 21.2 percent higher than it is for firms' patents (Universities = 2.68 vs. Firms = 2.21). The advantage of the predicted citations count that universities have over firms increases to 24.3 percent (Universities = 2.49 vs. Firms = 2.00) once we include fixed effects for state and application year, which is consistent with the other models.

Finally, in Models 13 and 14, we investigate whether academic spillovers are more or less localized than those of firms. To do that, we use tobit models to regress our explanatory variables on the fraction of local citations received by the focal patents. While Model 13 considers all US citations received by the focal patents, Model 14 only focuses on corporate citations for the computation of the dependent variable. In both models, the negative and significant coefficient of the university dummy indicates that university research spillovers are less likely to be geographically localized than those emerging from corporate research. An alternative explanation is that these results are driven by pre-existing patterns of geographic concentration of specialized R&D. In other words, the geographic concentration of specialized firms in technology clusters may lead to a high concentration of intra-state firm-to-firm citations. Universities, on the other hand, may not be as geographically localized as firms, increasing the likelihood of non-localized academic spillovers. By estimating Models 13 and 14 with state-fixed effects we are able to investigate if pre-existing patterns of geographic localization of firms are driving these findings. The coefficient of the university dummy remains negative after we include state- (and application year-) fixed effects, suggesting that the spillovers generated by academic patents are in fact less localized than those generated by firm patents, regardless of potential effects caused by industrial clustering.

Table 2.3 – Models estimating forward citations locally and non-locally (state level) *

	Negative binomial models				Tobit models	
	Total forward citations		Only corporate citations		Total forward. Cit.	Only corporate cit.
Variables	**(9) Same state**	**(10) Different states**	**(11) Same state**	**(12) Different states**	**(13) Fraction of local citations**	**(14) Fraction of local citations**
University dummy	-0.148**	0.268***	-0.227***	0.192***	-0.214***	-0.265***
	(0.057)	(0.028)	(0.060)	(0.031)	(0.023)	(0.027)
Average BPC's age	-0.070***	-0.040***	-0.073***	-0.040***	-0.016***	-0.022***
	(0.007)	(0.003)	(0.008)	(0.004)	(0.003)	(0.003)
Patent scope	0.137***	0.084***	0.145***	0.077***	0.004	0.013
	(0.038)	(0.017)	(0.040)	(0.019)	(0.014)	(0.017)
Core technology	0.021	0.331***	-0.066	0.302***	-0.100**	-0.145***
	(0.089)	(0.043)	(0.095)	(0.046)	(0.034)	(0.040)
Stock of patents (/1000)	-0.030	0.037***	-0.026	0.044***	-0.030***	-0.041***
	(0.019)	(0.008)	(0.020)	(0.008)	(0.006)	(0.007)
Constant	-0.131	0.938***	-0.131	0.845***	-0.304***	-0.304***
	(0.096)	(0.047)	(0.102)	(0.051)	(0.039)	(0.045)
Log-likelihood	-21,912.8	-54,447.5	-20,581.1	-50,219.1	-12,784.4	-11,960.4
Pseudo R^2	0.004	0.004	0.005	0.003	0.005	0.006
N	25,742	25,742	25,742	25,742	17,138	15,547
	Equations with application year and state fixed effects					
University dummy	0.069	0.296***	-0.056	0.217***	-0.115***	-0.154***
	(0.056)	(0.028)	(0.059)	(0.031)	(0.005)	(0.006)
Average BPC's age	-0.028***	-0.039***	-0.031***	-0.039***	-0.002***	-0.005***
	(0.007)	(0.003)	(0.007)	(0.003)	(0.001)	(0.001)
Patent scope	0.103**	0.066***	0.117***	0.058***	0.006*	0.014***
	(0.032)	(0.016)	(0.034)	(0.018)	(0.003)	(0.004)
Core technology	0.317***	0.337***	0.210*	0.300***	0.006	-0.011
	(0.077)	(0.041)	(0.083)	(0.044)	(0.007)	(0.008)
Stock of patents (/1000)	-0.055**	0.061***	-0.054**	0.066***	-0.051***	-0.062***
	(0.018)	(0.008)	(0.019)	(0.008)	(0.001)	(0.001)
Constant	-19.407	-1.517*	-22.751	-1.463*	-5.710***	-6.316***
	(-)	(0.688)	(-)	(0.674)	(0.006)	(0.008)
Log-likelihood	-20,584.5	-53,569.0	-19,286.8	-49,476.3	-11,583.8	-10,665.1
Pseudo R^2	0.065	0.020	0.067	0.018	0.098	0.114
N	25,742	25,742	25,742	25,742	17,138	15,547

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

*All forward citation counts are represented in a five-years moving window and exclude self-citations. These models consider only US citations. The regressions on the lower half of the table account for application year and state fixed effects. Robust standard errors are reported in parenthesis. Models 9 and 11 account for citations received within the same state as the focal organization, whereas Models 10 and 12 account for citations received from different states. Models 13 and 14 account for the fraction of local citations (at state level) received by the focal patents. While Models 9, 10 and 13 consider all citations received by the focal patents, Models 11, 12 and 14 consider only citations received by corporate patents.

Source: elaborated by the authors

2.5.4 Robustness checks

The use of citation-based measures as a proxy for knowledge spillovers requires caution, especially considering the different dimensions that could lead to biased results. By employing a stringent matching procedure, adequate control variables, and measuring citations in a fixed five-year moving window, we mitigate potential sources of bias at the focal patent level (cited patent). Among these are possible differences in the fertility of different patent cohorts, technological field effects, the experience of the focal organization with patenting and the proximity of the technology to basic science.

Nevertheless, there are also effects at the citing patents level that can lead to biased estimations. By considering the citations that the focal patents received exclusively from corporations as dependent variable, we were able reduce some of the bias caused by different kinds of assignee. However, it is also necessary to account for the effects of potential technological field heterogeneity in the patents citing universities and the patents citing firms. The share of examiner-added citations – which are less likely to represent spillovers (JAFFE; DE RASSENFOSSE, 2017) – varies considerably across fields. Examiner citations are less likely in industries where patents are more economically valuable, such as drugs and chemical, and more likely in fields where intellectual property is more fragmented, such as computers and electronics (ALCÁCER; GITTELMAN; SAMPAT, 2009; COTROPIA; LEMLEY; SAMPAT, 2013; LAMPE, 2012).

Thus, in order to account for potential bias due to technological field heterogeneity, we examine separately the citations that the focal patents received from corporations in each technology category. Table 2.4 presents the results from estimating these models. Model 15 suggests that academic and firm patents receive similar citation shares from chemical patents. Next, Models 16, 17 and 18 indicate that university patents are more frequently cited by patents in computers, drugs and electronics than their corporate counterparts. Finally, Models 19 and 20 point out that industry technologies are more frequently cited by patents in mechanical and others than university patents.

Overall, the effects of citations from different technological fields on the spillovers of academic and corporate patents are mixed. However, the only industries that cite firms more frequently than universities are mechanical and others; and they only represent 10.9 percent of the total citations received by our focal patents. In addition, the shares of examiner-added citations are high within these fields, which makes them less likely to represent knowledge flows. In this sense, we conclude that university patents are in general more likely to generate spillovers than do their corporate counterparts.

Table 2.4 – Negative binomial models estimating forward citations according to the citing patent technological category *

	Only corporate citations					
Variables	**(15) Citations from chem.**	**(16) Citations from comp.**	**(17) Citations from drugs**	**(18) Citations from elec.**	**(19) Citations from mech.**	**(20) Citations from others**
University dummy	-0.013	0.177**	0.263***	0.185**	-0.153*	-0.146+
	(0.049)	(0.068)	(0.049)	(0.056)	(0.076)	(0.086)
Average BPC's age	0.018**	-0.148***	-0.027***	-0.055***	0.002	0.042***
	(0.006)	(0.009)	(0.006)	(0.007)	(0.009)	(0.009)
Patent scope	0.291***	0.008	0.069+	0.018	0.196***	0.274***
	(0.032)	(0.037)	(0.037)	(0.035)	(0.046)	(0.045)
Core technology	-0.010	-0.296**	1.181***	-0.325***	-0.369**	0.037
	(0.076)	(0.105)	(0.077)	(0.090)	(0.122)	(0.106)
Stock of patents (/1000)	-0.062***	0.101***	-0.133***	0.130***	0.038+	0.046+
	(0.017)	(0.016)	(0.037)	(0.016)	(0.021)	(0.027)
Constant	-1.222***	0.773***	-0.204*	0.048	-1.545***	-2.496***
	(0.092)	(0.101)	(0.097)	(0.090)	(0.119)	(0.122)
Log-likelihood	-21,101.8	-22,366.7	-30,780.6	-24,819.8	-12,499.6	-10,083.6
Pseudo R^2	0.004	0.013	0.010	0.006	0.002	0.004
N	25,742	25,742	25,742	25,742	25,742	25,742
	Equations with application year and state fixed effects					
University dummy	0.037	0.180**	0.373***	0.206***	-0.228**	-0.169*
	(0.049)	(0.060)	(0.049)	(0.057)	(0.075)	(0.080)
Average BPC's age	0.020***	-0.137***	-0.025***	-0.041***	-0.001	0.039***
	(0.006)	(0.009)	(0.005)	(0.006)	(0.008)	(0.008)
Patent scope	0.270***	0.040	0.034	0.010	0.195***	0.267***
	(0.030)	(0.035)	(0.032)	(0.032)	(0.040)	(0.045)
Core technology	0.069	-0.334***	1.261***	-0.327***	-0.361**	0.143
	(0.076)	(0.095)	(0.072)	(0.087)	(0.118)	(0.102)
Stock of patents (/1000)	-0.028	0.099***	-0.114**	0.113***	0.047*	0.094***
	(0.020)	(0.015)	(0.035)	(0.016)	(0.021)	(0.025)
Constant	-1.896**	-18.564	-1.662	-20.697	-19.545	-21.576
	(0.605)	(72.618)	(1.288)	(-)	(59.589)	(-)
Log-likelihood	-20,769.3	-22,074.5	-30,181.8	-24,517.0	-12,359.8	-9,897.6
Pseudo R^2	0.019	0.026	0.030	0.018	0.014	0.023
N	25,742	25,742	25,742	25,742	25,742	25,742

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

* All forward citation counts are represented in a five-years moving window and exclude self-citations. These models sort the citations received by the focal patents according to the citing patent technological category. Citations from both the US and from outside the US are considered. The regressions on the lower half of the table account for application year and state fixed effects. Robust standard errors are reported in parenthesis.

Source: elaborated by the authors

Finally, we also checked the relative importance of industry and academic patents changed over time. To do this, we estimated Models 1 and 2 for five sub-periods: 1990-1991, 1992-1993, 1994-1995, 1996-1997, and 1998-2000. Overall, we do not find evidence that the relative importance of academic patents has changed over time. The results of these tests, represented in Table 2.5, suggest that university patents consistently generate more spillovers than their corporate counterparts over time.

Table 2.5 – Evolution of the relative spillovers of academic patents vis-à-vis firm patents over the years *

	Total forward citations			Only corporate citations		
Year	**University dummy**	**Average citations**	***N***	**University dummy**	**Average citations**	***N***
1990-1991	0.199**	4.418	2,248	0.098	3.813	2,248
	(0.065)			(0.070)		
1992-1993	0.137*	5.232	3,254	0.064	4.562	3,254
	(0.063)			(0.069)		
1994-1995	0.232***	5.188	5,494	0.171**	4.514	5,494
	(0.052)			(0.057)		
1996-1997	0.177***	5.942	5,392	0.107*	5.301	5,392
	(0.050)			(0.054)		
1998-2000	0.198***	3.071	9,354	0.130*	2.774	9,354
	(0.048)			(0.051)		
	Equations with state fixed effects					
1990-1991	0.290***	4.418	2,248	0.192**	3.813	2,248
	(0.067)			(0.071)		
1992-1993	0.206***	5.232	3,254	0.134*	4.562	3,254
	(0.062)			(0.068)		
1994-1995	0.284***	5.188	5,494	0.226***	4.514	5,494
	(0.051)			(0.054)		
1996-1997	0.214***	5.942	5,392	0.141*	5.301	5,392
	(0.052)			(0.055)		
1998-2000	0.212***	3.071	9,354	0.140**	2.774	9,354
	(0.049)			(0.051)		

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

* All forward citation counts are represented in a five-years moving window and exclude self-citations. The regressions on the lower part of the table account for state fixed effects. Robust standard errors are reported in parenthesis.

Source: elaborated by the authors

2.6 Limitations in the Use of Patent Citation-Based Measures

Despite the wide use of citations as a proxy for technology value and knowledge spillovers, there are also limitations in the utilization of citation-based measures. One of its main limitations is related to the way that citations can be generated (LAMPE, 2012; MOSER; OHMSTEDT; RHODE, 2018), in particular, the manner in which citations can be added, not only by the patentee organization, but also by patent office examiners (ALCÁCER; GITTELMAN, 2006; MOSER; OHMSTEDT; RHODE, 2018; SAMPAT, 2010).

Considering that examiner-added citations may not truly reflect the knowledge used by inventors (ALCÁCER; GITTELMAN, 2006; ALCÁCER; GITTELMAN; SAMPAT, 2009), there have been questions regarding the degree to which patent citations can be considered a good proxy for knowledge spillovers. Surveying inventors, Jaffe, Trajtenberg, and Fogarty (2000) explore the extent to which citations to the own inventors' patents in fact represent the dependence of their invention on earlier knowledge. Their findings indicate that up to half of citations may not represent true spillovers. Despite that, the authors conclude that citations can be a noisy but valid measure of knowledge spillovers. In another study, Alcácer and Gittelman (2006) explore the influence of examiner citations on knowledge flows. They find that, in general, examiner and inventors have similar citation patterns, so that pooled citations provide a good proxy for spillovers. More recently, investigating the limitations in the use of citation-based measures to trace knowledge spillovers, Roach and Cohen (2013) matched managers' reports on knowledge flows from public research with patent data. They conclude that, despite the errors, overall patent citations likely reflect important aspects of knowledge flows, thus they continue to be largely used to measure knowledge flows (MOWERY; ZIEDONIS, 2015; ROSELL; AGRAWAL, 2009; SINGH; AGRAWAL, 2011).

We have reasons to believe that the inclusion of citations by patent office examiners are less concerning in our study due to the matching sample technique we employ to compare university and firm patents. We are not aware of any research indicating that university (or firm) patents are relatively more (or less) likely to be added as backward citations in other patents by examiners. In other words, we have no evidence that when adding backward citations to newly applied patents, examiners will have a bias towards either university or firm patents additions. Given that our dependent variable is computed based on the citations that university and firm patents receive, we expect that any bias created by an examiner´s review of patent citations will be shared by both our focal university patents and their respective control group. Therefore, we expect that this potential issue is of less concern in our study.

2.7 Discussion

In this chapter, we investigate whether the spillovers generated by academic patents cross university boundaries or whether they remain trapped inside the ivory tower. In addition, we explore geographic patterns of spillovers from universities and firms. More specifically, we examine the generation of local and non-local spillovers and also the geographic concentration of spillovers generated by university and firm patents.

Since prior literature did not differentiate between knowledge spilling-in or spilling-out academia, it is possible that a great portion of what have been considered academic spillovers may be actually academic spill-ins, i.e., knowledge flows among universities. By employing spillover measures that exclude knowledge flows among universities, we provide evidence that university patents are indeed an important input for firm technologies. We find that academic patents generate more spillovers than corporate patents, even when inter-university knowledge flows are not regarded as spillovers. Of course, in this case, the relative importance of academic patents decreases when compared to those of firms. Still, the expected citations count for universities is 11.4 percent higher than it is for corporations. This share still increases to 17.1 percent after considering state and application year-fixed effects. In addition, we find that the gap between university and industry spillovers is smaller in industries where patents are important for appropriating returns from R&D (i.e., more economically valuable), such as chemical and drugs, and larger in industries with complex technologies (where firms have strong incentives to patent aggressively), such as computers and electronics.

In order to investigate the geography of spillovers, we compare intra- and inter-state knowledge flows of universities and firms. Our results show that, locally, industry patents generate more spillovers than their academic counterparts. However, the difference between university and industry local spillovers becomes insignificant once we consider state-fixed effects, which may indicate some degree of geographic concentration of firms. On the other hand, the spillovers of university patents are larger in different states. Finally, we find that academic spillovers appear to be less geographically localized than those of corporations, even when state-fixed effects are accounted for. In this sense, we do not believe that pre-existing patterns of geographic localization of firms may have biased our results.

Overall, our findings extend those of previous literature, ratifying that importance of universities as a source of knowledge and technology for firms. We attribute these findings to a number of potential mechanisms. First, the specific patenting strategies of firms and universities may lead to differences in knowledge spillovers. Different than firms, universities’ main goal is to license technologies (instead of commercializing them directly). Thus, it is plausible that they prioritize the quality of individual patents over the size of the patent portfolio, which could lead to more spillovers. However, not every firm would benefit from such a strategy. For example, in order to safeguard their investments through the use of ex ante mechanisms, firms operating in fragmented markets are likely to adopt aggressive patenting strategies (ZIEDONIS, 2004). These strategies may lead to the deposit of lower-quality patents, ultimately resulting in fewer spillovers. In addition, to avoid potential conflicts over intellectual property, firms may prefer to explore knowledge created within universities than technologies from other firms (BERCOVITZ; FELDMAN, 2007). Second, differences between university and firm citation rates might also be explained by within-technology differences (CZARNITZKI; HUSSINGER; SCHNEIDER, 2011).[5] The supposed basic and general nature of academic patents can make them more useful for a larger number of technologies. As stated by Trajtenberg, Henderson and Jaffe (1997), the basic nature of university technologies makes them more likely to serve as valuable input in a broad range of fields and industries. Third, the diffusion of knowledge is essential to the accomplishment of the university's mission, which encompasses the translation of scientific knowledge into economic and social utilities (ETZKOWITZ, 2001, 2003). Finally, academic inventions are likely to be disseminated through distinct channels such as conferences, journal publications, and faculty consulting (CZARNITZKI; HUSSINGER; SCHNEIDER, 2011; MOWERY; ZIEDONIS, 2015), which are also forms of spillover, while, in contrast, firm inventions are usually treated with secrecy and knowledge about them is not widespread.

2.8 Conclusion

Our work contributes to the literature in several distinct ways. By using an approach that does not consider university spill-ins as spillovers, we find evidence that academic technology-based knowledge is not trapped inside the ivory tower. Our findings suggest that firm technologies rely more often on academic patents than on technologies from other firms. As to the geography of knowledge spillovers, our results suggest that spillovers from firms are more likely to be localized than those of universities. Finally, this study also advances the methodology employed in prior research to find adequate control patents when analyzing knowledge flows. By employing coarsened exact matching to find our control patents, we reduce concerns about endogeneity-related biases.

As in other studies, our analysis is subject to limitations. First, the fact that citations can be added by patent examiners rather than by inventors may introduce noise and inflate the measurements of knowledge flows. Despite that, there is evidence pointing to the idea that a relevant fraction of examiner-added citations may complete inventor reporting gaps and actually correspond to spillovers. Alcácer and Gittelman (2006) show that examiners are more likely to add the self-citations of individuals than do the individuals themselves. Furthermore, Sampat (2010) finds that examiners account for all self-citations in 48% of the patents with at least one self-citation. It is plausible that an applicant may fail to find and disclose relevant patents from third parties. However, it is unlikely that she will fail to find her own patents.

[5] Even after applying CEM, we reduce but do not eliminate concerns related to within-technology differences.

Thus, despite the fact that examiner-added citations may create noise in citation-based measurements (ALCÁCER; GITTELMAN, 2006; JAFFE; DE RASSENFOSSE, 2017), a relevant fraction of them may fill in inventor reporting gaps and correspond to spillovers.

The second limitation of our study is that we do not consider patents with multiple assignees for our analyses. Although these patents may generate valuable spillovers, it would be challenging to determine the exact direction of the knowledge flow. Third, we do not identify inventions by university researchers that are assigned to firms. Academic patents that are assigned to firms may be more likely to cite other academic patents, which might lead to an overestimation of the total academic spillovers. However, we do not believe that the quantity of these patents is high enough to cause any significant effect on our results. Finally, our approach to measuring the geography of knowledge spillovers is limited to intra- and inter-state spillovers and does not directly consider the effects of distance on knowledge flows. Nevertheless, Belenzon and Schankerman (2013) find that academic patent spillovers are very sensitive to distances up to 150 miles and constant thereafter. Thus, given the sizes of American states, we do not expect that our approach might have biased our results. In addition, distance effects are also difficult to measure. For example, universities might have campuses located far from each other (the same is true for firm plants) and inventors living in different states or countries can still co-invent a patent.

To date, few studies have addressed the rationale behind the difference in spillovers from academia and industry (e.g., SAPSALIS; POTTERIE; NAVON, 2006). In this sense, we believe that the key challenge for future research is to identify the reasons that academic patents generate more spillovers and are less localized, vis-à-vis industry technologies. More specifically, the ways in which attributes of universities, firms and scientists involved in inventive activity determine the extent to which technology-based knowledge diffuses and is used by different kinds of organizations as input for new technologies should be examined. This is a promising research venue for future studies.

3 TTO’S HUMAN CAPITAL AND TECHNOLOGY TRANSFER OUTCOMES: EXAMINING TECHNOLOGY TRANSFER OFFICERS’ EXPERIENCE AND EDUCATIONAL BACKGROUND

Universities are increasingly expected to contribute to local economic growth and social development. In addition to the missions of teaching and developing knowledge, they are required to play an active role as economic actors, turning scientific discoveries into innovations (DEBACKERE; VEUGELERS, 2005). Among the main stakeholders involved in this process are the technology transfer offices (henceforth TTOs). These organizations are established to enforce intellectual property policies, mediate university-industry relationships, and promote the commercialization of academic knowledge to the private sector (ALDRIDGE; AUDRETSCH, 2011; GOBLE; BERCOVITZ; FELDMAN, 2017; OWEN-SMITH; POWELL, 2001). With the creation of TTOs, universities were able to formalize university-industry technology transfer (TT) and increase their share of revenue associated with technological innovation (SIEGEL; WALDMAN; LINK, 2003).

Despite the number of studies examining TTOs, the question of how they should recruit and train the appropriate caliber and mix of employees remains unanswered (GRIMALDI et al., 2011). In fact, the background of TTO staff can be very heterogeneous across universities and there is a need to understand how this heterogeneity affects TT outcomes (CUNNINGHAM; O’REILLY, 2018). Our study fills this gap by exploring how the industry experience and educational background of TTO employees affect the early and late stages of the TT process — i.e., invention disclosures and licensing agreements[6] (MARKMAN et al., 2005; THURSBY; THURSBY, 2002). Differences in both education and capabilities may affect the outcomes of each TT stage in a variety of ways. Understanding how this happens can help university managers to strategically align human resources with other university characteristics with the goal of attaining specific TT outcomes (GOBLE; BERCOVITZ; FELDMAN, 2017).

Previous studies have used an array of dimensions to investigate how TTO intrinsic attributes affect technology transfer. Among those dimensions are TTO experience (ARQUÉ-CASTELLS et al., 2016; CHAPPLE et al., 2005; KOLYMPIRIS; KLEIN, 2017); size (ALDRIDGE; AUDRETSCH, 2011; SIEGEL; WALDMAN; LINK, 2003; THURSBY;

[6] For a more detailed discussion on the stages of the technology transfer process, see Thursby and Thursby (2002).

KEMP, 2002); organizational structure (BATTAGLIA; LANDONI; RIZZITELLI, 2017; BRESCIA; COLOMBO; LANDONI, 2016; DEBACKERE; VEUGELERS, 2005); and effectiveness (MARKMAN et al., 2005; WU; WELCH; HUANG, 2015). To date, little attention has been given to understanding the impact of TTOs' human capital on TT activities, with only a few studies addressing this issue. Some examples follow below.

At the employee level, Conti and Gaule (2007) found a positive relation between the share of TTO staff with a PhD and the number of licensing agreements concluded by that TTO. In a subsequent study, the same authors examined the effect of TTO professionals with industry experience on licensing outcomes (CONTI; GAULE, 2011). Their results indicate that employing more staff with industry experience positively impacts licensing revenues, but has no effect on the number of licensing agreements. Recently, Goble, Bercovitz and Feldman (2017) investigated the impact of TTO directors' educational background and experience on TT. Their findings suggest that directors with an MBA are more successful in obtaining invention disclosures than those with a doctoral degree. They also found that TTO directors with either a PhD or an MBA have greater success in promoting licensing agreements than directors with a law degree. Although these studies bring important insights into how TTO human capital influences technology transfer outcomes, there is still a need to carry out more detailed analyses on this topic (CUNNINGHAM; O'REILLY, 2018; GRIMALDI et al., 2011). Therefore, with this study, we contribute to the literature by examining how the educational background and experience of TTO staff affect the early and late stages of the technology transfer process. We hope that our findings can generate insights as to ways to strategically hire and train TTO staff in order to improve the effectiveness of TTOs and achieve specific outcomes.

Our analysis is based on survey data in the context of Brazilian universities. There are three reasons that Brazil poses an interesting case. First, there was a sharp increase in the number of universities and research institutes with an operative TTO over the last years, especially in the aftermath of the Technological Innovation Law, enacted in 2004.[7] The number of operative TTOs in Brazil increased by 995% between 2006 and 2016, from 19 to 208 (MINISTÉRIO DA CIÊNCIA E TECNOLOGIA, 2009; MINISTÉRIO DA CIÊNCIA TECNOLOGIA INOVAÇÕES E COMINICAÇÕES, 2017). This context offers an excellent

[7] The Innovation Law is regarded as one of the main milestones in promoting technological innovation in Brazil. It created a series of incentives for universities to construct alliances with the private sector and engage in technology transfer activities. Among other tenets, the law established that every federal scientific and technological institution must have a TTO to manage its innovation policy.

opportunity to understand the type of employee background that contributes the most to the success of TT activities in young TTOs. Second, in contrast to those in more developed countries, universities carry out a significant portion of the inventions developed in Brazil, accounting for roughly 24% of all resident patent applications at the Brazilian Patent and Trademark Office (INPI). In fact, universities represented the top nine resident applicants at INPI in 2016 and nine of the top ten resident applicants in 2017 (INSTITUTO NACIONAL DE PROPRIEDADE INDUSTRIAL, 2017, 2018). Third, by focusing on one of the major developing countries, Brazil, we help to fill a gap in the literature concerning the commercialization of scientific research in the context of developing economies.

Our findings indicate that TTO employees with a doctoral degree positively affect invention disclosures, but have no effect on the number of licensing agreements concluded by universities. On the other hand, we find that TTO professionals with an MBA have a positive effect on licensing, but no (or only little) influence on the number of disclosures. Contrary to our expectations, employees with industry experience appear to have a negative impact on the number of licensing agreements. One possible explanation is that these individuals may place a greater emphasis on concluding fewer but more profitable licensing agreements, prioritizing the generation of revenue over the quantity of licenses. Next, we find no significant relation between the number of TTO professionals with a legal degree and either invention disclosures or licensing agreements. Finally, our analyses indicate that outsourcing IP-related tasks has a negative effect on new invention disclosures, but a positive impact on the number of new licenses concluded.

3.1 TTOs Human Capital and Technology Transfer Outcomes

TTOs can be understood as the interface between academic and industry actors (SIEGEL et al., 2004; SIEGEL; VEUGELERS; WRIGHT, 2007). To perform well, they need to be endowed with the necessary know-how and capabilities to communicate effectively with both groups of stakeholders (SIEGEL et al., 2004). We argue that the acquisition of this set of skills can be strongly affected by the professional and educational backgrounds of TTO employees, which may play an important role in shaping university commercialization practices. As stressed by Goble, Bercovitz and Feldman (2017), differences in the professional experience and education of TTO directors can cause them to prioritize certain activities of the TT process over others. We extend this assumption to the context of TTO employees and investigate how their educational backgrounds and industry experiences affect the outcomes of different TT stages. In the next sections, we discuss the role that TT officers with an MBA, PhD, industry experience and legal degree may play in the effectiveness of technology transfer activities.

3.1.1 MBA

It is well-known that, on average, academic inventors lack the set of skills necessary to identifying market opportunities and commercializing technologies (FRANKLIN; WRIGHT; LOCKETT, 2001; SHANE, 2002). In this context, TTOs play an important role in facilitating the commercialization of research results, serving as intermediates between scientists and firms (SIEGEL; VEUGELERS; WRIGHT, 2007). However, in order to be successful, they need to possess the right set of marketing and business skills (LOCKETT; WRIGHT, 2005; SIEGEL; VEUGELERS; WRIGHT, 2007; WRIGHT et al., 2009). TTOs lacking these capabilities may face difficulties in exploiting commercialization opportunities (WRIGHT et al., 2009). On the industry side, they may not be able to establish links to suitable commercial partners (CHAPPLE et al., 2005). For example, Siegel, Waldman and Link (2003) found evidence that the lack of marketing skills and inflexibility of TT officers led some firms to avoid working with those organizations, which are often sensed as being very aggressive in negotiation processes. Similarly, on the university side, there is evidence showing that scientists refrain from working with TTOs due to their inefficiency and lack of capabilities (JAIN; GEORGE; MALTARICH, 2009). In some cases, academic researchers by-pass the office and engage in more informal types of technology transfer (SIEGEL et al., 2004).

Altogether, these findings emphasize the need to recruit and develop human resources with a broad base of commercial capabilities (LOCKETT et al., 2005; SIEGEL; WALDMAN; LINK, 2003; WRIGHT et al., 2006). Hence, we believe that recruiting TTO staff with MBA degrees will positively affect TT outcomes, in both early and late stages. Possessing business skills may help TTOs by legitimizing their role as a commercial entity among the academic community (O'KANE et al., 2015), lowering the resistance of faculty to disclosing inventions and engaging in TT activities (early stages of TT). In addition, due to their training in business-related skills, they may be more effective in finding potential commercial partners and marketing intellectual property to private firms, positively affecting licensing outcomes (late stages of TT). We expect that the role of TTO MBAs will be especially important in the late stages of the TT process, which involve intense contact with commercial partners and require developed marketing and negotiation capabilities.

3.1.2 Doctoral degree

Every scientist willing to disclose inventions and become involved in formal technology transfer activities will have to deal with TTO staff. However, these groups of stakeholders have distinct motivations, perceptions and priorities in terms of technology transfer outcomes. According to Siegel et al. (2004), TTO employees' primary motivation is to protect and commercialize academic research results, thus securing additional funding for the institution via royalties, licensing fees and sponsored research agreements. Scientists, on the other hand, are mainly driven by the desire for recognition within the academic community, especially if they are untenured. Potential conflicts with tenure policies, which are primarily focused on academic publications, may create some resistance to engaging in technology transfer activities among faculty (MARKMAN et al., 2005). These divergent motivations and organizational cultures may compromise the relationship between TTOs and scientists, constituting barriers to technology transfer.

We argue that hiring staff with a doctoral degree may help TTOs to overcome these barriers. Officers with a PhD are more likely to be familiar with the academic culture and understand the weight of decisions and trade-offs for scientists involved in technology transfer. This cognitive congruence can facilitate informal exchanges, increasing the levels of trust (BRUNEEL; D'ESTE; SALTER, 2010) and lowering the barriers created by the conflicting motivations and objectives of TTOs and university researchers. In this sense, staff with a PhD may play a key role in encouraging faculty to disclose inventions and engage in TT activities. In addition, TTO employees with a doctoral degree are more likely to possess the required expertise to assess scientific inventions that are close to the knowledge frontier (COMACCHIO; BONESSO; PIZZI, 2012), diminishing the information asymmetry and, consequently, the transaction costs of the interaction scientist-TTO. Hence, we believe that TTO professionals with a PhD will positively impact TT outcomes, especially in the early stages of the technology transfer process. However, the late stages of this process require a set of commercial skills that these individuals (on average) do not possess, reducing their potential contribution.

3.1.3 Industry experience

Technology transfer officers are often thought of by firms as being very aggressive in technology transfer negotiations (SIEGEL et al., 2004). From one side, TTOs and scientists wish to maximize revenues and get the best deals they can. From the other, industry representatives may sense that universities overvalue their intellectual property and lack understanding of the true costs of commercializing an invention. These diverse perspectives and cultures may increase transaction costs and create barriers for effective TT. In this sense, we believe that recruiting staff with industry experience will enhance the effectiveness of TTOs. TT officers with an industry background may be more likely to find a balance between the enthusiasm of academic inventors and the more rational marketing strategy of firms, who do not wish to overpay for intellectual property (OWEN-SMITH; POWELL, 2003). Experience in the industry may also enhance the capabilities of TTO staff in negotiating with companies. In this vein, Siegel et al. (2004) found evidence that TTOs run by individuals with extensive business experience tend to be more skilled in creating relationships with firms and conducting IP due diligence. Similarly, Conti and Gaule (2011) observed that TTO employees with experience in the private sector positively impact licensing revenues. In line with these studies, we expect that the availability of TTO staff with industry experience will be positively related to technology transfer outcomes, especially in the late stages of TT that involve more contact with firms (licensing stage).

3.1.4 Legal degree

Before attempting to find potential licensees for a given technology, TTOs need to guarantee that the IP is clearly defined and protected (SIEGEL; VEUGELERS; WRIGHT, 2007). To do that effectively, they must rely on the assistance of patent attorneys, which can be either internal or external to the office (MARKMAN et al., 2005). In addition to supporting the TTO in IP-related tasks, these professionals play an important role in the commercialization of university technologies. Among others, their tasks may include priority searches, application and maintenance of patents, information regarding the state of IP legislation, litigation, negotiation of licensing terms, and drafting of legal contracts (not only licensing contracts, but also research and collaborations agreements) (BRESCIA; COLOMBO; LANDONI, 2016). In line with Swamidass and Vulasa (2009), we expect that hiring professionals with a legal degree will increase the effectiveness of the TTO in processing invention disclosures and filling patent applications (early stages of TT).

On the other hand, the effects of patent attorneys in the late stages of TT (commercialization of IP) may be more complex. The results of previous studies suggest that spending on external lawyers reduces the number of licenses concluded, but has a positive effect on licensing revenues (CHAPPLE et al., 2005; SIEGEL; WALDMAN; LINK, 2003). These studies explored three possible explanations for this finding. First, patent attorneys may adopt more aggressive negotiation strategies, which could help explain the positive effect of external IP expenditures on licensing income. Second, it is possible that universities outsourcing patent attorney tasks may focus on licensing more lucrative inventions, shelving less successful technologies. Finally, universities with more lucrative inventions may be more likely to spend on external IP services. However, since these studies do not use any information on either the existence/number of in-house patent attorneys or on the kind of tasks that were outsourced, it is difficult to draw any conclusions. By investigating both in-house patent attorneys and the outsourcing of IP tasks, we expect to shed some light on the debate of the role of both internal and external patent attorneys on the technology transfer process.

3.2 Data

In this study, we rely on data from the latest FORTEC Innovation Survey, regarding FY2017. FY2017 represents the first FORTEC Survey with publicly available data. We use this dataset to compile information on academic invention disclosures and licensing activities; and on TTOs, its practices and human capital. The FORTEC Innovation Survey FY2017 had a total of 102 respondents, among universities and research institutes. For our empirical analysis, we only consider respondents that were universities and had a fully operational TTO in 2017. In addition, we exclude respondents with missing data. Using these criteria, our final sample has 80 respondents, from which 66 are universities and 14 are polytechnic universities. We complement this data using two additional sources. First, we used the ISI's Web of Knowledge database to collect information on scientific publications of the universities within our sample. Second, we use the Geocapes database to gather data on the number of researchers that were active in the graduate programs of Brazilian universities in 2017.

3.3 Methodology

3.3.1 Dependent variables

Our main goal with this study is to understand how TTOs' human resources, in terms of education and industry experience, affect the early and late stages of the technology transfer process. To address this issue, we use the number of new invention disclosures (THURSBY; THURSBY, 2002; XU; PARRY; SONG, 2011) and licensing agreements (CALDERA; DEBANDE, 2010; CONTI; GAULE, 2011; SIEGEL; WALDMAN; LINK, 2003) as our dependent variables. In order to avoid confounding effects, we exclude plant patent licenses from the computation of new licensing agreements. Those licenses can be very numerous and unreasonably skew the total number of new licensing agreements.

Alternatively, we could have used the number of new patent applications to represent the outcomes of the early stages of the TT process (instead of the number of new invention disclosures). However, invention disclosures have the advantage of being less biased by different university patenting strategies and technology screening processes than do patents. Thus, we believe that invention disclosures more accurately represent the overall inventive activity of universities as well as the willingness of faculty to engage in TT-related activities.

3.3.2 Independent variables

In order to investigate the effects of TTOs' human capital on TT outcomes, we used the number of employees working full- and part-time, according to their educational backgrounds and industry experience, as reported by the respondents of the FORTEC Innovation Survey. The number of TTO employees with an MBA degree was measured as the number of full-time equivalent employees (FTE) with an MBA. Employees working full-time were counted as one FTE, while employees working part-time were counted as one-half of a FTE (ROTHAERMEL; THURSBY, 2005). Using the same criteria, we calculated our next three independent variables: the number of TTO employees with a PhD, the number of TTO employees with a law degree, and the number of TTO employees with industry experience.

Next, we used exploratory factor analysis (EFA) to create a scale as a proxy for TTOs' outsourcing of typical patent attorney tasks. This measure is based on a question of the FORTEC Innovation Survey that asks respondents to report with “yes” or “no” if their TTOs typically outsource the following activities: search for prior art; drafting of national patents; application and maintenance of national patents; drafting of international patents/PCT;

application and maintenance of international patents; representation in litigation cases; negotiation of licensing agreements; and drafting of licensing agreements. If an activity was typically outsourced, we coded it as 1. Otherwise, we coded it as 0. The first step was to examine the pairwise correlations between these tasks, which led us to drop four of the variables due to very high correlations (≥0.9). Our new set of variables (drafting of national patents; application and monitoring of national patents; drafting of international patents/PCT; and drafting of licensing agreements) yielded a significant Bartlett's test of sphericity at $p<0.001$ and overall Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) of 0.66 (with the lowest individual KMO being 0.61), indicating that we can proceed with the EFA[8] (HAIR et al., 2010). All the four variables loaded in a single factor with an eigenvalue of 2.14. However, since the factor loading of the task "drafting of licensing agreements" was poor (0.42), we decided to drop it and rerun the analysis with the three remaining variables. The Bartlett's test of sphericity was once again significant at $p<0.001$ and overall Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) was 0.63 (with the lowest individual KMO being 0.58). All the three variables loaded in a single factor, with an eigenvalue of 1.95. The results are presented in more details below, in Table 3.1.

[8] Since our analysis encompasses only dichotomous data, we did not use standard methods (based on a matrix of Pearson's correlations) to perform the Bartlett's test of sphericity, the KMO nor the EFA. Instead, we first calculated a polychoric correlation matrix (suitable for dichotomous and ordinal variables) and used it (along with the number of observations) as input to perform the EFA and related tests.

Table 3.1 – Exploratory Factor Analysis (Outsourcing of Patent Attorney Tasks)

Outsourcing of patent attorney tasks	Loading on factor 1	Communality	KMO
Final set of variables			
Drafting of national patents	0.91	0.82	0.58
Application and monitoring of national patents	0.80	0.65	0.64
Drafting of international patents/PCT	0.69	0.48	0.71
Omitted variables	*Cause*		
Search for prior art	Variable omitted due to multicollinearity – highly correlated with “Drafting of national patents” (0.92)		
Application and monitoring of international patents	Variable omitted due to multicollinearity – highly correlated with “Drafting of international patents/PCT” (0.92)		
Representation in litigation cases	Variable omitted due to multicollinearity – highly correlated with “Drafting of licensing agreements” (0.90)		
Negotiation of licensing agreements	Variable omitted due to multicollinearity – highly correlated with “Drafting of licensing agreements” (0.99)		
Drafting of licensing agreements	Variable omitted due to insufficient factor loading (0.42)		

Extraction method: principal factor
Eigenvalue of factor 1 = 1.95
Proportion of variance explained by factor 1 = 65.0%
Kaiser-Meyer-Olkin overall MSA level = 0.63
Bartlett’s test of sphericity significance = $p<0.001$
Cronbach’s alpha of factor 1 = 0.85
Source: elaborated by the authors

These outcomes support the creation of a single measure to investigate the outsourcing of typical patent attorney tasks. This measure, which we call “outsourcing of IP-related tasks,” is based on whether or not the TTO typically outsources following activities: drafting of national patents; application and monitoring of national patents; and drafting of international patents/PCT. If a task was typically outsourced by a TTO, we coded it as 1. Otherwise, we coded it as 0. Using this criterion we build a scale based on the sum of the tasks outsourced by the TTOs. The final measure ranges from 0 to 3, with 0 meaning that the TTO does not outsource any activity and 3 meaning that it outsources all the activities above listed. The Cronbach’s alpha for this scale is 0.85, indicating a high degree of reliability.

3.3.3 Control variables

In order to account for further characteristics that may affect universities’ technology transfer outcomes, we included six control variables in our analysis. First, we controlled for the age of the TTO (ARQUÉ-CASTELLS et al., 2016; CALDERA; DEBANDE, 2010;

MARKMAN et al., 2005). In line with Siegel, Waldman and Link (2003), we expect that age may be an indicative of efficiency in the task of transferring academic technologies to the market. More experienced TTOs are more likely to possess qualified personnel, to have improved internal processes for TT, and to have gained legitimacy among the academic community. We also controlled for the size of the TTO (ALDRIDGE; AUDRETSCH, 2011; KOLYMPIRIS; KLEIN, 2017; THURSBY; KEMP, 2002), measured as the number of FTE at each TTO. Since we are investigating the effect of number of staff with different background on university licensing outcomes, it is important to control for the total size of the TTO. Also, lack of personnel may compromise even the more basic routine tasks in TTOs, such as identifying, processing and assessing intellectual property (WRIGHT et al., 2006). Next, based on Aldridge and Audretsch (2011) and Conti and Gaule (2011, p.134), we measure the TTO specialization in licensing activities (percentage of employees devoted to "assessing the patentability of inventions, applying for patents and negotiating and managing licenses"). We use this variable as a proxy to the commitment of the TTO to protecting and licensing technologies relatively to other TTO tasks. Following prior studies, we used the number of pre-sample patent applications as a proxy for stock of intellectual property (ARQUÉ-CASTELLS et al., 2016). Universities with a higher stock of intellectual property may be more likely to craft licensing agreements than their peers. Similarly, we use the pre-sample stock of scientific publications as a proxy for the pool of technologies available at a university (CONTI; GAULE, 2011). We operationalized this variable for each university in our sample as the total number of scientific publications between 2012 and 2016, as reported in the ISI's Web of Knowledge database. Finally, based on Caldera and Debande (2010), we measure university research quality as the ratio between the stock of scientific publications and the number of researchers active in graduate programs at each university in our sample.

3.3.4 Estimation technique

Given the nature of our dependent variables – i.e. discreet and positive data (count data) with overdispersion (see Table 3.2) – we employed negative binomial regressions to assess the effect of TTOs' human capital on university technology transfer outcomes. We estimated following specification using data at university level (universities with several campuses were regarded as a single respondent):

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 Z_i + \varepsilon$$

where Y_i is either the number of new invention disclosures or the number of new licensing agreements concluded by university i in 2017. X_i is a set of independent variables including the number of TTO FTE with an MBA degree, the number of TTO FTE with a PhD degree, the number of TTO FTE with industry experience, the number of TTO FTE with a law degree, and the scale representing the outsourcing of IP-related tasks. Finally, Z_i is a set of control variables including TTO age, TTO size, TTO specialization in licensing activities, the pre-sample stock of intellectual property (licensing models only), the pre-sample stock of scientific publications (invention disclosure models only), and the research quality (licensing models only) of university i.

3.4 Results

3.4.1 Summary statistics and correlations

Table 3.2 reports descriptive statistics and the correlations for the dependent, independent and control variables considered in the regression analysis. The correlations between the variables raise no concerns about multicollinearity. We confirmed this with a VIF analysis. In our invention disclosure models, the highest VIF for any of our variables is 6.27 (mean VIF=2.62) – which is below the acceptable guideline of 10 suggested by Hair et al. (2010). Similarly, the highest VIF for any of our variables in our licensing models is 5.41 (mean VIF=2.39).

Table 3.2 – Descriptive statistics and zero-order correlations

	Variable	Mean	S.D.	N	1	2	3	4	5	6	7	8	9	10	11	12	13
1	New invention disclosures	24.65	29.22	80	1.00												
2	New licensing agreements	0.76	2.81	80	0.55	1.00											
3	FTE with MBA	1.09	1.83	80	0.26	0.14	1.00										
4	FTE with PhD	1.28	1.10	80	0.48	0.40	0.15	1.00									
5	FTE with industry experience	1.14	2.61	80	0.42	0.29	0.36	0.40	1.00								
6	FTE with law degree	0.95	1.31	80	0.49	0.38	0.27	0.45	0.26	1.00							
7	Outsourcing of IP-related tasks	0.88	1.06	80	0.01	0.21	0.19	0.14	0.25	-0.03	1.00						
8	TTO age	9.74	4.38	80	0.41	0.24	0.47	0.24	0.26	0.53	0.26	1.00					
9	FTE	7.35	10.32	80	0.57	0.51	0.37	0.63	0.74	0.57	0.14	0.49	1.00				
10	TTO specialization in licensing	0.59	0.17	80	0.04	-0.17	-0.18	-0.30	-0.17	-0.08	-0.03	-0.06	-0.31	1.00			
11	Stock of IP (/1000)	0.09	0.19	80	0.68	0.73	0.25	0.55	0.69	0.55	0.17	0.45	0.79	-0.18	1.00		
12	Stock of scientific pub. (/1000)	2.86	5.92	80	0.58	0.40	0.17	0.45	0.77	0.30	0.22	0.33	0.78	-0.14	0.80	1.00	
13	University research quality	5.64	2.45	77	0.16	0.19	0.02	0.01	0.24	0.21	0.19	0.30	0.22	0.21	0.32	0.33	1.00

Source: elaborated by the authors

3.4.2 General results

The results of the effect of TTO human resources on university invention disclosures and licensing agreements can be seen on Tables 3.3 and 3.4, respectively. The goal of the regression analysis is to investigate how the background of TTO employees, in terms of education and industry experience, affects the outcomes of the early and late stages of university technology transfer. We report robust standard error for all the estimates. The first column of each Table (Models 1 and 7) reports the estimations for the control variables. Next, columns 2 to 6 (Models 2-6 and 8-12) include our independent variables in a stepwise fashion. In addition, we also regressed each of our independent variables separately, along with the set of control variables. Since the results were very similar to our main results, we do not report them.

Table 3.3 – Negative binomial models estimating the effect of TTO human resources on invention disclosures

	Dependent variable: New invention disclosures					
Variables	**1**	**2**	**3**	**4**	**5**	**6**
FTE with MBA		0.028 (0.045)	0.044 (0.044)	0.066 (0.064)	0.073 (0.062)	**0.105+** (0.061)
FTE with PhD			**0.328*** (0.159)	**0.334*** (0.148)	**0.329*** (0.135)	**0.407**** (0.138)
FTE with industry experience				-0.053 (0.071)	-0.027 (0.085)	0.004 (0.084)
FTE with law degree					0.179 (0.135)	0.104 (0.141)
Outsourcing of IP-related tasks						**-0.387***** (0.085)
TTO age	0.043 (0.032)	0.039 (0.035)	**0.064+** (0.037)	0.055 (0.039)	0.043 (0.041)	**0.071+** (0.038)
FTE	**0.027*** (0.012)	**0.026*** (0.012)	-0.006 (0.020)	-0.003 (0.019)	-0.018 (0.020)	-0.030 (0.022)
TTO specialization in licensing	**1.973**** (0.700)	**1.987**** (0.700)	**1.940**** (0.672)	**1.992**** (0.680)	**1.994**** (0.681)	**1.923**** (0.673)
Stock of scientific pub. (/1000)	**0.079+** (0.044)	**0.080+** (0.043)	**0.068*** (0.029)	**0.078**** (0.027)	**0.081**** (0.029)	**0.100***** (0.027)
Constant	**0.954+** (0.502)	**0.959+** (0.500)	0.548 (0.584)	0.573 (0.565)	0.587 (0.605)	0.573 (0.554)
LR $\chi 2$	29.4	36.0	39.0	52.6	61.1	90.5
Log-likelihood	-319.3	-319.2	-317.0	-316.8	-315.9	-311.2
Pseudo R^2	0.045	0.045	0.051	0.052	0.055	0.069
N	80	80	80	80	80	80

$+ p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

Our specifications on invention disclosures, reported on Table 3.3, show that TTO employees with an MBA appear to have no (or only little) impact on new disclosures. Although the coefficients have all a positive sign, only one of them is significant (Model 6 at p<0.1). In what regards PhD education, the number TTO staff with a doctoral degree is positively associated with new invention disclosures. Holding all other variables at their means, an increase of 0.5 professionals with a PhD is associated with a rise of 22.5% in the number of disclosures (we used Model 6 to estimate this value). This finding may reflect a decrease in the cognitive distance between TTOs and the academic community promoted by the recruitment of TTO professionals with a doctoral degree.

Apparently, there is no significant relation between the number of TTO staff with either a legal degree or industry experience and disclosures. In what regards the role of outsourcing of IP-related tasks, our results suggest that it has a negative effect on invention disclosures. An increase of 1 standard deviation on the variable outsourcing of IP-related tasks is associated with a decline of 33.7% in the number of disclosures. A possible interpretation of this finding is that universities investing more resources in external services may only encourage the disclosure of inventions that are closer to the market, which could lead to fewer invention disclosures.

Table 3.4 – Negative binomial models estimating the effect of TTO human resources on university licensing

	Dependent variable: New licensing agreements					
Variables	**7**	**8**	**9**	**10**	**11**	**12**
FTE with MBA		**0.212**** (0.077)	**0.213**** (0.078)	**0.325**** (0.111)	**0.330**** (0.113)	**0.302**** (0.107)
FTE with PhD			0.017 (0.172)	-0.225 (0.209)	-0.147 (0.205)	-0.219 (0.196)
FTE with industry experience				**-0.222***** (0.056)	**-0.229***** (0.059)	**-0.233***** (0.062)
FTE with law degree					-0.111 (0.127)	0.034 (0.132)
Outsourcing of IP-related tasks						**0.608**** (0.228)
TTO age	0.017 (0.046)	-0.046 (0.061)	-0.046 (0.061)	**-0.121*** (0.059)	-0.096 (0.071)	**-0.128+** (0.070)
FTE	0.001 (0.033)	-0.009 (0.039)	-0.010 (0.038)	**0.052*** (0.023)	**0.054*** (0.024)	**0.064*** (0.030)
TTO specialization in licensing	1.166 (1.364)	1.501 (1.535)	1.509 (1.537)	1.982 (1.211)	2.583 (1.598)	**3.035+** (1.640)
Stock of IP (/1000)	**4.017**** (1.289)	**4.719**** (1.740)	**4.672**** (1.810)	**5.187***** (0.728)	**5.361***** (0.814)	**4.681***** (0.918)
University research quality	0.006 (0.083)	0.033 (0.079)	0.034 (0.080)	0.038 (0.064)	0.020 (0.072)	-0.008 (0.076)
Constant	**-2.247*** (1.056)	**-2.271+** (1.234)	**-2.301+** (1.253)	**-2.002*** (0.802)	**-2.543*** (1.202)	**-3.051**** (1.113)
LR $\chi 2$	65.5	58.9	59.3	703.6	653.2	1080.5
Log-likelihood	-66.5	-64.5	-64.5	-61.0	-60.6	-55.5
Pseudo R^2	0.185	0.210	0.210	0.253	0.257	0.319
N	77	77	77	77	77	77

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

The results on new licensing agreements, reported on Table 3.4, show a positive relation between the number of TT officers with an MBA and the number of agreements concluded by universities. Holding all other variables at their means, an increase of 0.5 TTO

MBAs is associated with a rise of 16.3% in the number of licenses concluded (we used Model 12 to estimate this value). MBA education may increase the negotiation and marketing capabilities of individuals, which are necessary skills for TTOs seeking to successfully exploit commercialization opportunities (WRIGHT et al., 2009). Regarding industry experience, the number of TTO professionals who have worked in the private sector has a negative effect on new licensing agreements. An increase of 0.5 TTO employees with industry experience is associated with a decrease of 11.0% in the number of licenses concluded. A possible explanation is that these individuals follow strategies prioritizing the maximization of licensing revenues and, therefore, place greater emphasis on concluding fewer licensing agreements that are more profitable.

Apparently, there is no significant relation between the number of TTO staff with a PhD and new licenses. This is also the case for TTO employees with a legal degree. On the other hand, our results suggest that outsourcing IP-related tasks positively impacts licensing outcomes. Holding all other variables at their means, an increase of 1 standard deviation on the variable outsourcing of IP-related tasks is associated with a growth of 91.0% in the number of new licensing agreements. External specialized patent attorney offices may be more efficient than TTO attorneys in conducting IP due diligence and drafting patents, ultimately resulting in patent portfolios with a higher quality. In addition, the outsourcing of IP-related tasks may free up TTO staff, shifting their focus towards commercialization activities. Finally, consistent with our previous discussion, universities spending on external services may follow strategies that increase the selectivity of the technologies they consider for patenting, favoring those with higher marketing potential. As stressed by Wu, Welch and Huang (2015), increasing the selectivity of inventions for patenting positively impacts licensing outcomes. In the same vein, Macho-Stadler, Pérez-Castrillo, and Veugelers (2007) found that, by selectively “shelving” less successful inventions, TTOs may raise the buyer’s perception of the quality of the university inventions.

3.4.3 Robustness checks

In Table 3.5 in this section we present the results of additional analyses we performed to examine the robustness of our findings. To do that, we reran Models 6 and 12 including additional fixed effects and control variables. In order to account for unobservable characteristics of the universities’ geographic location (e.g., existence of regional support mechanisms for technology transfer; or the presence of innovative firms able to absorb university technologies), we incorporated region-fixed effects. Next, we added a dummy to account for any institutional differences between universities and polytechnic universities that may affect technology transfer outcomes. This variable takes the value of 1 in the case of polytechnic institutions and zero otherwise. We also included a dummy variable for public universities (MARKMAN et al., 2005). While licensing strategies of private universities may focus on maximizing revenues, this may not be the case for public institutions (THURSBY; KEMP, 2002). Instead, public universities may prioritize the widespread dissemination of knowledge, aiming at maximizing the number of licensing agreements, regardless of profits. For each of our dependent variables, we include the fixed effects and controls in a stepwise fashion.

Table 3.5 – Negative binomial models estimating the effect of TTO human resources on technology transfer outcomes (robustness checks)

	New invention disclosures			***New licensing agreements***		
Variables	**13**	**14**	**15**	**16**	**17**	**18**
FTE with MBA	0.101 (0.067)	0.094 (0.063)	0.094 (0.064)	**0.308**** (0.115)	**0.308**** (0.104)	**0.306**** (0.100)
FTE with PhD	**0.452**** (0.158)	**0.424**** (0.154)	**0.378*** (0.184)	-0.298 (0.199)	**-0.328+** (0.184)	-0.220 (0.220)
FTE with industry experience	0.000 (0.082)	0.006 (0.082)	0.014 (0.080)	**-0.268***** (0.058)	**-0.258***** (0.053)	**-0.255***** (0.053)
FTE with law degree	0.041 (0.135)	0.031 (0.137)	0.029 (0.138)	0.065 (0.146)	0.085 (0.146)	0.034 (0.151)
Outsourcing of IP-related tasks	**-0.370***** (0.092)	**-0.395***** (0.099)	-0.305 (0.198)	**0.509*** (0.211)	**0.373+** (0.217)	0.246 (0.244)
TTO age	**0.089**** (0.034)	**0.083*** (0.036)	**0.083*** (0.036)	**-0.163*** (0.074)	**-0.182*** (0.073)	**-0.173*** (0.069)
FTE	-0.030 (0.023)	-0.027 (0.023)	-0.024 (0.024)	**0.082**** (0.028)	**0.075**** (0.027)	**0.074**** (0.026)
TTO specialization in licensing	**2.156**** (0.684)	**2.135**** (0.695)	**2.068**** (0.697)	**3.672*** (1.555)	**3.122*** (1.395)	**3.387*** (1.493)
Stock of scientific pub. (/1000)	**0.099***** (0.028)	**0.093***** (0.028)	**0.080*** (0.034)			
Stock of IP (/1000)				**4.906***** (0.735)	**4.876***** (0.701)	**4.938***** (0.694)
University research quality				-0.064 (0.079)	-0.030 (0.098)	-0.031 (0.099)
Polytechnic university dummy		-0.262 (0.315)	-0.302 (0.332)		**-16.781***** (0.564)	**-18.794***** (0.568)
Public university dummy			0.360 (0.600)			-0.472 (0.508)
Region fixed effects						
Constant	-0.335 (0.703)	-0.213 (0.740)	-0.435 (0.849)	**-2.642*** (1.167)	**-2.137*** (1.084)	**-2.104+** (1.137)
LR $\chi 2$	93.5	97.1	94.5	4555.8	6574.7	8307.3
Log-likelihood	-309.7	-309.4	-309.2	-53.2	-50.4	-50.1
Pseudo R^2	0.073	0.074	0.075	0.348	0.382	0.386
N	80	80	80	77	77	77

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

Overall, adding regional fixed effects and dummies for public and polytechnic universities does not change the size and significance of our results. Exceptions are in Models 15 and 18, where outsourcing of IP-related tasks is no longer significant. Nevertheless, both coefficients have the expected sign. Interestingly, Model 17 shows a negative and significant relation between TTO employees with a legal degree and the number of licenses concluded.

This may suggest a potential lack of business capabilities among these individuals, or even that "legal wrangling" may reduce the number of new licensing agreements (GOBLE; BERCOVITZ; FELDMAN, 2017).

3.5 Discussion

In light of the need to gain an understanding of the impact of TTOs' human capital on the commercialization of university research, we explore how the background of TT officers affects the early and late stages of university-industry TT. Specifically, we investigate how TTO employees with an MBA, PhD, industry experience, and law degree impact the number of university invention disclosures and licensing agreements. In addition, we examine the effects of employing external human capital for IP-related tasks. To explore these issues, we rely on survey data in the context of Brazilian universities.

We find that TTO employees with a doctoral degree are positively associated with the number of new invention disclosures, but have no effect on new licensing agreements. This is in line with our predictions that the role of these professionals is especially important in the early stages of the technology transfer process. TTO employees with a doctoral degree are cognitively closer to researchers; in fact, as stressed by Borgatti and Cross (2003), people are more likely to develop close relationships with those who are similar in terms of social attributes such as education. This cognitive congruence facilitates their role as boundary spanners and, consequently, the communication between the TTO and academic scientists. Because of their understanding of the academic culture, TTO employees with a PhD are more likely to overcome the barriers created by the conflicting goals and interests of TTOs and university researchers. Overcoming these obstacles is a fundamental step for the effective dissemination of an entrepreneurial culture within the academia (BRUNEEL; D'ESTE; SALTER, 2010; SIEGEL et al., 2004; SIEGEL; WALDMAN; LINK, 2003). In addition, due to their scientific capabilities, they may be more able "to translate the scientific language and to transform the abstract knowledge into applicative projects" (COMACCHIO; BONESSO; PIZZI, 2012, p.961). Despite that, lack of training in business-related skills might reduce their potential contribution in the late stages of technology transfer, which usually require strong negotiation and marketing capabilities (SIEGEL; VEUGELERS; WRIGHT, 2007; WRIGHT et al., 2009). This offers a possible explanation for our finding that the number of TTO professionals with a PhD does not affect the number of licensing agreements concluded by universities.

Our results indicate that TTO professionals with an MBA have a positive and significant impact on new licensing agreements. This suggests that hiring MBAs increases the business capabilities of TTOs and, consequently, their effectiveness in commercializing academic research results. In line with our expectations, MBAs appear to play a smaller role in the early stages of the technology transfer process (i.e., invention disclosures). Although the coefficient for MBA staff is positive across all specifications, it is only significant in one of them (at $p<0.1$). This might suggest that the set of business-related skills acquired by TTO MBAs helps TTOs to legitimize their role as a commercial entity, promoting to some (small) extent the engagement of the academic community in TT-related activities.

Contrary to our expectations, TTO employees with industry experience appear to negatively affect the number of new licensing agreements. One possible explanation is that the focus of these individuals is on obtaining licensing revenues rather than on maximizing the number of licensing agreements. This assumption is in line with Conti and Gaule (2011), who found that employing staff with industry experience leads to higher licensing revenues, but does not impact the number of licenses concluded. Unfortunately, we are unable to explore this possibility. Licensing revenues may represent royalty streams from transactions executed years ago (SIEGEL; WALDMAN; LINK, 2003; THURSBY; THURSBY, 2002). Considering the cross-sectional nature of our data and the high turnover rate among TTO staff (SIEGEL; VEUGELERS; WRIGHT, 2007; SIEGEL; WALDMAN; LINK, 2003), any analysis of licensing revenues would potentially lead to inconclusive or even spurious results.

Apparently, there is no relation between the number of TTO staff with a legal degree and any of the TT outcomes we investigated. On the other hand, outsourcing of IP-related tasks impacts all technology transfer outcomes we examined. Apparently, hiring external attorney services negatively impacts the number of invention disclosures, but has a positive effect on the number of new licenses concluded. TTOs spending on external services may be more selective in the technologies they encourage and choose to protect. This could lead to a patent portfolio that is closer to the market, increasing the chances of licensing. Of course, it is also possible (and even likely) that hiring external specialized services may improve the quality of the patent portfolios of universities, contributing to an increase in the number of licensing agreements. However, this would not necessarily imply fewer invention disclosures per se, especially if one considers that it might actually free up TTO staff to focus on other tasks (SIEGEL; WALDMAN; LINK, 2003). Thus, we believe that it is rather the strategy of the TTO, and not the actions of external human capital, that leads to an increase in the number of licensing agreements concluded (and also to a decrease in the number of new invention disclosures).

Our results contradict those of Chapple et al. (2005) and Siegel, Waldman and Link (2003), who found that spending on external legal IP has a negative impact on the number of licenses concluded (but a positive impact on licensing revenue). There are a number of explanations for this apparent discrepancy. For example, it is possible that the commercialization strategies of Brazilian universities are aligned with the spirit of the Brazilian Innovation Law, placing a greater emphasis on maximizing the number of licensing agreements. Alternatively, considering that technology transfer is a recent phenomenon in Brazil, the initial focus of Brazilian TTOs may be on learning how to commercialize their inventions. Thus, in order to gain experience, they might focus on concluding as many licensing agreements as possible, even if those are not profitable. If this is in fact the case, we expect to see a shift in the objectives of TTOs towards generating revenues as they develop their commercialization skills.

3.6 Conclusion

Our study contributes to the literature in distinct ways. To the best of our knowledge, this is the first study investigating how the industry and educational backgrounds of TTO employees affect the outcomes of different technology transfer stages. Based on survey data of Brazilian universities, it provides evidence suggesting that TTO professionals with different backgrounds affect distinct TT outcomes (namely invention disclosures and licenses concluded) differently. In this sense, we believe that our findings have the potential to help university managers to strategically develop TTO human resources when aiming at specific outcomes.

Also, the vast majority of studies investigating the performance of TTOs focus on the US (e.g., MARKMAN et al., 2005; THURSBY; KEMP, 2002; WU; WELCH; HUANG, 2015) and Europe — in which case, mostly UK (e.g., CHAPPLE et al., 2005; LOCKETT; WRIGHT, 2005; WECKOWSKA, 2015) and Italy (e.g., BATTAGLIA; LANDONI; RIZZITELLI, 2017; COMACCHIO; BONESSO; PIZZI, 2012; FINI et al., 2011). By focusing on Brazil, we contribute to the incipient literature on university-industry technology transfer in the context of developing economies. The case of Brazil is interesting for many reasons. Although technology transfer is still a recent phenomenon in the country, there was a remarkable rise in patenting activities of universities over the last years. Since the enactment of the Innovation Law (in 2004), the number of patent applications by universities has increased by 580%, representing 24% of all resident patent applications at INPI in 2017. In addition, the case of Brazil provides an opportunity to investigate relatively young TTOs, still in the beginning of their learning process. Finally, the absorptive capacity of the productive sector is relatively low, which poses an additional challenge for universities to commercialize their inventions.

Overall, this work provides important insights on how TTOs' human capital impacts technology transfer activities. Nevertheless, as in all other studies, ours is also subject to limitations. Although our sample is not limited to the most successful universities in research and technology transfer, as suggested by Grimaldi et al. (2011), our results should be interpreted with caution. The elements that make Brazil an interesting case (i.e., young TTOs, high participation of universities in the innovative landscape, low firm absorptive capacity, etc.) also hold us back from generalizing our findings to other contexts. In addition, the cross-sectional nature of our data does not allow us to claim causality among our variables of interest. It also hinders us from conducting any analysis on licensing revenues (as discussed in the previous section).

Finally, we only investigate a subset of the commercialization activities with which the TTO is involved. TTOs are often responsible for promoting university-industry R&D contracts (CALDERA; DEBANDE, 2010; DEBACKERE; VEUGELERS, 2005) and assisting academic entrepreneurs to create spin-off companies (CLARYSSE; TARTARI; SALTER, 2011; GUBITTA; TOGNAZZO; DESTRO, 2016; LOCKETT et al., 2005). However, there is a great heterogeneity in what comprises these tasks in Brazilian universities and TTOs are frequently not responsible for them. Considering this, it would be very challenging to make an accurate assessment of the role TTOs play to promote R&D contracts and spin-offs in the context of Brazilian universities.

In a nutshell, we believe that the core capacity of a TTO to successfully promote technology transfer activities resides in its human resources. Nevertheless, surprisingly little is known about how TTOs' human capital impacts TT activities in universities. Indeed, one of the key challenges for future research is to identify the optimal composition of a TTO. Possible frameworks could include an in-depth investigation of the different types of capabilities acquired by TTO professionals in the industrial sector. Another possibility would be to consider, not only the education and training acquired by TTO staff, but also other dimensions such as their cognitive capabilities and network of contacts. Overall, we believe this is a promising research venue for future studies.

4 UNIVERSITY SUPPORT MECHANISMS, REGIONAL DEVELOPMENT AND TECHNOLOGY TRANSFER

One of the central questions regarding the exploitation of university research remains how to encourage faculty to participate in TT activities. In fact, the involvement of scientists in the commercialization of technologies implies in important trade-offs and risk taking on behalf of the academics themselves (DEBACKERE; VEUGELERS, 2005). To mitigate these risks and reinforce TT activities, universities are increasingly investing in the creation of internal mechanisms aimed at reducing uncertainties, tensions and moral hazards related to the TT process (CALDERA; DEBANDE, 2010; FINI et al., 2011; GEUNA; ROSSI, 2011; GRIMALDI et al., 2011). The intention of these initiatives is to encourage commercialization activities that would otherwise be left aside, speeding up the technology transfer process. In this context, in the wake of Bayh-Dole-like legislations, universities around the world have started to implement internal regulations to provide support to TT-related activities.

Previous studies on this topic focused either on specific attributes of TT-related regulations, such as inventor share of royalties (ARQUÉ-CASTELLS et al., 2016; BALDINI, 2010; LACH; SCHANKERMAN, 2008) and inventor ownership of intellectual property rights (a.k.a., professor's privilege) (CONTI; GAULE, 2011; CZARNITZKI; HUSSINGER; SCHNEIDER, 2011; GEUNA; ROSSI, 2011; JACOBSSON; LINDHOLM-DAHLSTRAND; ELG, 2013), or on the sole availability of TT-related policies (BALDINI; GRIMALDI; SOBRERO, 2006, 2007; CALDERA; DEBANDE, 2010). To the best of our knowledge, the impact of the quality of university regulations on TT outcomes remains unexplored. To address this issue, we investigate the extent to which clear and well-defined TT regulations are available and enforced within universities. We argue that low quality regulations might hinder technology transfer agreements instead of promoting them.

Another important mechanism used by universities to promote technology transfer is the creation of intermediary organizations aimed at stimulating university-industry interactions, such as university business incubators (UBIs) and science and technology parks (STPs) (CALDERA; DEBANDE, 2010; PHAN; SIEGEL; WRIGHT, 2005; VILLANI; RASMUSSEN; GRIMALDI, 2017). Prior literature on UBIs and STPs frequently investigated their role in the performance of tenant firms (MCCARTHY et al., 2018; RAMÍREZ-ALESÓN; FERNÁNDEZ-OLMOS, 2018; ROTHAERMEL; THURSBY, 2005), as well as drivers of regional development (LAMINE et al., 2018; RATINHO; HENRIQUES, 2010). Fewer studies explored the impact of these organizations on TT outcomes other than academic spin-offs (DI GREGORIO; SHANE, 2003; FINI et al., 2011; FINI; GRIMALDI; SOBRERO, 2009). Among those are the recent studies of Villani, Rasmussen and Grimaldi (2017), who investigated how intermediary organizations reduce geographical, cognitive, social and organizational distance in U-I collaborations, and Kolympiris and Klein (2017), who examined the effect of business incubators on the quality of university innovations and licensing revenues. We complement this literature by investigating how the availability of UBIs and STPs affects technology transfer performance in terms of patenting and licensing activities. We assume that these organizations will encourage scientists to engage in TT activities and facilitate the commercialization of university technologies by increasing geographical and social proximity between university scientists and firms (VILLANI; RASMUSSEN; GRIMALDI, 2017). In addition, given that local and regional idiosyncrasies may also affect TT performance (CHAPPLE et al., 2005; CONTI; GAULE, 2011; FINI et al., 2011), we examine the impact of the local demand for technology and economic activity on TT performance.

We perform our analysis in the context of Brazilian universities, which is interesting for three main reasons. First, differing from in the US and UK (where most studies on TT were based), technology transfer is still a recent phenomenon in Brazil. This gives us the opportunity to investigate the commercialization of university technologies in the context of institutions with relatively little TT experience, still at the beginning of their learning curve. Second, despite the relative lack of experience of Brazilian universities, their role in the Brazilian innovative landscape has increased significantly over the last years. In 2017, they accounted for roughly 24% of all resident patent applications at INPI. Five years earlier (in 2012), their share of national patent applications was considerably lower (16%) and, 10 years earlier (in 2007), they accounted for only 8% of all resident patent applications at INPI. Third, with this study, our contribution serves to filling a gap in the literature concerning technology transfer activities in the context of emerging economies.

Our findings indicate that the quality of TT-related regulations has a positive impact on both patenting and licensing activities, whereas the sole existence of regulations has no (or only little) effect on TT outcomes. This suggests that analyses based solely on the availability of regulations may lead to confounding results. Apparently, there is no relation between the availability of either UBIs or STPs and patenting or licensing outcomes. It is possible that the diffusion of university technologies to UBIs and STPs takes place through alternative channels, such as R&D contracts, consultancy or even informal non-market spillovers.

Finally, our results suggest that regional economic development has a negative impact on patenting activities. Although puzzling, this finding may reflect the lack of patenting experience of universities in less developed regions. These universities may be less selective in the technologies they choose to protect, leading to larger patent portfolios of lower quality. On the other hand, universities located at regions with higher levels of economic activity generate more licensing agreements.

4.1 University Support Mechanisms

4.1.1 Institutional-level regulations for technology transfer

The opportunity costs for academic researchers to engage in technology transfer are usually high and their involvement in commercialization activities implies important trade-offs. Researchers spending a great deal of time engaged in TT-related activities may digress from more fundamental research, which usually carries greater weight in promotion and tenure decisions (SIEGEL et al., 2004). In addition, the decision to commercialize research results is filled with uncertainties and success cannot be assured ex ante. In this scenario, the lack of TT-related regulations may even further increase the perception of risks by academics considering engaging in technology transfer activities, discouraging them from doing so. On the other hand, the availability of such regulations might reduce potential uncertainties and moral hazard issues related to the technology transfer process (CALDERA; DEBANDE, 2010). The results of previous studies support this assumption. Baldini, Grimaldi and Sobrero (2006) found that the implementation of university patenting regulations almost tripled patenting activities in Italian universities. In line with this finding, a subsequent study by the same authors suggested that the existence of patenting regulations reduces the inventors' perceived obstacles to patenting activity (BALDINI; GRIMALDI; SOBRERO, 2007). In the same spirit, Caldera and Debande (2010) found the availability of TT-related policies to be positively related to the technology transfer performance of universities.

Despite the important contributions of these studies, they failed to assess the impact of the quality of university regulations on technology transfer outcomes. As suggested by Quélin et al. (in press), low quality regulations (i.e., unstable or ambiguous) can amplify transaction costs and potential hazards. In such cases, universities may not be able to efficiently conclude technology transfer agreements. This is in line with anecdotes we heard in discussions with TTO representatives about university regulations that, due to high levels of bureaucracy, lack of clarity, and ambiguity, end up hindering the conclusion of licensing agreements instead of promoting them. In this sense, we believe that examining the sole availability of regulations may lead to confounding outcomes. Furthermore, investigating the quality of TT-related regulations (instead of their availability) represents an important contribution to the literature, especially considering that low quality regulations may inhibit the conclusion of commercialization agreements and also lead researchers to engage in informal types of technology transfer.

4.1.2 Intermediary organizations and technology transfer

Intermediary organizations such as university business incubators and science and technology parks represent initiatives aimed at facilitating knowledge flows from the academia to the private sector (PHAN; SIEGEL; WRIGHT, 2005; ROTHAERMEL; THURSBY, 2005; VILLANI; RASMUSSEN; GRIMALDI, 2017). These organizations enable the co-location of universities and firms, which may play an important role in fostering technology transfer activities – especially considering the geographically localized nature of academic spillovers (BELENZON; SCHANKERMAN, 2013; JAFFE; TRAJTENBERG; HENDERSON, 1993; MOWERY; ZIEDONIS, 2015). In one way, geographic proximity allows universities to access resources, develop partnerships for applied research, and diminish the search costs related to finding potential commercial partners (VILLANI; RASMUSSEN; GRIMALDI, 2017). In another, it allows tenant firms to benefit from academic knowledge at lower costs (AHARONSON; BAUM; FELDMAN, 2007). In line with these arguments, the results of Caldera and Debande (2010) showed that the presence of science parks positively impacts the commercialization of university technologies. The authors suggested that the local concentration of technology-intensive firms contributes to the diffusion of university technologies to these firms. In the same vein, Mowery and Ziedonis (2015) found that proximity to universities increases the likelihood of firms to license or cite those universities' patents.

According Villani, Rasmussen and Grimaldi (2017), intermediary organizations reduce not only the geographic, but also the social distance between universities and firms. In order to do that, they frequently promote events to introduce industry and university representatives to one another, and act as mediators in the newly established relationships between these actors. As suggested by Bruneel, D'Este and Salter (2010), face-to-face interactions increase the level of trust between university and industry representatives, contributing significantly to the attenuation of cognitive barriers to technology transfer activities. This cognitive closeness, in turn, may contribute to the development of an entrepreneurial culture among faculty and “stimulate academic inventors to exploit opportunities that would otherwise be left unexplored” (WRIGHT et al., 2009, p.564). Therefore, we expect that the availability of UBIs and STPs will be positively related to technology transfer performance.

4.2 The Role of the Regional Environment

One of the possible reasons for cross-institutional variation in technology transfer activities is the regional environment in which universities are located. As stressed by Fini et al. (2011), the success of universities in technology transfer activities depends, not only on internal regulations and capabilities, but also on idiosyncratic attributes of the regions in which they are settled. In this sense, we believe that the set of competences and resources available in a given region (both tangible and intangible) is determinant for the commercialization of research results. For example, agglomeration effects of private R&D may increase the local demand for technologies developed by academia, making it easier for universities to find commercial partners for licensing agreements (CONTI; GAULE, 2011). In addition, there is also evidence suggesting that firms with higher R&D intensity are more likely to collaborate with universities (LAURSEN; SALTER, 2004). The higher the investments in R&D activities, the greater the absorptive capacity of the firm, i.e., its ability to assimilate and commercially exploit external knowledge (COHEN; LEVINTHAL, 1990). Thus, we expect that universities located in economically developed regions will perform better in technology transfer activities than their counterparts. This is in line with Chapple et al. (2005) and Siegel, Waldman, and Link (2003), whose results indicate that universities settled in regions with higher levels of R&D and economic activity are more efficient in technology transfer activities.

4.3 Methods

4.3.1 The sample

Our main source of data is the latest FORTEC Innovation Survey, regarding FY2017. FY2017 represents the first FORTEC Survey with publicly available data. We use this dataset to gather information on academic licensing and patenting activities; technology transfer policies; and university structures such as TTOs, UBIs and STPs. The FORTEC Innovation Survey FY2017 had a total of 102 respondents, among universities and research institutes. For our empirical analysis, we exclude research institutes, universities that did not have a fully operational TTO in 2017, and respondents with missing data. Using these criteria, our final sample is composed by 82 universities, from which 67 are full universities and 15 are polytechnic universities.

We complement these data using four additional sources. First, we use the Geocapes database to collect information on the number of researchers that were active in the graduate programs of Brazilian universities in 2017. Second, we use the ISI's Web of Knowledge database to gather data on scientific publications of the universities within our sample. Third, we use INPI data to collect information on regional non-academic patenting activities. Finally, we use the "Brazil in Synthesis" database (from the Brazilian Institute of Geography and Statistics) to obtain the gross domestic product (GDP) per capita at state level.

4.3.2 Dependent variables

Our main goal with this study is to understand how internal support mechanisms (i.e., technology transfer regulations, UBIs and STPs) and the regional context in which universities are settled affect their technology transfer performance. To address this issue, we use the number of university new patent applications (ARQUÉ-CASTELLS et al., 2016; BALDINI, 2010; BARRA; ZOTTI, 2018) and licensing agreements[9] (CALDERA; DEBANDE, 2010; CONTI; GAULE, 2011; SIEGEL; WALDMAN; LINK, 2003) as our dependent variables. As pointed out by Siegel et al. (2004), these measures represent important outputs of the university-industry technology transfer process. Although licensing income also represents an important proxy for TT performance (ARQUÉ-CASTELLS et al., 2016; CALDERA; DEBANDE, 2010; HEISEY; ADELMAN, 2011; SIEGEL; WALDMAN; LINK, 2003), we decided not to use it as a third dependent variable. Licensing revenues may incorporate royalties from agreements concluded in previous years. Thus, considering the cross-sectional nature of our data, including licensing income as a dependent variable could lead to specious results.

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[9] Considering that licenses of plant patents can be very numerous and unreasonable skew our data, we decided to exclude them from the computation of new licensing agreements.

4.3.3 Independent variables

Our first two variables represent the quality of university internal regulations related to intellectual property protection and licensing agreements. These variables were measured in a 5-point rating scale, ranging from “no regulation available” (coded as 1) to “clear and well-defined regulation available and completely enforced” (coded as 5). The first variable, representing the quality of IP protection regulations, was taken directly from the FORTEC Survey. The second, representing the quality of licensing regulations, is the summated average scale of the variables “university policies for licensing of protected IP”, and “university policies for licensing of technologies that are not protected” (e.g., know-how agreements and licensing of biological material). These measures allow us to investigate, not only the existence of university regulations to support technology transfer activities, but also the degree to which these regulations are clear, well-defined and, indeed, enforced.

Next, we use dummy variables to account for the presence of UBIs and STPs. Given that these organizations facilitate university-industry collaboration (CALDERA; DEBANDE, 2010; VILLANI; RASMUSSEN; GRIMALDI, 2017), we expect that their presence will have a positive impact on technology transfer outcomes. Finally, we include two measures to account for regional factors that may affect technology transfer performance at universities. First, based on Conti and Gaule (2011), we use the log of the total number of patent applications at the state level between 2012 and 2016 to measure the local demand for technology. We exclude university patents from this count. Second, we use the GDP per capita at state level as a proxy for local economic activity (CHAPPLE et al., 2005).

4.3.4 Control variables

We use a set of five control variables to account for further university attributes that may affect technology transfer performance. First, we control for the experience of the TTO (CONTI; GAULE, 2011; KOLYMPIRIS; KLEIN, 2017; SIEGEL; WALDMAN; LINK, 2003), which we measure in terms of its age. We expect that older TTOs will be more effective at technology transfer activities than their younger counterparts. Following previous studies (ALDRIDGE; AUDRETSCH, 2011; CALDERA; DEBANDE, 2010; SIEGEL; WALDMAN; LINK, 2003), we control for the size of the TTO in terms of its full-time equivalent employees (FTE). Understaffed offices are less likely to be effective in the commercialization of university-based technologies. We also control for the stock of IP of the university. This variable is measured as the log of the pre-sample aggregate number of patent applications (ARQUÉ-CASTELLS et al., 2016). A larger IP portfolio may increase the chances of universities finding potential commercial partners and concluding licensing agreements. Next, we use the pre-sample stock of scientific publications as a proxy for the pool of technologies available at a university (CONTI; GAULE, 2011). We operationalize this variable for each university in our sample as the log of the total number of scientific publications between 2012 and 2016, as reported in the ISI's Web of Knowledge database. Finally, based on Caldera and Debande (2010), we measure university research quality as the ratio between the stock of scientific publications (not logged) and the number of researchers active in graduate programs at each university in our sample.

4.3.5 Model specification

We employed negative binomial models to investigate the effects of institutional policies, university structures and regional contexts on university technology transfer performance. Considering the nature of our data – count data with overdispersion (see Table 4.1) – negative binomial regressions are an appropriate fit (GREENE, 2008). We estimated following specification using data at the university level (universities with several campuses were regarded as a single respondent):

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 Z_i + \varepsilon$$

where Y_i is either the number of new patent applications or the number of new licensing agreements concluded by university i in 2017. X_i is a set of independent variables, including two scales representing the degree to which clear university regulations related to IP protection (patenting models only) and licensing agreements (licensing models only) are available and enforced, two dummies for the presence of on campus business incubators and technology parks, the GDP per capita at state level, and the log of the total number of patent applications at state level (excluding academic patents). Finally, Z_i is a set of control variables that include TTO's age and FTE, the pre-sample stock of intellectual property (licensing models only), the pre-sample stock of scientific publications (patenting models only), and the research quality (licensing models only) of university i.

4.4 Results

4.4.1 Summary statistics and correlations

Descriptive statistics as well as the correlations for our variables are reported in Table 4.1 below. The correlations between our variables raise no concerns about multicollinearity[10], which we confirmed with a VIF analysis. In our patenting models, the highest VIF for any of our variables is 2.09 (mean VIF=1.65), well below the suggested cut-off point of 10 (HAIR et al., 2010). Similarly, the highest VIF for any of our variables in our licensing models is 2.18 (mean VIF=1.66).

[10] At first glance, the correlation between the stock of intellectual property and the stock of scientific publications might raise concerns. However, since we do not use these variables in the same regressions, this is not an issue in our analyses.

Table 4.1 – Descriptive statistics and zero-order correlations

	Variable	Mean	S.D.	N	1	2	3	4	5	6	7	8	9	10	11	12	13
1	New patent applications	12.89	19.11	82	1.00												
2	New licensing agreements	0.88	3.00	82	0.51	1.00											
3	Quality of IP protection regulation	4.29	1.13	82	0.27	0.16	1.00										
4	Quality of licensing regulation	2.99	1.43	82	0.38	0.33	0.59	1.00									
5	Business incubator dummy	0.72	0.45	82	0.13	0.14	0.11	0.16	1.00								
6	Technology park dummy	0.32	0.47	82	0.36	0.31	0.29	0.29	0.19	1.00							
7	Local demand for technology	6.61	1.53	82	0.01	0.22	0.18	0.17	0.04	0.22	1.00						
8	State GDP per capita (/1000)	1.29	0.40	82	-0.04	0.32	0.07	0.10	0.09	0.26	0.64	1.00					
9	TTO age	9.96	4.99	82	0.37	0.38	0.37	0.35	0.24	0.44	0.22	0.33	1.00				
10	TTO FTE	8.48	14.60	82	0.40	0.60	0.21	0.36	0.20	0.42	0.19	0.38	0.65	1.00			
11	Stock of intellectual property	3.20	1.75	82	0.66	0.40	0.48	0.44	0.16	0.45	0.32	0.25	0.58	0.47	1.00		
12	Stock of scientific publications	6.71	1.70	82	0.61	0.35	0.33	0.37	0.15	0.39	0.33	0.26	0.48	0.46	0.86	1.00	
13	University research quality	5.62	2.42	79	0.18	0.16	-0.12	0.15	0.00	0.21	0.33	0.29	0.24	0.12	0.28	0.28	1.00

Source: elaborated by the authors

4.4.2 General results

The results of the effect of university support mechanisms (i.e., technology transfer regulations, UBIs and STPs) and regional context on technology transfer performance are reported in Tables 4.2 and 4.3. We report robust standard error for all the estimates. The first column of each Table (Models 1 and 8) reports the estimations for the control variables. The subsequent columns include our independent variables in a stepwise fashion. In the last column of each table (Models 7 and 14), we substitute the quality of the TT-related regulations by dummy variables, indicating the availability of university-level regulations for IP protection and licensing agreements. In addition, we also regressed each of our independent variables separately, along with the set of control variables. Since most results were very similar to our main results, we do not report them.

Table 4.2 – Negative binomial models estimating the effect of university support mechanisms on university patenting

	Dependent variable: New patent applications						
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
IP protection regulation dummy							0.307
							(0.703)
Quality of IP protection regulation		**0.267***	**0.264***	**0.247***	**0.269***	**0.254***	
		(0.120)	(0.119)	(0.116)	(0.113)	(0.122)	
Business incubator dummy			0.055	0.052	0.086	0.086	0.126
			(0.277)	(0.272)	(0.242)	(0.242)	(0.245)
Technology park dummy				0.188	0.134	0.148	0.234
				(0.275)	(0.219)	(0.215)	(0.224)
Local demand for technology					**-0.254*****	**-0.229***	**-0.194***
					(0.068)	(0.089)	(0.085)
State GDP per capita (/1000)						-0.159	-0.303
						(0.369)	(0.339)
TTO age	0.033	0.022	0.020	0.018	0.033	0.034	0.039
	(0.030)	(0.029)	(0.031)	(0.031)	(0.027)	(0.027)	(0.027)
TTO FTE	**-0.013+**	**-0.012+**	**-0.012+**	**-0.013+**	-0.009	-0.008	-0.008
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.007)
Stock of scientific publications	**0.758*****	**0.716*****	**0.717*****	**0.709*****	**0.720*****	**0.713*****	**0.727*****
	(0.080)	(0.081)	(0.080)	(0.077)	(0.074)	(0.072)	(0.069)
Constant	**-3.366*****	**-4.170*****	**-4.188*****	**-4.085*****	**-2.826*****	**-2.704*****	**-2.115***
	(0.507)	(0.619)	(0.616)	(0.581)	(0.691)	(0.726)	(0.934)
LR $\chi2$	176.1	177.6	179.8	190.9	175.0	176.5	169.0
Log-likelihood	-249.4	-246.7	-246.7	-246.4	-239.6	-239.5	-242.0
Pseudo R^2	0.125	0.135	0.135	0.136	0.160	0.160	0.151
N	82	82	82	82	82	82	82

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

Our specifications on patent applications, reported on Table 4.2, show that the quality of regulations for IP protection has a positive impact on new patent applications (Models 2-6). In contrast, the mere existence of IP protection policies (Model 7) has no effect on patenting outcomes. There is considerable heterogeneity in the degree to which these regulations are clear, well-defined and actually enforced across universities. Apparently, there is no significant relation between the number of new patent applications and the presence of either UBIs or STPs. This suggests that the proximity to technology-intensive firms does not increase the interest of researchers in engaging in technology transfer activities. Alternatively, it is also possible that technology transfer to UBIs and STPs occur in a more informal manner, that does not involve patents. Interestingly, the local demand for technology has a negative and significant effect on university patenting activities. All things being equal, this suggests that universities located in less innovative regions are more likely to patent than those located in regions with higher levels of inventive activities. Similarly, the effect of the GDP per capita on the number of new patent applications is also negative, but not significant. Nevertheless, when we regressed GDP per capita along with the set of control variables, we found a negative and significant coefficient at 1%. A possible interpretation for these findings is that universities in more developed regions may be more selective in the technologies they choose to protect, whereas institutions in less developed regions might patent less strategically.

Table 4.3 – Negative binomial models estimating the effect of university and regional support mechanisms on university licensing

	Dependent variable: New licensing agreements						
Variables	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Licensing regulation dummy							1.480 (0.938)
Quality of licensing regulation		**0.488*** (0.233)	**0.478*** (0.224)	**0.482*** (0.237)	**0.539*** (0.252)	**0.673**** (0.237)	
Business incubator dummy			0.403 (0.495)	0.427 (0.494)	0.259 (0.500)	0.324 (0.527)	0.603 (0.571)
Technology park dummy				0.323 (0.542)	0.355 (0.566)	0.316 (0.582)	0.169 (0.503)
Local demand for technology					**0.343+** (0.186)	0.112 (0.229)	0.001 (0.209)
State GDP per capita (/1000)						**2.061***** (0.524)	**1.621**** (0.549)
TTO age	-0.030 (0.049)	-0.012 (0.044)	-0.018 (0.044)	-0.019 (0.044)	0.008 (0.042)	0.007 (0.030)	-0.029 (0.047)
TTO FTE	**0.034*** (0.014)	**0.021+** (0.012)	**0.022+** (0.013)	0.020 (0.013)	0.014 (0.012)	-0.013 (0.009)	0.009 (0.012)
Stock of IP	**0.577**** (0.213)	**0.471*** (0.206)	**0.463*** (0.200)	**0.428*** (0.217)	**0.397+** (0.212)	**0.647**** (0.238)	**0.658**** (0.237)
University research quality	0.033 (0.085)	0.027 (0.086)	0.023 (0.088)	0.010 (0.095)	-0.126 (0.135)	**-0.214+** (0.116)	-0.107 (0.103)
Constant	**-3.170**** (1.041)	**-4.525***** (0.807)	**-4.678***** (0.813)	**-4.619***** (0.820)	**-6.463***** (1.388)	**-8.478***** (1.746)	**-6.551***** (1.606)
LR $\chi 2$	76.5	85.0	86.6	85.8	75.2	117.9	84.4
Log-likelihood	-70.6	-66.8	-66.5	-66.4	-64.6	-61.0	-65.7
Pseudo R^2	0.197	0.241	0.243	0.245	0.266	0.306	0.253
N	79	79	79	79	79	79	79

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

The results on new licensing agreements, reported on Table 4.3, show a positive relation between the quality of regulations for licensing and the number of agreements concluded by universities (Models 9-13). Similar to our findings on new patent applications, the mere availability of licensing regulations (Model 14) does not appear to impact licensing outcomes. Within our sample, 76% of the universities stated having regulations for licensing agreements in place. Nevertheless, the degree to which these are unambiguous and indeed enforced varies strongly across institutions. In fact, we often hear anecdotes from TTO employees that licensing regulations within their institutions are not clear and/or demand high levels of bureaucracy. In such cases, these regulations may end up hindering the conclusion of licensing agreements instead of promoting them.

Next, our findings show no relation between new licensing agreements and the presence of either incubators (Models 10-14) or science and technology parks (Models 11-14). Contrary to our expectations, this may suggest that the presence of technology-intensive firms on campus has no effect on the dissemination of university technologies through licensing agreements. It is possible that, in this case, the main channel for the diffusion of academic knowledge is through R&D contracts. This is in line with Caldera and Debande (2010), who found evidence that the presence of STPs has a positive effect on the number of R&D contracts, but no effect on the number of licensing agreements concluded (however, they found that the presence of STPs has a positive impact on licensing revenues). As to the local demand for technology (Models 12-14), we find only weak evidence suggesting a positive relation between local levels of innovative activity and the number of licensing agreements. Although the coefficient for this variable has a positive sign across all specifications we tested, it is only significant in one of them (at 10%). The lack of significance in these results may reflect the low absorptive capacity of Brazilian firms. Finally, considering that the coefficient for GDP per capita is positive and significant, our results suggest that universities located in economically developed regions generate a greater number of licensing agreements.

4.4.3 Robustness checks

In this section, we present the results of additional analyses we performed to examine the robustness of our findings. To do that, we rerun our full specifications on new patent applications (Models 6 and 7) and licensing agreements (Models 13 and 14) including additional fixed effects and control variables. The results are reported on Tables 4.4 and 4.5, respectively. In both cases, we first employ region-fixed effects. This allows us to account for fixed characteristics of the universities' geographic location that may affect technology transfer outcomes. Next, we use a dummy variable to account for any unobservable heterogeneity between universities and polytechnic universities that may affect TT. This variable takes the value of 1 in the case of polytechnic institutions and zero otherwise. We also use a dummy to control for the public status of universities. Private institutions may be keener than their public peers to generate revenues from intellectual property, which might lead to distinct technology transfer strategies and outcomes.

Table 4.4 – Negative binomial models estimating the effect of university and regional support mechanisms on university patenting (robustness checks)

	Dependent variable: New patent applications					
Variables	**15**	**16**	**17**	**18**	**19**	**20**
IP protection regulation dummy				0.167 (0.738)	0.164 (0.658)	0.182 (0.653)
Quality of IP protection regulation	**0.243+** (0.130)	**0.235+** (0.123)	**0.238+** (0.122)			
Business incubator dummy	0.161 (0.237)	0.262 (0.225)	0.246 (0.226)	0.209 (0.235)	0.313 (0.228)	0.299 (0.230)
Technology park dummy	0.028 (0.212)	0.040 (0.217)	0.018 (0.223)	0.114 (0.217)	0.126 (0.220)	0.106 (0.217)
Local demand for technology	**-0.419**** (0.146)	**-0.426**** (0.145)	**-0.429**** (0.145)	**-0.410**** (0.148)	**-0.419**** (0.149)	**-0.421**** (0.149)
State GDP per capita (/1000)	0.394 (0.693)	0.425 (0.674)	0.330 (0.670)	0.054 (0.641)	0.103 (0.600)	0.021 (0.607)
TTO age	0.037 (0.029)	0.049 (0.030)	0.045 (0.029)	0.039 (0.029)	**0.051+** (0.030)	0.047 (0.030)
TTO FTE	-0.007 (0.010)	-0.011 (0.010)	-0.010 (0.009)	-0.005 (0.009)	-0.009 (0.009)	-0.008 (0.009)
Stock of scientific pub.	**0.708***** (0.072)	**0.823***** (0.094)	**0.854***** (0.116)	**0.725***** (0.069)	**0.843***** (0.091)	**0.869***** (0.108)
Polytechnic university dummy		**0.764*** (0.342)	**0.844*** (0.388)		**0.785*** (0.359)	**0.853*** (0.397)
Public university dummy			-0.213 (0.472)			-0.183 (0.448)
Region fixed effects	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Constant	**-3.150*** (1.490)	**-4.169**** (1.541)	**-4.011**** (1.540)	-2.007 (1.533)	**-3.095*** (1.525)	**-2.967+** (1.520)
LR $\chi2$	198.0	194.2	201.7	185.6	200.2	208.5
Log-likelihood	-238.1	-235.7	-235.6	-240.4	-237.9	-237.8
Pseudo R^2	0.165	0.173	0.174	0.157	0.166	0.166
N	82	82	82	82	82	82

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

Table 4.5 – Negative binomial models estimating the effect of university and regional support mechanisms on university licensing (robustness checks)

	***Dependent variable: New* licensing agreements**					
Variables	**21**	**22**	**23**	**24**	**25**	**26**
Licensing regulation dummy				**1.532+**	**1.403+**	0.808
				(0.869)	(0.828)	(0.872)
Quality of licensing regulation	**0.664****	**0.666****	**0.577***			
	(0.237)	(0.244)	(0.261)			
Business incubator dummy	0.335	0.019	-0.333	0.666	0.400	-0.229
	(0.538)	(0.500)	(0.585)	(0.590)	(0.535)	(0.575)
Technology park dummy	0.261	0.152	0.103	-0.048	-0.110	-0.149
	(0.766)	(0.738)	(0.744)	(0.650)	(0.621)	(0.644)
Local demand for technology	0.257	0.224	0.250	-0.044	-0.065	0.063
	(0.527)	(0.475)	(0.445)	(0.491)	(0.480)	(0.434)
State GDP per capita (/1000)	1.802	1.733	1.116	1.623	1.460	0.334
	(1.487)	(1.389)	(1.461)	(1.417)	(1.369)	(1.484)
TTO age	0.009	0.001	-0.007	-0.040	-0.051	-0.058
	(0.039)	(0.039)	(0.039)	(0.065)	(0.071)	(0.067)
TTO FTE	-0.011	-0.007	0.000	0.019	0.025	0.033
	(0.014)	(0.015)	(0.020)	(0.021)	(0.025)	(0.032)
Stock of IP	**0.643****	**0.619***	**0.798****	**0.669****	**0.583***	**0.879****
	(0.238)	(0.245)	(0.279)	(0.217)	(0.234)	(0.276)
University research quality	-0.202	-0.202	**-0.238+**	-0.077	-0.044	-0.127
	(0.124)	(0.132)	(0.145)	(0.109)	(0.143)	(0.165)
Polytechnic university dummy		**-16.065*****	**-14.896*****		**-15.377*****	**-15.093*****
		(0.881)	(0.911)		(0.651)	(0.696)
Public university dummy			-0.885			**-1.581****
			(0.587)			(0.588)
Region fixed effects	*YES*	*YES*	*YES*	*YES*	*YES*	*YES*
Constant	**-8.960****	**-8.209****	**-6.291***	**-7.046****	**-6.129***	-2.979
	(2.759)	(2.706)	(3.022)	(2.472)	(2.427)	(2.764)
LR $\chi 2$	1345.0	1465.8	1481.0	795.4	2135.8	2571.5
Log-likelihood	-60.8	-58.8	-58.1	-65.1	-63.0	-61.1
Pseudo R^2	0.308	0.331	0.339	0.260	0.283	0.305
N	79	79	79	79	79	79

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

Overall, our findings are robust to these alternative specifications. One notable exception is the variable GDP per capita, seen in Table 4.5. Although the effect of GDP per capita is positive across all specifications, it is not significant in any of them. Nevertheless, we attribute this to the inclusion of region fixed-effects, which probably absorbed the effects of the variable GDP per capita. In addition, the existence of licensing regulation appears to have a positive effect on new licensing agreements. However, the licensing dummy is only significant at 10% and in two out of the three specifications we tested (Models 24-26).

Finally, we used a dummy for new licensing agreements as an alternative dependent variable and reran our specifications using probit models. The results, presented on Table 4.6, are in line with our previous findings and suggest that both the quality of licensing regulations and regional development positively impact the likelihood of universities concluding new licensing agreements.

Table 4.6 – Probit models estimating the effect of university and regional support mechanisms on university licensing

	Dependent variable: Dummy for new licensing agreements						
Variables	**27**	**28**	**29**	**30**	**31**	**32**	**33**
Licensing regulation dummy							**1.422+**
							(0.766)
Quality of licensing regulation		**0.387****	**0.388****	**0.386****	**0.409****	**0.516****	
		(0.144)	(0.144)	(0.148)	(0.149)	(0.166)	
Business incubator dummy			-0.038	-0.048	-0.029	-0.115	0.096
			(0.403)	(0.405)	(0.408)	(0.450)	(0.425)
Technology park dummy				0.237	0.240	0.192	0.184
				(0.398)	(0.402)	(0.415)	(0.391)
Local demand for technology					0.205	-0.116	-0.187
					(0.148)	(0.197)	(0.203)
State GDP per capita (/1000)						**1.970***	**1.797***
						(0.771)	(0.764)
TTO age	-0.010	-0.003	-0.002	-0.005	-0.004	0.018	-0.013
	(0.053)	(0.054)	(0.054)	(0.053)	(0.052)	(0.050)	(0.051)
TTO FTE	**0.035+**	0.024	0.024	0.020	0.016	0.010	0.027
	(0.020)	(0.020)	(0.020)	(0.018)	(0.016)	(0.022)	(0.023)
Stock of IP	**0.348***	**0.273+**	**0.274+**	**0.262+**	**0.263+**	**0.363***	**0.394***
	(0.143)	(0.149)	(0.149)	(0.149)	(0.150)	(0.185)	(0.157)
University research quality	0.072	0.080	0.079	0.075	0.040	-0.057	-0.004
	(0.063)	(0.061)	(0.062)	(0.063)	(0.074)	(0.112)	(0.088)
Constant	**-2.441*****	**-3.480*****	**-3.468*****	**-3.425*****	**-4.705*****	**-5.489*****	**-4.605*****
	(0.638)	(0.770)	(0.813)	(0.825)	(1.168)	(1.347)	(1.221)
LR $\chi 2$	22.3	30.4	34.5	39.9	42.1	32.4	26.3
Log-likelihood	-34.4	-30.6	-30.6	-30.4	-29.5	-26.8	-29.5
Pseudo R^2	0.264	0.346	0.346	0.349	0.368	0.427	0.368
N	79	79	79	79	79	79	79

+ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
Robust standard errors are reported in parenthesis.
Source: elaborated by the authors

4.5 Discussion

In this study, we explore how university support mechanisms for technology transfer affect their patenting and licensing activities. Specifically, we investigate how the quality of internal TT-related regulations and the availability of UBIs and STPs impact the number of university new patent applications and licensing agreements. In addition, we also examine the effects of regional development on university patenting and licensing activities. We explore these issues in the context of Brazilian universities.

Our results show that the quality of technology transfer regulations is positively associated with the number of new patent applications and licensing agreements. This is in line with our expectations and suggests that high quality regulations may diminish uncertainties and provide clarity in university patenting and licensing processes. On the other hand, the mere availability of regulations has no effect on patenting activities and only little effect on licensing outcomes. Two important conclusions emerge from these results. First, universities wishing to improve technology transfer performance should be particularly active in creating clear, well-defined and unambiguous policies for the commercialization of their technologies. As suggested by previous literature, transparent and well-articulated regulations are not only desirable, but fundamental for effective technology transfer (DEBACKERE; VEUGELERS, 2005; LOCKETT; WRIGHT, 2005).

Second, when addressing the impact of university internal policies on technology transfer performance, it is important to consider not only the availability of these policies, but also their quality. While high quality regulations mitigate uncertainties related to the technology transfer process, low quality regulations may exacerbate potential hazards and transaction costs (Quélin et al., in press). In the latter cases, the availability of regulations may end up hindering the conclusion of licensing agreements and discouraging faculty members and firms from engaging in technology transfer. In this sense, we believe that analyses based solely on the adoption of TT-related regulations may lead to incomplete or even misleading results.

Contrary to our expectations, neither UBIs nor STPs appear to affect technology transfer performance. This finding is intriguing, especially considering that intermediary organizations such as STPs attract firms with high absorptive capacity (RAMÍREZ-ALESÓN; FERNÁNDEZ-OLMOS, 2018), i.e., firms able to assimilate and commercially exploit external knowledge (COHEN; LEVINTHAL, 1990) – in our case, university knowledge spillovers. However, one possible explanation is that the diffusion of academic knowledge to UBIs and STPs occurs through channels that do not necessarily involve intellectual property, such as R&D contracts, consultancy or informal non-market spillovers.

Interestingly, we find that universities located in regions with lower levels of economic and innovative activities (GDP per capita and number of non-academic patents) generate more patent applications. Although puzzling, this effect may be caused by the lack of patenting experience of those universities. As suggested by previous studies, universities with less experience and expertise in patenting activities are less selective in the technologies they choose to protect (MOWERY; SAMPAT; ZIEDONIS, 2002; MOWERY; ZIEDONIS, 2002). In fact, analyzing the age of the TTOs of universities within our sample, we perceived that those of institutions located in less developed regions tend to be younger.

Finally, in line with prior studies (CHAPPLE et al., 2005; SIEGEL; WALDMAN; LINK, 2003), we find that universities located in regions with higher levels of economic activity generate more licensing agreements, which may suggest the localization of university technology transfer spillovers. These results also suggest that institutions located in less developed regions may face additional challenges in the commercialization of their technologies. In such contexts, the availability of internal university support mechanisms may play a more prominent role in promoting technology transfer activities than it does in more developed regions. As suggested by Fini et al. (2011), lower levels of regional economic development makes it more urgent for universities to strongly invest in internal support mechanisms.

4.6 Conclusion

This work contributes to the literature in distinct ways. To the best of our knowledge, this is the first study investigating the effect of the quality of university policies on technology transfer performance. The results show that the quality of TT-related regulations is positively related to patenting and licensing activities, whereas the mere availability of regulations has no (or only little) effect on technology transfer outcomes. These findings stress the importance of investigating, not only the availability of regulations, but also the degree to which these are transparent, well- defined, unambiguous and truly enforced. Further, our results reveal that analyses based solely on the adoption of TT-related regulations may lead to confounding results.

In addition, our findings on the local contexts of universities may have important managerial and policy implications. Universities located in regions with lower levels of economic and innovative activities appear to be spending time and resources protecting inventions with low commercial potential. Instead, these universities should adopt a more selective patenting strategy, especially considering that the absorptive capacity of the firms in their surroundings is likely to be low. Also, in order to maximize technology transfer outcomes, it might be necessary for those universities to invest in the creation of strong technology transfer support mechanisms (such as clear regulations for technology transfer and initiatives to promote the commercialization of research results).

A third contribution of this study is that, by focusing on the Brazilian case, it adds to the incipient literature on technology transfer in the context of developing countries. The Brazilian case is interesting for many reasons. To start, it provides an opportunity to investigate technology transfer in universities with relatively little experience, still in the beginning of their learning curve. Also, the national innovative landscape is very different from those in the US and UK, countries that represent the majority of studies on TT-activities. Although university technology transfer is a recent phenomenon in Brazil, universities carry out a good portion of innovative activities in the country. For example, 24% of the total resident patent applications at INPI in 2017 came from universities. On the other hand, in the same year, firms accounted for less than 30% of all applications, which may suggest a low absorptive capacity of the productive sector and pose an additional challenge for universities attempting to commercialize their inventions.

As in other studies, ours is also subject to limitations. First, although we do not limit our analysis to the most successful universities in research and technology transfer (as suggested by Grimaldi et al., 2011), the results of this study should be interpreted with caution. Regional, economic and institutional idiosyncrasies of the Brazilian case prevent us from generalizing our findings to other contexts. Second, since our analysis is based on data at one point in time, we cannot claim causality relations among our variables of interest. The cross-sectional nature of our data also kept us from using licensing revenues as a further dependent variable (as previously discussed). Third, we focus solely on the existence of on-campus incubators and science parks. The absorptive capacity of tenant firms (ROTHAERMEL; THURSBY, 2005) as well as the management strategies used by UBIs and STPs (MCCARTHY et al., 2018) may be very heterogeneous and our approach does not take this heterogeneity – which may have significant effects on TT outcomes – into consideration. Therefore, further research could include a more detailed investigation of role of specific attributes of UBIs and STPs on technology transfer outcomes. Despite these limitations, we are confident that this study represents an important step towards understanding the impact of universities' support mechanisms and local context on technology transfer outcomes.

5 CONCLUSION

This dissertation aims to improve our understanding of the dissemination of academic-based knowledge to the industrial sector. To do that, it examines three main questions concerning the diffusion of university inventions to firms. These questions are explored in three different essays, building on the knowledge spillover and technology transfer literatures. The common point of departure of all three essays is the dissemination of academic technologies that are protected by IP rights. While the first one focuses on the diffusion of university research through non-market spillovers (i.e., citations to academic patents), the second and third investigate the dissemination of academic inventions through market-mediated transactions (i.e., technology transfer agreements). Although prior studies have comprehensively increased our understanding of the ways in which academic knowledge is disseminated, several important questions remain open. Accordingly, the essays in this dissertation join the existing literature that aims at understanding how and under which circumstances academic inventions are disseminated and deployed by the private sector.

The three essays in this dissertation contribute to the literature in distinct ways. To the best of my knowledge, the first one represents the first study on knowledge spillovers that differentiates between academic spill-ins and academic spill-outs. This is an important distinction with which to understand the broad impact of university inventions beyond academia; especially considering that knowledge flows among universities (i.e., academic spill-ins) may lead to an overestimation of the overall spillovers of academic inventions. As to the second essay, it is one of the few studies addressing the effects of TTO human resources on technology transfer outcomes. Despite the extensive literature on TTOs, surprisingly little is known about the ways in which TTOs' human capital affects technology transfer activities. As to the third one, I am not aware of any other study investigating the impact of the quality of university regulations on TT outcomes. Finally, another important contribution of this dissertation (more specifically of essays 2 and 3) is that it adds to the incipient literature of university-industry technology transfer in the context of developing countries. The case of Brazil provides an excellent opportunity to investigate universities with relatively little experience in the commercialization of technologies, still at the beginning of their learning curves.

The findings of this dissertation have also important managerial implications for several actors involved in the TT process. For example, the finding that the spillovers of university inventions are greater and less localized than those of firms has implications for university administrators, industrial managers and policymakers. As stressed by Mowery and Ziedonis (2015), managerial decisions on the location of innovative activities of firms are often affected by beliefs about the localization of academic knowledge spillovers. University administrators, in turn, can use these findings to leverage funding with policymakers at both regional and national level. Next, the findings regarding the effects of TTO human resources on TT activities can help university managers to strategically develop staff aiming at specific outcomes. Finally, the findings on TT regulations suggest that university managers need to devote more resources to the development of regulatory frameworks that are clear, well defined and stable.

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