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University-Industry Knowledge Interactions

People, Tensions and Impact

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In memory of Prof. Paul Benneworth (1974–2020), a researcher who was truly engaged with both the academic community and society. Thank you for your inspiring work. You will be always remembered.

The Editors

Many years of fruitful personal and professional interactions with Paul Benneworth granted us the privilege of getting to know an extremely engaged, supportive, brilliant, joyful and inspiring person, who had an extraordinary sense of humour and was a wonderful companion. Paul always challenged us to defy the current state of the art, and to think about how to make a difference in a meaningful way. Thank you, Paul, for all these years of intellectual growth by your side. We miss you very much. You will remain alive in our memory forever. Rest in peace dear friend.

Elena, Julia and Reetta (his co-authors in this book)

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Contents

Chapter 1
Introduction: People, Tensions and Impact in University Interactions

Joaquín M. Azagra-Caro, Pablo D'Este, and David Barberá-Tomás

Abstract University-industry interaction combines several layers of actors, states and effects. *People* make choices, based on their individual characteristics, at different stages of a scientific career, in a highly internationalised profession. *Tensions* arise when university administrators and managers need to strike a balance among different promotion instruments, or when the university or public research organisation tries to solve the trade-offs between long- and short-term relationships, or among new management practices. *Impacts* are related to scientific agendas, the economic returns for firms or the societal benefits. This book adopts a *people-tension-impact* approach to identify key insights, by combining qualitative and quantitative research, established and novel methodologies, and different geographic settings. The chapters in this volume provide new perspectives on university-industry interactions related to gender biases, entrepreneurial involvement of PhD students and the role of international mobility. They also focus on how the positive impacts of university-industry interactions coexist with unresolved tensions linked to policy combinations, long-term contractual relationships, management practices and organisational strategies.

Keywords University-industry interaction · Knowledge transfer · Academic entrepreneurship · Public research organisations · Societal impact

1.1 Introduction

University-industry knowledge interactions are crucial for smart specialisation and sustainable growth. However, they involve problems related to navigating the different university-industry logics, management of the tensions in academic

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organisations and the impact of the interactions on science, firms and society. Several research fields have studied these aspects, using different approaches. The chapters in this book are based on the presentations made at the 2018 Technology Transfer Society (T2S) Conference, held in Valencia, Spain, and discuss some developments related to this *people-tension-impact* approach.

Compared to other works on this topic, this book presents some novelties. First, some of the chapters focus on public research organisations rather than universities, and on society rather than industry, on the grounds that their interactions are based on similar problematisations. The aim is to include a wide range of the players involved in the diffusion of academic knowledge to non-academic audiences and the related themes, such as societal impact, and policy mixes. Second, the book does not adhere to either a quantitative or qualitative bias, but offers a balanced representation of a range of analytical methodologies. Third, the empirical evidence and the study context provide a varied picture of global university-industry interactions, in Germany, Italy, Japan, Slovenia, Spain and other countries, and their importance in either a national or international setting. We hope that the chapters in this book will provide the reader with information on a selection of hot topics that expand both our understanding of and scope for management and policy action.

The book is organised in three parts, following the proposed pillars of university-industry interaction: people, tension and impact, although presented in reverse order for easier reading. The chapters in Part I discuss the effects of university interactions on science, industry and society. Part II describes the policy mix designed to promote university-industry knowledge transfer and trade-offs that universities make among short- and long-term relationships with industry and soft and hard technology transfer practices, and research flexibility or specialisation. Part III examines some unexplored individual aspects of university interactions: gender, youth and mobility.

Part I examines how university interactions affect science, industry and society and, particularly, the effect of corporate involvement on early scientific choices. In Chap. 2, entitled ‘PhDs with industry partners – assessing collaboration and topic distribution using a text mining methodology’, Kilian Buehling and Matthias Geissler discuss whether, in the case of collaborative research, PhD supervisors influence their students’ dissertation topics. The study examines whether there is a significant influence of industrial interests on researchers’ agendas. An original analysis of dissertation contents shows that topic choices remain fixed, regardless of collaborative status.

In Chap. 3, ‘The heterogeneous impact of academic patent characteristics on firms’ economic performance’, by Giovanni Cerulli, Giovanni Marin, Eleonora Pierucci and Bianca Maria Potì, the authors investigate how university technology contributes to increased financial returns for firms. They analyse firm patents with academic inventors, and the characteristics of these patents that contribute to firm financial success. Their analysis challenges the current view that radical and explorative academic patents are the most useful for companies and argue that, by distinguishing between short and long term value, incremental and exploitative academic patents can be also beneficial for firms.

In Chap. 4, ‘Rethinking the role of productive interactions in explaining SSH research societal impacts’, written by Paul Benneworth, Elena Castro-Martínez, Julia

Olmos-Peñuela and Reetta Muhonen, the authors show that societal benefits matter. They study multiple cases of social science and humanities research projects (music, philosophy, theatre) and their 'productive interactions' with the wider social systems. They identify the mechanisms that shape societal impact, by coupling user and researcher interests, evaluating their interactions and distinguishing value in useful knowledge practices.

Part II examines the different kinds of tensions that policymakers and organisations are required to manage in their interactions with industry. Chapter 5, by José Guimon and Caroline Paunov, is entitled 'The policy mix to promote university-industry knowledge transfer', and provides a comprehensive account of university-industry policies. The authors distinguish among the most frequent policy instruments according to such dimensions as the nature of the instrument, its target group and its implementation. They assess how different policy instruments interact when implemented as part of the same policy mix. Their analysis provides an original and useful framework for understanding the positive and negative interactions between different policy instruments.

Policies and their mix set the framework for the links established by universities with different partners. The aim is to establish and nurture long-lasting relations. However, this is not always straightforward. Tohru Yoshioka-Kobayashi and Makiko Takahashi in Chap. 6, 'Determinants of contract renewals in university-industry contract research: going my way, or good Sam?', investigate university-industry research collaborations from a longitudinal perspective. The chapter examines the prevalence of extensions to and renewals of research collaborations between industry and universities, and the factors influencing these decisions. The study uses data on the research contracts with firms, of a leading Japanese research university, over the period 2005–2014. Their findings show that research collaboration extensions and renewals are frequent phenomena. Their results show, also, that high scientific performance by the university partner, measured by paper publications and technological capability, is crucial for the firm's decision to renew or extend the collaboration.

Technology Transfer Offices (TTOs) are a specific tool used by universities to foster interaction with industry. TTO managers implement a range of practices to achieve their goals. Mario Benassi, Matteo Landoni and Francesco Rentocchini discuss these practices in Chap. 7, 'The relationship between university management practices and the growth of academic spin-offs'. They examine the impacts of different management practices put in place by universities to support the performance of academic spin-offs, including performance monitoring, target setting, incentive setting and people management. The study looks at the effects of these management practices on the growth of academic spin-off firms, using survey data on university management practices, and a longitudinal sample of 790 Italian university spin-offs (from 42 universities), observed over the period 2006–2014. The findings show that university management practices contribute to explaining the variation in the growth of academic spin-offs, but that the effects vary widely across management practices. The authors point out that these differentiated effects, which may be a result of adverse-selection, short-termism or weak enforceability, suggest that universities need to give careful consideration to the management practices implemented by university managers, since they could have unintended consequences for the growth of academic spin-offs.

Public research organisations face similar challenges in their interactions with industry. However, they have idiosyncratic coping mechanisms, especially if they are large organisations with expertise in a range of scientific disciplines, spread across the whole national territory. In Chap. 8, ‘Public research organisations and technology transfer: flexibility, spatial organisation and specialisation of research units’, by Ugo Finardi, Isabella Bianco and Secondo Rolfo, the authors study the case of the CNR, the Italian National Research Council, to explore the interactions between its research groups and companies. They find that some characteristics of CNR facilitate the spatial, organisational and cognitive proximity of researchers and firms, and compare this situation to that of university-industry relationships in Italy.

The contributions in Part III address some of most topical person-specific conditions that affect university-industry interactions. The study of gender is peremptory given current efforts to reduce the marginalisation of women in science. Dolores Modic, Ana Hafner and Tamara Valič-Besednjak in Chap. 9, ‘Every woman is a vessel: an exploratory study of gender and academic entrepreneurship in a nascent technology transfer system’, contribute to research on the gender gap in science by examining the barriers to women scientists’ engagement in academic entrepreneurship. The study analyses internal barriers (e.g., work-family balance, risk-taking, experience) and external barriers (e.g., lack of presence, access to finance, peer effect) and contrasts the perspectives of researchers and TTO heads. The authors use a case-oriented approach combining interview analysis and fuzzy-set qualitative comparative analysis, in the context of an emerging university technology transfer system (i.e., Slovenia). They identify particular combinations of internal and external barriers as having a major influence on the gender gap in science. They suggest that internal barriers are perceived as more important than external barriers, by both groups of respondents, and explain the low levels of women scientists’ participation in academic entrepreneurship. However, TTOs and researchers disagree about specific barriers, which, the authors claim, could have a negative impact on the effectiveness of the mechanisms implemented to mitigate the gender gap in academia.

Another individual personal characteristic affecting university-industry interactions is age and the involvement of young scholars in the process. This involvement can take the form of a new business started by doctoral students. In Chap. 10, ‘The effects of the academic environment on PhD entrepreneurship: new insights from survey data’, Alessandro Muscio, Sotaro Shibayama and Laura Ramaciotti emphasise how their situational context conditions their choices. This chapter investigates attitudes to entrepreneurship and entrepreneurship behaviours among early stage researchers – that is, students enrolled in PhD programmes. It focuses on PhD students’ involvement in the formation of new business ventures and their attitudes to entrepreneurship, such as the intention to establish a start-up and abandonment of their entrepreneurial idea. Based on a large-scale survey, conducted in 2016, of Italian doctoral students enrolled in a PhD course between 2008 and 2014, the authors examine the effect of the university's entrepreneurial environment on PhD students' entrepreneurship. They find that universities with policies supporting academic entrepreneurship, such as clear guidance for potential entrepreneurs and establishment of business incubators, are associated significantly with PhD students' attitudes and behaviours related to firm creation.

The final individual variable examined in this book is mobility. Chapter 11, 'International academic mobility and entrepreneurial opportunity identification: a resource-based view' by Kevin De Moortel, Thomas Crispeels, Jinyu Xie and Qiaosong Jing, contributes to filling a major gap in the literature on university-industry interactions. It provides a conceptualisation of the links to researcher mobility. To our knowledge, this is the first detailed theoretical analysis of this issue. The authors focus on temporary geographical mobility and one aspect of university-industry interactions, namely, opportunity identification. They argue that mobility favours the acquisition of external, heterogeneous knowledge, which is a precondition for the identification of entrepreneurial opportunities. They highlight that mobility generates larger social networks, which fuel knowledge acquisition and entrepreneurship, suggesting a double-effect of international academic mobility.

Some of the contributions in this book hint at multiple types of societal impacts, emerging from different scientific research fields. However, most chapters show that it is only under particular circumstances that certain policy combinations, long-term contractual relationships, management practices and organisational strategies are effective. This suggests that the positive impacts of university-industry interactions are coexisting alongside unresolved tensions and unfruitful endeavours. We hope that the chapters in this book and the messages they convey about the people-tension-impact approach, will inspire practical decisions and future research.

Part I
Scientific, Economic and Societal Impact of University Interactions

Chapter 2
PhDs with Industry Partners – Assessing Collaboration and Topic Distribution Using a Text Mining Methodology

Kilian Buehling and Matthias Geissler

Abstract Collaboration between universities and industry partners is thought to facilitate knowledge diffusion and provide resources and new ideas for academic researchers. However, recent evidence also suggests a possible trade-off or cost with regard to individual productivity. Given its focus on quantitative output, the literature is rather silent on possible qualitative shifts in researchers' agendas when engaging with industry partners. We contribute to a discussion on potential negative effects of university-industry engagement by comparing the topic distributions of PhD theses based on collaborative and noncollaborative research. The results indicate little difference between the two kinds of dissertation projects. We conclude that fears of agenda setting in collaborative research are unwarranted.

Keywords University-industry collaboration · Latent Dirichlet analysis · Topic modelling

2.1 Introduction

Universities have become increasingly open in recent decades. Hailed by some as an overdue renewal of a conservative institution and feared by others as eroding a successful way to amass knowledge, collaborations between universities and external stakeholders have attracted considerable attention. Proponents of increased collaboration highlight the importance of publicly financed research for industrial research & development (R&D) (Cohen et al., 2002). University-industry

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interactions are also believed to foster the diffusion of knowledge (Laredo, 2007; Azagra-Caro & Consoli, 2016) and the translation of new insights into tangible applications, thus contributing to overall economic prosperity (Etzkowitz & Leydesdorff, 2000). For individual researchers, access to additional resources may provide strong incentives to engage in collaboration (Tartari & Breschi, 2012; Perkmann et al., 2013), which also opens opportunities for individual learning (Perkmann & Walsh, 2009; Bikard et al., 2018). Furthermore, Ooms et al. (2018) document an increased likelihood of obtaining a professorship if heterogeneity in "basic" and "applied" research topics is increased. Highly productive individuals ("star scientists") are thought to possess character traits that help them excel in both academic and industrial realms (Zucker & Darby, 1996).

Increased collaboration with industry partners may, however, also lead to trade-offs regarding the allocation of time for the individual, and losses in productivity for scientists occupied with basic research are to be expected (Banal-Estañol et al., 2015). Publications, a yardstick for academic excellence, drop significantly in quantity and quality if research is increasingly determined by industrial requirements (Hottenrott & Thorwarth, 2011). Moreover, an "anti-commons" effect originating in formal intellectual property rights (IPR) protection may negatively affect the reception of findings within the scientific realm (Murray & Stern, 2007), which devalues engagement with industry partners. Furthermore, recent evidence suggests a higher likelihood of leaving academia when engaging in collaboration (especially consulting), which may lead to a significant "brain drain" towards industry (Fudickar et al., 2018).

Other potential negative effects include an increased (political) focus on collaboration that may be detrimental, especially if collaboration serves as a criterion for success for the individual. Researchers react to (external) incentives and shift their resources accordingly (Espeland & Sauder, 2007). In addition to the already mentioned decreases in academic value, agenda-setting effects may ensue if the applicability of results becomes a criterion for rewarding research efforts. The selection of research topics through direct (e.g., funding) or indirect (e.g., the hiring of specific personnel) means may result in a "Matthew effect" (Merton, 1968; van Looy et al., 2004), which threatens the freedom of science in the long run. Whether occurring on an individual or a community level, the selection of research endeavours in the realm of basic science on grounds of assumed application potential and the inevitable shift of resources towards what external stakeholders deem relevant and interesting rather than what the scientific community agrees to be worthy of attention bears a pretence of knowledge problem (Von Hayek & August, 1989). Most of the questions basic science is dealing with relate to very abstract phenomena, and social value should not be determined ex ante because such research involves unknown time frames and high uncertainty with regard to usability, be that usability scientific, economic or social in nature.

Contributing to the literature on the effects of university-industry collaboration, which has mostly focused on quantitative output indicators (publications), we combine machine learning and text mining approaches to delineate collaborative and noncollaborative university-industry projects and shed light on the distributions of their underlying research topics. Our unit of analysis is dissertations with industrial partners completed at four German universities. This specific kind of collaboration is common in a number of countries (see Salimi et al., 2015 for the Netherlands and Morichika & Shibayama, 2016 for Japan) but remains relatively underexplored in the literature. Dissertation projects are relatively long-lasting engagements for the student, the supervising professor, and the involved industry partner (if collaborative). Moreover, both collaborative and noncollaborative projects have to adhere to scientific standards to count as a formal component in qualifying for a PhD, although such projects are not always fully disclosed in scientific journals. Last but not least, open publication, at least in the university's library and the German National Library, is mandatory in virtually all 83 German universities that can grant PhDs. These attributes make dissertations an interesting case for our attempt to contribute to the discussion of potential agenda-setting effects caused by the increased interaction between universities and industry partners. However, distinguishing between collaborative and noncollaborative projects is difficult because the relevant information is usually not systematically disclosed. We use machine learning techniques to distinguish one from the other based on the acknowledgments disclosed in full-text dissertation documents. While not without shortcomings, this approach vastly reduces the number of documents that have to be processed manually in a relatively complex classification task. Thus, machine learning seems to be a promising tool for examining data sources that have been largely unexplored due to a lack of labour capacity.

Comparing similarities between the two groups of dissertations with the help of semantic topic modelling, we find no agenda-setting effects in a sample of dissertations supervised by professors who have supervised at least two collaborative projects. Supporting earlier findings by Salimi et al. (2015), we conclude that universities have no reason to shun collaboration on the grounds of undesired effects on research topics. Criticism of increased interactions between universities and external stakeholders is probably unwarranted in this regard. Collaborative dissertation projects, as a form of noncommercializing academic engagement (Perkmann et al., 2013), seem to be chosen largely on the basis of existing research interests, probably with the prospect of gaining access to additional resources (Tartari & Breschi, 2012).

The paper proceeds with a short literature summary on the effects of university-industry collaboration and "industrial" dissertation projects and text-mining techniques in Sect. 2.2. Section 2.3 introduces the sample and the semisupervised machine-learning approach used to classify projects as collaborative or noncollaborative. The construction of the corpora for text mining is explained in Sect. 2.4, and the results are presented in Sect. 2.5. The last section (Sect. 2.6) discusses the implications and limitations of our findings and concludes with suggestions for future research.

2.2 Literature on Collaboration, PhD Theses and Topic Modelling

The literature on university-industry interactions has traditionally focused on commercialization, mostly dealing with licensing (Jensen & Thursby, 2001) and spin-offs (Shane, 2004). Recent contributions have highlighted other forms of engagement and significantly broadened the notion of "collaboration". Perkmann et al. (2013), for example, distinguish "commercialization activities" from "academic engagement". The latter are usually closer to the academic interests of scientists and are mainly pursued to advance the researchers' own research agendas or help them gain access to resources (Tartari & Breschi, 2012). Scientists may also have a desire to gain insights into the actual applications of their research (Lee, 2000). When engaging with industry partners, scientists are usually sensitive to encroachments on their academic freedom (Tartari & Breschi, 2012). Accordingly, engagement is fuelled by prior experience and the building of trust between the parties involved (Bruneel et al., 2010).

Much of the literature on the effects of collaboration has focused on the scholarly productivity of individuals or organizations (Lee & Bozeman, 2005; Bikard et al., 2018). Studies differ slightly with regard to the delineation of "collaboration" but often consider publications and/or patents as output measures. The results usually reveal a slightly positive but nonlinear effect of collaboration on publication output (Manjarrés-Henríquez et al., 2008; 2009; Banal-Estañol et al., 2015). Other studies have painted a gloomier picture when contributing evidence on the effects of increased industry funding. The latter is usually associated with fewer and more inferior publications (Hottenrott & Thorwarth, 2011; Hottenrott & Lawson, 2014). However, "applied" collaboration projects may have the advantage of fostering learning through increased degrees of interdependence, leading to new ideas and projects on the side of academics (Perkmann & Walsh, 2009). Moreover, the increased output of applied research is potentially more important for the diffusion of knowledge into society at large (Hottenrott & Thorwarth, 2011). Ooms et al. (2018) assert that an individual is more likely to obtain a professorship if he or she increases the heterogeneity of his or her research topics (in terms of the number of "basic" and "applied" projects).

University-industry collaboration in dissertation projects is a very special form of engagement, and only a few studies have examined its effects. Salimi et al. (2015) compare collaborative and noncollaborative dissertations at the University of Eindhoven with a focus on patents, publications and citations of the two. Collaborative projects in this sample exhibit a higher likelihood of generating output (both patents and publications) and increased reception (number of citations). Although they conclude that universities have no reason to shun collaborative dissertation projects, they acknowledge that the identified effects are mainly driven by collaboration with nonuniversity research institutes and a single large firm (Philips). Another example of the application of PhD theses comes from Morichika and Shibayama (2016), who use data on Japanese PhD theses for a case study on the production of scientific knowledge in Japan.

Most of the research outlined above focuses on quantitative dimensions. For examining potential qualitative effects, we rely heavily on machine learning techniques and topic modelling as a form of quantitative text analysis. First, we employ a support vector machine model (SVM) used to classify dissertations into collaborative and noncollaborative projects. SVMs are supervised machine learning models that are suitable for classifying high quantities of text data, as they are adequate for handling certain text data properties, such as high-dimensional feature space, redundancy and sparse document vectors (Joachims, 2001; Sun et al., 2009; Giles & Councill, 2004). The SVM used in this analysis uses a string kernel function (Lodhi et al., 2002). Latent Dirichlet allocation (LDA) is employed to identify topics in the corpora of dissertation abstracts (Blei et al., 2003; Wei & Croft, 2006; Yau et al., 2014). LDA is a very flexible topic modelling approach that has been applied, among other areas, in innovation research for bibliometric patent analysis (Choi et al., 2018; Korobkin et al., 2017; Suominen et al., 2017) and in the realm of knowledge transfer for the correlation of topics on the websites of universities and local firms in Denmark (Woltmann et al., 2016).

2.3 University Selection and Data Availability

The data for our analyses were acquired from the German National Library (DNB) and several university homepages listing or linking to dissertations. In Germany, PhD candidates are obliged to publish their thesis and hand in a copy to the DNB. Therefore, the DNB has a comprehensive collection of every dissertation thesis successfully completed at a German university since 1969. The database for the DNB titles (not only dissertations) is available under a Creative Commons Zero license and contains metadata such as the author name, the thesis title, the university, the thesis supervisors and a link to the full digital text (if available). Often, these full texts are not hosted by the DNB itself but by the universities that are hyperlinked in the DNB database. The university websites usually contain richer data for each thesis, e.g., an abstract or a more detailed account of the institute/department where the thesis was written.

For this study, four universities were chosen to provide a representative picture of the different research foci in Germany and to account for possible idiosyncrasies in eastern and western parts of Germany, which may have arisen from the country's separation until 1990. Based on these considerations, we focus on the University of Aachen, the Technical University of Dresden, the University of Jena and the University of Göttingen. Dresden and Aachen both host technology schools and are the largest of their kind in East Germany and West Germany, respectively. The Universities of Jena and Göttingen are considered general universities and therefore do not focus on science, engineering, technology or mathematics (STEM) disciplines, but they do have strong departments in the social sciences and humanities.

Table 2.1 Published PhD theses in the German National Library and on university websites

University	DNB	Full texts online (tot.)	Full texts on websites (tot.)	Full texts on websites (%)
TU Dresden	7799	2330	2163	27.73
Göttingen	6507	4639	4041	62.1
RWTH Aachen	6150	3870	3326	54.08
Jena	6167	1862	2197	35.63

The economic environs, which are important for collaboration opportunities, in Jena and Göttingen are similar. In the case of the cities of Aachen and Dresden, the former has a larger economic capacity, but the latter is one of East Germany's largest economic centres and therefore seems the best choice to ensure representation along the East/West dimension.

Another criterion for the selection of universities was data availability. The universities chosen were among those that provided the highest amount of data online (Table 2.1). Because the number of full-text dissertations available has risen considerably since 2008, our research focuses on dissertations accepted between 2008 and 2016. The first column of Table 2.1 shows the result of the thesis search for each university in the DNB catalogue, and the results are representative of all doctoral degrees awarded in that time frame. Dresden accepted a slightly higher number of dissertations in the period, but there are not many other differences between the universities otherwise.

In contrast, the number of full texts available online varies significantly, mostly along East/West lines. The information in the DNB database shows that 67% of all dissertations from Göttingen and Aachen are available online in full (column 2 of Table 2.1), while the East German universities have made only approximately 30% of theirs available online. The last column shows the number of full texts available on the university websites themselves. The reason for the differences is that there are a number of broken hyperlinks and some theses are behind a paywall if they were only published through a commercial publisher. The metadata on the university repositories usually contain information on the thesis title, author, language, institution, full text, acceptance date, keywords, document type, supervisor, and abstract in German and (rarely) English for every thesis.

2.4 Classification and Sample for Topic Modelling

For our analysis, it is essential to identify the dissertations based on a collaboration between universities and industry partners. This is no small challenge because "cooperative" dissertations are very common (in Germany and many other countries), but they are rarely described as such in any meta-data (though there are efforts to indicate this information in official reports to the German government), and a definition of what constitutes a "cooperative dissertation" is lacking. To overcome these two challenges, we exploit the fact that virtually all of the full texts contain elaborate acknowledgments in which the authors thank the parties involved in the dissertation process (Paul-Hus et al., 2017; Giles & Councill, 2004). One advantage of this approach is the that it identifies self-reported perceptions of the collaborative nature of the research process, whereas a disadvantage is the lack of ability to consider resource effects on the supervisor or research group level that might affect the probability of and motivations for cooperation. A vital issue is the scaling of classification (Giles & Councill, 2004), which is a mostly qualitative task when assessing acknowledgments. We employed a combination of semisupervised machine learning and (quasi-) manual dictionary-based classification as described below.

As for the question of what constitutes a collaboration with an industry partner, informal talks revealed a continuum of collaborative elements in dissertation projects that differ along multiple dimensions, such as financial involvement or the mutual exchange of knowledge. Additionally, there are huge differences in the ex-ante probability of industry collaboration across disciplines. We employ a rather conservative criterion and classify dissertations as "collaborative" only if their acknowledgments a) hint at cooperation with a for-profit entity and b) signal mutual knowledge exchange in the generation of the obtained results. Joint projects with publicly financed research organizations, government bodies or charitable foundations are not considered collaborative for the purpose of this study. Furthermore, interactions between firms and universities were not taken into account if they related to unidirectional contributions, such as free donations of sample material (which is common, for example, in material and life sciences) or permission for the free use of a specific piece of firm equipment. If PhD candidates thanked specific firm-employed research partners individually, indicated "fruitful discussions", etc., the work underlying the thesis was thought to be at least partly based on mutual knowledge exchange and therefore included in the selection.[1]

The classification itself was conducted in two steps. In order to find a scalable solution for the classification of large numbers of acknowledgments, a combination of support vector machines (SVMs) and random forest classification (RFC) was used. SVMs are supervised machine learning models that are suitable for classifying high quantities of textual data, as they are adept at handling certain text data properties, such as high-dimensional feature space, redundancy and sparse document vectors (Joachims, 2001). The SVM used in this analysis uses a string kernel

[1]We are aware that our second restriction leaves room for discussion and leads to a somewhat blurred understanding of "collaboration". However, constructing the training sample for the classification algorithm and subsequently doing a fair amount of manual classification convinced us that donating sample materials or allowing the use of equipment did not necessarily involve an element of knowledge exchange. Firms also engage in these "giveaways" for strategic reasons, for example to expand the diffusion of specific materials/equipment among the scientific community. Notwithstanding the fact that firms may benefit from this kind of activities to some extent, we believe it is not justified to label these actions as "collaboration".

Table 2.2 Number of dissertations retrieved

	No. of dissertations	After dictionary-based classification	Collaborative	Collaborative (% of all dissertations)
Aachen	3326	1316	141	4.23
Dresden	2163	991	107	4.95
Göttingen	4041	1462	11	0.27
Jena	2197	815	36	1.64
Total no. of dissertations	11,727	4584	295	2.52

function. In an attempt to overcome the limitations of the bag-of-word assumption inherent in all machine learning models, we trained the SVM on a corpus of bigrams. The SVM and RFC were trained on a random sample of 1200 manually classified acknowledgments. K-fold cross validation yielded a model precision of 0.97, a recall of 0.66, a specificity of 0.84 and an F-Score of 0.78. Therefore, the approach was not suitable for fully automatized acknowledgment classification.

The precision value, however, indicated the usefulness of the combination of SVM and RFC as a filter: noncollaborative dissertations were detected with high certainty. Conversely, there were only a few acknowledgments that indicated a collaborative dissertation project that were mistakenly classified as noncollaborative (false negatives). As a result, the part of the sample that had to be classified manually was dramatically reduced. The manual classification for both the training sample of the model and the "residual" cases afterwards were carried out using a dictionary-based text analysis with common abbreviations of international incorporation statuses (such as "Ltd." or "GmbH") and a list of names of large companies (e.g., "Siemens" is often used without indication of the company's legal status). The resulting positives were grouped by two individual coders into collaborative and noncollaborative.

In the first step, the complete set of online available dissertations was classified with the machine learning process specified above. The total number of dissertations available online was 11,725, which accounted for an average of 44.04% percent of the whole DNB population for the sampled universities. After using the dictionary approach with the available full texts, we found 4584 acknowledgments that referenced a firm (Table 2.2). However, after applying the machine learning ensemble as a filter and manually classifying the results by the criterion of "mutual knowledge exchange", only 295 (2.5%) were identified as "collaborative" according to our definition.

Although the differences in coverage with regard to the online availability of dissertations were mainly between East and West Germany (Table 2.1), the varying engagement in a collaborative thesis projects seem to originate in the diverging research foci of the chosen universities. At the University of Dresden, 107 dissertations (5.0% of theses available online) were classified as collaborative, and at the University of Aachen, this number was 141 (4.2%). In Jena and Göttingen, there were only 36 (1.6%) and 11 (0.3%) collaborative dissertations, respectively.

Therefore, the technical universities in the sample accounted for 84% of all collaborative dissertations (which is not surprising because the other two universities do not have an engineering department, where collaboration with industry partners is most frequent).

The authors of the 295 theses classified as "collaborative" were supervised by 233 individual professors. There is a positive relationship between the number of supervised theses per professor and the number of collaborative theses supervised, with a highly significant Pearson's correlation coefficient $r = 0.55$ (the greater the number of theses supervised in general, the higher the likelihood of engaging in collaboration (or the inverse). For the regression analysis (see Sect. 2.5), we determined the (cosine) distance between text corpora according to collaboration status. Accordingly, professors were included if they had supervised at least two collaborative dissertations (otherwise, a cosine distance for the group "collaborative" cannot be computed). This reduced our sample to 1572 observations (theses) supervised by 47 individual professors who had supervised at least two collaborative theses (134 collaborative theses in total).

2.5 Topic Modelling and Regression Analyses

The method used for topic detection in the corpora of abstracts was latent Dirichlet allocation (LDA), which was proposed by Blei et al. (2003). LDA is based on the assumption that texts are generated in a three-level structure constituted by words, topics and documents. In this document-generation process, documents are characterized by their topic distribution, and words are sampled from a topic-specific word distribution. Because the number of topics is assumed to be determined ex ante, LDA is an unsupervised learning technique that enables topic detection and comparisons within text corpora. Since the results of LDA are highly sensitive to the number of topics (Cao et al., 2009), correlated topic models (CTMs) have been proposed as a refinement of the LDA process. The models select an optimal number of topics based on topic correlation. Other procedures to deduce a computational optimum in topic numbers, such as those proposed by Arun et al. (2010) and Griffiths and Steyvers (2004), were also applied to check for the robustness of our results.

In our data, all abstracts of the dissertation theses supervised by a specific professor were assumed to constitute one corpus each. Within each corpus exists a discrete number of topics that are being researched, all of which can be detected via LDA. The number of topics is determined with the three methods mentioned above ("Cao", "Arun" and "Griffith" in the following). After calculating the topic distributions for each professor, the topic distribution of each dissertation thesis (abstract) was compared to the topic distributions of all other documents in the corpus. As a measure of similarity, cosine distance was used (Yan et al., 2012; Cao et al., 2009). Figure 2.1 shows an example of how the topics are distributed across different PhD theses. The bars for each topic depict the share of words in the document that are

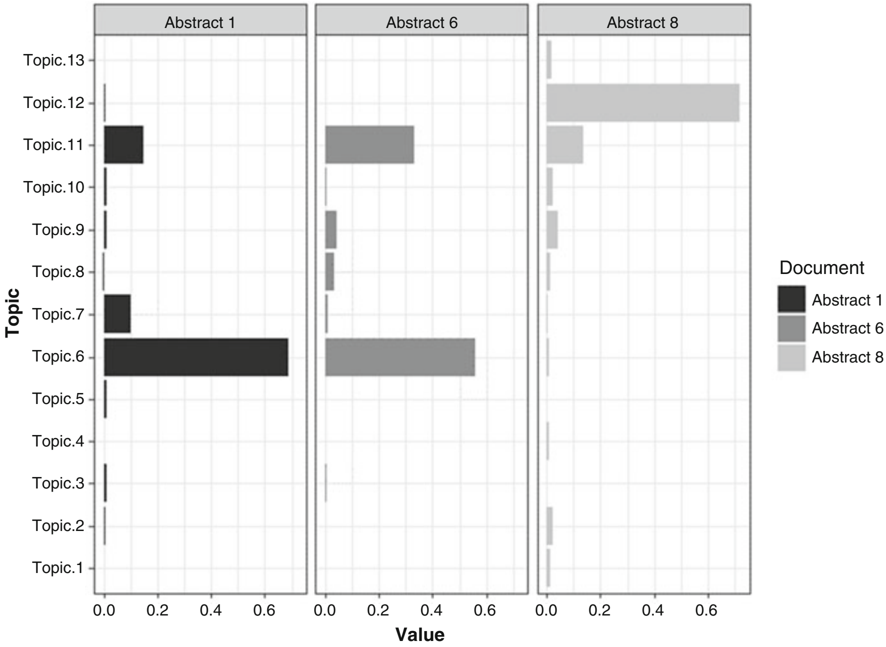

Fig. 2.1 Sample result of topic modelling

assigned to one of the 13 topics in the corpus (the research topics of the professor). As can be seen, the topic distributions of documents 1 and 6 in this figure are more similar to each other than they are to document 8.

In the final step of our analysis, we used the (dis)similarity of topic proportions between collaborative PhD theses and noncollaborative PhD theses that have been supervised by the same professor (Dist_to_non_collaborative) as the dependent variable. The aim was to measure how much the topics of a PhD thesis deviate from what can be assumed to be the research interest of the professor, e.g., the academic research she supervises without any incentives that might be offered by industry collaboration, based on the collected data. In turn, Dist_to_collaborative describes the average (dis)similarity of the topic distribution of a thesis to all collaborative theses supervised by a specific professor. To this end, the mean cosine distance to all other dissertations with the same and opposing collaboration status (associated with the same professor) is calculated for each thesis. The variable Collaborative is built according to the process described in Sect. 2.4 of this paper. To control for cases in the field of engineering, we used the Dewey Decimal Classification (DDC) that was stated for each thesis. Summary statistics of the variables can be found in Table 2.3. This method was only possible where there were at least two observations of each group in a corpus, thus considerably reducing our sample (see last paragraph of Sect. 2.4).

Table 2.3 Descriptive statistics for sample/variables used in OLS regression

Variable	Description	N	Mean (Std. Dev.)	Min	Max
Dist_to_non_collaborative	Dependent variable, continuous, topical distance to all non-collaborative theses (same supervisor)	1572	0.77 (0.12)	0.23	0.98
Dist_to_collaborative	Continuous, individual topical distance to all collaborative theses (same supervisor)	1572	0.78 (0.16)	0.03	0.99
Collaborative	Binary, thesis written in collaboration with industry partner, according to classification	1572	0.09 (0.28)	0	1
Engineer	Binary, bibliographic classification for thesis according to Dewey Decimal Classification (DDC)	1531	0.36 (0.48)	0	1

47 supervisors with at least two collaborative theses, total theses supervised by these professors: 134 collaborative (8.5%); 1438 non-collaborative (91.5%)

A simple t-test already revealed that the difference between the two groups (average distance to theses with the same collaboration status and average distance to theses with the opposing collaboration status) was significantly different from 0 if the topic numbers were determined using the "Griffith" or "Arun" algorithms.[2]

In Table 2.4, we show regressions for the mean cosine distance of a thesis's topics to the topics of noncollaborative theses (dependent variable) on collaboration status, calculate the distance to the topics of the collaborative group (Models 1a, 2a and 3a) and control for engineering dissertations (Models 1b, 2b and 3b). If collaboration prompted professors to engage in more dissimilar topics (which might result in an agenda-setting effect in the long run), we would expect collaboration status ("Collaborative") to exhibit a positive effect on the distance to noncollaboration theses (akin to a fixed effect). Additionally, Dist_to_collaborative was used as a control variable for the overall topical coherence of the collaborative and noncollaborative theses with each PhD supervisor. A negative coefficient for the topical distance to the collaborative group would signify a greater coherence of both groups. This would allow for the interpretation that a larger topical distance to collaborative dissertation theses goes along with being situated in a topical cluster with noncollaborative theses. "Engineering" should at least partially capture a presumably higher relevance for the application of theses in this field, which should result in

[2]For topic distributions following "Cao" the results did not significantly differ from 0. As the three procedures were based on different methods to determine the optimal topic number, the "Cao" procedure seems to systematically estimate a lower number. The mean number of topics according to the "Cao" procedure was 5.5 in our setting, whereas the "Griffith" and "Arun" procedures presented an average of 14.3 and 14.1 topics, respectively.

Table 2.4 OLS regression for cosine distance to non-collaborative dissertation topics

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Intercept	0.353***	0.347***	0.411***	0.404***	0.401***	0.393***
	(0.013)	(0.014)	(0.022)	(0.022)	(0.021)	(0.021)
Collaborative	0.006	0.004	0.017	0.008	0.012	0.006
	(0.016)	(0.015)	(0.009)	(0.008)	(0.008)	(0.008)
Dist_to_collaborative	0.444***	0.454***	0.459***	0.459***	0.475***	0.476***
	(0.018)	(0.019)	(0.027)	(0.027)	(0.025)	(0.026)
Engineer		0.006		0.02***		0.018***
		(0.009)		(0.005)		(0.005)
N	1572	1531	1572	1531	1572	1531
R_sq	0.336	0.348	0.368	0.38	0.389	0.399

S. E. clustered according to supervisor/professor). Standard errors in parentheses. *** denotes p-value < 0.001, ** denotes p-value < 0.01, * denotes p-value < 0.05

higher topical coherence between collaborative and noncollaborative work in this field than in other fields.

Estimation was carried out using OLS with standard errors clustered according to supervisor/professor.[3] No models revealed a "fixed" effect for the status of being collaborative (according to our classification from Sect. 2.4). A positive and significant coefficient estimate for the distance to the collaborative dissertations hints at the fact that "unusual" or "dissimilar" topics for a given professor tend to be "distant" from other topics/theses regardless of whether they are based on collaboration or not. The positive coefficient of this control variable as well as the relatively low incidence of truly "collaborative" dissertation projects (0.3% to 5.0%; see a description of the sample in Sect. 2.4) point towards the conclusion that differences in topical distances between the two groups are driven mainly by the broad and diversified research interests of the supervisor rather than any agenda-setting effect of engagement in collaboration. Professors active in basic science obviously supervise "industrial" topics that either fit into their academic interests (no "fixed" effect of collaboration) or are exotic in general (distance to the "noncollaborative" topic cluster grows with increasing distance to the "collaborative" topic cluster).

2.6 Conclusions

This study aims to contribute to the discussion of possible agenda-setting effects in research topics due to collaborations between universities and industry partners. For this purpose, the topic distribution of collaborative and noncollaborative dissertation projects of individual supervisors (professors) was compared. The study used a

[3] In an unreported variant, we employed a university fixed-effect model with no significant effect on the estimated coefficients.

novel classification approach relying on supervised machine learning models to identify collaboration through acknowledgment texts. Topic models for quantitative text analysis were employed to detect possible dissimilarities in dissertations with regard to collaboration status. The results indicate that the topics of collaborative and noncollaborative dissertation projects do not differ in "distance" from the estimated research interests of the supervisor. Corroborating previous evidence from Salimi et al. (2015) on quantitative aspects such as patents, publications and citations, we conclude that universities have no reason to shun collaborative dissertations. Furthermore, fears of the distortion of research agendas through increased interactions between universities and industry partners seem unwarranted. In line with Perkmann et al. (2013) and Tartari and Breschi (2012), we find that researchers select topics for industry collaboration based on their academic interests (and probably competences). At least on an individual basis, this study finds no evidence for a qualitative difference in research conducted together with industry partners when compared to topics that are pursued outside of such collaboration.

As with any research, this study is not without limitations. First, the data were not without flaws and may have been subject to selection effects based on what is available online in full-text form.[4] Some dissertations also do not contain acknowledgments, although such cases are relatively rare. Second, machine learning and topic modelling techniques constitute rather new scientific tools. Accordingly, a basic understanding of what these techniques can do, what their limitations are and how the results can be interpreted are still missing in some instances. For example, our approach to classification revealed that an SVM alone is not sufficient for complex sorting problems. Furthermore, our results may have been influenced by the initial choice of the optimal number of topics within corpora, as the employment of different algorithms revealed. Last, the limitation with the most far-reaching implications is probably the reliance on "within" comparisons. Contrasting the topics of collaborative projects with others from the same supervisor may not reveal the full picture of the potential distortion of research agendas because it only takes the reactive behaviour of individuals into account. Long-term effects through, for example, a positive selection of individuals with more applied agendas, cannot be detected. Last but not least, this study motivated divergence between collaborative and noncollaborative research from a somewhat negative viewpoint: an agenda-setting effect on research in academia. However, because such collaboration affects both parties, a shift in the research interest of an individual researcher may not be an inherently harmful outcome for academia. Hence, changes in research topics due to collaborative research can also be interpreted as having positive outcomes of university-industry interaction if they lead to a broadening of the research focus of senior researchers. Unfortunately, this aspect can hardly be measured with the cross-sectional approach used in this study.

[4] Initial fears of "collaborative" dissertations being treated differently may be soothed by talks at a practitioner conference that assure researchers that the German bureaucracy treats all dissertations equally.

Especially regarding the issue of using only a within comparison method, we plan to compare topics across different supervisors and dissertation theses in the future. This should also take into account possible differences across disciplines, which are currently only addressed by sampling full texts from a diverse set of universities. Based on data availability, it may also be feasible to extend the approach to other countries (e.g., the U.S. or Japan) to shed light on possible agenda distortion on a global level.

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References

Arun, R., Suresh, V., Veni Madhavan, C. E., & Narasimha Murthy, M. N. (2010). On finding the natural number of topics with latent Dirichlet allocation: Some observations. In M. J. Zaki, J. X. Yu, B. Ravindran, & V. Pudi (Eds.), *Advances in knowledge discovery and data mining* (pp. 391–402). Lecture Notes in Computer Science. Springer.

Azagra-Caro, J. M., & Consoli, D. (2016). Knowledge flows, the influence of national R&D structure and the moderating role of public–private cooperation. *The Journal of Technology Transfer, 41*(1), 152–172.

Banal-Estañol, A., Jofre-Bonet, M., & Lawson, C. (2015). The double-edged Sword of industry collaboration: Evidence from engineering academics in the UK. *Research Policy, 44*(6), 1160–1175.

Bikard, M., Vakili, K., & Teodoridis, F. (2018). When collaboration bridges institutions: The impact of university–industry collaboration on academic productivity. *Organization Science., 30*, 426.

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent Dirichlet allocation. *Journal of Machine Learning Research, 3*(Jan), 993–1022.

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

Cao, J., Xia, T., Li, J., Zhang, Y., & Tang, S. (2009). A density-based method for adaptive LDA model selection. *Neurocomputing, 72*(7–9), 1775–1781.

Choi, H., Oh, S., Choi, S., & Yoon, J. (2018). Innovation topic analysis of technology: The case of augmented reality patents. *IEEE Access, 6*, 16119–16137.

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

Espeland, W. N., & Sauder, M. (2007). Rankings and reactivity: How public measures recreate social worlds. *American Journal of Sociology, 113*(1), 1–40.

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

Fudickar, R., Hottenrott, H., & Lawson, C. (2018). What's the price of academic consulting? Effects of public and private sector consulting on academic research. *Industrial and Corporate Change, 27*(4), 699–722.

Giles, C. L., & Councill, I. G. (2004). Who gets acknowledged: Measuring scientific contributions through automatic acknowledgment indexing. *Proceedings of the National Academy of Sciences, 101*(51), 17599–17604.

Griffiths, T. L., & Steyvers, M. (2004). Finding scientific topics. *Proceedings of the National Academy of Sciences, 101*(suppl 1), 5228–5235.

Hottenrott, H., & Lawson, C. (2014). Research grants, sources of ideas and the effects on academic research. *Economics of Innovation and New Technology, 23*(2), 109–133.

Hottenrott, H., & Thorwarth, S. (2011). Industry funding of university research and scientific productivity. *Kyklos, 64*(4), 534–555.

Jensen, R., & Thursby, M. (2001). Proofs and prototypes for sale: The licensing of university inventions. *American Economic Review, 91*(1), 240–259.

Joachims, T. (2001). A statistical learning learning model of text classification for support vector machines. In *Proceedings of the 24th annual international ACM SIGIR conference on research and development in information retrieval* (pp. 128–136. SIGIR '01). ACM.

Korobkin, D., Fomenkov, S., Kravets, A., & Kolesnikov, S. (2017). Methods of statistical and semantic patent analysis. In A. Kravets, M. Shcherbakov, M. Kultsova, & P. Groumpos (Hrsg.), *Creativity in intelligent technologies and data science* (pp. 48–61). Springer International Publishing.

Laredo, P. (2007). Revisiting the third mission of universities: Toward a renewed categorization of university activities? *Higher Education Policy, 20*(4), 441–456.

Lee, S., & Bozeman, B. (2005). The impact of research collaboration on scientific productivity. *Social Studies of Science, 35*(5), 673–702.

Lee, Y. S. (2000). The sustainability of university-industry research collaboration: An empirical assessment. *The Journal of Technology Transfer, 25*(2), 111–133.

Lodhi, H., Saunders, C., Shawe-Taylor, J., Cristianini, N., & Watkins, C. (2002). Text classification using string kernels. *Journal of Machine Learning Research, 2*(Feb), 419–444.

Manjarrés-Henríquez, L., Gutiérrez-Gracia, A., Carrión-García, A., & Vega-Jurado, J. (2009). The effects of university–industry relationships and academic research on scientific performance: Synergy or substitution? *Research in Higher Education, 50*(8), 795.

Manjarrés-Henríquez, L., Gutiérrez-Gracia, A., & Vega-Jurado, J. (2008). Coexistence of university-industry relations and academic research: Barrier to or incentive for scientific productivity. *Scientometrics, 76*(3), 561–576.

Merton, R. K. (1968). The Matthew Effect in science: The reward and communication systems of science are considered. *Science, 159*(3810), 56–63.

Morichika, N., & Shibayama, S. (2016). Use of dissertation data in science policy research. *Scientometrics, 108*(1), 221–241.

Murray, F., & Stern, S. (2007). Do formal intellectual property rights hinder the free flow of scientific knowledge?: An empirical test of the anti-commons hypothesis. *Journal of Economic Behavior & Organization*, Academic Science and Entrepreneurship: Dual engines of growth*,* *63*(4), 648–687.

Ooms, W., Werker, C., & Hopp, C. (2018). Moving up the ladder: Heterogeneity influencing academic careers through research orientation, gender, and mentors. *Studies in Higher Education, 44*, 1–22.

Paul-Hus, A., Mongeon, P., Sainte-Marie, M., & Larivière, V. (2017). The sum of it all: Revealing collaboration patterns by combining authorship and acknowledgements. *Journal of Informetrics, 11*(1), 80–87.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., et al. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy, 42*(2), 423–442.

Perkmann, M., & Walsh, K. (2009). The two faces of collaboration: Impacts of university-industry relations on public research. *Industrial and Corporate Change, 18*(6), 1033–1065.

Salimi, N., Bekkers, R., & Frenken, K. (2015). Does working with industry come at a price? A study of doctoral candidates' performance in collaborative vs. non-collaborative Ph.D. projects. *Technovation, 41–42*(July), 51–61.

Shane, S. A. (2004). *Academic entrepreneurship: University spinoffs and wealth creation*. Edward Elgar Publishing.

Sun, A., Lim, E. P., & Liu, Y. (2009). On strategies for imbalanced text classification using SVM: A comparative study. *Decision Support Systems, 48*(1), 191–201.

Suominen, A., Toivanen, H., & Seppänen, M. (2017). Firms' knowledge profiles: Mapping patent data with unsupervised learning. *Technological Forecasting and Social Change, 115,* 131–142.

Tartari, V., & Breschi, S. (2012). Set them free: Scientists' evaluations of the benefits and costs of university–industry research collaboration. *Industrial and Corporate Change, 21*(5), 1117–1147.

Van Looy, Bart, M. R., Callaert, J., Debackere, K., & Zimmermann, E. (2004). Combining entrepreneurial and scientific performance in academia: Towards a compounded and reciprocal Matthew-effect? *Research Policy, 33*(3), 425–441.

Von Hayek, & August, F. (1989). The pretence of knowledge. *The American Economic Review, 79*(6), 3–7.

Wei, X., & Croft, W. B. (2006). LDA-based document models for Ad-Hoc retrieval. In *Proceedings of the 29th annual international ACM SIGIR conference on research and development in information retrieval* (pp. 178–185). ACM.

Woltmann, S., Clemmensen, L. H., & Alkærsig, L. (2016). From university research to innovation detecting knowledge transfer via text mining. In *21st international conference on science and technology indicators (STI 2016) science and technology indicators conference*.

Yan, E., Ding, Y., Milojević, S., & Sugimoto, C. R. (2012). Topics in dynamic research communities: An exploratory study for the field of information retrieval. *Journal of Informetrics, 6*(1), 140–153.

Yau, C.-K., Porter, A., Newman, N., & Suominen, A. (2014). Clustering scientific documents with topic modeling. *Scientometrics, 100*(3), 767–786.

Zucker, L. G., & Darby, M. R. (1996). Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences, 93*(23), 12709–12716.

Chapter 3
The Heterogeneous Impact of Academic Patent Characteristics on Firms' Economic Performance

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Abstract Many studies have proven the relevance of patent characteristics to predict firms' economic returns. The most studied ones concern the (technological, scientific or radically new) type of knowledge embedded into the patents; the technological impact on society, measured by the forward citations; the economic value attributed by the firms to the patents, measured by their renewal and, more recently, the closeness of the patent to the firm's technological profile. We build on this literature, focusing on a less studied topic, the characteristics associated to the academic patents held by firms and the profit stream generated by these assets. We empirically examine these research issues using longitudinal data from a cross-industry study of 712 units of observation over a recent 10-year period (1996–2007). The paper focuses on the units' idiosyncratic effects and the heterogeneous impact of the academic patents. We analyse the effect of academic patents characteristics with a one- and a three-year time lag structure, following the literature indication that academic patents can show a different impact at medium-long term. Contrary to previous findings, what matters for academic patents to improve firms' economic performance both at short and at long term is not their radicalness or explorative nature, but the stock of technical and scientific knowledge on which inventions are based, measured through the backward citations to patent and non-patent literature and the closeness to firm's core technologies, in which companies have good competences and invest more resources. These results open the way to more in-depth analyses.

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Keywords Academic inventors · Patent quality indicators · Technology trajectories · Firms' profitability

3.1 Introduction

Inventions based on academic research are crucial drivers of innovation. Policymakers often deem academic patents (patents in which at least one inventor is an academic, regardless of assignee) as a vital tool for technology transfer (Lissoni and Montobbio, 2015). The literature considers academic contributions as a way for firms to expand their capacity to engage in exploration, which is essential for their mid- to long-term innovation activities (Nelson & Winter, 1982; Dosi, 1988; March, 1991; Ahuja & Lampert, 2001; Lester & Piore, 2004).

Many scholars have recognized some fundamental differences of academic patents, compared with corporate patents, such as tighter linkages to the scientific literature and a higher degree of generality (much broader applications). This is the consequence of academic patents being a product of the "public" science, whose distinctive features suggest a significant contribution to technological progress and growth. By comparing patents with at least one academic inventor to a control group of pure business patents, researchers showed that academic patents are on average more important, resulting in greater knowledge externalities, as measured by forward citations (Henderson et al., 1998; Sampat et al., 2003; Bacchiocchi & Montobbio, 2009).

A relatively recent literature recognised the importance of distinguishing academic patents by their assignee and looked at the relationship between ownership structure and characteristics of academic inventions. Ljunberg and McKelvey (2012) wrote that university owned and firm owned academic patents differ in their nature (see also Geuna & Rossi, 2011). While the first one may largely result from scientific opportunities, the firm owned academic patents should probably not be considered the result of scientific opportunities transferred to firms, but a by-product of firms involving academics in their invention processes (Azagra-Caro, 2011). Other scholars (Bishop et al., 2011) sustained that while university-owned academic patents may result from a science-push contribution of university to industrial innovation, the firms' owned ones derive more probably from a demand-pull mechanism.

More rarely researchers have strictly focused on the firm side, by comparing for example the effect of patents with and without academic participation on firm performance: the adoption of the firm perspective and of the relative value of academic patents remains partially unanswered (Geuna & Rossi, 2011; Lissoni, 2012).

In this work, we focus on firms and on their owned academic patents by studying how the characteristics of these patents affect firms' economic performance. Academic patents owned by firms are particularly relevant because these industrial inventions are those that, by definition, may entail contrasting incentives and structures of both academics and firms (Ljungberg et al., 2013).

The issue with this kind of setting is that most of the previous literature have studied the impact of firms' patent portfolio on firms' performance without distinguishing between academic and the other type of patents and often analysing single characteristic individually, without offering a view of the relative impact of each aspect vis-à-vis all the main others.

Our aim is to enhance the existing literature on the relation between firms' patents and economic performance, looking at the less explored field of firm owned academic patents and to a large account of patent indicators of firm performance in their interaction, heterogeneity and dynamics. The paper focuses on the units' idiosyncratic effects and the heterogeneous impact of academic patents according to their characteristics.

The paper proceeds as follows: Section 3.2 sets out the theoretical background concerning the characteristics influencing academic patent performance. Section 3.3 presents the dataset and a description of the variables employed in the empirical part. Section 3.4 provides a short explanation of the responsiveness score approach. Section 3.5 illustrates the main results organised in two sub-paragraphs: (i) the effect of academic patents on firms' profitability, (ii) a short and long term breakdown of the analysis. Section 3.6 provides a brief discussion and conclusion.

3.2 Theoretical Background of the Factors Influencing the Impact of Academic Patents

In economic terms, patents have generally been regarded as a useful instrument to grant inventors temporary exclusionary rights. However, the potential economic significance of patented products varies remarkably (Artz et al., 2010; Bogner & Bansal, 2007; Encaoua et al., 2006), with only a relatively small number of patents being of such impact to generate significant economic returns (Schankerman and Pakes, 1986). There is also considerable evidence that, in many contexts, patents do not work and there are numerous explanations given for patent ineffectiveness in improving firm performance such as, for example, firms' defensive or strategic use. The inability of patent counts to distinguish between high-impact and low-impact patents is also well documented (Hall et al., 2001; Trajtenberg, 1990).

In the literature, there is a large number of contributions to the definition and measurement of patent technological and economic value. These indicators mirror different – although interrelated – aspects, sometimes having a mainly technological (backward citations) or preponderantly economic connotation (patent renewals), or both (forward citations, generality). Furtherly, depending on the indicator considered, the meaning of patent impact might be closer to that of private value or of social value (OECD, 2013).

Many studies have proven the relevance of studying patent characteristics. Deng et al. (1999) and Thomas et al. (2001) used patent characteristics to predict stock returns and market-to book ratios; Cheng et al. (2010) to predict return on assets (ROA). Various indicators were considered to evaluate patents' advantage and their impact through the exploitation of different databases (e.g. CHI Research, Inc.).

We selected patent characteristics based on the relevance they raised in the literature. The list of patent characteristics and the associated indicators is the following:

- New to the firm knowledge content (measured by patent radicalness);
- Economic value attributed by the firm (measured by patent renewal);
- Technological impact (measured by forward citations);
- Technological knowledge content (measured by backward citations to patent literature);
- Scientific knowledge content (measured by backward citations to non-patent literature);
- Exploitative versus explorative character of the academic patent relative to the firm's technological profile (measured by technological closeness)

In this study, we used the OECD dataset (OECD, 2013) including several measures of academic patents, with the exception of the exploitative/explorative character of the academic patent. This last characteristic was not included in the OECD dataset, however we calculated it in order to account for some interesting theoretical insights raised by a recent literature (Belderbos et al., 2010; Ljungberg et al., 2013; Peeters et al., 2018).

In the following, we report some literature whose goal is to assess the effect of different patent characteristics on firm economic success.

3.2.1 Characteristics of Academic Patents Affecting Firms' Profits

How does a new knowledge content of patents impact on firm' performance? Interest in radical innovation originated with Schumpeter (1934), one of the first to claim that radical technological change is a powerful mechanism that can challenge the power of monopolists and bring to relevant economic results. Many empirical studies have tested Schumpeter's ideas (Anderson & Tushma, 1990; Henderson, 1993; Cooper & Schendel, 1976; Tripsas, 1997). Compared with incremental inventions, radical inventions imply the start of a new trajectory for the firm, which involves costs of adjustment. More generally, radical inventions can underperform vis-à-vis an established technology, before it catches up and surpasses the old technology (Christensen & Rosenbloom, 1995). The literature tells us that the impact of patent radicalness can be positive, but does not have a strong effect in a short time.

As to the economic value attributed by firms to patents, many industrialized countries charge patent holders' periodic maintenance with renewal fees. This phenomenon has been exploited by scholars to estimate the patent economic value, measured by the length of patent protection (Pakes & Schankerman, 1984; Schankerman and Pakes, 1986; Pakes, 1986; Lanjouw et al., 1998). Harhoff et al. (1998) found a highly rightward-skewed distribution of patent protection values. Exploring the distribution properties of the tail is important, because with skewed distributions, outlying tail values account for a large fraction of the cumulative value over all observations. The literature tells us that the closer the patents' renewal is to the full term, the higher is the firms' expectation of economic returns. However, the relation with the economic returns has a high volatility, meaning that other factors can influence it.

As to technological impact, much of the research on forward citations has the scope to validate them as an appropriate measure. Highly cited patents have been associated to measures of technological importance, such as inventor awards and high-value inventions. Other studies have revealed a positive relationship between forward citations and various measures of economic and commercial success, including stock market valuations (Breitzman & Narin, 2001), stock price movements (Narin et al., 2004) and increased sales and profits (Narin et al., 1987). It has been shown that high-quality, high-impact and valuable patents tend to be cited more frequently by later patents (Breitzman & Mogee, 2002). Many scholars, studying the relationship between patent and corporation performances, have confirmed the positive relation between patent citations and market value in industries, such as manufacturing, pharmaceutical as well as semiconductor industries (Chen & Chang, 2010; Griliches, 1990; Hall et al., 2000, 2005; Lanjouw & Schankerman, 2004). Therefore, we can safely draw the conclusion that high patent citations reflect high knowledge spillovers and (social and private) economic value.

The technological knowledge base is measured by backward citations to the patent literature (PL). In order to evaluate the novelty of the innovation requiring patent protection, patent applicants are asked to disclose the prior knowledge they have relied on. During technical examination, the patent examiner checks such references. Backward citations have been found to be positively related to the economic value of an invention (Harhoff et al., 2003). Large numbers of backward citations may signal the innovation to be more incremental in nature (Lanjouw & Schankerman, 2001). However, Podolny and Stuart (1995) argue that building upon pre-existing innovation can indicate a way to success.

Patent applications can include a list of references to earlier non-patent literature (NPL), scientific papers that set the boundaries of patents' claims for novelty, inventive activity, and industrial applicability. Non-patent literature consists of peer-reviewed scientific papers, conference proceedings, databases and other relevant literature. Backward citations to NPL can be considered an indicator of the contribution of public science to industrial technology (Narin et al., 1997). They may reflect how close a patented invention is to scientific knowledge and help depict the proximity of technological and scientific developments (Callaert et al., 2006). Cassiman et al. (2008) suggest that patents that cite scientific works may contain more complex and fundamental knowledge, and this in turn may influence the "generality" of patents (a large range of applications), which could bring to a high economic return. We conclude that references to NPL can be an indicator associated to positive economic return to firms.

A new approach links academic patents' technology content and firms' technological profile and look at the specific patent performance. Ljungberg and McKelvey (2012) and Ljungberg et al. (2013) in their important contribution studied the relation between patents' technological content and their technological impact measured by forward citations, by comparing firm-owned patents with and without academic involvement. Before controlling for the technological profile, results showed that academic patents have a significant negative effect on both short-term and long-term citations. However, when these scholars controlled whether firm's core technologies are involved in patenting, the negative effect of "academic inventor" is weakly statistically significant in the short-term and disappears in the long-term. In sum, their results showed that academic involvement per se is not adequate in order to evaluate the patent impact, which has to be assessed under the consideration of the specific technological profile the patent belongs to and the time lag.

Peeters et al. (2018) regard patent's novelty in the firms' technology base as essential to assess knowledge-creation dynamics. They studied the contribution of academics to corporate technology development through self-forward citations. Following Belderbos et al. (2010), Peeters et al. (2018) distinguished between trajectories of an exploitative and an exploratory nature, i.e. academic patents in technologies that are "novel to firms" from those related to firm's existing technological domains. The firm can make a different use of the academic patent, either if it is familiar with the patent's underlying technology (*exploitation*) or not (*exploration*). The main result of Peeters et al. (2018) is that forward self-citations are higher in exploratory trajectories when academic inventors are involved or in exploitative trajectories without academic involvement. These scholars stress that involving academics in exploitative trajectories seems to have a detrimental effect on firm inventive performance. The presence of dead-end outcomes, measured by zero self-forward citations, might represent the explanation of this result.

By and large, we can conclude that the indicator of the technological content of the academic patent in relation to the firm technological profile is relevant to study firm economic performance. Following the literature, we can expect a negative effect on firm economic return if the academic patent has a technological content similar to those of the firm, stronger at short- than at long-term. However, if we could control for the association of the technological academic patent profile with some indicators of firm "core" technology, the effect is expected to become positive.

3.2.2 The Impact of Academic Patents' Characteristics on Short and Long Term

Some literature has found relevant to distinguish the effect of academic patents in short and long term. Two recent studies have found that firm-owned academic patents are associated with short-term technological impact while university-owned patents are associated with long-term technological impact (Czarnitzki et al., 2012; Sterzi, 2013). Ljungberg and McKelvey (2012) and Ljungberg et al. (2013) in their analysis of patent impact explicitly address the differentiation of short-term and long-term value. They assumed that there might be an interaction between the technological profile of a patent and its short-term and long-term impact. In particular, the scholars found that in case of an academic patent content close to the technology knowledge of the firm holding them there is a significant decrease of the negative effect on the long-term citations. We will check the different time effect for each specific characteristics of the academic patents.

3.3 Data and Variables

Our dataset consists of a panel of Italian firms that owned at least one academic patent, as well as non-academic patents, covering the period from 1996 to 2007. Patents co-owned by a firm and a public institution were excluded. Two large micro-level databases form the basis of this analysis. The first database is the EPO Worldwide Patent Statistics Database (PATSTAT), which contains detailed information on firm patent applications from more than 80 patent offices. The second one is the firm-level commercial database ORBIS developed by Bureau van Dijk. Our sources are a revised version of Lotti and Marin (2013) matching PATSTAT and Bureau van Dijk, and the list of academic patents produced by the Academic Patenting in Europe (APE-INV) project, linked together through patent publication codes.[1] Budget data are cross-referenced with the patent's priority date, identifying the invention. Our unit of analysis was the firm/patent pair. After eliminating data on patents whose academic nature was unknown, we had a sample of 31,180 units for analysis, of which 29,748 referred to non-academic patents and 1432 to academic ones. The panel include firms of large, medium and small size as well as manufacturing and service sectors.

We considered six patent characteristics (then used to construct responsiveness scores). The dataset refers to EPO patent applications data. Data are generally presented in the form of normalized indexes ranging between zero and one. These

[1] These two good-quality datasets (i.e. Lotti & Marin, 2013 and APE-INV) provide a unique tool to investigate the research questions at hand on a European country. Furthermore, given that the two datasets have already been largely employed (separately) in academic research, they are scientifically validated, thus providing reliability to our results.

are obtained by dividing the initial results by the maximum score obtained by any patent in the same year and technology field cohort patent, without distinguishing between academic and non-academic ones.

- *Radicalness.* Radicalness of a patent is measured as a time invariant count of the number of IPC technology classes in which the patents cited by the given patent are, but in which the patent itself is not classified. The more a patent cites previous patents in classes other than the ones it is in, the more the invention should be considered radical.
- *Renewal.* Patent renewals 'rates can be used to estimate the economic value that firms attribute to patents protection. The OECD patent renewal indicator corresponds to the simple count of years during which a granted patent has been kept alive. Years are counted starting from the year in which a patent has been applied
- *Forward citations* are the number of citations received by patent application from its publication. Forward citations are counted over a period of five or seven years after the publication date (OECD, 2013). Their number includes self-citations. We used the number of forward citations per patent over a period of seven years.
- *Backward citations to PL* are the number of citations per patent made by patent applicants to disclose the prior knowledge on which they have relied. References to non-patent literature have been excluded from the count, whereas self-citations have not. The distribution of backward citations has a very long right tail. 5%-10% of patents do not rely on any prior art, i.e. features zero backward citations and only a very small percentage of patent documents contain more than ten backward citations.
- *Backward citations to NPL* are the number of citations per patent made by patent applicants to non-patent literature on which they have relied. The majority of patents generally do not cite any non-patent literature as prior art, the distribution of NPL citations is skewed and it features a very long right tail.
- *Technological closeness.* We measured it as the number of 4-digit IPCs in the academic patent that already existed within the firm's patent portfolio before the academic patent's priority date. This indicator ranges between zero (maximum technological distance) and one (no technological distance). Maximum distance means that the firm's portfolio had no IPCs that matched any IPCs in the academic patent before the academic patent's priority date. For instance, if only one of the academic patent's IPC categories is present in the four IPC categories of the firm's existing patent portfolio, the share is 1/4 = 0.25. The closer to one is the share the lower is the distance or differentiation of the technological contribution provided by academic inventors. We excluded so-called first patents, which have not history. There were 4750 first patents, or around 15% of all patents and 155 first academic patents, representing around 11% of all academic patents. After these eliminations, our sample contained 26,000 units of analysis, including 1277 academic ones, once considering all the variables (outcome, treatment, and control variables).

The economic outcome variable (our dependent variable) is represented by the *operating profit margin* before taxation (OPM), i.e. the ratio between net income and production revenues.

For estimation, we also consider a series of control variables, distinguished between firm- and patent-level covariates. Firm-level controls include: the *number of employees*, to control for firm size; *labour intensity*; the ratio between labour costs and production value; *labour cost per employee*; *R&D intensity*, the ratio between R&D expenditures and production value; *capital stock*, the ratio between the firm's material assets and production value; *indebtedness*, the ratio between long-term debt and total assets; *age*, number of years since the firm's founding.

As for patent-level controls, we used the *patent portfolio quality*, a composite indicator published by the OECD (2013). This indicator captures both the technological and economic value of inventions and is based on patent citations, claims, patent renewals, and patent family size. It correlates with the social and private value of patented inventions.

3.4 The Responsiveness Scores Model

The responsiveness scores (RS) model is a regression model where the parameters are random variables instead of fixed numbers. In our study, the model takes the following form (Cerulli, 2017):

$$y_{it+1} = a_{ijt} + b_{ijt}x_{ijt} + \phi(\mathbf{z}_{it}) + e_{it} \tag{3.1}$$

The dependent variable y represents the OPM one year after the academic patent's priority year. Both a and b are random coefficients, with b_{ij} representing the responsiveness of firm i's outcome to academic patent characteristic x_j. The vector z represents the set of control variables. As indicated, we considered six academic patent characteristics x_j, and calculated how the firm's economic performance responded to each characteristic. Note that both the regression parameters a and b are both non-constant as they depend on every characteristic except the one being analysed separately (x_j in the previous equation).

Responsiveness scores measure the change in a given outcome y when a given factor x_j changes, conditional on all other factors $\mathbf{x}_{-j}$. Algebraically, it is the derivative of y on x_j, given $\mathbf{x}_{-j}$, allowing each observation to receive its own RS. Responsiveness scores are obtained via an iterated random coefficient regression developed in Cerulli (2017), whose basic econometrics build on Wooldridge (2002). The calculation of responsiveness scores follows this simple protocol:

- Define y, the outcome (or response) variable.
- Define a set of factors Q believed to affect y, and specify the generic factor as x_j.

- Define a random coefficient regression (RCR) model linking y to the various genetic factors x_j, and extract the unit-specific responsiveness effect of y on the set of factors x_j, with $j = 1, ..., Q$.
- For the generic unit i and factor j, indicate their effect as b_{ij} and assemble all of the effects in a matrix **B.**
- Finally, aggregate the b_{ij} by unit (row) and/or by factor (column), generating synthetic unit and factor responsiveness measures.

Analytically, an RS is the partial effect of a factor, x, in a random coefficient regression (Wooldridge, 1997, 2002, 2005) defined by the following system of equations:

$$\begin{cases} y_i = a_{ij} + b_{ij}x_{ij} + e_i \\ a_{ij} = \gamma_0 + \mathbf{x}_{i,-j}\boldsymbol{\gamma} + u_{ij} \\ b_{ij} = \delta_0 + \mathbf{x}_{i,-j}\boldsymbol{\delta} + v_{ij} \end{cases} \tag{3.2}$$

where e_i, u_{ij} and v_{ij} are freely correlated error terms.

3.5 Results

3.5.1 *Academic Patents Characteristics: A Descriptive Analysis*

Table 3.1 sets out the descriptive statistics of academic patents' characteristics herein considered.[2]

The mean of the *Technological closeness* index was 0.84, which is close to one, the value corresponding to pure exploitation. However, half of the observations have values between zero and one, as the median is 1. This result is similar to that of

Table 3.1 Descriptive statistics on each single-patent indicator (n = 712)

	Mean	Median	Std. Dev.	Minimum	Maximum
Radicalness	0.292	0.242	0.264	0	1
Renewal	9.697	10.000	4.586	1	20
Forward Citations (7)	1.029	0.000	2.418	0	36
Backward citations to PL	4.177	3.000	5.888	1	139
Backward citations to NPL	2.160	0.000	9.463	0	229
Technological closeness	0.844	1.000	0.325	0	1

[2]The descriptive statistics of our sample are extremely close to the statistics of the entire academic patent population. Therefore, the representativeness of our sample, notwithstanding the presence of missing values, is not biased.

Ljungberg and McKelvey (2012) who found out that academic involvement mainly takes place in inventions highly related to firms' technology bases. The scholars suggested that firms involve academics mainly for the current problem-solving activities. Similar result is in Peeters et al. (2018): exploitative trajectories still constitute the lion's share of technology developments in which academics play a role.

Radicalness refers to how much new an invention is in relation to the firm's previous patented output. In our sample, radicalness has a low mean, which indicates that a large percentage of academic patents cites zero or a low number of previous technologically different inventions.

The *Renewal* index shows that, on average, firms renewed their academic patent rights for a period around half the typical life of a patent, which varies between 1 and 20 years.

The number of *Forward citations* received by academic patents over a period of 7 years had a large probability spike at zero and varied between 0 and 36, with a low mean of 1.02 citations.

As for *backward citations to PL*, the average patent featured four backward citations, with a highly skewed distribution, a long right tail, a median of three citations and a high variation rate. Our results for academic patent held by firms are close to those of OECD for EPO patents in general: average values are around 0.3 and 75th percentile values are around 0.4 (OECD, 2013).

The indicator of linkage to science*, Backward citations to NPL,* shows an average patent featuring two backward citations to non-patent literature, with a very high variation rate.

Finally, we calculated the correlation among our patent indicators within the estimation sample. Except for the correlation between *Backward citations to NPL* and *Backward citations to PL*, which is significant and around 82%, all the other indicators are poorly correlated. This means that it makes sense to consider them as separate treatments in our estimation model.

3.5.2 Estimation and Analysis of Responsiveness Scores

3.5.2.1 Academic Patent Effect on Firms' Profitability

Table 3.2 illustrates the descriptive statistics of the responsiveness scores model with a one-year lag from the patent's priority year, whereas Fig. 3.1 shows the distribution of the responsiveness score for the different characteristics at short term.

The mean value indicates the average magnitude of responsiveness score to each academic patent characteristic.

Radicalness can be a measure of a firm's explorative research trajectory. It has the smallest, even if positive, effect on the firm economic performance with an RS of 0.009 in the short term. The score distribution is a pretty bell-shaped one, with the presence of a right tale of higher values of positive response (maximum value is 2.5).

Table 3.2 Descriptive statistics of the OPM's responsiveness scores to patent indicators, with a one-year lag (n = 712)

	R-squared	Mean	Std. Dev.	Min.	Max.	Median	25th Percen-tile	75th Percen-tile
Radicalness	0.26	0.009	0.112	−0.104	2.524	0.001	−0.033	0.039
Renewal	0.27	0.273	1.875	−41.427	5.746	0.342	−0.215	0.919
Forward Citations (7)	0.27	0.026	0.104	−0.305	0.312	0.045	−0.005	0.09
Backward citations to PL	0.27	0.058	0.127	−0.331	0.274	0.078	−0.01	0.154
Backward citations to NPL	0.26	0.041	0.03	−0.05	0.143	0.049	0.03	0.062
Technological closeness	0.27	−0.035	0.262	−0.203	5.72	−0.077	−0.119	−0.007

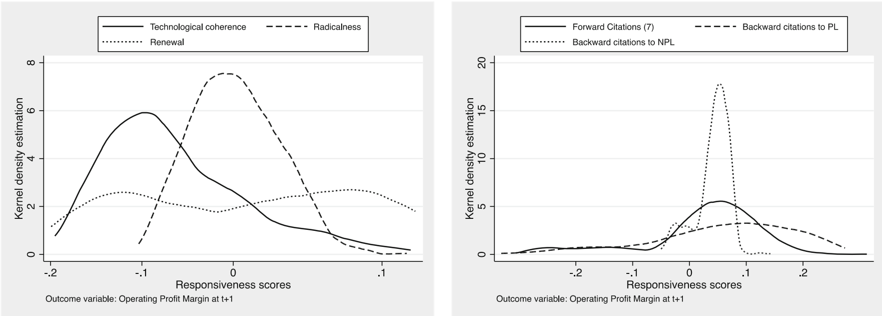

Fig. 3.1 Distribution of the OPM's responsiveness scores to patent indicators, with a one-year lag. The term *Technological coherence* in the figure must be intended as *Technological closeness*

Patent *Renewal,* meaning firms 'attribution of economic value to the patent, exhibits the highest effect on profitability, but with the highest variability. A very wide dispersion of results is present and at the 75th percentile the Response Score is equal to 0.9, showing that the extreme values in the right tail drives the mean.

The two indicators of prior art exhibit relatively more important responsiveness scores. *Backward citations to PL* have a positive mean, meaning that firms' economic return responds positively to an increase in the stock of cumulated knowledge.

Backward citations to NPL, suggesting a link with science and basic research, have the lowest dispersion of values around the positive mean. Firms' profit responds rather homogeneously to this factor. An increase in backward citation to scientific literature has a positive effect on the economic return and this support Cassiman et al. (2008) suggestion that patents that cite science contain more complex and fundamental knowledge and this influences positively their generality. *Forward citations* manifest one of the lowest effects, with a mean RS of 0.02. It has an asymmetric distribution of the responsiveness scores, both on the left and the right sides. Probably the use of only self-forward citations that specifically measure how much the firm applicant builds on a patented invention in its later technological activities (Sørensen & Stuart, 2000; Rosenkopf and Nerkar, 2001; Peeters et al., 2018), could exhibit a stronger and more regular relation with the private economic return.

The *Technological closeness* of the academic patents to the firms' technological profile shows a negative sign, i.e. an increase towards a full exploitative trajectory leads to a decrease in the OPM, all other variables held constant. The negative mean score is around −0.03.[3] However, the distribution shows a right-side skewness with a long tale of positive scores.

[3]Precisely a one standard deviation increases in academic patent technological closeness led to a 0.3 standard deviation decrease in the projected OPM, all other variables held constant.

Table 3.3 Descriptive statistics for Responsiveness Scores - High renewal (n = 366)

	Mean	Std. Dev.	Minimum	Maximum	Median	25th Percentile	75th Percentile
Technological closeness	0.055	0.563	−0.264	9.794	−0.008	−0.081	0.074
Radicalness	−0.027	0.138	−0.891	0.661	−0.019	−0.084	0.043
Renewal	−0.299	3.009	−5.925	32.833	−0.709	−1.873	0.618
Forward Citations (7)	0.033	0.105	−0.241	1.019	0.042	−0.026	0.086
Backward citations to PL	−0.022	0.180	−0.592	0.241	0.004	−0.139	0.126
Backward citations to NPL	0.036	0.069	−0.148	0.162	0.043	0.014	0.085

Outcome variable: Operating Profit Margin at t + 1. Table 3.3 and Table 3.4 must be read together; the sum of the number of observations is 366 + 346 = 712

It could be interesting to check if any conditions may alter the negative effect of the technological closeness of the academic patents to the technical profile of the holding firm. Ljundberg et al. (2012) showed that when a patent's technological closeness is associated to a firm core technology, i.e. a technology in which the firm invest a high share of resources and in which it has a competitive advantage, the impact of the patent is positive. We checked if the association of patent technological closeness with patent high renewal value, indicator of firm's high expectation of patent economic value and consequently of firm's interest in investing resources in that patent, exhibit a positive score and we found out a confirmation.

Our result denies Peeters et al. (2018) conclusion that when the academic patents are characterised by an exploitative character (closeness to a firm's technological domain), the effect on the firm technical development is always negative, while the academic inventors' involvement in technology development can benefit to a firm when they are exploration-oriented. Our result corroborates the statement of Ljungberg and McKelvey (2012) and Ljungberg et al. (2013). The meaning of this result is that where the firm has strong competences in a field and invests resources there, the associated external contributions, complementing firm's knowledge in some way, can produce a positive return.

Tables 3.3 and 3.4 show that firm's academic patents characterized by high renewal have a positive score measuring the response of operating profit margin, while academic patents with a low renewal have a negative score. We simply divided the sample into two components: with high and low active life of patents (Renewal). The negative value (−0.133) is higher than the mean value −0.035 without an association to patent renewal (Table 3.3). Note that the responsiveness score of the renewal component is negative for firms with an already high renewal intensity and positive for those with low renewal intensity. This can be interpreted as a scale effect: at high level of renewal intensity, a marginal increase of renewal may have a negative effect on profitability, as the induced costs are higher than the benefits of

Table 3.4 Descriptive statistics for Responsiveness Scores - Low renewal (n = 346)

	Mean	Std. Dev.	Minimum	Maximum	Median	25th Percentile	75th Percentile
Technological closeness	−0.133	0.201	−1.665	0.048	−0.073	−0.171	−0.019
Radicalness	0.017	0.207	−0.427	1.079	−0.01	−0.116	0.099
Renewal	0.174	2.282	−14.116	3.795	0.633	−0.526	1.481
Forward Citations (7)	0.033	0.205	−0.453	0.792	0.02	−0.097	0.121
Backward citations to PL	0.1	0.38	−0.586	2.723	0.039	−0.148	0.264
Backward citations to NPL	0.138	0.225	−0.501	0.866	0.118	−0.03	0.275

Outcome variable: Operating Profit Margin at t + 1. Table 3.3 and Table 3.4 must be read together; the sum of the number of observations is 366 + 346 = 712

marginal renewal extension. The opposite occurs when firms start from significantly lower renewal level.

3.5.2.2 Short and Long-Term Analysis

In this section, we check the presence of different effects of the patent characteristics on firms' economic performance in the long term. Given data availability, we use a lag of three years. The literature supports our choice: technical knowledge evolves rapidly in most technology fields, losing most of its technical and economical relevance within five years (Ahuja & Lampert, 2001; Hall et al., 2005; Leten et al., 2007). A technology domain remains relatively new and unexplored immediately after a firm embarks on technological activities and it keeps its explorative status for a period of around three consecutive years (Belderbos et al., 2010).

Figure 3.2 plots the relative frequency distribution of the RS with the mean and standard deviation respectively at one year and three years after patent application.

In the short time the better effect is shown by the academic patent's knowledge base (prior art), whose two indicators exhibit relatively higher and less dispersed positive results. In the long term, it is the technological knowledge base of academic patents (*Backward citations to PL*) which reveals a positive improvement: there is a higher concentration of response scores around positive values and the left right tail is reduced. As to the scientific knowledge base (*Backward citations to NPL*) there is a slight increase of the negative response scores, even if the response scores distribution remain bell-shaped and concentrated, indicating that firms' profits respond rather homogeneously. The long-term effect may reveal possible failures in case of less familiar knowledge base, but only in a few cases.

In the short term an academic patent with a knowledge base new to the firm (*Radicalness*) manifests the lower positive effect on firms' profit and in the long term the effect gets worse. The distribution of the response scores changes and exhibits a

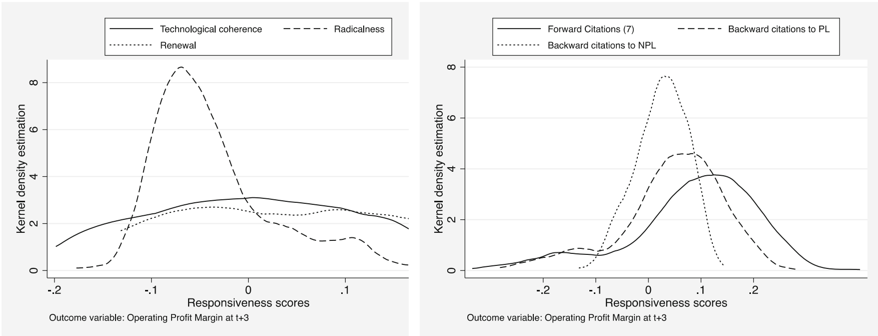

Fig. 3.2 Distribution of the OPM's responsiveness scores to patent indicators, with a three-year lag. The term. *Technological coherence* in the figure must be intended as *Technological closeness*

higher concentration on negative scores; at the same time, it has a bit longer right tail. It seems likely to indicate a strong heterogeneity in the firms' capacity of commercially exploiting new and unfamiliar technological fields.

When an academic patent has a technological content very similar to the firm's current knowledge (*Technological closeness*), the effect (profit response scores) on average is negative at short time, but with a right-side skewness, i.e. a long tale of positive scores, most likely due to idiosyncratic aspects**.** The distribution's shape changes at long term, by slightly increasing the frequencies of positive response scores. This would ask for more analysis, in general, when the academic patent is technologically close to the firm's technological profile, but it concerns a firm's core field, i.e. a technological field from which firms expect good economic results, the effect of this last characteristic prevails and change the impact on profit for the positive.

3.6 Discussion and Conclusions

The goal of this study was to analyse the link between academic involvement in firms' research and firm's economic performance, through academic patents and their associated technological and economic characteristics. We found only a few contributions in the literature on this specific topic and their results gave little attention to the large heterogeneity characterising both academic patents and their industrial applicants. Mainly focused on average effects, these contributions have provided a polarised view of the academic patents' contribution to the commercial and economic success of their industrial assignees, i.e. only a small part of firm owned academic patents, those with a more radical and exploration-oriented character, would have a positive effect (mainly in the long term) on firms' performance.

Our findings support a more nuanced kind of conclusions, opening up to further investigation on this topic. In accordance with the literature, we found that academic patents held by firms have on average a problem-solving characteristic, i.e. they are oriented to help firm to find solutions to difficult or complex current issues, that is different from an activity of explorative research. However, this incremental knowledge contribution given by scientists, probably on aspects that firms cannot manage well, does not bring to dead ends. Our results show that, when we look at the academic patents in the firms' portfolio, they can produce better results at short and long term mostly when the invention has a strong technical base. The incremental content of these patents, that can be roughly identified with the prior art technological background (*Backward citations to PL)* has only a small left tail identifying negative response scores of profitability. It has rather concentrated positive scores in the short term, with a score distribution becoming more centred on positive values in the long term. A scientific knowledge base of the invention is also positively relevant for the firm's economic performance, but at long term some failures appear, probably due to knowledge absorption capacity on the firm side.

The difficulty of managing unfamiliar knowledge is more evident when the invention is the result of an explorative strategy: The Radicalness indicator showed a low and not stable effect at long term. Negative scores and a long right tail reveal a strong heterogeneity in the firms' capacity of commercially exploiting new technological fields. Entering in a new field is a risky and costly strategy for firms: only some of them are able to become successful.

Our results show a satisfactory degree of coherence. Dealing with the exploitation-oriented character of academic patents (*Technological Closeness)*, i.e. academics' research contribution on familiar-to-the-firm technical fields, we find again the presence of nuanced effects. There is a strong skewness of firms' profit response on the right side, showing the presence of positive effects due to idiosyncratic characteristics of industrial assignees or of academic patents. In particular when these academic patents are associated with some indicator of firm's core technological field-invention on which firms has positive expectations and invest more- the mean of the profit response score is positive.

Finally, if managers are interested in identifying a positive relation between academic patents and firm's economic return, they have to look for complementing the knowledge base in which firms have an advantage; more radical and distant strategies bring a premium only in a few cases.

The approach we followed in this study presents some limitations. In particular, RS are descriptive measures of the level of firm responsiveness and the long term should be prolonged at a bit more than three years. However, we believe that this work and its empirical approach can contribute to our understanding of the economic effects of academic patents held by firms. Further works should try to assess the robustness of our results, by giving relevance to effects' heterogeneity as done in this work.

References

Ahuja, G., & Lampert, C. M. (2001). Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal, 22*(6-7), 521–543.

Anderson, P., & Tushma, M. (1990). Technological discontinuities and dominant designs: A cyclical model of technological change. *Administrative Science Quarterly, 35*(4), 604–633.

Artz, K. W., Norman, P. N., Hatfield, D. E., & Cardinal, L. B. (2010). A longitudinal study of the impact of R&D, patents, and product innovation on firm performance. *Journal of Product Innovation Management, 27*, 725–740.

Azagra-Caro, J. M. (2011). Do public research organisations own most patents invented by their staff? *Science and Public Policy, 38*(3), 237–250.

Bacchiocchi, E., & Montobbio, F. (2009). Knowledge diffusion from university and public research. A comparison between US, Japan and Europe using patent citations. *Journal of Technology Transfer, 34*(2), 169–181.

Belderbos, R., Faems, D., Leten, B., & Van Looy, B. (2010). Technological activities and their impact on the financial performance of the firm: Exploitation and exploration within and between firms. *Journal of Product Innovation Management, 27*(6), 869–882.

Bishop, K., D'Este, P., & Neely, A. (2011). Gaining from interactions with universities: Multiple methods for nurturing absorptive capacity. *Research Policy, 40(1)*, 30–40.

Bogner, W. C., & Bansal, P. (2007). Knowledge management as the basis of sustained high performance. *Journal of Management Studies, 44*(7), 165–188.

Breitzman, T., & Mogee, M. E. (2002). The many applications of patent analysis. *Journal of Information Science, 28*(3), 187–206.

Breitzman, A. F., & Narin, F. (2001). *Method and apparatus for choosing a stock portfolio, based on patent indicators.* US Patent 61758214.

Callaert, J., Van Looy, B., Verbeek, A., Debackere, K., & Thijs, B. (2006). Traces of prior art: An analysis of non-patent references found in patent documents. *Scientometrics, 69*(1), 3–20.

Cassiman, B., Veugelers, R., & Zuniga, M. P. (2008). In search of performance effects of (in) direct industry science links. *Industrial & Corporate Change, 17*(4), 611–646.

Cerulli, G. (2017). Estimating responsiveness scores using RSCORE. *The Stata Journal, 17*(2), 422–441.

Cheng, Y. C., Kuan, F. Y., Chuang, S. C., & Ken, Y. (2010). Profitability decided by patent quality? An empirical study of the U.S. semiconductor industry. *Scientometrics, 82*(1), 175–183.

Chen, Y. S., & Chang, K. C. (2010). The relationship between a firm's patent quality and its market value. The case of U.S, pharmaceutical industry. *Technological Forecasting and Social Change, 77*(1), 20–33.

Christensen, C. M., & Rosenbloom, R. S. (1995). Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research Policy, 24*(2), 233–257.

Cooper, A. C., & Schendel, D. (1976). Strategic responses to technological threats. *Business Horizon, 19*(1), 61–69.

Czarnitzki, D., Hussinger, K., & Schneider, C. (2012). The nexus between science and industry: Evidence from faculty inventions. *The Journal of Technology Transfer, 37*(5), 755–776.

Deng, Z., Lev, B., & Narin, F. (1999). Science and technology as predictors of stock performance. *Financial Analyst Journal, 55*(3), 20–32.

Dosi, G. (1988). Sources, procedures, and microeconomic effects of innovation. *Journal of Economic Literature, 26*(3), 1120–1171.

Encaoua, D., Guellec, D., & Martinez, C. (2006). Patent Systems for Encouraging Innovation: Lessons from economic analysis. *Research Policy, 35*(9), 1423–1440.

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

Griliches, Z. (1990). Patent statistics as economic indicators - a survey. *Journal of Economic Literature, 28*(4), 1661–1707.

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools, *National Bureau of Economic Research* Working Paper 8498.

Hall, B. H., Jaffe, A., Trajtenberg, M. (2000) "Market value and patent citations: A first look" *National Bureau of Economic Research* Working Paper 7741. Available at http://www.nber.org/papers/w7741

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of Economics, 36*(1), 16–38.

Harhoff, D., Narin, F., Scherer, F. M., & Vopel, K. (1998). Citation frequency and the value of patented inventions. *Review of Economics and Statistics, 81*(3), 511–515.

Harhoff, D., Scherer, F. M., & Vopel, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy, 32*(8), 1343–1363.

Henderson, R. (1993). Underinvestment and incompetence as responses to radical innovation: Evidence from the photolithographic alignment equipment industry. *RAND Journal of Economics, 24*(2), 248–270.

Henderson, R., Jaffe, A. B., & Trajtenberg, M. (1998). Universities as a source of commercial technology: A detailed analysis of university patenting, 1965–1988. *Review of Economics and Statistics, 80*(1), 119–127.

Lanjouw, J. O., Pakes, A., & Putnam, J. (1998). How to count patents and value intellectual property: The uses of patent renewal and application data. *The Journal of Industrial Economics, 46*(4), 405–432.

Lanjouw, J. O., & Schankerman, M. (2001). Enforcing intellectual property rights. *National Bureau of Economic Research* Working Paper 8656.

Lanjouw, J. O., & Schankerman, M. (2004). Patent quality and research productivity: Measuring innovation with multiple indicators. *The Economic Journal, 114*(495), 441–465.

Lester, R. K., & Piore, M. J. (2004). *The missing dimension*. Harvard University Press.

Leten, B., Belderbos, R., & Van Looy, B. (2007). Technological diversification, coherence and performance of firms. *The Journal of Product Innovation Management, 24*(6), 567–579.

Lissoni, F. (2012). Academic patenting in Europe: An overview of recent research and new perspectives. *World Patent Information, 34*(3), 197–205.

Lissoni, F., Montobbio, F. (2015). The ownership academic patents and their impact. Evidence from five European countries. *Revue Economique, 66*(1), 143–171.

Ljungberg, D., & McKelvey, M. (2012). What characterizes firms' academic patents? Academic involvement in industrial inventions in Sweden. *Industry and Innovation, 19*(7), 585–606.

Ljungberg, D., Bourelos, E., & McKelvey, M. (2013). Academic inventors, technological profiles and patent value: An analysis of academic patents owned by Swedish-based firms. *Industry and Innovation, 20*(5), 473–487.

Lotti, F., & Marin, G. (2013). Matching of PATSTAT applications to AIDA firms: discussion of the methodology and results, *Questioni di Economia e Finanza*, Occasional Paper, N 166, Banca d'Italia.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science, 2*(1), 71–87.

Narin, F., Noma, E., & Perry, P. (1987). Patents as indicators of corporate technological strength. *Research Policy, 16*(2-4), 143–155.

Narin, F., Hamilton, K. S., & Olivastro, D. (1997). The increasing linkage between U.S. technology and public science. *Research Policy, 26*(3), 317–330.

Narin, F., Breitzman, A., & Thomas, P. (2004). Using patent citation indicators to manage a stock portfolio. In H. F. Moed, W. Glänzel, & U. Schmoch (Eds.), *Handbook of quantitative science and technology research*. Springer. https://doi.org/10.1007/1-4020-2755-9_26

Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Harvard University Press.

OECD. (2013). Measuring patent quality: indicators of technological and economic value, *OECD Science, Technology and Industry Working Papers*, Organization for Economic Co-operation and Development, Paris. (Authors: Squicciarini, M., Dernis, H., and Criscuolo, C.).

Pakes, A., & Schankerman, M. (1984). The rate of obsolescence of patents, research gestation lags, and the private rate of return to research resources. In Z. Griliches (Ed.), *R&D, patents, and productivity*. University of Chicago Press.

Pakes, A. (1986). Patents as options: Some estimates of the value of holding European patent stocks. *Econometrica, 54*(4), 755–784.

Peeters, H., Callaert, J., & Van Looy, B. (2018). Do firms profit from involving academics when developing technology? *The Journal of Technology Transfer*. https://doi.org/10.1007/s10961-018-9709-x

Podolny, J. M., & Stuart, T. E. (1995). A role-based ecology of technological change. *American Journal of Sociology, 100*(5), 1224–1260.

Rosenkopf, L., & Nerkar, A. (2001). Beyond local search: Boundary-spanning, exploration, and impact in the optical disk industry. *Strategic Management Journal, 22*, 287–306.

Sampat, B. N., Mowery, D. C., & Ziedonis, A. (2003). Changes in university patent quality after the Bayh–Dole Act: A re-examination. *International Journal of Industrial Organization, 21*(9), 1371–1390.

Schumpeter, J. (1934). *The theory of economic development; and inquiry into profits, capital, credit, interest and the business cycle*. Harvard University Press.

Sørensen, J. B., & Stuart, T. E. (2000). Aging, obsolescence, and organizational innovation. *Administrative Science Quarterly, 45*(1), 81–112.

Sterzi, V. (2013). Patent quality and ownership: an analysis of UK faculty patenting. *Research Policy, 42*(2), 564–576.

Thomas, P., Research Inc, C. H. I., McMillan, G. S., & Abington, P. (2001). Using science and technology indicators to manage R&D as a business. *Engineering Management Journal, 13*(3), 9–14.

Trajtenberg, M. (1990). A penny for your quotes: Patent citations and the value of innovations. *The Rand Journal of Economics, 21*(1), 172–187.

Tripsas, M. (1997). Unravelling the process of creative destruction: Complementary assets and incumbent survival in the typesetter industry. *Strategic Management Journal, 18*(Summer Special issue), 119–142.

Wooldridge, J. (1997). On two-stage least squares estimation of the average treatment effect in a random coefficient model. *Economics Letters, 56*(2), 129–133.

Wooldridge, J. M. (2002). *Econometric analysis of cross-section and panel data.* Cambridge, Mass: MIT Press.

Chapter 4
Rethinking the Role of Productive Interactions in Explaining SSH Research Societal Impacts: Towards a Conceptual Framework for Productive Science System Dynamics

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Abstract In this paper we seek to realise the potential that Spaapen and van Drooge's productive interactions concept offers, but which we argue has been lost through its operationalisation as a process of 'counting interactions'. Productive interactions arise through moments of contact between two very different systems (the societal and the scientific), and each system values societal impact in very different ways. Finding mutual value in that interaction is important, and we argue that value in both arises when network arrangements shift, as academic disciplines solve urgent scientific problems and as societies improve living conditions. Productive interactions approach assumes the value-frameworks of the wider networks within which particular knowledge sets become actionable. However, our constructive critique highlights the omission of the wider elements of science and social systems within which productive interactions takes place (and whose dynamics ultimately determine the final scientific and societal impact of that research). Indeed,

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research evaluation to date has not considered the consequences of the productive interactions in terms of these changing relationships. To contribute to this lacuna, we propose a model that conceptualises a meso-level system comprising interactions between actors within two subsystems, highlighting the importance of coupling between researchers and users, valuation signals given to particular productive interactions from researcher and societal communities and the way these signals in turn embed useful knowledge practices. We apply it to a set of examples of productive interactions in the field of social sciences and humanities (SSH) gathered in the framework of a European project.

Keywords Research evaluation · Research impact · Social sciences and humanities · Science policy · Science studies

4.1 Introduction

A dominant concern for contemporary science, technology and innovation policy-makers is driving public research investments to create socio-economic impact. Recognising knowledge capital's contributions to productivity growth drove decades of public investments in science & research (Temple, 1999). But the policy belief persists that upstream public research investments only weakly drive technology development and innovation: the research 'impact' notion has emerged, making a science mission of driving socio-economic innovations. Scientists are increasingly *evaluated* on how far their research drives societal changes, the UK Research Excellence Framework being exemplary (Sivertsen, 2017). Across Europe research impact is also increasingly important in research evaluation.

However, in rushing to evaluate the research impact, policy development has overtaken theoretical reflection (Donovan, 2007). Patents, license income and spin-offs remaining a dominant frame for science studies' analysis of impact creation (Perkmann et al., 2013), but are useless for evaluation practice (Crossick, 2009). European research councils funded many impact creation studies, but these were primarily technical, avoiding understanding how evaluation systems influence on impact creation (Watermeyer & Chubb, 2018). The European project SIAMPI proposed the concept of 'productive interactions' (Molas-Gallart & Tang, 2011; Spaapen & van Drooge, 2011), as interactions between two actors in different systems, researchers and users.

Their systems have different values, norms and practices: productive interactions require aligning these different systems. Whilst an *interaction* offers an 'evaluation object', aligning these systems is a more significant impact element. Productive interactions may represent a single event, or drive a systemic change. These systemic changes are more desirable for policy-makers, and in this chapter, we conceptualise these wider systemic dynamics by asking the following research question: how do the elements of scientific and societal production systems become better aligned through productive interactions?

We develop a conceptual framework contextualising productive interactions within their wider systems, highlighting three additional elements shaping productive interactions: coupling, parallel progress and structuration. We use this framework to extend case study set of productive interactions derived from the Spanish National Research Council (CSIC) in the social sciences and humanities (SSH). We identify that coupling is driven by mobility, motivation and circumstance, that parallel progress requires valuation signals, and structuration is legitimated by parallel value signals out of the respective spheres. We conclude the productive interaction concept is useful for research impact evaluation, but it requires further theoretical development to become an academic concept.

4.2 Developing a Conceptual Theory for Evaluating SSH Research Impact

The productive interaction concept did not drive a wider conceptual breakthrough of how research impact is articulated or evaluated, and became dulled into a process of 'counting interactions'. The productive interactions concept avoids dealing with how academic knowledge becomes actionable, creating social value by promoting societal development. Productive interactions arise through moments of contact between two different spheres (societal and scientific), where each sphere values those impact-creating activities very differently. Effective productive interactions involve finding 'mutual value' for actors in both systems: academic value arises from research solving scientific problems, societal value arises from improving 'negative living conditions'.

4.2.1 The Emergence of the Productive Interaction Concept

Impact creation became an explicit research evaluation object in leading countries after 2005 (Benneworth et al., 2016; Petersohn & Heinze, 2017). From 2002, UK research council grant applications should include an impact statement; from 2014, *ex post* impact creation became (via the REF) specifically tied to resource allocation (Bulaitis, 2017). The first Dutch Standard Evaluation protocol in 2000 stated impact as a policy goal, the second in 2005 provided guidelines on evaluating it, and since 2010 impact has been a substantive consideration in research evaluation. (Benneworth et al., 2016; Van der Meulen & Rip, 2000). But these evaluation processes remained ambiguous regarding precisely what need be assessed, and against which criteria (Molas-Gallart, 2015). A few commercial indicators suggesting research could drive economic growth popularised impact with policy-makers, but were too limited to measure impact, even if the UK's Higher Education Innovation Fund used them to allocate funds (Benneworth & Jongbloed, 2013).

Scientometrics defines a publication's 'scientific impact' as uptake by other researchers (Petersohn & Heinze, 2017). Citations help measure scientific impact–citing an author shows dependence on their contribution. Imperfect and prone to behavioural distortions (Hall & Martin, 2019), scientometrics is sufficiently conceptualised to allow citations to represent to both policy-makers and scientists a reasonably legitimate *proxy* of scientific impact (even if decision-makers refuse to use bibliometric data responsibly, Hicks et al., 2015; Wilsdon, 2016). Societal impact measures never achieved comparable legitimacy, creating an urgent policy pressure to define social impact that (a) can be operationalised and measured, and (b) is legitimate to academics and policy-makers.

Several work-arounds filled these gaps: the UK adopted a peer-review methodology using departmental impact case studies assessed qualitatively and scored subjectively against three criteria (scale, scope and value) (HEFCE, 2011; Martin, 2011; Sivertsen, 2017). Bibliometrics companies developed proprietary societal impact measures (e.g. Altmetrics, PLUM (qv)) which largely lacked legitimacy (Andrews, 2018; Haustein et al., 2015). There have been surveys measuring behavioural and attitudinal aspects of scientists' orientation in the UK and Spain (Hughes et al., 2011; Llopis et al., 2018; Olmos-Peñuela & Castro-Martinez, 2014). But these failed to build legitimacy as a new impact measurement frame amongst both policy-makers and scholars (Wróblewska, 2017). Science policy-makers responded by funding research into research impact measurement. The Dutch-funded Evaluating Research in Context (ERIC), and the later European funded project 'SIAMPI' (Benneworth et al., 2016; Molas-Gallart & Tang, 2011) created the **productive interactions** concept as a first research impact definition (van Drooge, *pers. Comm.*).

4.2.2 Productive Interactions as One Element of a Productive Science System

Spaapen and van Drooge (2011) define productive interactions as:

> Exchanges between researchers and stakeholders in which knowledge is produced and valued that is both scientifically robust and socially relevant. These exchanges are mediated through various 'tracks', for instance, a research publication, an exhibition, a design, people or financial support. The interaction is productive when it leads to efforts by stakeholders to somehow use or apply research results or practical information or experiences. Social impacts of knowledge are behavioural changes that happen because of this knowledge (Spaapen & van Drooge, 2011, p. 212).

The productive interactions concept has a materiality, the 'transaction', linked to an underlying scientific process, avoiding two common traps in evaluating societal impact, assuming scientific research was intrinsically productive, or demanding extraordinary outcomes (Sivertsen & Meijer, 2020). Their definition provided both academics and policy-makers with a legitimacy claim: academics appreciated its relation to everyday research activities, and policy-makers valued its capacity to include user demand. There are three kinds of productive interactions, direct (personal) interactions, indirect interactions (mediated through artefacts) and financial interactions (economic transactions). Productive interactions *imply* more substantive change as transactions between partners are embedded within different contexts, and those transactions could impact upon those contexts. Spaapen and van Drooge (2011) acknowledged their concept does not address those wider systemic changes although those wider changes are non-trivial. This downplays two important elements of productive interactions, namely how impact generation becomes integrated within everyday scientific practices, and how using scientific knowledge changes societal behaviour.

Productive interactions take place within (well-ordered) science systems involving regular interactions between scientific and social decision-makers (Kitcher, 2001; Sarewitz, 2016). Societal interests may influence on scientific practices, with mechanisms by which scientific researchers become aware of societal partners' interests and needs (Gläser, 2019; Kitcher, 2001; Laudan, 1978). Societal partners may influence scientific decisions by contributing to shared knowledge activities that produce knowledge from which they may later benefit (Olmos-Peñuela et al., 2015; Azagra-Caro et al., 2020). A productive interaction is a moment of coupling in these well-ordered science systems, where scientific actors encounter societal actors and in which new kinds of scientific and societal value may emerge (Benneworth & Olmos-Peñuela, 2018; Gläser, 2019). New scientific value may emerge through inspiration and problem-setting, shaping what kinds of questions are deemed 'good' research leading to new scientific domains (Olmos-Peñuela et al., 2015). Social value emerges when a knowledge asset drives socio/economic development (Corea's, 2007), which may be economic, such as technology spin-offs, or socio-political, where academic knowledge contributes to democratic renewal or challenges deeply-held societal beliefs (Benneworth et al., 2016; Bozeman et al., 2015). This system change effects are present in productive interactions as a concept, but are largely absent in its practical utilisation, something which undermines its validity.

4.3 Distinguishing the Conceptual Elements of Productive Science Systems

Productive interactions involve knowledge activities spanning scientific and societal spheres. Science typically seeks to produce open general-universalist knowledge, maximising uptake. Societal users value locally-specific knowledge with direct private benefits. These differences can potentially undermine productive interactions, when actors cannot find ways to both benefit from interactions. Any successful productive interaction has managed to fit these dynamics and benefits of societal and scientific partners together, which we conceptualise as three characteristics:

1. Coupling – actors work together around a shared purpose, interacting and sharing the knowledge through collective working;

2. Progress – the work undertaken by the two actors becomes visible and has impacts on other actors in their respective societal and scientific systems;
3. Structuration – there are changes in the overall systems topologies within which the two actors are active.

First is coupling, the mutual exchange process which benefits each participant by providing access to resources valued by each partner. Societal partners benefit from a capitalisation effect: knowledge can later be mobilised as capital within their own social systems. Through proximity to the societal partner, a scientific partner can quickly respond to their input, providing an "early warning system" for emerging topics. In some productive interactions, mutual benefit may not be directly visible to either participant; but following Kitcher (2001), we argue a societal user using a piece of scientific knowledge sends a signal to the scientist that may shape the scientist's future inspiration, planning and framing activities. In financial interactions, the mutual benefit is obvious, the societal partner provides resources to the scientific partner, which may support further research. But financial interactions are not always significant, particularly in social sciences and humanities (Olmos-Peñuela, Molas-Gallart, & Castro-Martínez, 2014), and tightly focusing on finance hinders a wider understanding.

Second is progress, parallel progression within distinct connected systems: (a) scientists seeking to create new knowledge by addressing urgent research questions, and (b) societal users seeking to drive societal development. Moments of 'coupling' allow the creation of a shared common knowledge resource, but the mutual activities become a temporary common direction of travel changing both subsystems ('progress'). Academic progress comes through new knowledge being created, and potentially new domains, fields and practices of research (Neff, 2014). Societal progress comes through societal partners using that knowledge to create things they value.

Third is structuration, changes within scientific and societal systems resulting from that 'progress', actors achieving outcomes that are positive in their own. That may in turn affect those actors' contexts, creating connections and resources with a more regular effect, representing new systemic capacities. Scientists may develop newly accepted ways of working that facilitates: (a) additional future productive interactions with societal partners, and/ or (b) creating assets, infrastructures and knowledge cognate with social partners which ensure that social partner knowledge is better used in future research (a simple example here being living laboratories). Societal partners experience structuration as one-off networks becoming more generalised, potentially creating new classes of professionals, new curricula or new kinds of legislation and regulation. Although the interaction does not *cause* these systemic shifts, productive interactions make them possible.

4.4 Methodology

These three elements provide our conceptual framework, which we use to characterise a set of narrative examples of societal impact in terms of four conceptual elements: productive interactions, coupling, progress and structuration. The cases, drawn from Spain from the SIAMPI project, examine how these three additional elements of dynamic science systems – coupling, progress and structuration – function in practice. Although repurposing antecedent information for our own needs, there is sufficient correspondence between the questionnaire structure and our model of productive science systems to make the dataset fit for this purpose within an unashamedly exploratory piece of work. The underlying Spanish dataset contained twelve interviews with SSH research groups: interviews were undertaken with these research groups, as well as with users of the knowledge created by these groups. We selected five examples with a clear productive interaction. Where there was insufficient data to provide a reasonable stylised representation of the three elements, we approached the research group for clarification. An initial first analysis revealed the presence of the four dimensions whilst providing a degree of diversity, and a degree of depth in the empirical material to avoid presenting excessively synthetic findings.

4.5 Introduction to the Case Studies

4.5.1 Music: Recovering Unpublished Spanish Musical Works

The first research group is an early music research group, recovering unpublished Spanish poetic-musical works from the 16th/ 17th centuries, translating them into modern notation and contextualising them using literature studies to support contemporary performance of disappeared Spanish culture (Castro-Martínez et al., 2013). One leading research partner was the director of a vocal and instrumental early music ensemble, also executive of a small record company specializing in early music, who met the group while doing his doctorate. Madrid's regional government wanted to commemorate the 400th anniversary of Don Quixote's publication, so commissioned him to very quickly publish an album. Hitting the anniversary deadline was only possible because the group had in-depth knowledge of the Don Quixote text and contemporary musical works that could be adapted to each selected text. The company subsequently developed a commercial line of previously-unpublished Spanish poetic music revitalised using research results, interacting with the CSIC research group though the stages of musicological research. This involves (a) finding and identifying largely unpublished musical works in national and international libraries or cathedral archives, (b) transcribing to modern notation (for current musicians), their study/ musical analysis, comparison with other versions (where applicable), and definitively fixing score and poetic texts (c) historical, aesthetic and cultural contextualization to support transcription and scientific rigor, then (d) making these recovered compositions available to other researchers (musicologists) or current practical musicians.

Interactions between the ensemble conductor and the CSIC research group occurs at all stages: exchanging documents, discussing interpretations and analyses. These interactions also occur during the CD production process, in selecting the composer analysed, the works included in the CD (selecting the most appropriate/ original), writing the *libretto* and selecting images. All editions are produced very carefully, its market being strongly dependent on commemorations and anniversaries. Although the company's commercial interests influenced the research group's choices, all the 'rediscovered' works contributed to creating new knowledge about Spanish poetic-music work.

Commercial 'influence' on the research group included sharing information on opportunities, proposing potential new works, and together agreeing on collaboration areas with potential scientific and societal impact. The research group sought to enrich its transcripts to be useful to the interpreters. The ensemble director, whose market niche was specifically in recording of newly recovered and never-performed Spanish works, used the interaction to affect how he directed and interpreted the works. The richness of documents analysed by the research group indicated suitable instruments to be played, ways of playing and the creation context, thereby helping with a richer, historically faithful interpretation.

4.5.2 Theatre: Placing Spanish Baroque Theatre in a Wider Context

The second research group analysed Spanish baroque theatre; in contrast to more traditional approaches to theatre studies (philological text interpretation), the research group focused on analysing the whole performance in an integral way (from staging, interpretation, production, through scene, direction, to the performance's reception critics and audiences). This broader approach produced different results, providing directors and actors additional elements (beyond the texts) for representing the works more reliably in terms of staging and interpretation. These broad approaches partly derived from the research group leader's previous experience as director of the Almagro International Classical Theatre Festival, where he realised the value of approaching theatre as text and interpretation. This approach lent itself to supporting theatre companies, drama festivals and drama schools seeking to perform those pieces more accurately, most notably the Director of Spain's National Classical Theatre Company (NCTC).

The collaboration began in 2004 with the appointment of a new NCTC director inspired by these scientific approaches and interested in performing theatrical works of the Spanish Baroque. He was specifically interested in expanding the NCTC's repertoire with works retrieved and interpreted in accordance with these new approaches. They collaborated for several years, finding and analysing documents about how works were performed, and contrasting different versions of the works. The NCTC was interested in historical and literary analyses of the works/ authors of the Spanish Baroque, in the relations between works and their authors, and in representing the work in a coliseum (or current theatre). One important finding was recognising that classical Spanish theatre representations were strongly influenced until the 1960s by French 18th fashions, rather different to Spanish fashions.

Research results were published in an NCTC collection, providing an interpretation more faithful to the prevailing fashions at the time of writing and first performance. The NCTC collection was aimed at disseminating these new approaches via actors and directors, as well as the general public and secondary school teachers. Results were also disseminated in scientific activities and conferences, where actors and directors participated influencing representations of Spanish theatrical works, not only in the NCTC, but more generally across Spanish theatre.

4.5.3 Philosophy: Using Insights on Barbarism to Improve Road Safety

The third case came from a philosophy research group analysing barbarism, particularly promoting public reflections about violence victims defined from terrorism and genocide to road accidents, using practical examples to promote critical thinking in society. The group was a European pioneer in approaching these problems from the centrality of the victims. The research group was known to the Road Safety Prosecutor, who asked the group leader to address a conference of public prosecutors regarding Spain's high automotive mortality (c. 6000 deaths in 1989, falling 1100 in 2014, partly resulting from the policy developed). The researchers focused on drivers' awareness of driving within modern society: speed is regarded as positive, speed's benefits are more immediately visible, whilst its attendant costs and risks are invisible to speed's beneficiaries.

In 2007, the Prosecutor asked the group to identify human rather than technological causes of societal insensitivity to traffic accidents from their humanities perspective (philosophical, cultural, anthropological and psychological). The group ran a research project funded by the Ministry of Science, involving seminars, inviting different stakeholder representatives to jointly discuss the issue, guiding discussions to achieve the expected practical results (such as proposals or recommendations). The group already had experience on other social issues, such as terrorism, where they deployed a similar strategy. The Prosecutor came whenever possible to the activities, and was apprised of the group's results.

The group used all available means to disseminate the results. Stakeholders supported this by conducting their own dissemination in their own outlets such as the press, training, victims' associations' websites and conferences. The project website disseminated materials generated, operated discussion forums (including for consultations), and linked to stakeholders' web pages. They organised seminars and symposia with stakeholders to discuss this topic, involving journalists, researchers from other interested areas, the road victims' association, the Royal Automobile Club and the Prosecutor's office. Many results were incorporated by the Prosecutor's report to Spain's Congress of Deputies (2015) to support improving legislators' insights into road traffic fatalities and new legislative proposals for road education, accident prevention and punitive responses.

4.5.4 Archaeology: A Research Group Valorising Historical Excavations

The fourth group was an archaeology group studying cultural heritage, how societies ascribe significance and value to heritage assets, and its change over time. The 1985 Spanish Heritage Act provided a first framework for managing and protecting cultural heritage, requiring *ex ante* archaeological and environmental impact assessments for public works, creating a new business sector, 'archaeological services' (Parga-Dans et al., 2012). Regional governments developed their own archaeological laws for territorial heritage presentation leaving no standardized reporting formats or procedures.

The Act stimulated several companies to establish formal agreements with the group, and the research group's agenda evolved from primarily archaeology into heritage in a wider sense. The archaeology service clients had a substantial interest on the group's research choices, methodologies, new technologies, reporting approaches and frameworks. Public agencies developed informal connections to the group as experts to receive advice on how to best implement protocols and interact with community groups to understand anthropologically how local communities respond to excavations. The group's scientific outputs were ultimately shaped by a range of influences, purposive and non-purposive, reflecting both scientific and societal choices.

4.5.5 Heritage, Memory and Conflict: Regeneration & Franco's Legacy

The fifth research group was working on heritage, memory and conflict, understanding social processes of communities or societies managing 'uncomfortable or painful' heritage assets for the present and future. One project studied the Carabanchel prison (near Madrid), imbued with a shared sadness from the Franco regime, where many political prisoners were imprisoned, carrying emotional and emotive significance for neighbours and other groupings (political prisoners, associations of historical memory). The prison was abandoned in 1998: both neighbours and 'La Comuna' (The Commune association of former political prisoners) attempted to reinvent its place-identity as exemplifying repair within Spain's transition to democracy. Government plans to demolish the jail inspired the project, the group making a full documentary record of the prison exploring how local residents came to accept the uncomfortable asset heritage; the demolition produced a desire to transform the jail site into a cultural centre to the memory of repression. The researchers produced a historical record (storing and archiving memorials, as well as photos and audio recordings around the memorials) of those monuments as a first step in analysing those mourning practices (Ortiz-García & González-Ruibal, 2015). The local community valued the group's work to harness the negative emotions of living in a 'tainted' community towards accepting and reusing the building. The project produced a photo exhibition of former inmates, alongside a DVD charting the estate's expansion in Francoist political context. Despite the group's proposals and the community desires, the prison was completely demolished in 2008; although being split across two jurisdictions at the time of writing it remains derelict.

4.6 Coupling, Progress and Structuration around Productive Interactions

To answer our research question regarding how the elements of scientific and societal production systems become better aligned through productive interactions, we structure these five case studies around the three systemic elements surrounding individual productive interactions (see Table 4.1).

4.6.1 Coupling, Progress and Structuration Around Musicology Productive Interactions

In musicology, there were two separate development trajectories, excellent scientific knowledge on lost manuscripts, and a company producing new recordings of rediscovered pieces. The productive interaction was embedded in coupling interests already operating for a relatively long period. The company executive already knew of the research group from the time of his own Ph.D., and knew the group and their expertise prior to contacting them. The group's ability to react to the business case (anniversaries and deadlines) also facilitated the productive interaction, creating activities that contributed to public awareness of Spanish baroque inside and outside Spain, and value for that interpretative approach/ new research objects, validating the researchers' quality. An extended community of artists who had participated in La Grande Chapelle Ensemble taking this approach left many Spanish and European

Table 4.1 Coupling, progress and structuration of the five selected case studies

	Coupling	Progress	Structuration
Music	User had prior knowledge of research group from own experience as Ph.D. researcher. Ability of research group to react to timescales of commercial partner.	Producing new research lines (a new book on the rediscovered music) and commercially valuable products (published music).	Construction of a new interpretation approach, 'anniversary rediscovered music'. Legitimation of 'music rediscovery' as a field of academic study suitable for SSH research funding and publication.
Theatre	Achieved by an outplacement of professor as cultural festival director inspired to make own work more influential on cultural products. User as a laboratory for professor to experiment on dramatology.	New research line for professor inspired in a sociological approach of Spanish vernacular baroque theatre, not only texts studying. Creation of new cultural products: vernacular Spanish baroque theatre and books to widely disseminate the approach developed.	Embedding of new ways of working in the system: the co-creation of the research subject through cultural production that then forms the basis for both cultural consumption and academic hermeneutic research.
Philosophy	The group research approach was already appreciated by the public prosecutor because of a previous piece of work. Professor valued the invitation because the proposed topic (road safety) fit with the main line of the group (the centrality of victims).	A new research project including some activities with social actors were produced (seminars and symposia) on the barbarism and drivers theme. The prosecutor was able to influence legislators to address a key public safety issue (RTA fatalities).	Legitimation of this more contemporary research approach in philosophy of which the group was a pioneer in Europe. Acceptance of the value of academic knowledge by legislators in addressing RTA problems.
Archaeology	Coupling driven by mutual interest between users and academics as they sought to make sense of how to operationalise new law.	Creation of a new archaeology service sector with (some) links back to academic archaeology to establish archaeological impact statement processes. Academics shifted to studying 'archaeology practice' and regulations' effects on businesses.	Construction of coherent field of users and academics with many mutual interactions as part of routine 'way of doing business' driving both practice and research.
Heritage, memory and conflict	Willingness of researchers to adopt 'campaigning' role for Carabanchel residents and prisoner associations. Fit of 'natural' curiosity	Construction of symbolic academic value (published books, a PhD thesis). Memorialising of a tainted site, recording	Memorialisation of the site as demonstration of value of academic involvement in citizen activities. Relations between the group and

(continued)

Table 4.1 (continued)

	Coupling	Progress	Structuration
	with residents' desire to memorialise a tainted location.	prisoners' histories and producing cultural artefacts (videos).	the prisoners' association once the project has been completed. Further validation of academic legitimacy of overall field.

Source: authors' own design

artists knew and valued the approach, and were keen to participate in new productions, feeling participation helped drive their artistic growth. The research group, disseminating its work openly, saw transcriptions being downloaded extensively both in Spain and abroad, and its approach being valued in international musicological media.

4.6.2 Coupling, Progress and Structuration Around the Theatre Productive Interactions

The second example addressed a productive interaction between a theatre company and a theatre studies research group reimagining Spanish baroque theatre without vestiges of French courtly practices. These two systems' coupling was achieved by a CSIC professor's successful residency as a cultural festival curator. This residency firstly influenced *academic* progress inspiring the professor to new research lines tailored to excavating baroque theatre, in turn the basis for successful new forms of renewing cultural practice via NCTC (*societal* progress). Structuration involved two fields, building a sense of legitimacy of the co-created cultural activities in each system, rediscovered theatre as a legitimate object of research, but a new approach as a form of patrimonic culture. This had a wider symbolic value to NCTC alongside other theatre professionals who adopted this more authentic approach in their own productions. The group continued to direct its research towards "dramatology".

4.6.3 Coupling, Progress and Structuration Around the Philosophy Productive Interactions

Thirdly, the application of the philosophy research group's approach (centrality of victims in processes of social suffering) to the road safety case arose at the request of the Attorney General (AG) for Road Safety. The AG was aware of the group's work and considered their approach relevant for attempts to reduce the number of traffic victims. Coupling followed a brief correspondence where professor and Prosecutor realised that productive interactions were possible in this case. At the prosecutor's request, the group developed a multi-disciplinary research project, financed under the national R&D plan, where bringing together specialists from various disciplines (philosophy, anthropology, law, sociology) alongside open seminars for various social actors (victims' associations, automobile clubs, journalists). The interaction represented scientific progress because it drove research activities (seminars and symposia), opening up a new research beyond the philosophy of history into public policy areas. It represented societal progress helping the prosecutor to inform legislators to encourage death reduction actions. There were not obviously observable structural changes in either societal and scientific systems, although this applied interdisciplinary philosophy practice has wider consequences for the social value of philosophy in Spain, helping legitimate philosophy's value more generally at a time when the humanities were under pressure by being considered as luxury disciplines.

4.6.4 Coupling, Progress and Structuration Around the Archaeology Productive Interactions

The fourth case involved regular productive interactions between an archaeology research institute and archaeology services, a sector that emerged in response to a law creating new definitions of heritage and a mandate for action around architectural preservation. This societal progress, creating this new service field, stimulated the academic progress, namely new archaeology research domains. Productive interactions came through many exchanges as these two sides tried to navigate these legal provisions. This well-structured community drove continued interactions, and continued validation of these two fields as being socio-economically and academically legitimate respectively. In response to the financial crisis reducing public construction projects, both firms and the research group reoriented part of their activity towards other stages of the patrimonial processes (Parga-Dans et al., 2017).

4.6.5 Progress, Coupling and Structuration in the Heritage Productive Interactions

The fifth case involved were interactions between researchers in heritage, memory and conflict and local residents, to explore the memorialisation and preservation of an infamous Franco-era prison complex scheduled for demolition. The research group already had a strong public profile because of their successful previous project exploring the memorialisation of the 2004 Madrid train bombings. Earmarking Carabanchel for closure piqued their curiosity and drew engagement with local residents around closure. Academic resources and the documentary making stimulated local cohesion, adopting the academic idea as a cultural production activity expanding to the memorialisation of prisoners. Coupling was produced by the research group's engagement expertise finding a connection into a symbolically significant development, co-constructing a cultural production activity that also drove academic production, including a scholarly volume. The multidisciplinary team were exposed to a range of social engagement practices, historians to community engagement, anthropologists to politicians, film directors, photographers, legitimating those engaged approaches as 'scientific'. The societal actors progressed by incorporating 'scientific criteria', vocabulary and concepts about their experiences and thereafter, their public activities were expressed deploying that vocabulary.

The structuration produced a memorialisation of the role of Carabanchel in Franco-era repressions. The relationship with the group profoundly impacted the social actors: the neighbourhood association sought contact with other similar places, the association of ex-prisoners formed as a direct consequence of the project. Other civic groups were created: a photographer (Jesús Rodríguez, now retired) collaborated with the neighbours and others; Sergio García, an anthropologist, organised guided tours for the neighbourhood, influencing its urban development. This experience gave rise to a doctoral thesis, published as a book (Martínez-Zauner, 2019), launched in association with 'La Comuna'. These scientific results demonstrated that highly engaged co-creative research can be academically legitimate, changing academic practices.

4.7 Dynamics of Progress, Coupling and Structuration in SSH Dynamics

These five cases allow a stylisation of the operation of our model in practice. In Table 4.1 below, we summarise the five cases distinguishing characteristics of these three elements. Coupling involves micro-scale resolution of user-researcher interest conflicts around the mutual activity. Progress involves creating novel artefacts and activities which are valued by other actors in the respective communities. Structuration involves wider expressions of value, with those activities to achieve a more permanent and enduring impact in societal and scientific practice. More detail is provided below.

Coupling involves resolving researcher and user interests to allow productive interactions. We identify three coupling mechanisms, namely mobility, predilection and circumstance. Mobility involves individual actors moving between the spheres, whether a Ph.D. student later becoming a commercial publisher, or an academic playing a role in societal or cultural production, like a festival director. Predilection involves an actor wanting to play a role in another sphere, evident where researchers developed their own roles as public intellectuals or activist researchers. Third was when circumstance effectively created or facilitated this coupled community, most evidently when contract archaeology was created as a highly regulated field, or the urgency to document a controversial prison scheduled for demolition.

The second element was *progress,* involving novel activities and artefacts in which others then expressed legitimacy and value. These activities and artefacts were observable in research when new fields were created: knowledge created in productive interactions unlocked further academic progress. The dependence of societal artefacts from productive interactions involves those artefacts' value depending at least partly on qualities brought by academic knowledge. In two cases, a new kind of cultural interpretative approach was created (rediscovered classical music and vernacular baroque theatre) embodying cultural capital depending on authenticity derived from academic knowledge.

The third element was *structuration*, where validation mechanisms expressed through progress change the overall systems facilitating (or potentially inhibiting) future productive interactions. Scientific progress builds upon user knowledge in creating new research pathways and lines, and validates the use of societal knowledge in research, creating alternative research pathways. There is the production of new kinds of norms, for example: (a) the use of cultural production as 'laboratory' for humanities knowledge creation as in the vernacular theatre case, and (b) user practice and knowledge circulating in academic research practices, as with seminars and symposia on barbaric road users. Societal structuration involves creating artefacts with a persistent effect. This may be a landmark effect, seen most evidently in Carabanchel, where a memorial record was created of place-specific human rights abuses. These may be unselfconscious practices that diffuse into user communities, such as the behaviour of public prosecutors or archaeological consultants, whose ongoing practices were shaped by regulations in turn shaped and interpreted involving academics. It may finally be at the wider societal level creating a new strand in societal debate, relating to cultural patrimony and national identity, visible in some degree in the theatre, music and heritage and memory cases.

Structuration involves validation mechanisms where that value makes the productive interaction seem useful. One element arises though the validation of that academic research including societal interests as being rigorous, in turn validating the academic norms that produced that knowledge by incorporating societal knowledge. The aggregate effect at system level permits research practice to incorporate user knowledge to perceive phenomena that would otherwise remain invisible. The societal structuration involves creating something persistent, with an underlying societal interest, whether a new kind of interpretative approach within a cultural product or a landmark like a memorial.

4.8 Discussion and Conclusion

The five cases provide a means to observe that productive interactions are embedded within wider changes within science and societal systems. This adds a depth to the productive interactions concept, highlighting wider changes in the scientific and societal systems, related to the observable productive interactions. These wider changes represent a form of impact, and by studying this value-creation process, associating it with the production of scientific knowledge, we can better understand what matters about productive interactions and, therefore, what precisely policy-makers should seek to encourage if they wish to optimise scientific valorisation. With the caveat that this was a relatively small exploratory study, our findings therefore can contribute to academic and policy development.

We find productive interactions are embedded within wider value production processes and productive interactions happen where there is the potential for a productive interaction between the scientific and societal spheres (*cf.* Muhonen et al., 2020). We can better specify this 'potential for constructive interaction' as something that can actively be built and influenced. Because scientific production is forward-looking, with scientists planning activities in terms of their expectations of the reception their work will receive academically, the potential also reflects the expectations on how work incorporating societal knowledge will be received. One element is something giving the two spheres insights into each other's mindsets, whether mobility, predilection or circumstance. The second element is where shared production is valued in both respective spheres. The third element is these value signals legitimate these activities and artefacts and lead to their wider (unselfconscious) diffusion in science and society.

Therefore, we argue that the productive interaction concept has value in understanding (as well as for evaluating) how scientists create value in society. We also emphasise a need to better understand these value creation processes theoretically to produce understandings of research impact that better reflect the societal value that is created. Productive interactions are intrinsically beneficial, because they may be associated with distortion or substitution effects – they have been popular because they lead to something that is countable for evaluation purposes, but are ill-equipped to make higher level aggregate claims. By focusing on these parallel production processes and pointing to wider structural changes, a modified productive interaction concept can provide a useful lens for understanding how engaged scientists in productive science systems contribute to wider socio-economic development processes.

Our heuristic also has three implications for policy-makers. Productive interactions are a useful focus for research evaluation on societal impact because they capture something for which scientists are themselves responsible and are not themselves dependent on the quality of the absorption environment. Certainly, science policy should seek to encourage antecedent coupling activities as well as simply evaluating the resultant productive interactions, particularly stimulating and rewarding mobility and predilection (although this, itself, requires a better understanding of scientists' motivations for engagement). Our heuristic also highlights the importance of scientific valuation practices in establishing scientific development and, therefore, the need to ensure that scientific evaluation procedures are promoted in such a way that offers the opportunity to validate and signal value for engaged research practices. Finally, the systemic approach allows the understanding of the intensity and scope of productive interactions in terms of their coupling, progress and structuration, and this may be very useful to identify, recognise and assess a field's scientific contribution.

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Bibliography

Andrews, P. C. S. (2018). "Putting it together, that's what counts": Data foam, a snowball and researcher evaluation. In P. Moore, M. Upchurch, & X. Whittaker (Eds.), *Humans and Machines at Work - monitoring, surveillance and automation in contemporary capitalism* (pp. 203–229). Palgrave Macmillan.

Azagra-Caro, J. M., Fernández-Mesa, A., & Robinson-García, N. (2020). 'Getting out of the closet': Scientific authorship of literary fiction and knowledge transfer. *Journal of Technology Transfer, 45*, 56–85.

Benneworth, P., & Jongbloed, B. (2013). Policies for promoting university-community engagement in practice. In P. Benneworth (Ed.), *University engagement with socially excluded communities* (pp. 243–261). Springer.

Benneworth, P., & Olmos-Peñuela, J. (2018). Reflecting on the tensions of research utilization: Understanding the coupling of academic and user knowledge. *Science and Public Policy, 45*(6), 764–774.

Benneworth, P., Hazelkorn, E., & Gulbrandsen, M. (2016). *The impacts and future of arts and humanities research*. Palgrave.

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

Bulaitis, Z. (2017). Measuring impact in the humanities: Learning from accountability and economics in a contemporary history of cultural value. *Palgrave Communications, 3*(1), Article number: 7. https://doi.org/10.1057/s41599-017-0002-7

Castro-Martínez, E., Recasens, A., & Jiménez-Sáez, F. (2013). Innovation systems in motion: An early music case. *Management Decision, 51*(6), 1276–1292.

Corea, S. (2007). Promoting development through information technology innovation: The IT artefact, artfulness, and articulation. *Information Technology for Development, 13*(1), 49–69.

Crossick, G. (2009). *So who now believes in the transfer of widgets?* Presented at Knowledge Future Conference. Goldsmiths College, London 16h-17 October 2009. Accessed 20 Nov 2011 from http://www.london.ac.uk/fileadmin/documents/about/vicechancellor/Knowledge_transfer_without_widgets.pdf.

Donovan, C. (2007). The qualitative future of research evaluation. *Science and Public Policy, 34*(8), 585–597.

Gläser, J. (2019). How can governance change research content? Linking science policy studies to the sociology of science. In D. Simon, S. Kuhlmann, J. Stamm, & W. Canzler (Eds.), *Handbook on science and public policy* (p. 419). Edward Elgar Publishing.

Hall, J., & Martin, B. R. (2019). Towards a taxonomy of research misconduct: The case of business school research. *Research Policy, 48*(2), 414–427.

Haustein, S., Bowman, T. D., & Costas, R. (2015). Interpreting "altmetrics": viewing acts on social media through the lens of citation and social theories. *arXiv preprint arXiv*:1502.05701.

HEFCE. (2011). Decisions on evaluating research impact, HEFCE Guidance Note 2011.1, Bristol: HEFCE. Accessed 30 January 2015 from http://www.ref.ac.uk/media/ref/content/pub/decisionsonassessingresearchimpact/01_11.pdf.

Hicks, D., Wouters, P., Waltman, L., de Rijcke, S., & Rafols, I. (2015). Bibliometrics: The Leiden Manifesto for research metrics. *Nature, 520*(7548), 429–431.

Hughes, A., Kitson, M., & Probert, J. (2011). *Hidden Connections: Knowledge exchange between the arts and humanities and the private, public and third sectors*. Cambridge: CEBR and Bristol: Arts & Humanities Research Council. Accessed 29 Feb 2016 from http://www.cbr.cam.ac.uk/fileadmin/user_upload/centre-for-business-research/downloads/special-reports/specialreport-hiddenconnections.pdf.

Kitcher, P. (2001). *Science, truth and democracy*. Oxford University Press.

Laudan, L. (1978). *Progress and its problems: Towards a theory of scientific growth*. University of California Press.

Llopis, O., Sánchez-Barrioluengo, M., Olmos-Peñuela, J., & Castro-Martínez, E. (2018). Scientists' engagement in knowledge transfer and exchange: individual factors variety of mechanisms and users. *Science and Public Policy, 45*(6), 790–803.

Martin, B. (2011). The research excellence framework and the 'impact agenda': Are we creating a Frankenstein monster? *Research Evaluation, 20*(3), 247–254.

Martínez-Zauner, M. (2019). *Presos contra Franco. Lucha y militancia política en las cárceles del tardofranquismo*. Galaxia Gutenberg.

Molas-Gallart, J. (2015). Research evaluation and the assessment of public value. *Arts and Humanities in Higher Education, 14*(1), 111–126.

Molas-Gallart, J., & Tang, P. (2011). Tracing 'productive interactions' to identify social impacts: An example from the social sciences. *Research Evaluation, 20*(3), 219–226.

Muhonen, R., Benneworth, P., & Olmos-Peñuela, J. (2020). From productive interactions to impact pathways: Understanding the key dimensions in developing SSH research societal impact. *Research Evaluation, 29*(1), 34–37.

Neff, M. W. (2014). Research prioritization and the potential pitfall of path dependencies in coral reef science. *Minerva, 52*(2), 213–235.

Olmos-Peñuela, J., & Castro-Martínez, E. (2014). How CSIC researchers in the humanities and social sciences interact with societal agents outside institutional channels? *Revista Española de Documentación Científica, 37*(4), e072. https://doi.org/10.3989/redc.2014.4.1165

Olmos-Peñuela, J., Molas-Gallart, J., & Castro-Martínez, E. (2014). Informal collaborations between social sciences and humanities researchers and non-academic partners. *Science and Public Policy, 41*(4), 493–506.

Olmos-Peñuela, J., Benneworth, P., & Castro-Martinez, E. (2015). What stimulates researchers to make their research usable? Towards an 'openness' approach. *Minerva, 53*(4), 381–410.

Ortiz-García, C., & González-Ruibal, A. (2015). The prison of Carabanchel (Madrid, Spain). A life story. In M. L. S. Sorensen & D. Viejo Rose (Eds.), *War and cultural heritage: Biographies of place* (pp. 128–155). Cambridge University Press.

Parga-Dans, E., Castro-Martínez, E., & Fernández de Lucio, I. (2012). La arqueología comercial en España: ¿un sistema sectorial de innovación? *Cuadernos de Gestión, 12*(2), 139–156.
Parga-Dans, E., Castro-Martínez, E., & Sánchez-Barrioluengo, M. (2017). External knowledge sourcing in the Spanish archaeological sector: Mapping the emergent stage of a business activity. *Revista Española de Documentación Científica, 40*(1), 1–14.
Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., & Krabel, S. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy, 42*(2), 423–442.
Petersohn, S., & Heinze, T. (2017). Professionalization of bibliometric research assessment. Insights from the history of the Leiden Centre for Science and Technology Studies (CWTS). *Science and Public Policy, 45*(4), 565–578.
Sarewitz, D. (2016). Saving science. *The New Atlantis, 49*, 4–40.
Sivertsen, G. (2017). Unique, but still best practice? The Research Excellence Framework (REF) from an international perspective. *Palgrave Communications, 3*, Article number: 17078. https://doi.org/10.1057/palcomms.2017.78
Sivertsen, G., & Meijer, I. (2020). Normal versus extraordinary societal impact: How to understand, evaluate, and improve research activities in their relations to society? *Research Evaluation, 29*(1), 66–70.
Spaapen, J., & van Drooge, L. (2011). Introducing 'productive interactions' in social impact assessment. *Research Evaluation, 20*(3), 211–218.
Temple, J. (1999). The new growth evidence. *Journal of Economic Literature, 37*(1), 112–156.
Van der Meulen, BJR, ., & Rip, A. (2000). Evaluation of societal quality of public sector research in the Netherlands. Research Evaluation*,* 8(1), 11–25.
Watermeyer, R., & Chubb, J. (2018). Evaluating 'impact' in the UK's Research Excellence Framework (REF): Liminality, looseness and new modalities of scholarly distinction. *Studies in Higher Education*. https://doi.org/10.1080/03075079.2018.1455082
Wilsdon, J. (2016). *The metric tide: Independent review of the role of metrics in research assessment and management*. SAGE.
Wróblewska, M. N. (2017). *Staging research impact. How academics write and talk about the wider impact of their research in the context of REF*. Paper presented to RESSH2017 - Research Evaluation in the Social Sciences and Humanities, Antwerpen, 6th–7th July 2017.

Part II
Organisational and Institutional Tensions in Public Knowledge Transfer

Chapter 5
The Policy Mix to Promote University-Industry Knowledge Transfer: A Conceptual Framework

José Guimón and Caroline Paunov

Abstract Countries deploy a variety of policy instruments to promote university-industry knowledge transfer. While these instruments are often discussed in isolation, they are implemented collectively and may reinforce and complement but also weaken or even negatively affect each other. This chapter presents a conceptual framework to map policy instruments for knowledge transfer and assess the interactions between them. Positive interactions occur, for example, when a new grant scheme to support spin-offs is accompanied by the adoption of more flexible regulations regarding the participation of university professors in firms, leading to a stronger combined impact. In contrast, negative interactions are associated with potential contradictions between policy instruments or with the coexistence of various policies targeting simultaneously the same types of actors, which increases complexity, creates confusion and results in higher administrative costs. The conceptual framework developed in this chapter also aims to explain how the choice of policy instruments is influenced by national contexts and broader international trends. This framework is a useful tool for those involved in the design and evaluation of university-industry knowledge transfer policies, while offering a broad point of departure for future research.

Keywords Policy-mix · Policy instrument · Knowledge transfer · Co-creation · Public research · Intermediary organizations · Evaluation · Interaction · Intellectual property · Collaboration · Spin-offs

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5.1 Introduction

With large public investment in research and mounting budgetary pressures, policy-makers have placed increasing emphasis on boosting the impact of these investments, specifically by building stronger university-industry links. The notion of knowledge transfer or exchange refers to relationships between universities and firms that are not unidirectional and linear but rather interactive and collaborative, as it is not only universities that are relevant to firms but also firms are an important source of knowledge for universities. What is more, the *co-creation* of knowledge where mixed teams of researchers from universities and industry engage in joint knowledge creation is increasingly recognised as important for strong innovation performance (De Silva & Rossi, 2018; Koschatzky & Stahlecker, 2016).

This chapter develops a conceptual framework to analyse the policy mix for knowledge transfer. We use the term "policy mix" to refer to the combination of policy instruments implemented to deliver public action in a specific policy domain and their interactions. The study was developed within the context of our work for the knowledge transfer project (2017–2018) of the Technology and Innovation Policy (TIP) Working Party of the Organization for Economic Cooperation and Development (OECD).[1]

In recent years, the policy mix concept has been widely adopted in innovation studies, following the influential contribution of Flanagan et al. (2011). Borrás and Edquist (2013) rely on the policy mix concept to discuss the critical issue of how to choose policy instruments in a specific territory and at a given point in time. Other authors have used the policy mix concept to assess the complex interplay between different levels of government in the field of innovation policy (Magro & Wilson, 2019). A central argument behind the literature on innovation policy mixes is that the prevailing focus on designing and evaluating individual instruments in isolation is problematic, because often several policy instruments simultaneously target the same types of actors and policy objectives (Cunningham et al., 2016) and "each new policy instrument will clearly interact with and affect existing policy instruments in a complex and often unpredictable manner" (Martin, 2016: p. 167). Along these lines, Rogge and Reichardt (2016) propose an analytical framework to evaluate policy mixes based on various characteristics such as consistency of its elements, coherence of processes, credibility and comprehensiveness.

Rather than considering the entire innovation policy mix, this chapter focuses on policies to promote knowledge transfer. As sketched in Fig. 5.1, the proposed conceptual framework entails *mapping* the different types of policy instruments and assessing the *interactions* between them. In the following section, we map policy instruments by classifying them according to different criteria, including: (i) whether they are financial, regulatory or soft instruments; (ii) whether they target primarily firms/industry, researchers or universities; (iii) the type of knowledge

[1] The full results of this Project, including various policy papers, workshop reports and national case studies, are available at: http://oe.cd/colab

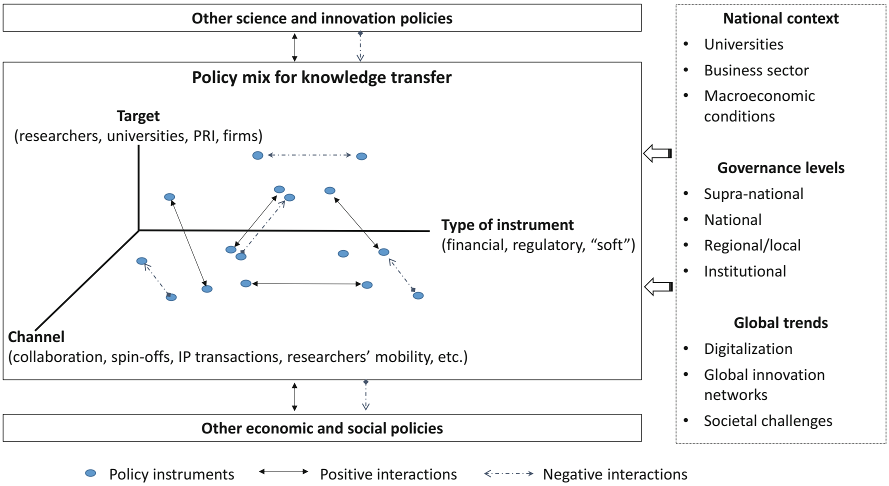

Fig. 5.1 Conceptual framework

transfer channels being addressed; and (iv) the instruments' supply- or demand-side orientation. In Sect. 5.3, we discuss the importance of taking into account the interactions (both positive and negative) between the policy instruments focussing on knowledge transfer. In addition, we acknowledge how the policy mix to promote knowledge transfer is also influenced by broader developments in a country's science, technology and innovation policies and by other policy domains such as labour market policies or financial regulations. Section 5.4 looks into the contextual factors that influence the policy mix, including national characteristics, multi-level governance arrangements, and global trends.

5.2 Mapping Policy Instruments

Table 5.1 presents the results of a mapping exercise of the main policy instruments available to support university-industry knowledge transfer, resulting in 21 different types of policy instruments. This taxonomy builds on the existing academic literature (useful reviews are provided in Bozeman, 2000 and Kochenkova et al., 2016), as well as on previous work of the OECD on knowledge transfer (e.g. OECD, 2013, 2017). Besides the distinction between financial, regulatory and soft instruments, other relevant criteria to classify policy instruments are the target groups, the main channel of knowledge transfer addressed, and whether the policy is a supply- or demand-side oriented instrument. In any case, this list does not constitute a final and closed inventory of policy instruments to promote knowledge transfer, as public policies in this as in other fields are subject to change. Moreover, the number of instruments could become shorter or longer depending on the level of granularity used for the taxonomy. An additional challenge in any attempt to classify policy

Table 5.1 A taxonomy of policy instruments to support knowledge transfer

	Brief description	Target groups	Main channels	Supply vs. demand
Financial instruments				
1. R&D and innovation subsidies or grants	Direct financing of collaborative projects, ranging from generic to mission-oriented calls, and from small-scale, challenge-driven competitions, to large consortia.	Researchers, Universities, Firms	Collaboration	Supply
2. Tax incentives	Tax credits for companies that engage in collaborative research or purchase services from universities.	Firms	Collaboration, contracts, consulting	Supply
3. Financial support to academic spin-offs	Including proof-of-concept, seed funds, business plan competitions, public venture capital, etc.	Researchers, Entrepreneurs	Spin-offs	Supply
4. Grants for IP applications	Covering the costs of registration in patent offices, to encourage researchers to disclose and commercialize their inventions.	Researchers	IP licencing	Supply
5. Financial support to recruit PhDs or post-docs	Financial support for firms to recruit PhDs or post-docs, covering part of the salary.	Firms, Researchers	Researchers' mobility	Supply
6. Financial support to host industry researchers	Financial support schemes for universities to host industry researchers temporarily.	Universities, Researchers	Researchers' mobility	Supply
7. Public procurement of technology	When firms are encouraged to collaborate with universities to develop innovative solutions.	Firms	Collaboration, contracts	Demand
8. Innovation vouchers	Small financial support for firms (especially SMEs) to purchase R&D services from certified researchers from universities.	Firms	Contracts, consulting	Demand

(continued)

Table 5.1 (continued)

	Brief description	Target groups	Main channels	Supply vs. demand
9. Public-private partnerships creating joint research laboratories	To create joint research centres co-funded by the public sector and a company. Sometimes called collaborative, co-created, or competence centres.	Universities, Firms	Collaboration	Demand, Supply
10. Performance-based funding systems	To reward linkages with industry, e.g. providing earmarked funding based on number of contracts with industry, IP licenses, spin-offs, etc.	Universities	Publications, spin-offs, IP licencing	Supply
11. Funding of infrastructures and intermediaries	Including technology transfer offices (TTOs), science parks, business incubators.	Universities	IP licencing, spin-offs, collaboration, networking	Demand, Supply
Regulatory instruments				
12. IP rights regime	Ownership of IP resulting from public-private research. Allocation of IP revenue from publicly funded research.	Researchers, Firms, Universities	IP licencing, spin-offs	Demand, Supply
13. Regulation of spin-offs founded by researchers and students	Conditions for university's involvement as shareholder, distribution of revenue, implications for academics' salaries, contractual possibilities for university staff to participate in spin-offs, etc.	Researchers, Universities	Spin-offs	Supply
14. Career rewards for professors and researchers	Rewards for mobilizing private research funds, earning income from IP licensing, creating spin-offs. Regulations can also facilitate industry financed chairs, as well as part-time positions for practitioners.	Researchers	All channels	Supply

(continued)

Table 5.1 (continued)

	Brief description	Target groups	Main channels	Supply vs. demand
15. Sabbaticals and mobility schemes	Regulations allowing sabbaticals for scientists to join industry and temporary recruitment of industry researchers.	Researchers, Universities	Researchers' mobility, spin-offs	Supply
16. Open access and open data provisions	Requirements to publish in open access results of publicly-funded research and to make the data freely available.	Researchers, Universities	Publications	Supply
Soft instruments				
17. Awareness-raising	Outreach activities to raise awareness, including information brochures and websites, conferences and seminars.	Universities, Firms	All channels	Demand, Supply
18. Training programmes	Training delivered by government agencies covering different aspects of knowledge transfer.	Researchers, TTO staff	All channels	Supply
19. Networking	Events, workshops, and fairs where firms can express their technology needs and scientists can present the results of their research.	Universities, Firms	Networking	Demand, Supply
20. Collective road-mapping and foresight exercises	Initiatives bringing together actors from business and academia to identify technological opportunities and priorities for future research.	Universities, Firms	Networking	Demand, Supply
21. Voluntary guidelines, standards and codes of conduct	Guidelines for the management of IP developed through collaborative projects; sample contracts for collaborative research, etc.	Universities, Firms	Collaboration, IP licencing	Demand, Supply

instruments is that they are subject to a high degree of "interpretive flexibility", because they carry "different meanings from time to time, place to place and actor to actor" (Flanagan et al., 2011: p. 706).

5.2.1 Nature of the Policy Instrument

Policies to promote university-industry knowledge transfer comprise a diverse mix of financial, regulatory and "soft" instruments, following the general classification used in Borrás and Edquist (2013). Financial instruments include different kinds of economic transfers from the state to firms or universities on the condition that they collaborate among each other. Regulatory instruments aim at providing incentives to the different parties involved in university-industry knowledge transfer, including laws affecting the careers of researchers, the funding of universities or the ownership of patent rights, among other relevant issues. Finally, "soft" instruments include less interventionist modes of public policy focussed on facilitating relationships, mobilizing, networking, integrating and building trust.

5.2.2 Target Groups

Policy instruments may target universities or firms. Public policies should provide incentives for both sides to collaborate, with the aim of attenuating barriers associated to transaction costs and misalignment of expectations (Bruneel et al., 2010). The target of policies may be set below the institutional level of universities or firms. For example, competitive funding schemes often target individual researchers, research groups or students. Policy programmes can also be targeted to certain types of firms (e.g. start-ups, SMEs, large firms, foreign multinationals, etc.) or universities (e.g. top ranked universities, polytechnics, research universities, universities in backward regions, etc.). Policy instruments may be generic or targeted to selected actors, industries or technologies. Some policy instruments target the whole population, as is the case of tax-based reliefs or IP rights schemes and different types of regulations. Others focus on selected researchers/universities and/or firms (as is the case with different grant schemes that only apply to those selected).

5.2.3 Policy Instruments and Different Channels of Knowledge Transfer

The circulation of knowledge between universities and firms does not occur only through formal channels (e.g. collaborative research, contract research, provision of specialised services, IP transactions, spin-offs, etc.) but also through informal channels (e.g. publications, conferences, networking, facility sharing, etc.) (Arza, 2010; Bekkers & Bodas Freitas, 2008). Acknowledging the variety of linkages is particularly important for public policy instruments to adequately support knowledge transfer and the diversity of its motivations, activities, and outcomes. Support for more formal linkages may have lower benefits than expected if informal linkages are weak and not supported. Formal channels can be more easily measured, but informal channels are equally important and are often a necessary condition to build up and maintain formal knowledge transfer interactions (Grimpe & Hussinger, 2013). Individual policy instruments may focus on a single channel of knowledge transfer or address several channels jointly. Conversely, a single channel of knowledge transfer can be promoted through a mix of financial, regulatory and soft policy instruments.

5.2.4 Supply- Versus Demand-Side Policy Instruments

A further distinction can be made between supply-side policies that focus on supporting firms and research centres in the generation of new knowledge that may eventually lead to new products and services, and demand-side policies, which focus on stimulating the demand for innovative products, thus providing incentives for firms to innovate by reducing risks (Guerzoni & Raiteri, 2015; OECD, 2011). In recent years, a shift towards a more demand-side focussed policy mix can be observed (OECD, 2016a). For example, Halme et al. (2019) discuss how Finland's policy mix has evolved from a more supply-driven approach towards a stronger focus on developing competences and incentives for demand or user-driven innovation activity, promoting public-private partnerships, increasing citizens' participation opportunities, and developing new co-operating models and platforms.

5.2.5 Other Categorisations

The time horizon of policy instruments, i.e. whether they are oriented to short-term linkages (setting up a first contact) or forming long-term linkages (long term collaborations in research) also differs across instruments. The need to invest over the long run in building effective linkages between universities and firms is increasingly recognised (Frølund et al., 2018). Other relevant attributes to consider when evaluating policy instruments are their flexibility (i.e. possibilities to adapt to specific cases where justified), stability (i.e. actors can rely on the instrument being available to them as specified), cost efficiency, and operational complexity.

5.3 Assessing the Interaction Between Policy Instruments

Beyond the *composition* of the policy mix, it is of paramount importance to assess the *interactions* between its elements. Different kinds of positive and negative interactions may arise when policy instruments are combined in a policy mix (Table 5.2). In recent years, the importance of carefully analysing these kinds of

Table 5.2 Types of interaction between policy instruments

Positive interactions	
Precondition	X is necessary in order to implement Y (i.e. the sequence by which policy instruments are introduced matters).
Facilitation	X increases the effectiveness of Y, but Y has no impact on X
Synergy	X increases the effectiveness of Y, and vice versa
Negative interactions	
Contradiction	X decreases the effectiveness of Y, and vice versa
Complexity	Using too many policy instruments results in confusion for target groups, operational difficulties, and increased administrative costs

interactions has been stressed in the broader literature on science and innovation policies (Cunningham et al., 2016; Flanagan et al., 2011; Martin, 2016).

5.3.1 Positive Interactions

The combination of several policy instruments may increase their individual impacts. Such positive interactions may occur in the form of precondition, facilitation or synergy. *Precondition* effects imply that, besides the combination of policy instruments, it is also important to consider the sequence whereby they are introduced. For instance, a precondition to the implementation of policy instruments that provide financial support to academic spinoffs is to ensure that university employment regulations do not act as a barrier. In Colombia, for example, following the introduction of new grants for spin-offs in 2010, it was later deemed necessary to remove regulatory barriers that impeded employees of public universities and research institutes to create a new company or hold a second post, leading to the enactment of a new law in 2017 (Botero et al., 2019). A more careful sequencing would have improved the impact of the policy mix.

Governments are increasingly aware of the importance of soft policy instruments given their *facilitation* effect over other financial and regulatory instruments to support knowledge transfer. For instance, several countries have complemented Bayh-Dole-type regulatory frameworks on the ownership of IP rights generated from publicly funded research and the distribution of revenues from commercialisation with "soft instruments" to facilitate implementation. In the UK, the so-called Lambert toolkit provides guidelines and model contracts for the management of IP in collaborative research projects between universities and industry. Likewise, in 2015 the Japanese government launched the "Guidelines for Intellectual Property Management in Government-commissioned Research and Development" to support the implementation of the Japanese version of the Bayh-Doyle Act dating back to 1999.

Finally, a *synergy* will occur, for example, when two different grant programmes offer funding for different activities or focus on different stages of the commercialization cycle. A single research project can benefit from being funded by different sources, with each source funding different elements (e.g. personnel, equipment, etc.) or simply because the amount needed for the whole project is higher than what a single source can provide. Obtaining funding from one source, even a small amount, may be used as a 'quality signal' to leverage funding from other private or public sources. For example, Lanahan and Feldman (2015) discuss how the Small Business Innovation Research (SBIR) programme, implemented by the US Federal Government since 1982, has benefited substantially from complementary outreach programmes and matching grants offered at State level. This case also illustrates the positive interactions of complementary policy instruments across different levels of government.

Scattered evidence from evaluation studies point to different possible synergies between policy instruments. Some have found that grants for collaborative R&D projects between universities and firms will result in more joint projects if combined with policies that promote exchange of post-graduate students to gain experience of project management in an industrial context (Cunningham & Gök, 2016). Similarly, the development of infrastructure and intermediary organizations for knowledge transfer (i.e. incubators, science parks, TTOs) has more impact if accompanied by other regulatory and financial instruments. For example, a recent review of innovation policies in Lithuania argued that the development of science parks is more efficient if combined with reforms in universities' regulations for technology transfer (OECD, 2016b). With regard to financial policy instruments, business incubators work better if accompanied by financial support to provide early stage funding for entrepreneurs, for example through public venture capital funds. This is especially important in laggard countries where the business environment is weak and financial markets are underdeveloped. In the absence of such complementary policies, science parks often become pure real estate ventures with unsustainable financials, as discussed in a World Bank review of university-industry collaboration in Sri Lanka (Larsen et al., 2016).

The combination of demand and supply side measures may also lead to synergies (Guerzoni & Raiteri, 2015). Moreover, Kivimaa and Kern (2016) have emphasized that policy mixes to address grand societal challenges (such as the transition to renewable energy) will be more efficient if support to the 'creation' of new technologies is combined with measures to facilitate structural change and shift consumer demand to new and more sustainable products.

In view of positive interactions, several policy instruments are often grouped together under one broader initiative or policy programme. For example, "cluster programmes" frequently group together several policy instruments to foster knowledge transfer, including financial support schemes to promote collaboration in innovation and soft instruments such as networking events, in addition to policy instruments belonging to other domains such as joint international promotion and export support.

5.3.2 Negative Interactions

Negative interactions between policy instruments for knowledge transfer also need consideration. For example, there might be a *contradiction* between policy initiatives that aim at providing incentives for inventors by enhancing the IP rights regime, and those that aim to foster knowledge sharing through open access and open data (Herstad et al., 2010). Moreover, policy instruments that focus on a specific channel of knowledge transfer may exert a negative effect over other alternative channels. For example, an excessive emphasis given to technology commercialisation through patent transactions can work in detriment of other modes of knowledge transfer such as R&D collaboration, contracting and two-way mobility of researchers, as suggested in a review of innovation policies in Malaysia (OECD, 2016c). Thus, it is important to seek for a balanced use of various policy instruments targeting alternative channels for knowledge transfer. More broadly, an increasing pressure on universities to foster commercialisation and industry engagement may create conflicts with the spheres of research and teaching, which calls for policy frameworks that enhance the integration of those three missions of universities (Laredo, 2007; Pinheiro et al., 2015). Besides the opportunity cost in terms of attention being diverted away from teaching and research, other potential risks that policy-makers should be aware of include the privatization of public research outputs and the unethical behaviour of researchers due to conflicts of interest (Arza, 2010).

In addition to contradictions between policy instruments, negative interactions can derive from the *complexity* of using too many instruments simultaneously. In particular, the coexistence of different financial instruments targeting simultaneously the same types of actors can create confusion and result in higher administrative costs. Moreover, when similar financial instruments are offered both by the national and the regional governments, this might lead to undesired situations where the same collaborative project is funded twice. The proliferation of public support programmes at different levels can lead to inconsistencies, bureaucratic and political conflict, and lack of consensus when setting priorities. More at the horizontal policy level, the challenge is that the responsibility for the design and implementation of public policies in support of knowledge transfer is often scattered across different ministries, notably, ministries of science and innovation, education, the economy, health as well as ministries of finance. This leads to complex systems of governance that require effective inter-ministerial co-ordination. In particular, the co-ordination between higher education and research policies is a frequent concern across many countries, as is the co-ordination of research and innovation policies (Borrás & Edquist, 2019).

Besides those multi-level governance issues, a key concern relates to the total number of policy instruments available and the overall complexity of the policy mix. Using too many policy instruments can lead to higher administrative costs for the government and confusion for target firms/universities. Indeed, the policy mix may improve by adding complementary policy instruments, but only up to a certain point (Braathen, 2007; OECD, 2010). The "policy layering" process (Howlett & Rayner,

2013) whereby new policy programmes tend to be piled on top of one another, often as a result of sequential changes in government, may lead to over-complex and incoherent policy mixes. For example, in view of the vast and complicated array of programmes in place to support business innovation, the Government of Canada announced in 2018 a major reform aimed at simplifying the policy mix by making it easier to navigate and more adapted to the needs of target firms. As a result, total overall funding for business innovation programming will increase, but the total number of business innovation programmes (currently 92), will be reduced by up to two-thirds.

Policy makers' choice of performance indicators to evaluate intermediary organizations (such as number of spin-offs, patent licencing contracts, research contracts, or joint research projects) can lead to undesirable effects if performance indicators are not well aligned with policy objectives or if indicators focus only on a few channels of knowledge transfer just because they are easier to measure (Russo et al., 2018). For example, Gulbrandsen and Rasmussen (2012) found that using the number of spin-offs as a performance indicator for technology transfer offices in Norway led to the adverse effect of pushing them to launch as many firms and as fast as possible, even if their survival chances were low. Other authors have warned that the frequent practice of evaluating TTOs based on the revenues they generate may slow down the dissemination of knowledge and inhibit other more open forms of knowledge transfer (Litan et al., 2007). Therefore, it is important to reflect further on how to design performance indicators that better align intermediary organizations with policy objectives.

5.3.3 Interactions with Other Policy Domains

Policies to promote knowledge transfer are a subset of a country's overall science and innovation policies. Thus, it is important to consider not only interactions between the policy instruments focussing on knowledge transfer, but also other science and innovation policy instruments that do not aim directly at promoting knowledge transfer are also important even if their influence is more indirect. For example, mission-oriented innovation policies, which are becoming increasingly popular around the world, have an influence over the specific technologies and industries where knowledge transfer will be prioritized. Similarly, at subnational level, the scope of knowledge transfer is strongly influenced by cluster policies and "smart specialization strategies".

Broader social and economic policies also shape the scope of knowledge transfer. These include all policies that affect what innovations are undertaken, including health, energy and environmental policies as they influence the demands for certain types of technologies (Caiazza, 2016). Policies that affect the business framework conditions are also important, in particular labour market policies, education and training policies, financial market regulations, competition policy, the international trade regime, etc. For example, labour market policies (such as the characteristics of work contracts and the regulation of unemployment and retirement benefits) influence the mobility of researchers, an important channel of knowledge transfer (Williamson & Allard, 2018). In particular, the need for more temporary mobility between research and industry and vice versa is often made difficult by the nature of labour contracts at research institutions which, in turn, are a reflection of general labour market contracts in the public sector (for countries where such contracts apply to researchers).

5.3.4 Implications for Policy Evaluations

These interactions suggest that, when it comes to evaluating the success of policy instruments, it is important to take into account the entire policy mix, as several policy instruments simultaneously target (or affect) the same actors, and thus observed outcomes are the result of the combined effect of several policies. So far, typical evaluations focus on individual policy instruments in isolation, without considering how different instruments interact within a policy mix (Borrás & Laatsit, 2019; Edler et al., 2012). Greater efforts are necessary to move towards evaluation methods that consider the combined effects of policy instruments, as well as potential redundancies, contradictions and remaining problems that could be addressed with new instruments (Edler et al., 2008; Magro & Wilson, 2013). This could be done by more systematic evaluations of entire policy mixes and by introducing, within the templates used to evaluate individual policy instruments, a specific section that focusses on their interaction with the broader policy mix.

At the time of introducing a new policy instrument, it is important to link up with existing policy mixes and implementation structures. An ex-ante evaluation of the policy mix may help improve policy design by avoiding negative interactions between policy instruments. For example, in Greece, at the time of launching a new public venture capital fund to promote spin-offs in 2017, concerns were expressed about the potential overlap with a programme providing direct grants for spin-offs, which had been in place since 2001. As a result, it was decided to fine-tune the eligibility criteria, so that the grant programme would focus on the earlier stages, and to delay the next call of the grant programme until the first results of the venture capital fund would be available (Spilioti et al., 2019).

5.4 Contextual Factors Affecting the Policy Mix

5.4.1 National Characteristics

Previous studies suggest that countries tend to use the same type of innovation policy instruments (e.g. Veugelers, 2015), which can be attributed to “policy diffusion” and peer learning (Knill, 2005; Stone, 2004). However, there are also significant differences across countries in the relative importance given to each type of policy (e.g. in terms of budget or number of initiatives) and in the detailed design or implementation of the policy instrument (e.g. in terms of target groups, eligibility criteria, time horizon, monitoring methods, etc.). Regarding knowledge transfer, countries facing similar problems might opt for different solutions given their different institutional and socioeconomic structures, including their level of socio-economic development, size, R&D intensity, and other structural and institutional factors (Lepori et al., 2007; Seppo et al., 2014). The following factors are particularly important when assessing a country's policy mix: (i) characteristics of the business sector; (ii) characteristics of universities; and (iii) macroeconomic conditions.

5.4.1.1 Characteristics of the Business Sector

Knowledge transfer depends on the characteristics of the country's business sector, specifically firms' size, sector of activity, technological capabilities, and ownership structure. First, the challenges faced by SMEs are different from those of larger firms. Informal channels of knowledge transfer (e.g. networking, facility sharing, on the job training, etc.) are often very important for those SMEs with limited capabilities to engage in more formal channels of collaboration, although SMEs are of course very diverse and also include dynamic technology-based start-ups. Second, the mechanisms for knowledge transfer in high tech industries are quite different from those in low tech industries and services (Bekkers & Bodas Freitas, 2008; Johnston & Huggins, 2017; Perkmann et al., 2013). Third, different policy approaches may be necessary to support knowledge transfer towards firms with weak technological capabilities. For example, innovation vouchers and technology extension services may be useful policy instruments to initiate a virtuous circle between the demand for innovation and the offer of innovative solutions in environments where there is a lack of formalised demand for innovation. Finally, the ownership characteristics of firms are also important to understand their innovative behaviour and the potential of different policy instruments to promote knowledge transfer. In particular, a better understanding of how foreign-owned multinational subsidiaries collaborate with universities in the host country may offer insights to shape knowledge transfer policies (Guimón & Salazar-Elena, 2015). The same applies to state-owned enterprises, the collaborative behaviour of which may be influenced more directly by government prescriptions (Tonurist, 2015).

5.4.1.2 Characteristics of Universities

Differences in the characteristics of universities should also be considered when analysing the policy mix for knowledge transfer. While there is a trend towards greater autonomy and increasing use of performance-based systems of public funding (Henkel, 2005; Hicks, 2012), the division of labour between different kinds of universities varies substantially across countries. Some countries, such as

Germany and Portugal, are characterized by institutional configurations where research universities (driven toward excellence but under mounting pressure to also produce useful research-based innovation) coexist with universities of applied research or 'polytechnics' (which engage in practice-based research and professional development, with close relationships with local communities and SMEs, in particular through innovation). Moreover, there tends to be a strong concentration of universities within countries, with many smaller universities and a few very large institutions that concentrate the bulk of academic research. The disciplinary structure of universities and their research quality are critical factors to understand the channels through which they link with industry (Paunov et al., 2017). Smaller and less research-intensive universities often rely on different channels for knowledge transfer, focusing less on patent transactions or joint research projects, and more on student entrepreneurship and informal networking. Governments should be sensitive to this heterogeneity when evaluating their policy mix to support knowledge transfer.

5.4.1.3 Macroeconomic Conditions

It is also necessary to consider the general macroeconomic conditions when analysing the policy mix, as these will influence the public resources available, the broad strategies of private firms, and the mobility of researchers. Given the long-term nature of innovation processes, a stable policy environment is invaluable, providing continuous public support independently of political and financial cycles. But this is a daunting challenge in many countries, particularly in the event of severe crises. For example, following a deep economic depression in recent years, Greece has faced challenges that affect knowledge transfer directly, such as the emigration of high-quality researchers, the rise of corporate taxes that affect entrepreneurship and the constraints to state support to innovation due to financial austerity measures (Spilioti et al., 2019). This has also been the case in other Southern European countries such as Italy, Portugal and Spain, leading to a growing divergence in innovation performance between advanced and catching-up European countries during the recent economic downturn (Azagra-Caro et al., 2019; Cruz-Castro & Sanz-Menéndez, 2016).

5.4.2 Multi-Level Governance

Different levels of governance intervene in designing and implementing policies to promote knowledge transfer, including the national, regional and supra-national levels. In addition to policies designed at national level, regional governments are becoming increasingly involved in knowledge transfer policies, as university-industry links are considered key drivers of regional development (Lanahan & Feldman, 2015; Magro & Wilson, 2019). Moreover, some policies developed at supra-national level also target knowledge transfer, complementing those developed at national or regional levels. The most evident case is the European Union, which encompasses various policy instruments to support knowledge transfer such as large funding schemes for collaborative research projects, mobility grants for researchers, support for entrepreneurship, knowledge and innovation communities, and support for industrial PhD programmes, among others. Likewise, the World Trade Organization has had a strong influence over national intellectual property rights regimes, through the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

Beyond the government level, policies to foster knowledge transfer are also designed and implemented at the institutional level (i.e. by universities and public research institutes themselves). Over the last decades universities have received more autonomy across the world (Borowiecki & Paunov, 2018; Henkel, 2005; Paradeise et al., 2009), allowing them to deploy their own support programmes for knowledge transfer, including specific grant schemes, incentives to researchers, and support for patenting, on top of those offered across the board by the national or regional governments. This allows for a wide variety of approaches to promote knowledge transfer across different universities.

Furthermore, governments rely on different kinds of "intermediary organizations" to implement knowledge transfer policies, including innovation agencies, technology transfer offices (TTOs), research and technology organizations, business incubators, etc. (Clayton et al., 2018; OECD, 2013). In particular, a growing number of TTOs have been developed across the world since the mid-1990s to support different stages of the commercialization cycle such as patent applications, invention disclosures, pilots and prototypes, establishing spin-off companies, contracts with industry, identifying business needs, searching for partners and funding sources, etc. (Geuna & Muscio, 2009). Intermediary organizations differ in their size, mission, activities, ownership, and funding structure (Cartaxo & Godinho, 2017; Russo et al., 2018; Schoen et al., 2014). Some are autonomous agencies tasked with promoting knowledge transfer and innovation more generally while others are established as units of a specific university, as is often the case of TTOs and science parks.

Recent contributions have also advocated for a stronger involvement of the civil society in research policy and technology transfer through 'citizen science' processes (Bonney et al., 2016) and for the adoption of flexible and open approaches to governance based on experimentation and learning (Kuhlmann et al., 2019).

5.4.3 Global Trends

Current global trends that influence the policy mix for knowledge transfer include the digital transformation, the spread of global innovation networks, and the increasing urgency to address grand societal challenges such as climate change.

5.4.3.1 Digital Transformation

The digital transformation is changing the way that economic interactions and business models are organised (Guellec & Paunov, 2018). New forms of open innovation have emerged including more intense collaborations between firms and universities than in the past, through new practices including online communities of experts, tournaments, open calls and crowdsourcing (Yoo et al., 2012; West & Lakhani, 2008). Digital platforms play an increasingly relevant role in disclosing technology and creating opportunities for universities and firms to identify potential partners, thereby increasing transparency and substantially reducing transaction costs. In addition, research results and data are becoming more easily (and freely) available through open data and open access practices, while the interactions of science and the civil society are being enhanced through open science. These developments influence the mechanisms for science-industry knowledge transfer and call for new policy approaches (OECD, 2019).

5.4.3.2 Global Research Networks

New policy strategies are emerging to benefit from the spread of global innovation networks. In particular, governments are increasingly aware of the importance of attracting multinationals' R&D centres, and for this purpose policies to support knowledge transfer needs to embrace a broad scope to ensure that the ecosystem is attractive not only for local players but also for foreign multinational enterprises (Belderbos et al., 2016; Thursby & Thursby, 2006). More recently, some countries have also launched dedicated programmes to attract international universities and public research institutes to establish new research centres locally in collaboration with national universities and firms (Guimón & Narula, 2019; Horta & Patrício, 2016). Similar to the case of incentives to attract foreign direct investments from multinational corporations that generate spillovers on local firms, the expectation is that attracting "world-class" universities or public research institutes will enhance the country's science base and improve science-industry links.

5.4.3.3 Grand Societal Challenges

Knowledge transfer is not an end in itself but an intermediate objective that contributes to better attaining the broader goals of science, innovation and, more generally, economic policies to promote more inclusive growth. By transforming scientific breakthroughs into new products and services, knowledge transfer may contribute to addressing more efficiently grand societal challenges such as climate change, public health, energy, food and water supply, etc. (OECD, 2016a; Trencher et al., 2013). Recent studies emphasize the transformative potential of innovation policies that set the direction of change through more ambitious interventions focussing on designated priority areas and societal challenges, where science-industry knowledge transfer can play a crucial role (Fagerberg, 2018; Kuhlmann & Rip, 2018; Mazzucato, 2011).

5.5 Conclusion

This chapter has developed a conceptual framework to analyse policy mixes for knowledge transfer by mapping policy instruments; assessing interactions between different policy instruments; and considering the influence of countries' structural conditions as well as global trends. The combination of several policy instruments may create synergies but may also reduce the success of individual instruments. To attain maximum synergies and avoid negative interactions, existing policy instruments should be mapped and the implications of different combinations of policy instruments evaluated. This requires moving away from evaluating the impact of single instruments in isolation. Broader evaluations will be valuable at the moment of deciding whether and, if so, how to introduce new policy instruments to the existing policy mix.

In any case, it needs to be stressed that the choice of a policy mix is not the simple outcome of one-off optimization decisions subject to a budget constraint, because the cost-benefit structure of different combinations of policy instruments is highly uncertain and context-specific. Moreover, policy mixes develop incrementally over many years as path-dependent outcomes influenced by previous policy choices and by different interest groups (Howlett & Rayner, 2013). Thus, policy mixes reflect complex social relations, changing rationales, and historical dynamics of government intervention. As such, any attempt to search for the optimal policy mix would be out of place.

References

Arza, V. (2010). Channels, benefits and risks of public-private interactions for knowledge transfer: Conceptual framework inspired by Latin America. *Science and Public Policy, 37*(7), 473–484.

Azagra-Caro, J. M., Tijssen, R. J., Tur, E. M., & Yegros-Yegros, A. (2019). University-industry scientific production and the Great Recession. *Technological Forecasting and Social Change, 139*, 210–220.

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

Belderbos, R., Sleuwaegen, L., Somers, D., & De Backer, K. (2016). Where to locate innovative activities in global value chains: does co-location matter? *OECD Science, Technology and Industry Policy Papers*, No. 30.

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2–16.

Borowiecki, M., & Paunov, C. (2018). How is research policy across the OECD organised? Insights from a new policy database. *OECD Science, Technology and Industry Policy Papers*, No. 55, OECD Publishing, Paris.

Borrás, S., & Edquist, C. (2019). *Holistic innovation policy: Theoretical foundations, policy problems, and instrument choices*. Oxford University Press.

Borrás, S., & Edquist, C. (2013). The choice of innovation policy instruments. *Technological Forecasting and Social Change, 80*(8), 1513–1522.

Borrás, S., & Laatsit, M. (2019). Towards system oriented innovation policy evaluation? Evidence from EU28 member states. *Research Policy, 48*(1), 312–321.

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

Botero, M., Sánchez, A. E., & Pontón, J. (2019). *Technology transfer in Colombia*. Case study produced for the OECD TIP Knowledge Transfer Project. https://oe.cd/2xx

Braathen, N. A. (2007). Instrument mixes for environmental policy: How many stones should be used to kill a bird? *International Review of Environmental and Resource Economics, 1*(2), 185–235.

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

Caiazza, R. (2016). A cross-national analysis of policies affecting innovation diffusion. *Journal of Technology Transfer, 41*(6), 1406–1419.

Cartaxo, R. M., & Godinho, M. M. (2017). How institutional nature and available resources determine the performance of technology transfer offices. *Industry and Innovation, 24*(7), 713–734.

Clayton, P., Feldman, M., & Lowe, N. (2018). Behind the scenes: Intermediary organizations that facilitate science commercialization through entrepreneurship. *Academy of Management Perspectives, 32*(1), 104–124.

Cruz-Castro, L., & Sanz-Menéndez, L. (2016). The effects of the economic crisis on public research: Spanish budgetary policies and research organizations. *Technological Forecasting and Social Change, 113*, 157–167.

Cunningham, P., Edler, J., Flanagan, K., & Larédo, P. (2016). The innovation policy mix. In J. Edler et al. (Eds.), *Handbook of innovation policy impact* (pp. 505–542). Edward Elgar.

Cunningham, P., & Gök, A. (2016). The impact of innovation policy schemes for collaboration. In J. Edler et al. (Eds.), *Handbook of innovation policy impact* (pp. 239–278). Edward Elgar.

De Silva, M., & Rossi, F. (2018). The effect of firms' relational capabilities on knowledge acquisition and co-creation with universities. *Technological Forecasting and Social Change, 133*, 72–84.

Edler, J., Berger, M., Dinges, M., & Gök, A. (2012). The practice of evaluation in innovation policy in Europe. *Research Evaluation, 21*(3), 167–182.

Edler, J., Ebersberger, B., & Lo, V. (2008). Improving policy understanding by means of secondary analyses of policy evaluation. *Research Evaluation, 17*(3), 175–186.

Fagerberg, J. (2018). Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy. *Research Policy, 47*(9), 1568–1576.

Flanagan, K., Uyarra, E., & Laranja, M. (2011). Reconceptualising the "policy mix" for innovation. *Research Policy, 40*(5), 702–713.

Frølund, L., Murray, F., & Riedel, M. (2018). Developing successful strategic partnerships with universities. *MIT Sloan Management Review, Winter Issue*, 71–79.

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

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

Guellec, D., & Paunov, C. (2018). Innovation policies in the digital age. In *OECD science, technology and industry policy papers, 59*. OCDE Publishing.

Guerzoni, M., & Raiteri, E. (2015). Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix. *Research Policy, 44*(3), 726–747.

Guimón, J., & Narula, R. (2019). When developing countries meet transnational universities: Searching for complementarity and dealing with dual embeddedness. *Journal of Studies in International Education, 24*(3), 314–336. https://doi.org/10.1177/1028315319835536

Guimón, J., & Salazar-Elena, J. C. (2015). Collaboration in innovation between foreign subsidiaries and local universities: Evidence from Spain. *Industry and Innovation, 22*(6), 445–466.

Gulbrandsen, M., & Rasmussen, E. (2012). The use and development of indicators for the commercialisation of university research in a national support programme. *Technology Analysis & Strategic Management, 24*(5), 481–495.

Halme, K. et al. (2019). *Overview of the policy mix for science-industry knowledge transfer in Finland*, Case study produced for the OECD TIP Knowledge Transfer Project. https://oe.cd/2xx

Henkel, M. (2005). Academic identity and autonomy in a changing policy environment. *Higher Education, 49*(1–2), 155–176.

Herstad, S. J., Bloch, C., Ebersberger, B., & Van De Velde, E. (2010). National innovation policy and global open innovation: Exploring balances, tradeoffs and complementarities. *Science and Public Policy, 37*(2), 113–124.

Hicks, D. (2012). Performance-based university research funding systems. *Research Policy, 41*(2), 251–261.

Horta, H., & Patrício, M. T. (2016). Setting-up an international science partnership program: A case study between Portuguese and US research universities. *Technological Forecasting and Social Change, 113*, 230–239.

Howlett, M., & Rayner, J. (2013). Patching vs packaging in policy formulation: Assessing policy portfolio design. *Politics and Governance, 1*(2), 170–182.

Johnston, A., & Huggins, R. (2017). University-industry links and the determinants of their spatial scope: A study of the knowledge intensive business services sector. *Papers in Regional Science, 96*(2), 247–260.

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy, 45*(1), 205–217.

Knill, C. (2005). Cross-national policy convergence: Concepts, approaches and explanatory factors. *Journal of European Public Policy, 12*(5), 764–774.

Kochenkova, A., Grimaldi, R., & Munari, F. (2016). Public policy measures in support of knowledge transfer activities: A review of academic literature. *The Journal of Technology Transfer, 41*(3), 407–429.

Koschatzky, K., & Stahlecker, T. (2016). *Public-private partnerships in research and innovation: Trends and international perspectives*. Fraunhofer Verlag.

Kuhlmann, S., & Rip, A. (2018). Next-generation innovation policy and grand challenges. *Science and Public Policy, 45*(4), 448–454.

Kuhlmann, S., Stegmaier, P., & Konrad, K. (2019). The tentative governance of emerging science and technology—A conceptual introduction. *Research Policy, 48*(5), 1091–1097.

Lanahan, L., & Feldman, M. P. (2015). Multilevel innovation policy mix: A closer look at state policies that augment the federal SBIR program. *Research Policy, 44*(7), 1387–1402.

Laredo, P. (2007). Revisiting the third mission of universities: Toward a renewed categorization of university activities? *Higher Education Policy, 20*(4), 441–456.

Larsen, K., Bandara, D. C., Esham, M., & Unantenne, R. (2016). *Promoting university-industry collaboration in Sri Lanka: Status, case studies, and policy options*. World Bank.

Lepori, B., Van den Besselaar, P., Dinges, M., Potì, B., Reale, E., Slipersæter, S., Thèves, J., & Van der Meulen, B. (2007). Comparing the evolution of national research policies: What patterns of change? *Science and Public Policy, 34*(6), 372–388.

Litan, R. E., Mitchell, L., & Reedy, E. J. (2007). Commercializing university innovations: Alternative approaches. *Innovation Policy and the Economy, 8*, 31–57.

Magro, E., & Wilson, J. R. (2019). Policy-mix evaluation: Governance challenges from new place-based innovation policies. *Research Policy, 48*(10), 1–10.

Magro, E., & Wilson, J. R. (2013). Complex innovation policy systems: Towards an evaluation mix. *Research Policy, 42*(9), 1647–1656.

Mazzucato, M. (2011). *The entrepreneurial state*. Penguin.

Martin, B. R. (2016). R&D policy instruments – a critical review of what we do and don't know. *Industry and Innovation, 23*(2), 157–176.

OECD. (2019). *Seizing the opportunities for digital innovation: Options for innovation policy*. OECD Publishing.

OECD. (2016a). *OECD science, technology and innovation outlook 2016*. OECD Publishing.

OECD. (2016b). *OECD reviews of innovation policy: Lithuania 2016*. OECD Publishing.

OECD. (2016c). *OECD reviews of innovation policy: Malaysia 2016*. OECD Publishing.

OECD. (2013). *Commercialising public research: New trends and strategies*. OECD Publishing.

OECD. (2011). *Demand side innovation policy: Theory and practice in OECD countries*. Organization for Economic Cooperation and Development.

OECD. (2010). The innovation policy mix. In *OECD science, technology and industry outlook 2010*. OECD Publishing.

OECD. (2017). *Knowledge triangle synthesis report: Enhancing the contributions of higher education and research to innovation.* OECD Publishing, Paris.

Paradeise, C., Reale, E., Bleiklie, I., & Ferlie, E. (2009). *University governance. Western European comparative perspectives*. Springer.

Paunov, C., Planes-Satorra, S., & Moriguchi, T. (2017). What role for social sciences in innovation? Reassessing how scientific disciplines contribute to different industries. *OECD Science, Technology and Industry Policy Papers*, 45. OECD Publishing, Paris.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., et al. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy, 42*(2), 423–442.

Pinheiro, R., Langa, P. V., & Pausits, A. (2015). The institutionalization of universities' third mission: Introduction to the special issue. *European Journal of Higher Education, 5*(3), 227–232.

Rogge, K. S., & Reichardt, K. (2016). Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Research Policy, 45*(8), 1620–1635.

Russo, M., Caloffi, A., Rossi, F., & Righi, R. (2018). Innovation intermediaries and performance-based incentives: A case study of regional innovation poles. *Science and Public Policy, 46*(1), 1–12.

Seppo, M., Rõigas, K., & Varblane, U. (2014). Governmental support measures for university-industry cooperation-comparative view in Europe. *Journal of the Knowledge Economy, 5*(2), 388–408.

Schoen, A., de la Potterie, B. V. P., & Henkel, J. (2014). Governance typology of universities' technology transfer processes. *The Journal of Technology Transfer, 39*(3), 435–453.

Spilioti, A., Gongolidis, V., & Gypakis, A. (2019). *Supporting the establishment and development of spin-offs, Greece*. Case study produced for the TIP Knowledge Transfer Project. https://oe.cd/2xx

Stone, D. (2004). Transfer agents and global networks in the 'transnationalization' of policy. *Journal of European Public Policy, 11*(3), 545–566.

Thursby, J., & Thursby, M. (2006). Where is the new science in corporate R&D? *Science, 314*, 1547–1548.

Tonurist, P. (2015). Framework for analysing the role of state owned enterprises in innovation policy management: The case of energy technologies and Eesti Energia. *Technovation, 38*, 1–14.

Trencher, G., Yarime, M., McCormick, K. B., Doll, C. N., & Kraines, S. B. (2013). Beyond the third mission: Exploring the emerging university function of co-creation for sustainability. *Science and Public Policy, 41*(2), 151–179.

Veugelers, R. (2015). *Mixing and matching research and innovation policies in EU countries*. Bruegel Working Paper 2015/16.
West, J., & Lakhani, K. R. (2008). Getting clear about communities in open innovation. *Industry and Innovation, 15*(2), 223–231.
Williamson, C., & Allard, G. (2018). University – Industry collaboration in R&D: The role of labor market rigidity. *R&D Management, 48*(4), 410–421.
Yoo, Y., Boland, R. J., Jr., Lyytinen, K., & Majchrzak, A. (2012). Organizing for innovation in the digitized world. *Organization Science, 23*(5), 1398–1408.

Chapter 6
Determinants of Contract Renewals in University–Industry Contract Research: Going my Way, or Good Sam?

Tohru Yoshioka-Kobayashi and Makiko Takahashi

Abstract Long-term university–industry contract research benefits both universities and the industry, as it can potentially reduce transaction costs and improve the quality of such collaborations. Nevertheless, trade-offs between the advantages and disadvantages of long-term contracts motivate firms to enter stage-gate contracts (i.e., a shorter contract period with an expectation of renewal or extension) to avoid uncertainty over collaboration's performance. This study addresses two less understood questions in the contract renewal or extension decision: longitudinal changes in the strength of the commitment to the collaboration and the determinants of renewals. We empirically test these issues with 1562 research contracts from a leading Japanese university, and we match this database to a questionnaire survey results obtained from its industrial counterparts. Our empirical test identified an inverse-U-shaped effect on the degree of commitment in the time elapsed since the first research contract. We also found that firms are more likely to renew or extend a contract when they perceive technological knowledge learning or co-publish an academic paper. Our findings suggest that university–industry contract research focused on academic research-related activities (or academic researcher's "going my way") is likely to establish long-term collaborations.

Keywords Contract research · Contract renewal · University–industry collaboration

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6.1 Introduction

Managing university–industry linkages is an essential topic in national and regional science and technology policy as well as in organizational management and open innovation contexts. A multitude of research studies address the determinants of successful collaboration, such as the alignment of motivations for interactions (Morandi, 2013), the formation of mutual personal trust (Santoro & Saparito, 2006; Plewa & Quester, 2006), and the management of pervasive uncertainty (Morandi, 2013; Petruzzelli, 2011). Nonetheless, no universally applicable determinants have emerged, because of the diversity of interaction modes.

Following a framework developed by D'Este et al. (2019), which characterizes a university–industry interaction, we can systematically identify and understand multiple determinants. The framework differentiates relational arrangements from transactional arrangements—the former referring to a personally based relationship, with frequent communication, and the latter corresponding to relationships that do not include frequent personal interactions, such as patent licensing. Relational arrangements are a major aspect of university–industry collaborations (Bodas Freitas et al., 2013). Interactions in this relational arrangement inexorably require mutual trust between individuals from both the industry and university levels (Bruneel et al., 2010; Bstieler et al., 2015; Santoro & Saparito, 2006). Without trust, both parties are not likely to openly share information (Plewa et al., 2013).

A key factor of trust formation is long-term linkage (Bruneel et al., 2010; Garcia et al., 2020). Shared vocabularies and reduced communicational barriers stimulate necessary information sharing and such reciprocal communication enhances the formation of trust (Bstieler et al., 2015), which subsequently increases the frequency and efficiency of personal communication. Furthermore, a long-term linkage reduces the transaction costs associated with interorganizational communication (Weckowska, 2015), allowing both parties to establish flexible modification in the collaborative arrangement as needed. Accordingly, such longitudinal linkages not only demonstrate superior academic productivity in contrast to short-term collaborative research and development (R&D) activities (Bstieler et al., 2015; Garcia et al., 2020) but also have the potential to elicit innovation based on radical scientific discoveries (Motoyama, 2014). Consequently, in many cases, both academia and industry prefer to develop long and stable collaborative arrangements (Ankrah et al., 2013).

Long-term collaborative arrangements are often associated with multiple reciprocal outcomes. One of the main outcomes of longitudinal joint R&D projects is that both parties gain additional benefits beyond R&D results. Academic scholars benefit from the learning opportunities available through engaging in industry research and receiving feedback from industry collaborators (Perkmann & Walsh, 2007; D'Este & Perkmann, 2011; Landry et al., 2010). This can result in the publication of academic papers that are co-authored with industry colleagues (Tijssen et al., 2009; Yegros-Yegros et al., 2016). Collaborating industry firms foster the development of technological capabilities (Bishop et al., 2011; Ankrah et al., 2013) and social capital with academia (Hagedoorn et al., 2000), while sustaining continuous access to the latest scientific knowledge. Most of these benefits emerge from frequent, trust-based communication between industry and academia (Petruzzelli, 2011; D'Este et al., 2019).

Nevertheless, formal contracts are associated with the necessity of management. The establishment of a long-term research contract is equivalent to a request for both parties to tolerate uncertainties regarding the potential outcomes to be obtained and the indeterminate performance-outcome effectiveness of a linkage (e.g., Perkmann et al., 2011). As firms generally endeavour to prevent uncertain investment, contractual arrangements that reduce risks from uncertainties are often sought. A stage-gate contract is one such solution. This contractual arrangement establishes phased-reviews and subsequent contract renewals (i.e., new contract arrangements between the same parties to continue joint research) or extensions (i.e., an extension of contract terms and/or increased budgets or monetary contributions) to balance the reduction of uncertainty and the continuation of long-term interactions. Many firms employ such arrangements in R&D outsourcing (Wang et al., 2018), and some scholars have also recommended this approach in university–industry collaborations (Starbuck, 2001; Jelinek & Markham, 2007). Although no data currently exist supporting the efficacy of the actual use of stage-gate contracts in university–industry collaborations, Garcia et al. (2020) provide indirect evidence. Among collaborative research between industry and Spanish academic researchers, only 38% establish contracts lasting for more than 1 year. This proportion seems to be low, considering the nature of contract research, which often involves research with open-ended goals. We can assume that the wide use of stage-gate contracts simplifies the termination of underperforming university–industry interactions when necessary.

Even when establishing a long-term relationship, using stage-gate contracts as an effective approach, both industry liaison officers and academic researchers engaged in the interaction face two puzzles. First, at the beginning of the interaction, they cannot estimate how long the relationship will be maintained, as it is unreasonable to expect a long-lasting commitment to interaction. We can assume that firms increase their commitment to a renewed collaborative relationship in the first couple of years and potentially decrease after that. If they can determine general trends in the strength of commitment, both industry and research institutions will be better able to predict how long a relationship will be maintained. Second, it is difficult to estimate the probability of a contract renewal in the beginning of a collaboration, as the determinants of continuity remain even less understood. Although Perkmann et al. (2011) clarify multiple performance measurements for firms, we do not fully know how these measurements are actually considered. R&D managers and policymakers occasionally emphasize the assimilation of academic researchers in the industry context. To maintain long-term collaboration, which actions should an academic researcher take: assimilation into the industry, behaviour as a helpful partner ("a good Sam"), or maintenance of their academic principles ("going my way")?

Long-term university–industry relationships are often desirable; however, little is known about how these long-term relationships form or evolve. We examine these processes by studying both contract renewals and extensions. To our knowledge, this has never been done previously in such a systematic manner. Using research contract data from an anonymous Japanese university, covering contract research entered into from 2005 to 2014 (approximately 500 contracts per year) and ultimately yielding 1562 research contracts, this paper examines two critical issues of university–industry contract research: time-dependent changes in the strength of commitment and the determinants of continuity. The main contributions are empirical evidence of contract renewals and related managerial insights.

The remainder of this paper is organized to present a literature review and attending hypotheses in Sect. 6.2, followed by an overview of the methodology employed for the study in Sect. 6.3. Section 6.4 describes the detailed results of the study, and Sects. 6.5 and 6.6 offer a discussion of the results and research conclusions.

6.2 Literature Review and Hypotheses

6.2.1 Strength of Interaction Commitment and Contract Length

Two perspectives encompass the trade-offs of long-term interaction. From a resource development perspective, the time duration of interactions is linearly beneficial. Long-term interaction is associated with greater communication and mutual trust (Bruneel et al., 2010; Garcia et al., 2019). Heightened trust increases the expectations for collaborative research outputs, and strengthens counterparties' commitment to the focal interaction, characterized by the willingness to engage in a two-way collaborative process that complies with the goals of both partners (Frasquet et al., 2012; Lauvas & Steinmo, 2019). In contrast, from a resource exchange perspective, different consequences are expected of the duration. Time in collaboration develops shared vison, norms, and language (Al-Tabbaa & Ankrah, 2016; Dingler & Enkel, 2016), which stimulate the efficient and effective exchange of knowledge (Galan-Muros & Plewa, 2016). However, over time, these shared normative and behavioural elements tend to construct rigid routines to facilitate now-familiar knowledge patterns of exchange and act to filter out novel ideas (Zheng & Yang, 2015). Long-term linkages run the risk of drifting into exploitation at the expense of exploration (Koza & Lewin, 1998). This is an undesirable consequence for firms, as they often use university–industry linkages as a measure for exploration (Perkmann et al., 2011). In other words, longitudinal collaborations are often effective for an exchange of specific knowledge, but are not considered favourable to the advancement of continuous learning from counterparts. The resource exchange perspective implies a nonlinear effect of time. Combining different consequences from two perspectives, we can assume that the length of collaboration exerts an inverse-U-shaped effect on commitment.

This assumption is supported by several points of collateral evidence. In a simulation study, the value of R&D collaboration hits a peak of around 2–4 years because of an accompanying saturation of learning (Katz & Allen, 1982). Im and Rai's (2008) university–industry collaboration study also demonstrates that some firms do not prefer lengthy interactions. Another study indicates that lengthy university–industry interactions actually decrease academic productivity (Banal-Estañol et al., 2015). These studies are consistent with the implied consequences of our argument above, leading to the following hypothesis:

Hypothesis 1 Renewed or extended contracts are associated with greater commitment, which is saturated by the time length of past collaborations.

6.2.2 The Determinants of Contract Renewals or Extensions of Research Contracts

The above hypothesis only relates to renewed or extended contracts. Before a renewal or extension, a firm makes a "Continue or Not" decision. The essence of a stage-gate contract, (i.e., performance based-evaluation of the collaboration), indicates how an intermediate outcome is important for such a decision. In evaluating a tentative outcome, a firm can estimate performance-outcome effectiveness. This approach can be applied to every type of personal-based university–industry research contract other than staged contracts. Scholarly works on both university–industry contract research and research consortia among firms imply that such a tentative outcome directly affects the perceptions of the performance-outcome effectiveness of a collaboration or constitutes an essential part of experiential learning (Ebers & Maurer, 2016).

Experiential learning is important in collaboration, and is accompanied by specific uncertainties. Firms often interpret projects' performance based on the actual experience of the project in reference to further resource allocation decisions (Schwab & Miner, 2008). Ebers and Maurer (2016) found that satisfaction with the outcomes of a previous collaboration is an excellent sign of experiential learning on performance-outcome effectiveness and subsequently increases the likelihood of the collaboration continuing. Although their study does not include research collaborations, its theoretical contribution can be applied in the context of university–industry R&D collaboration. As argued above, firms often have great concern with effectiveness. Satisfaction with outcomes directly indicates the dissolution of this concern. Hence, it will increase the probability of a continuity decision. Hypothesis 2 follows this line of thought:

Hypothesis 2 Satisfaction with the outcome obtained is positively related to the renewal or extension of a collaboration.

Nevertheless, from a resource exchange perspective, we expect that firms are less likely to repeat a collaboration when faced with doubt regarding a future outcome. Considering the heterogeneity of outcomes, we suspect that some types of outcomes may result in the suspension of additional collaboration because of their unrepeatability or future constraints.

Before debating the different outcome influences, we need to investigate the established typology of contract research outcomes. Following the work of Perkmann et al. (2011), from the industry perspective, outcomes can be classified into outputs and impact. Outputs include new technologies, new scientific knowledge, and skilled and trained staff. Impact corresponds to innovative ideas for products or services, new solution concepts (i.e., architectures or designs representing solutions to particular problems), improvements of ongoing R&D programs, and human capital development (i.e., the recruitment of staff from the university, and building network capital). Outputs are a direct achievement of collaboration, but do not always generate any direct business impact. Impact, conversely, potentially contributes to the business directly.

In terms of outputs, all of them support the technological capability development of firms. As more prolonged collaborations develop absorptive capacity, which stimulates knowledge exchange and subsequent mutual learning (Schildt et al., 2012), once firms perceive some extent of technological capability development through focal contract research, renewals become a reasonable option. New technologies, new scientific knowledge, and staff skills and training are regarded as positive intermediate outputs for a continuation.

In this regard, Perkmann et al. (2011) emphasize explicit outputs, such as patents or publications, as their measurements. We differentiate explicit and implicit outputs, in consideration of the inherent opportunistic behaviour of firms. When firms recognize improved capabilities, they may engage their bargaining power to maintain such interactions informally (Hamel, 1991). Particularly, clear evidence of capability development may negatively affect the maintenance of formal interactions, as firms can internally improve and build on the knowledge acquired (Olk & Young, 1997). In the university–industry collaborative research context, co-authored papers, patent filings, or valuable data acquisitions are explicit signals of technological capability development. This may result in a decreased probability of continuation.

Meanwhile, staff skills and training are related to a different constraint that derives from rational organizational decisions. A human resource management study asserts a necessity of justification for scarce resource allocation (Swanson, 2001). When firms aim at training incumbent R&D personnel, they face a challenge to continue the allocation of previously developed human resources to the contract research, as R&D personnel are often scarce human resources for a firm. Alternatively, allocated personnel can be replaced on a collaborative project, but such a replacement is inconsistent with the development and positive outcomes of personal-based relationship. Thus, we can assume that staff skill development is negatively related to contract continuation.

From the same perspective, we assume that similar trade-offs emerge in some types of impact, including new ideas for products or services, new concepts for solutions, or improvements to ongoing R&D programs seem to face similar trade-offs. The internal justification for further formal resource allocation to the collaboration may be diminished for firms because they have already achieved impact and academic researchers are generally not suitable partners for the downstream product or service development process (e.g., Vohora et al., 2004).

Network capital development is an aspect that is distinctive from others. Particularly under the increasing recognition of the development of social networks as one of the drivers of innovation when firms collaborate with academic researchers (Steinmo & Rasmussen, 2018), firms expect future knowledge acquisitions and human resource development through the social network developed with academic researchers. Considering the personal nature of university–industry collaborations, which are sustained for a long period (De Fuentes & Dutrénit, 2012), maintaining a formal relationship is an effective way to strengthen personal connections.

The arguments above do not lead to clear hypotheses regarding the influence of specific kinds of outcomes. Nevertheless, we can at least expect that each type of outcome has a potentially heterogeneous influence on decisions concerning renewal or extension. Some outcomes will positively increase the probability of renewal or extension, while others will not. Hypothesis 3 endeavours to accurately capture this question.

Hypothesis 3 Types of outcomes obtained are related to the renewal or extension of the collaboration.

6.3 Methodology

6.3.1 Dataset

Our examination used a research contract database from an anonymous Japanese university, a leading research university that conducts approximately 500 research projects in collaboration with the industry sector annually. The database covers the university's contract research entered into from 2005 to 2014. The data for each contract include the research budget, names of the principal investigators (PIs) and counterpart firms, contract start and end dates, and extended contract end date (if any). An advantage of these Japanese data is its volume. Multiple incentives since the early 2000s have compelled academic researchers to sign formal contracts, rather than collaborating through traditional informal channels (Kameo, 2015).

We identified contract renewals by aggregating contracts that shared the same PI and counterpart-firm pairs, calling a set of contracts *a project*. This method simplifies the university–industry connection as the relationship between an individual academic researcher and a specific firm. We distinguish contract renewals from contract extensions (see Fig. 6.1), as such research budget allocations are fundamentally

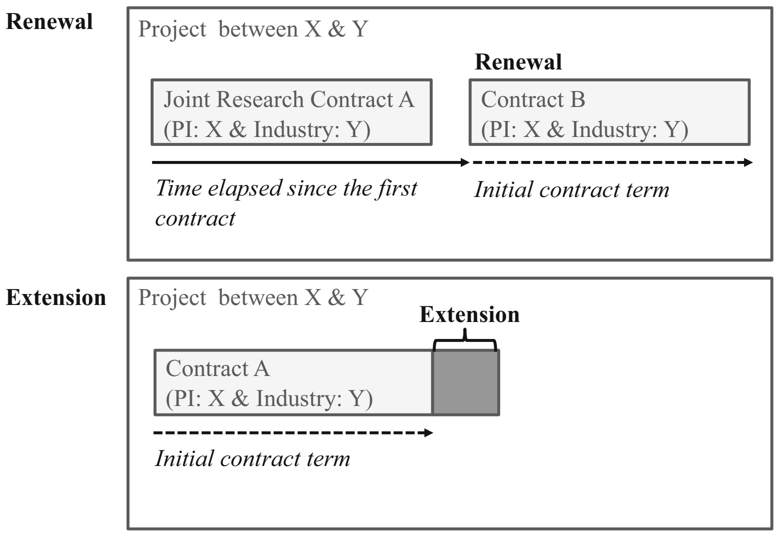

Fig. 6.1 Definitions of contract renewals and extensions

Table 6.1 Descriptive statistics of contract research in our observation (2005–2014)

Term	Individual contracts		Projects: Aggregated by PI–firm pairs	
1 year and less	3894	(75.7%)	1513	(53.4%)
2 years	634	(12.3%)	710	(25.0%)
3–4 years	426	(8.3%)	426	(15.0%)
5–7 years	157	(3.1%)	155	(5.5%)
8–years	35	(0.7%)	31	(1.1%)
Average term	1.32	Years	1.96	Years

different. Considering the freedom of contracts, as previously argued, some extensions are assumed to be substantially equal to a contract renewal. However, in our dataset, only 4% of extended research contracts received significantly large amounts of additional budget (more than 50% of the initial budget). Thus, we maintain the formal distinction between renewals and extensions in our tests.

Table 6.1 displays the descriptive statistics of the contract terms in our dataset. When we aggregate contracts and calculate the duration between the first contract start date and the final contract end date, we find that 46.6% of contract research projects were maintained for more than 1 year. The average contract term of a project reveals a 1.96-year average, 49% longer than the average term of an individual contract.

As the projects in our operationalization have a truncation bias, our examination limited data from 2008 to 2011, to ensure sufficient time intervals. Furthermore, PIs' moves to other institutions generate another truncation bias, and thus, we excluded all data that included principal researchers who transferred to other institutions before 2013. Finally, we omitted contracts led by non-teaching staff, such as

Table 6.2 Comparisons of our two sets of samples

	Full sample (2008–2011)	Subset sample (2008, 2011)
Number of contracts	1562	137
Average contract terms (years)	1.31	1.35
Average budgets (million JPY)	2.98	2.92
Renewed or extended	61%	66%
Departments of PIs		
Medical/pharmaceutical	15%	13%
Biology/other medical	4%	7%
Science/engineering	79%	77%
Humanities/social sciences	2%	2%

technicians, medical doctors, and visiting professors, as some of these projects are too heterogeneous. The final number of observations in our sample is 1562 research contracts.

We also linked questionnaire survey results with the database, as the questionnaire covers collaborations' initial purposes and tentative or final outcomes. The technology licensing office conducts this survey every 3 years for all joint research contracts entered into in that year, with a response rate of approximately 40%. Thus, our subset sample is reduced to 137 research contracts. The contracts in this sample have longer terms, lower budgets, and a higher probability of renewal or extension (Table 6.2). Our unit of analysis is a contract. Extended contracts are not counted independently from base contracts.

6.3.2 *Models and Variables*

6.3.2.1 Models and Variables for Analysis 1

We examine our hypotheses by constructing two analysis models. Analysis 1 investigates H1, using our full samples. Table 6.3 displays the descriptive statistics.

We considered that the strength of interaction commitments can be measured by budget allocations. Budgets are of critical importance for university researchers (Lee, 2000) and represent a partner firm's perception of the expected value of a collaboration. Thus, our dependent variable in Analysis 1 is the size of the industry-funded research budgets for each research contract at the time of the contract ending. We calculated quarterly research budgets by considering the industry sector's accounting practices and the fact that the majority of contacts expired within 1 year. We took the natural logarithm of research budgets per quarter plus one and conducted an ordinary least-squares regression to estimate the dependent variable.

Our main independent variable is the time elapsed from the first contract to the date of the focal contract. This variable is 0 if the contract is the first contract between a PI and a firm; otherwise, it is the length of time elapsed from the start date of the

Table 6.3 Descriptive statistics for Analysis 1

		Mean	Std. Dev.	Min	Max
1	Ln (quarterly research budgets +1)	12.10	3.24	0	16.18
2	Time elapsed from the first contract (years)	1.14	1.43	0	6
3	Extension dummy	0.15	0.36	0	1
4	Initial contract periods (quarters)	5.25	5.48	1	58
5	On-site industry researchers	0.17	0.48	0	5
6	PIs' U–I linkages	2.87	3.34	0	21
7	Professor	0.76	0.43	0	1
8	Associate Professor	0.18	0.38	0	1
9	Lecturer/Assistant Professor	0.07	0.25	0	1
10	Medical/Pharmaceutical	0.15	0.36	0	1
11	Biology/Other Medical	0.04	0.20	0	1
12	Science/Engineering	0.79	0.41	0	1
13	Humanities/Social Sciences	0.02	0.13	0	1

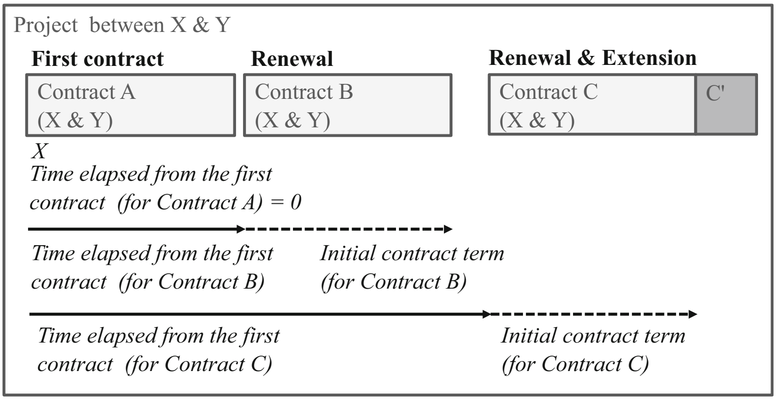

Fig. 6.2 Examples of time elapsed from the first contract

first contract to the start date of the focal contract (see Fig. 6.2). As argued in H1, we inserted squared terms for these two time-related variables to test the curvilinear effects.

As a control variable, we added the initial contract periods noted in the quarters. This variable is used to control a potential discount of the research budget accompanying a long-term contract since firms may consider risk premium coming from performance-outcome effectiveness uncertainty. Additionally, as a factor in the commitment, we inserted the number of PIs in other university–industry collaborations which indicates the number of firms that conducted contract research with the PI in the contract's initial year. It is reasonable to assume that the greater the number of firms that connect with a particular PI, the less the investigator is able to commit to a single project. Conversely, this variable also represents a researcher's popularity. As such, this may have both a negative and a positive influence on commitment. We also used the number of researchers who belong to the counterparty, and who are registered as full- or part-time research fellows at the PI's office or laboratory. This variable potentially captures as a strength of the commitment. Finally, we added the PIs' positions and their school/department categories.

6.3.2.2 Models and Variables for Analysis 2

To test Hypotheses H2-H3, Analysis 2 examines the probability of renewal or extension using our subset samples. Table 6.4 displays the descriptive statistics.

A dependent variable of Analysis 2 is the renewal or extension dummy, which assumes a value of one if the joint research contract was renewed or extended substantially and zero otherwise. In our data, 66% of contracts experienced a renewal or extension. We chose to conduct a logit regression analysis to estimate the probability of a renewal or an extension.

The independent variables are outcome-related factors. For the test of H2, we employed the overall score in satisfaction with outcomes (*satisfaction with outcomes*) using a five-point Likert scale, in which five indicates "high satisfaction with outcomes." For the test of H3, we prepared eight variables that represent the values

Table 6.4 Descriptive statistics for Analysis 2

		Mean	Std. Dev.	Min	Max
1	Subsequent renewal or extension dummy	0.66	0.48	0	1
2	Satisfaction with outcomes (5-scale)	4.18	0.71	2	5
3	Technological knowledge acquisition	0.51	0.43	0	1
4	Patent application	0.10	0.23	0	1
5	Academic paper publication	0.22	0.32	0	1
6	Valuable data acquisition	0.35	0.42	0	1
7	Staff skill development	0.14	0.27	0	1
8	Creating social ties with faculty	0.15	0.20	0	1
9	New project establishment	0.06	0.24	0	1
10	Contribution to R&D/NPD	0.17	0.30	0	1
11	Time elapsed from the first contract (years)	1.16	1.44	0	6
12	On-site industry researchers	0.24	0.65	0	5
13	Ln(research budgets +1)	12.58	2.37	0	16.03
14	Initial contract periods (quarters)	5.40	4.99	1	24
15	PIs' U–I linkage	2.62	2.33	0	14
16	Professor	0.78	0.42	0	1
17	Associate Professor	0.17	0.38	0	1
18	Lecturer/Assistant Professor	0.05	0.22	0	1
19	Medical/Pharmaceutical	0.13	0.34	0	1
20	Biology/Other Medical	0.07	0.26	0	1
21	Science/Engineering	0.77	0.42	0	1
22	Humanities/Social Sciences	0.02	0.15	0	1

obtained from individual types of outcomes. First, we asked the project's counterparty for the outcomes obtained—including both favourable and unfavourable ones—in each category, which included technological knowledge acquisition, patent application, academic paper publication, valuable data acquisition, staff skill development, creating social ties with faculty, new project establishment, contribution to internal R&D and new product development (NPD) activities. Each category was sequentially ranked between 1 and 10 (where 1 represents "high value"), following the subjective value for counterparties if any outcomes were obtained. We adopted reciprocal numbers of these ranks as our independent variables; for example, if an outcome's value is ranked 3rd, a corresponding outcome variable takes 0.33 (=1/3).

We must note that all these variables require an intermediate outcome. However, 16 respondents chose not to answer their outcomes and two did not disclose their score on satisfaction with outcomes. To check the sampling bias, we run the regression using a dummy variable, which takes one if the respondent answered their outcomes. The result[1] does not indicate a significant sampling bias.

Multiple control variables are adopted to reduce an unobserved variable bias. The existence of previous formal collaborations formulates mutual trust (Bruneel et al., 2010) and reduces transaction costs (Weckowska, 2015); thus, it may stimulate a renewal or an extension. Our analysis used the time elapsed from the first contract. In line with the discussion in Sect. 6.2.1., it may influence an extension decision in an inverse-U shape. We also used research budgets and contract periods to control for the size of individual research contracts. Finally, we added the PIs' positions and their school/department categories.

6.4 Results

6.4.1 Estimation of Quarterly Research Budgets (Analysis 1)

Table 6.5 displays the results of OLS regression analysis. Although the estimation models exhibit a low fit, the result from Model 2 reveals that the time elapsed from the first contract has an inverse-U-shaped effect, peaking at 2.2 years (58% increase) and budgets decrease when these ties exceeded 4 years (Fig. 6.3). These results are consistent with H1 regarding contract renewals.

Analysis 1 also reveals that a curvilinear effect of contract periods. The result implies a research budget discount, resulting from the risks of uncertainty in performance-outcome effectiveness accompanying with a long-term contract. Interestingly, on average, PIs in the humanities and social sciences receive a larger budget per quarter than those in other fields. The result is influenced by several field

[1] Reported in the digital supplement are available at the authors' institutional repository: http://pubs.iir.hit-u.ac.jp/admin/en/pdfs/show/2478

Table 6.5 Analysis 1: OLS regression results for quarterly research budgets

	Ln (quarterly research budgets +1)	
	Model 1	Model 2
Time elapsed from the first contract	0.055 (0.071)	0.410** (0.071)
Time elapsed from the first contract (squared)		−0.092*** (0.008)
Extension	0.870 (0.396)	0.895 (0.398)
Initial contract periods (quarters)	−0.118** (0.023)	−0.116** (0.023)
On-site industry researchers	0.669** (0.172)	0.676** (0.171)
PIs' U–I linkages	−0.007 (0.011)	−0.012 (0.010)
Position (baseline: Lecturer/assistant professor)		
Professor	0.855* (0.299)	0.849* (0.296)
Associate Professor	0.568 (0.280)	0.558 (0.285)
Department (baseline: Humanities/social sciences)		
Medical/Pharmaceutical	−1.231*** (0.056)	−1.214*** (0.057)
Biology/Other Medical	−1.766*** (0.113)	−1.748*** (0.115)
Science/Engineering	−0.657*** (0.020)	−0.642*** (0.022)
Constant	12.590*** (0.290)	12.432*** (0.291)
Year dummies	Yes	Yes
Observations	1562	1562
R-squared	0.056	0.060

***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$. Cluster robust standard errors in parentheses (clustered by PI's department)

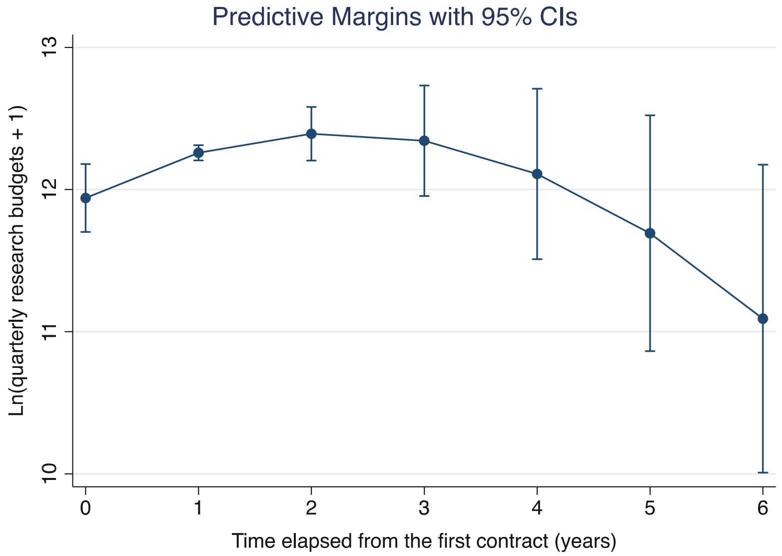

Fig. 6.3 Marginal effect of time elapsed from the first contract

experiment projects in psychology and behavioural economics, which have shorter contract periods and larger budgets.

6.4.2 Estimation of the Probability of Extension or Renewal (Analysis 2)

Table 6.6 displays the results of logit regression analysis. Model 2 exhibits a significantly better fit than Model 1. The results indicate that satisfaction with outcomes shows a significant positive impact on extension or renewal. This finding is consistent with H2.

Table 6.6 Analysis 2: Logit regression results of the probability of extension or renewal

	Subsequent renewal or extension dummy	
	Model 1	Model 2
Satisfaction with outcomes	1.286* (0.195)	1.483** (0.293)
Outcomes		
Technological knowledge acquisition		2.412** (0.831)
Patent application		0.569 (0.275)
Academic paper publication		4.600*** (2.398)
Valuable data acquisition		1.006 (0.419)
Staff skill development		0.168*** (0.046)
Creating social ties with faculty		3.219*** (1.273)
New project establishment		0.987 (0.670)
Contribution to R&D/NPD		0.207*** (0.032)
Time elapsed from the first contract	1.811 (0.658)	2.158*** (0.644)
Time elapsed from the first contract (squared)	0.932 (0.068)	0.877** (0.055)
On-site industry researchers	0.879 (0.139)	0.920 (0.117)
Ln(research budgets +1)	1.335*** (0.110)	1.390*** (0.036)
Contract periods (quarters)	1.065 (0.066)	1.108*** (0.039)
PIs' U–I linkage	1.020 (0.045)	1.073 (0.068)
Position (baseline: Lecturer/assistant professor)		
Professor	0.191 (0.311)	0.220 (0.258)
Associate Professor	0.177 (0.320)	0.180 (0.278)
Department (baseline: Humanities/social sciences)		
Medical/Pharmaceutical	3.523*** (0.415)	5.058*** (1.619)
Biology/Other Medical	3.508*** (0.225)	4.435*** (1.052)
Science/Engineering	5.406*** (0.262)	11.669*** (1.564)
Constant	0.008* (0.021)	0.001*** (0.001)
Observations	137	137
Pseudo R-squared	.109	.202

***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$. Odds ratio. Cluster robust standard errors in parentheses (clustered by PI's department)

Some output-related outcome categories (see Perkmann et al., 2011) have a significant positive effect on the probability of subsequent contracts. Technology acquisition and academic paper publication increase this probability. The odds ratio for recognizing technological knowledge acquisition as an important outcome is 2.4. Contradicting our argument presented in the literature review, academic paper publication also increases the probability of renewal or extension, with the odds ratio for this outcome being 4.6, a higher value. Other explicit outputs, such as patents or valuable data, do not have statistically significant effects. Another output, staff skill development, significantly decreases the probability of the renewal or extension; its odds ratio is 0.17.

Among impact-related outcomes, creating a social network with faculties increases the probability of extension or renewal. When firms recognize a contribution to their internal research and development, they are less likely to continue the collaboration. However, the establishment of a new project does not increase the probability of renewal or extension. Overall, a heterogeneity in outcomes has a different influence on renewal or extension decisions, which is consistent with H3.

Other than the independent variables, the time elapsed from the first contract has a curvilinear effect similar to Analysis 1. Its inverse-U-shaped effect hit the peak at the point of 2.9 years from the first contract.

6.5 Discussion

6.5.1 The Gap Between Contract Periods and Ideal Length of Collaboration

The results of Analysis 1 display the inverse-U-shaped effect of time elapsed from the start of a collaboration on the commitment, as theories predicted. Firms increase their commitment to the collaboration within the first 2–3 years. This estimated average ideal period of collaboration almost overlaps with Katz and Allen's (1982) findings, which identified the peak of the value of collaboration at around 2–4 years. Nevertheless, the majority (76%) of contracts in our dataset expire within 1 year. These contracts indicate a higher probability of renewals and extensions (63%) than longer-term contracts (56%) ($\chi^2 = 5.22$, $p < 0.05$). This means that contract renewals and extensions are essential for firms to at least acquire the best return from contract research.

This gap between contract practice and an ideal interaction illustrates the value of contract management in relational-based interactions. As debated in our literature review section, a long-term interaction carries a trade-off between the pros of stable relationships (e.g., efficient communication and the formation of trust) and the cons of long-term formal commitment (e.g., uncertainty in performance-outcome effectiveness). To balance, firms implement a research management system, such as meetings among managers, informal contacts, technical reports, or research plan reviews (Morandi, 2013). Our study finds that contract management also constitutes an essential part of such a research management system in university–industry collaboration. We also reveal that the trade-off leads to a long-term commitment discount on the budget. A single long-term contract will involve a slightly lower budget, and its length linearly decreases the budget. We can assume that a PI and the industry–university liaison office discount research budgets to obtain stable funding and that firms reduce budgets in consideration of the risks of uncertainty.

We must note one limitation of the interpretation of our empirical results. Combined with our other finding that a long-term contract often discounts its research budgets, some may conclude that our results evidence the stage-gate system's superiority for university fundraising. Such an interpretation, however, neglects the probability of the termination of the research project. The subsequent collaboration contracts observed survive because of their prospects. It is natural for firms to allocate a higher budget to prospective collaborations. Our estimated model shows that even in the ideal case, in which a PI and his or her counterparts have already collaborated for 2 years, the probability of continuation remains around 75%. An expected total volume of funds in a stage-gate system is not always larger than in a long-term contract. Our results only emphasize the importance of efforts to maintain collaborations for universities when they enter short-term or stage-gate research contracts.

6.5.2 Determinants of a Long-Term Contract Research Project

The empirical test in Analysis 2 illustrates how experiential learning is essential for firms to overcome unease regarding the prediction of performance-outcome effectiveness (Schwab & Miner, 2008; Ebers & Maurer, 2016). Innovation studies emphasize the importance of legitimizing an innovation project in a firm, as its uncertainty frequently generates internal pressures not to continue (Takeishi et al., 2010). Thus, once certain intermediate outcomes are perceived and deemed satisfactory, they will consider the maintenance of collaborative relationships legitimate.

In addition to the effect of overall satisfaction of outcomes, our results prove that the characteristics of outcomes strongly influence the decision to continue a collaboration. Among multiple outcomes expected in contract research (Perkmann et al., 2011), a perception of technological knowledge acquisition positively affects the maintenance of a collaboration. This result is in line with the literature emphasizing that many firms place a priority on continuous technology acquisition and learning from the university–industry connection (Cyert & Goodman, 1997; McKelvey et al., 2015).

Other than the implicit perception of technological capability development, it is noteworthy that academic publications increase the probability of long-term formal relationships, whereas patents and data do not. These results are counterintuitive, as the industry generally prioritizes patents and data over publications. One may suspect that academic publications merely capture the scientific basis of contract research, which typically takes a long time. Publications may be considered a sign of the smooth progress of the project. This interpretation partly explains the result; however, it neglects firms' inherent opportunistic behaviour (Olk & Young, 1997). Once firms acquire general knowledge, they can choose not to collaborate with the focal academic researcher in a formal contractual relationship. They can continue research internally, as published scientific knowledge is nonexclusive, or they can collaborate with other academic researchers with expertise in their applied fields. Our result seems to be a puzzle.

This puzzle can be understood from two theoretical perspectives. From the perspective of the formation of trust, these formal outputs are likely a proxy of mutual trust (Bruneel et al., 2010). Most publications are jointly authored. Writing academic papers creates reciprocal communication that facilitates and strengthens trust. In addition to that, successful publications increase the commitment of academic researchers to contract research (Lauvas & Steinmo, 2021), as publication is important for academic scholars. This increased commitment may strengthen firms' expectation for further deliverables from the project. From an organizational decision perspective, the existence of explicit deliverables legitimatizes further spending for the research project. Publications are apparent "boundary-objects" (Koskinen, 2005) that link project members with their colleagues and managers and validate the progress of the project (Morandi, 2013).

Nevertheless, other explicit outputs, such as patents and valuable data, do not always increase the probability of contract continuation. A traditional R&D management model can explain the difference (e.g., Balachandra & Brockhoff, 1995). The model sets a typical decision point between development and manufacturing/marketing launch. Although we cannot say that all these explicit outputs correspond to the transition in the R&D process, we expect that many of them are signs of proceeding to the downstream phase. In such a phase, academic researchers often have little expertise. Firms do not have sufficient internal legitimization to maintain formal connections with academic researchers anymore. If so, patents and valuable data may have mixed effects on contract continuation. As fruits of mutual trust or boundary-objects, they increase the probability of the further formal collaboration, whereas they eliminate the legitimacy of maintaining the collaboration, as they indicate the appropriate timing of the termination of the collaboration. Therefore, they do not have any significant effects. Our interpretation is consistent with the estimation result of the effect of contribution to R&D/NPD, as it is also regarded as a sign of the transition to the development phase.

The argument above emphasizes firms' constraints in resource allocation coming from rational organizational decisions. Both academic publications and technological capability development are almost dominant outputs from the academic sector, whereas other outputs and impact can be archived through collaboration with the non-academic sector. Firms may prioritize the unique value of academia as a part of rational decisions. The confirmed negative effect of staff skill development seems to share the same theoretical ground. Continuing the allocation of already-developed R&D personnel in contract research is irrational behaviour.

Nevertheless, perceived social ties with PIs are correlated positively with the contract renewal or extension decision. We can interpret this as a consequence of a sense of reciprocity, which is heightened through social exchange relationships (Gouldner, 1960). Firms seem to believe that opportunistic behaviour, which concludes contract research and maintains a social network with the focal PI via informal channels, will decrease the accessibility of academic knowledge. They may recognize the importance of reciprocity and mutual trust in technological learning (Mody, 1993). In this sense, it also constitutes rational decisions.

6.6 Conclusion

This paper investigated longitudinal changes in the commitment to collaborative university–industry research and the determinants of contract renewals. We focused on industry firms' decision to renew or extend an existing research contract to reveal the effects of project-related factors. Our empirical analyses find that the strength of the commitment to the renewed contract follows an inverse-U-shaped relationship in the time elapsed from the first contract. We also demonstrated that the perceived development of technological capability and academic paper publication lead to a further formal collaboration with the counterparts. Concurrently, our results imply that firms are likely to terminate the relationship when there is no longer a rational business reason to continue the formal collaboration with the academic researcher. This finding sets a limitation to the argument by Ankrah et al. (2013), who emphasizes that firms have fundamental motives to maintain long-term connections. Although this argument is partly true, firms also seek a unique value from university–industry collaboration.

Our findings suggest that concentrating on academic publications and knowledge-sharing with industry collaborators is, in general, likely to establish long-term university–industry connections. It is noteworthy that these activities are fundamental university roles. Some claim the need for academic scholars to be good partners of industry (or "good Sams"), but data show the opposite need. Based on our research findings, academic scholars are encouraged to be "going my way," even in university–industry collaborations.

This paper's main academic contribution lies in its discovery of the importance of contract renewals in the context of university–industry relational arrangements. As De Wit-de Vries et al. (2019) find, most papers have focused on the informal management aspects of university–industry research partnerships, and limited studies have been conducted on the formal management of such collaborative efforts. Our paper confirms the value of a long-neglected perspective for future research.

One essential practical contribution of this study is the confirmation of concrete determinants of long-term university–industry collaborations. Establishing an open atmosphere in academic publishing is beneficial for both academia and industry.

However, as Battilana et al. (2009) noted, firms sometimes emphasize the secrecy of research outputs, placing some constraints on the academic publication of academic counterparts. Such constraints seem to be reasonable acts of risk aversion, but our findings imply that these constraints may lack foresight for firms. In order to avert these adverse conditions, technology transfer offices, research administrators, and industry liaison offices play an important role in negotiating research contracts (e.g., Berbegal-Mirabent et al., 2015).

As with most empirical research, this study has some limitations. First, the empirical analysis still has several unobserved variable biases, although we constructed a rich dataset based on highly reliable trajectories of research contracts matched with multiple data sources. Typically, we would neglect the PIs' scholarly productivity because of data availability; instead, we inserted PIs' university–industry connections as a control variable. This variable primarily proxies for the weakness of commitment, but the indicator simultaneously reflects the focal point of PIs' attractiveness, which might correspond to academic productivity (e.g., Gulbrandsen & Smeby, 2005). Second, the majority of our samples are contracts between Japanese firms and the Japanese research university from which the data were derived, while contract practices likely differ among countries. Further validations are necessary to generalize our findings. Finally, our subset of samples in Analysis 2 is not completely balanced with the full samples of Analysis 1, meaning that the results of Analysis 2 are potentially biased.

A long-term relationship is beneficial, but has limitations. Short-term contracts are sometimes the result of inevitable choice. Our findings provide one significant implication, in that going academic way is a key to collaborate with the industry in the long term.

References

Al-Tabbaa, O., & Ankrah, S. (2016). Social capital to facilitate 'engineered' university–industry collaboration for technology transfer: A dynamic perspective. *Technological Forecasting and Social Change, 104*, 1–15.

Ankrah, S. N., Burgess, T. F., Grimshaw, P., & Shaw, N. E. (2013). Asking both university and industry actors about their engagement in knowledge transfer: What single-group studies of motives omit. *Technovation, 33*(2-3), 50–65.

Arza, V., & Carattoli, M. (2017). Personal ties in university-industry linkages: A case-study from Argentina. *The Journal of Technology Transfer, 42*(4), 814–840.

Balachandra, R., & Brockhoff, K. (1995). Are R&D project termination factors universal? *Research-Technology Management, 38*(4), 31–36.

Banal-Estañol, A., Jofre-Bonet, M., & Lawson, C. (2015). The double-edged sword of industry collaboration: Evidence from engineering academics in the UK. *Research Policy, 44*(6), 1160–1175.

Battilana, J., Leca, B., & Boxenbaum, E. (2009). How actors change institutions: Towards a theory of institutional entrepreneurship. *Academy of Management Annals, 3*(1), 65–107.

Berbegal-Mirabent, J., García, J. L. S., & Ribeiro-Soriano, D. E. (2015). University–industry partnerships for the provision of R&D services. *Journal of Business Research, 68*(7), 1407–1413.

Bishop, K., D'Este, P., & Neely, A. (2011). Gaining from interactions with universities: Multiple methods for nurturing absorptive capacity. *Research Policy, 40*(1), 30–40.

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

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

Bstieler, L., Hemmert, M., & Barczak, G. (2015). Trust formation in university–industry collaborations in the US biotechnology industry: IP policies, shared governance, and champions. *Journal of Product Innovation Management, 32*(1), 111–121.

Cyert, R. M., & Goodman, P. S. (1997). Creating effective university-industry alliances: An organizational learning perspective. *Organizational Dynamics, 25*(4), 45–58.

De Fuentes, C., & Dutrénit, G. (2012). Best channels of academia–industry interaction for long-term benefit. *Research Policy, 41*(9), 1666–1682.

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

D'Este, P., Llopis, O., Rentocchini, F., & Yegros, A. (2019). The relationship between interdisciplinarity and distinct modes of university-industry interaction. *Research Policy, 48*(9), 103799.

De Wit-de Vries, E., Dolfsma, W. A., van der Windt, H. J., & Gerkema, M. P. (2019). Knowledge transfer in university–industry research partnerships: A review. *The Journal of Technology Transfer, 44*(4), 1236–1255.

Dingler, A., & Enkel, E. (2016). Socialization and innovation: Insights from collaboration across industry boundaries. *Technological Forecasting and Social Change, 109*, 50–60.

Ebers, M., & Maurer, I. (2016). To continue or not to continue? Drivers of recurrent partnering in temporary organizations. *Organization Studies, 37*(12), 1861–1895.

Frasquet, M., Calderón, H., & Cervera, A. (2012). University–industry collaboration from a relationship marketing perspective: An empirical analysis in a Spanish University. *Higher Education, 64*(1), 85–98.

Galan-Muros, V., & Plewa, C. (2016). What drives and inhibits university–business cooperation in Europe? A comprehensive assessment. *R&D Management, 46*(2), 369–382.

Garcia, R., Araújo, V., Mascarini, S., Santos, E. G., & Costa, A. R. (2020). How long-term university-industry collaboration shapes the academic productivity of research groups. *Innovations, 22*(1), 56–70.

Garcia, R., Araújo, V., Mascarini, S., Santos, E. G., & Costa, A. R. (2019). How the benefits, results and barriers of collaboration affect university engagement with industry. *Science and Public Policy, 46*(3), 347–357.

Gouldner, A. W. (1960). The norm of reciprocity. *American Journal of Sociology, 25*, 161–178.

Gulbrandsen, M., & Smeby, J. C. (2005). Industry funding and university professors' research performance. *Research Policy, 34*(6), 932–950.

Hagedoorn, J., Link, A. N., & Vonortas, N. S. (2000). Research partnerships. *Research Policy, 29*(4-5), 567–586.

Hamel, G. (1991). Competition for competence and interpartner learning within international strategic alliances. *Strategic Management Journal, 12*(S1), 83–103.

Im, G., & Rai, A. (2008). Knowledge sharing ambidexterity in long-term interorganizational relationships. *Management Science, 54*(7), 1281–1296.

Jelinek, M., & Markham, S. (2007). Industry-university IP relations: Integrating perspectives and policy solutions. *IEEE Transactions on Engineering Management, 54*(2), 257–267.

Katz, R., & Allen, T. J. (1982). Investigating the not invented here (NIH) syndrome: A look at performance, tenure, and communication pattern of 50 R&D project groups. *R&D Management, 12*(1), 7–19.

Kameo, N. (2015). Gifts, donations, and loose coupling: Responses to changes in academic entrepreneurship among bioscientists in Japan. *Theory and Society, 44*(2), 177–198.

Koskinen, K. U. (2005). Metaphoric boundary objects as co-ordinating mechanisms in the knowledge sharing of innovation processes. *European Journal of Innovation Management, 8*(3), 323–335.

Koza, M. P., & Lewin, A. Y. (1998). The co-evolution of strategic alliances. *Organization Science, 9*(3), 255–264.

Landry, R., Saïhi, M., Amara, N., & Ouimet, M. (2010). Evidence on how academics manage their portfolio of knowledge transfer activities. *Research Policy, 39*(10), 1387–1403.

Lauvas, T., & Steinmo, M. (2019). The role of proximity dimensions and mutual commitment in shaping the performance of university-industry research centres. *Innovations, 23*(2), 1–27.

Lee, Y. S. (2000). The sustainability of university-industry research collaboration: An empirical assessment. *The Journal of Technology Transfer, 25*(2), 111–133.

McKelvey, M., Zaring, O., & Ljungberg, D. (2015). Creating innovative opportunities through research collaboration: An evolutionary framework and empirical illustration in engineering. *Technovation, 39–40*, 26–36.

Mody, A. (1993). Learning through alliances. *Journal of Economic Behavior and Organization, 20*(2), 151–170.

Morandi, V. (2013). The management of industry–university joint research projects: How do partners coordinate and control R&D activities? *The Journal of Technology Transfer, 38*(2), 69–92.

Motoyama, Y. (2014). Long-term collaboration between university and industry: A case study of nanotechnology development in Japan. *Technology in Society, 36*, 39–51.

Olk, P., & Young, C. (1997). Why members stay in or leave an R&D consortium: Performance and conditions of membership as determinants of continuity. *Strategic Management Journal, 18*(11), 855–877.

Perkmann, M., & Walsh, K. (2007). University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews, 9*(4), 259–280.

Perkmann, M., King, Z., & Pavelin, S. (2011). Engaging excellence? Effects of faculty quality on university engagement with industry. *Research Policy, 40*(4), 539–552.

Petruzzelli, A. M. (2011). The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation, 31*(7), 309–319.

Plewa, C., & Quester, P. (2006). Satisfaction with university-industry relationships: The impact of commitment, trust and championship. *International Journal of Technology Transfer and Commercialisation, 5*(1-2), 79–101.

Plewa, C., Korff, N., Baaken, T., & Macpherson, G. (2013). University–industry linkage evolution: An empirical investigation of relational success factors. *R&D Management, 43*(4), 365–380.

Santoro, M. D., & Saparito, P. A. (2006). Self-interest assumption and relational trust in university-industry knowledge transfers. *IEEE Transactions on Engineering Management, 53*(3), 335–347.

Schildt, H., Keil, T., & Maula, M. (2012). The temporal effects of relative and firm-level absorptive capacity on interorganizational learning. *Strategic Management Journal, 33*(10), 1154–1173.

Schwab, A., & Miner, A. S. (2008). Learning in hybrid-project systems: The effects of project performance on repeated collaboration. *Academy of Management Journal, 51*(6), 1117–1149.

Starbuck, E. (2001). Optimizing university research collaborations. *Research-Technology Management, 44*(1), 40–44.

Steinmo, M., & Rasmussen, E. (2018). The interplay of cognitive and relational social capital dimensions in university-industry collaboration: Overcoming the experience barrier. *Research Policy, 47*(10), 1964–1974.

Swanson, R. A. (2001). Human resource development and its underlying theory. *Human Resource Development International, 4*(3), 299–312.

Takeishi, A., Aoshima, Y., & Karube, M. (2010). Reasons for innovation: Legitimizing resource mobilization for innovation in the cases of the Okochi Memorial Prize Winners. In H. Itami,

K. Kusunoki, T. Numagami, & A. Takeishi (Eds.), *Dynamics of knowledge, corporate systems and innovation* (pp. 165–189). Springer Berlin Heidelberg.

Thomas, Lauvås Marianne, Steinmo (2021) The role of proximity dimensions and mutual commitment in shaping the performance of university-industry research centres. *Innovation 23*(2) 182–208. https://doi.org/10.1080/14479338.2019.1662725

Tijssen, R. J., Van Leeuwen, T. N., & Van Wijk, E. (2009). Benchmarking university-industry research cooperation worldwide: Performance measurements and indicators based on co-authorship data for the world's largest universities. *Research Evaluation, 18*(1), 13–24.

Vohora, A., Wright, M., & Lockett, A. (2004). Critical junctures in the development of university high-tech spinout companies. *Research Policy, 33*(1), 147–175.

Wang, C., Schmidt, G., & van der Rhee, B. (2018). Stage–gate contracts to screen agents with inside information. *Decision Sciences, 49*(6), 1156–1186.

Weckowska, D. M. (2015). Learning in university technology transfer offices: Transactions-focused and relations-focused approaches to commercialization of academic research. *Technovation, 41*, 62–74.

Yegros-Yegros, A., Azagra-Caro, J. M., López-Ferrer, M., & Tijssen, R. J. (2016). Do university–industry co-publication outputs correspond with university funding from firms? *Research Evaluation, 25*(2), 136–150.

Zheng, Y., & Yang, H. (2015). Does familiarity foster innovation? The impact of alliance partner repeatedness on breakthrough innovations. *Journal of Management Studies, 52*(2), 213–230.

Chapter 7
The Relationship between University Management Practices and the Growth of Academic Spin-Offs

Mario Benassi, Matteo Landoni, and Francesco Rentocchini

Abstract There is a paucity of studies which have analysed the role of internal processes for academic spin-offs in a systematic way. We focus on a specific nuance of internal processes which relate to the management practices that universities can put in place to influence the growth of academic spin-offs. Building upon recent literature on the empirical economics of management, we investigate whether and how different forms of management practices contribute to the growth of academic spin-offs. We collect survey data on universities' management practices by focusing on technology transfer offices, as well as drawing on a longitudinal sample of 790 Italian university spin-offs founded by 42 different Italian universities, which were observed over the period of 2006 to 2014. Our findings show that management practices help to explain the growth of academic spin-offs, although their effect varies across management practices. Supporting operations in the form of patenting and training as well as the existence of incentives are found to have a positive association with spin-off growth. A negative association is instead found for target setting (spin-off growth targets) and hiring of external management with private sector experience. We provide an explanation of these results by pointing to a combination of adverse selection, short-termism and weak enforceability by universities. Drawing on our results, the adoption of management practices by university managers and policy makers should be carefully considered, as they might have unintended consequences on the growth of academic spin-offs.

Keywords Management practices · Academic spin-offs · Spin-offs growth · Internal processes

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7.1 Introduction

Academic spin-offs – defined as companies where either a founder is affiliated with the university or the university itself holds a share in the company[1] – have gained increasing attention from scholars in recent decades (Rasmussen et al., 2011, Mathisen & Rasmussen, 2019; for a systematic review, see Rothaermel et al., 2007; Schmitz et al., 2017).

Within the large body of literature investigating academic entrepreneurship, two main areas of research have gained prominence. A first stream of the literature has focused on the antecedents of academic entrepreneurship, attempting to address the main drivers leading to the creation of academic spin-offs. A second stream of research has concentrated on the outcome of university entrepreneurship processes, evaluating the performance of academic spin-offs from different perspectives (Zhang, 2009). In evaluating the performance of academic spin-offs, growth is a key issue as academic spin-offs often remain small, are exposed to market selection and face very low survival rates. These two streams of research have been seldom connected with the investigation of internal processes universities employ with academic spin-offs. As universities may exhibit marked differences in their attitudes towards spin-offs (Benassi, 2014), university internal processes can play a pivotal role for spin-offs growth.

In our work, we focus on a specific nuance of internal processes which relate to the management practices that universities can put in place to help the growth of academic spin-offs. We build upon the recent literature on the economics of management practices (Bloom et al., 2012, 2014, 2017) which has consistently shown how a defined set of management practices (i.e. monitoring performance, target setting, incentive setting and people management) contributes to explaining a large proportion of the variability in the performance of organisations (both private and public) (Bloom & Van Reenen, 2010; Bloom et al., 2014). Building upon this literature, management practices can be conceived as routines, rules and processes, which relate to the deep-seated structure of organisations (Bloom et al., 2014). Our goal is twofold. First, we want to assess whether management practices in a university affect the growth of academic spin-offs. Existing research on management practices posits that they matter also in universities (McCormack et al., 2014). However, this is not necessarily the case of academic spin-offs, as they originate from organisations with primary goals that are far from profit-oriented (Merton, 1973; Dasgupta & David, 1994). Second, we want to assess which management practices are related to academic spin-offs' growth, and how.

In order to investigate the two research questions outlined above, we rely on a longitudinal dataset comprising 790 Italian university spin-off companies observed over the period of 2006 to 2014.

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[1] We adopt this last definition in accordance with the report of Netval, the Italian association for the valorisation of results from public research (Ramacciotti & Daniele, 2015).

The remainder of this article is organised as follows. Section 7.2 offers a review of the most recent research on academic spin-offs and management practices and sets forward our key research questions. Section 7.3 presents data and methodology, Section 7.4 outlines and discusses the results, and Sect. 7.5 concludes.

7.2 Literature Review and Research Questions

7.2.1 Academic Entrepreneurship, Management Practices and Universities' Internal Processes

Academic spin-offs are a possible vehicle to extract value from the innovative knowledge universities produce (Di Gregorio & Shane, 2003), nevertheless the adoption of an entrepreneurial model and the creation of academic spin-offs can be a quantum leap for universities. Institutional rules and cultural barriers can make entrepreneurship inside universities a nearly impossible mission (Markman et al., 2004; Bercovitz & Feldman, 2008; Sauermann & Stephan, 2012). Furthermore, norms and beliefs shared among faculties might significantly limit entrepreneurial behaviour (Louis et al., 1989). Therefore, academic spin-offs can be comparatively more exposed to the "liability of newness" problem (Stinchcombe, 1965). These limits make some scholars sceptical of universities' contribution to fostering entrepreneurship (Cohen et al., 1998; Florida & Cohen, 1999; Miranda et al., 2018).

We share the view that the tasks involved in the creation and support of spin-offs represent new challenges for universities, as they are quite different from the ones that these organisations have been exposed to for centuries. One way of dealing with these challenges is to adopt specific management practices in the process of creating and assisting academic spin-offs, providing support and selectivity policies and programs that reduce administrative burdens or provide tax incentives and access to financing, business networks, and training (Patzelt and Shepherd, 2009).

Management practices are a key concept in organisational theory since the 1960s (Likert, 1961).[2] The central tenet is that organisations learn which management practices to pursue and discriminate among different alternatives while, at the same time, they redefine them by learning as they evolve (March, 1999). By placing good and effective practices in place, managers can improve the performance of their organisation. Management practices are not an attribute of single managers: they reflect the collective accumulation of knowledge and can change over time.

Literature on management practices has gained momentum in recent years (Bloom et al., 2012, 2014, 2017). This stream of research investigates and explains differences in management practices across organisations and countries in different

[2] Management practices should not be confused with managerial capital, which refers mainly to the talent and skills of individuals (such as a manager) and comes as the aggregation of individual contributions but lacks an organisational dimension (Bertrand & Schoar, 2003).

sectors (Bloom et al., 2012). The authors show how practices put in place by managers contribute to explaining a large proportion of the variability in the performance of organisations. The former literature has grouped management practices into three broad areas: monitoring (how well organisations monitor what goes on inside and apply to continuous improvement), targets (whether organisations set the right targets, track the right outcomes, and take appropriate action if the two are inconsistent), and incentives (how well organisations promote and reward employees based on performance, and try to hire and keep their best employees) (Bloom & Van Reenen, 2006).

Management practices have been found to explain variation among organisations' performance. Bloom and Van Reenen (2010) found that management practices are associated with firm performance in terms of productivity, sales and growth rate. Similarly, Bloom and Van Reenen (2010) concluded that firms with better management practices tend to have better performance on a wide array of dimensions. A well-managed organisation is defined as one that continuously monitors and attempts to improve its processes, sets comprehensive and stretching targets, and promotes high-performing employees.

Management practices are also useful for explaining variations among different kinds of organisations, whether private or public such as hospitals and schools (Bloom & Van Reenen, 2010; Bloom et al., 2014). They have also been found to influence universities' performance. For example, McCormack et al. (2014) explored management practices in British universities and found that better management practices are associated with better performance in both research and teaching assessments. Notably, the authors find that the provision of incentives for faculty recruitment, in the form of promotion and retention of talent, is positively associated to research and teaching performance of British universities.

7.2.2 Management Practices Oriented towards Academic Spin-Offs

Building upon the former literature, we explore the management practices implemented by universities to support academic entrepreneurship.

In the existing studies on academic spin-offs, the role and impact of management practices is normally left in the background. Evidence on the role of management practices is indirect, scant and mostly oriented to the establishment of academic spin-offs, such as setting a specific entrepreneurial programme (Reitan, 1997), expanding business development capabilities of TTO's (Lockett et al., 2005), and defining appropriate general rules and regulations (Muscio et al., 2016). Even when differences in management practices are considered, they are usually referred to as conditions favouring or discouraging spin-off creation rather than their performance (see Lockett et al., 2003, on university spin-offs in the UK; and O'Shea et al., 2005 for the US). For example, O'Shea et al. (2005) argued that knowledge accumulation inherent in the process of generating university spin-offs influences a university's future ability to produce university spin-off companies. In a similar way, Pazos et al. (2012) show that the tradition of the university's spin-off activity and the existence of incubation services positively influence spin-offs. Vinig and Van Rijsbergen (2012) found that the stock of technology, in terms of scholarly publications, and the presence of an incubator have a positive impact on the number of spin-offs. This literature is extremely variegated, and the results seem to depend upon contextual factors, which are largely specific to the domain under investigation.

Empirical literature has mainly addressed the issue of academic spin-off growth at individual (e.g. inventor involvement), firm (i.e. business model) and institutional level (e.g. university relationship). Few studies investigated how universities internal processes (e.g. internal processes, support programmes, management practices) might facilitate spin-off growth (Mathisen & Rasmussen, 2019). Degroof and Roberts (2004) explored spin-off policies in the largest Belgium universities to assess how selectivity in spin-off policies and support affect the growth of new ventures. Using a sample of academic spin-offs from the Netherlands, Norway and the United Kingdom, Soetanto and Jack (2016) analysed the potential moderating effect of incubation support on the performance of academic spin-offs.

In our work we take into consideration the classification of management practices proposed by Bloom and Van Reenen (2006) and investigate whether and how specific instances of management practices (i.e. management of operations, monitoring processes, setting targets, providing incentive schemes and managing people) influences academic spin-off growth. Borrowing from existing literature on the empirical economics of management practices, and recalling universities need to adopt specific rules to deal with a new mission, we do in general expect management practices to be positively associated to academic spin-off growth. However, significance and sign of each management practice set cannot be taken for granted. For instance, one may expect that support operation practices help selecting more robust projects. However, encouraging by far and large an entrepreneurial attitude might be self-defeating without a rigorous selection process. For example, universities might launch support initiatives like entrepreneurial and start-up courses, but lack the internal knowledge to discriminate promising projects from good ideas impossible to implement. Monitoring and targeting practices can be effective, as they promote control of performances and set goals. However, they can be out of focus as universities might pursue conflicting objectives. For instance, universities might be interested in promoting successful spin-off, but also in attaining scientific excellence, thus making financial and economic performances secondary. Professional oriented practices should positively contribute to stimulate spin-off growth. For instance, reward and incentive practices, when aligned with academic spin-off growth targets, could produce visible effects. Similarly, recruitment of professionals with previous experience in business could might contribute to strengthen academic spin-offs. On the other hand, reward and incentive practices might turn out to be ineffective if perceived as unfair (e.g. incentives and rewards way lower the market average). Likewise, complying with the organizational procedures of universities by professionals with previous business experience might become impossible, making their recruitment ineffective.

By building upon the contribution of the literature on the empirical economics of management (systematisation of management practices in higher order constructs, widely tested survey methodology and robust measures of management practices), we surmise that the analysis of management practices oriented towards academic spin-offs is a meaningful way also to better systematise the results from the academic entrepreneurship literature in relation to the growth of academic spin-offs.

7.3 Data and Methods

7.3.1 Data Sources

The empirical analysis is based on a longitudinal dataset comprising 790 Italian university spin-off companies observed over the period 2006–2014. It combines data from three main sources.

Our starting point is the list of Italian university spin-offs provided by *Spinoff Italia* (http://www.spinoffricerca.it/) as of June 2015.[3] *Spinoff Italia* reports the following information for these companies: spin-off name, university of affiliation; foundation year; year of exit.[4]

We match this information with balance sheet data from the Bureau van Dijk AIDA database over the period 2006–2014. Notably, we collect information on turnover, capital stock (tangible and intangible), industrial sector (2-digit NACE rev.2 industrial classification) and geographical location of companies (NUTS 2 level of geographical aggregation).

Lastly, we collect information about university management practices relating to spin-offs by administering a structured questionnaire to the key individuals in the academic spin-off's process inside Italian universities, mostly the head of the TTO and/or their designates.[5] The TTO is the place where the distinct logics of scientific production and innovation get reconciled and where a number of important

[3]Building upon the definition provided by NETVAL (Muscio et al., 2016) and adopted by the Italian National Agency for the Evaluation of the University (ANVUR), *Spinoff Italia* defines a company an academic spin-off if it satisfies one of the following conditions: (i) Italian university holds a share of the company; (ii) at least one member of the founding team is a tenured member of staff of a university.

[4]Unfortunately, the data does not allow to distinguish exit by acquisition from exit by end of operations (i.e. bankruptcy) thus making the option of measuring performance by firm death unfeasible in the present case.

[5]It is critical to point out that faculty reporting on third stream activities is mandatory in the Italian higher education system. Notably, all contractual arrangements should be directly reported to the university central services and TTOs. Failing to report on contracting arrangements on the side of the faculty would be considered as illegal in the Italian higher education system. Therefore, the data collected is liable to be a very accurate and comprehensive.

Table 7.1 Management practices supporting the creation and development of academic spin-offs: main actors involved

Variables	Description	Main actors
1 Support operations		
Support operations – training	counselling activity for the academic spin-off founding team; on-the-job training activities	1, 2, 3, 4, 5
Support operations – Patent	support in the proof of concept; assistance in the process of filing	1, 2
Support Operations – Funding	fund raising activity	2, 3, 5
2 Target setting		
Target growth	relative importance of academic spin-offs growth and employment creation	1, 3
Target Scientific Excellence	relative importance of academic spin-offs scientific and technological excellence	1, 3
3 Monitoring		
Monitoring Management	monitoring activities to track the performance of the academic spin-offs; measures like balance sheet information, reports from the spin-off management team	1, 2, 3
4 Incentives		
Incentives Management	reward system for personnel linked to the achievement of targets/objectives set out for the academic spin-offs	1, 2, 5
5 Professional		
Professional management	TTO employees with experience in the private sector	1

Source: own elaboration on introductory semi-structured interviews and survey data. According to the introductory semi-structured interviews made, the main actors involved in the academic spin-offs process are the following: (1) TTOs, (2) University board of directors, (3) Ad-hoc committees, (4) faculty programme directors, (5) head of schools

operational decisions are taken (Sauermann & Stephan, 2012). As the recent literature on management practices refers to very operational constructs, we do believe that the TTO' are an appropriate source of information for our study.

To collect information about the management practices enforced by each university, we interviewed TTO's responsible as they have a clear view of what occurs both at central (e.g. Board, Committees) and peripheral (e.g. spin-offs) levels. In fact, different actors can design, promote and put in place academic spin-offs-oriented management practices. Table 7.1 gives an overview of the main actors involved for each category of management practices, as resulting from preliminary face-to-face interviews conducted with six key informants (mainly head of TTOs but also head of university incubators and responsible of university technology transfer temporary committees).

The population of reference consists of 64 public universities who were invited to participate to a telephone interview. The survey was conducted between July 2015 and March 2016 and interviewees reported responses covering the period 2010–2014. We obtained 42 valid responses, totalling a 65.6% response rate.

These responses were representative of the population of Italian public universities in relation to size (t = 1.19, p-value = 0.24), patenting activity (t = 1.203, p-value = 0.23), research funding (t = 1.35, p-value = 0.18) and contract research (t = 1.114, p-value = 0.268).[6]

Our final sample comprises information for the variables of interest for 790 companies. Our resulting dataset is thus an unbalanced panel of 790 academic spin-offs affiliated with 42 different Italian universities and observed over the period 2006–2014.[7] Unfortunately, we do not have information on each company over the full period (e.g. half of the companies are observed over a 5-year period), which reduced our estimating sample to 3695 firm-year observations.

We are aware of the issue arising from our research design due to a possible problem of reverse causality: our survey on university management practices is not antecedent to our firm-level measures. We believe this is not affecting our results because management practices tend to be persistent and to take much effort and time to change. The persistency of management practices for academic spin-offs was confirmed by introductory semi-structured interviews we had with six key informants (head of TTO or university incubator, head of school and the like) before initiating the large-scale survey. Several interviewees stressed how the Italian university system has been historically characterised by long and painful adaptations to university systems of other European countries and that the support and practices for academic spin-offs do not represent an exception to this general trend. The point above supports the idea that university management practices in 2010–2014 have been there for a long time and that they can be treated as time invariant constructs for the sake of our analysis.

7.3.2 Estimation Method and Dependent Variable

As discussed in the theoretical section, we are interested in examining the relationship between university-level management practices aimed at academic spin-offs and firm growth. We measure company growth using data on the turnover retrieved from the Bureau van Dijk AIDA database. Specifically, our dependent variable is the turnover growth rate and has been calculated as the difference between the logarithm

[6]Data on the number of patents, the amount of research funding and contract research comes from the Italian National Research Assessment (VQR 2004–2010) and refers to the period 2004–2010. Information on the size of universities comes from the Ministry of Education, Universities and Research (MIUR) and refers to period 2006–2014.

[7]Our starting point was the 1226 academic spin-offs contained in *Spinoff Italia*. The final number of unique companies was reduced to 790 for two reasons: (1) we were not able to match information from AIDA for 181 companies and (2) we did not obtain responses to our survey from 22 universities which generated 255 spin-offs over the period under consideration.

of real turnover in year t and the logarithm of real turnover in year $t - 1$.[8] We are aware that firm growth can be investigated using a wide variety of measures (Delmar et al., 2003). Unfortunately, information about the number of employees is under-reported in our data, so we prefer to use turnover growth, which has the advantage of maximising the number of non-missing information.

Building upon the approach adopted in several empirical works, which focused on the determinants of firm growth, we employ a quantile regression approach (Coad & Rao, 2008; Goedhuys & Sleuwaegen, 2010; Kesidou & Demirel, 2012). When investigating firms' growth quantile analysis is preferred over standard least squares for a number of reasons (Buchinsky, 1998). First, the quantile approach provides a more robust and efficient alternative to OLS when the error term is non-normal, as well as in the presence of outliers. Second, the distribution of growth rates is recognised to be highly non-linear and considerably heavy-tailed (Bottazzi & Secchi, 2003). The quantile approach allows for richer characterisation of the data, as it estimates the effects of the different explanatory variables at the different quantiles of the growth distribution rather than at the conditional mean only. Since different types of management practices might have different effects on companies located at different points of conditional growth distributions (e.g. high-growth firms vs low-growth firms), the quantile approach can serve the purpose to uncover these effects.

As our data have a hierarchical structure – our key explanatory variables are measured at the university level while the dependent variable is measured at the firm level – standard errors are likely to be clustered and this would lead to a loss of efficiency in the estimates. In an attempt to control for the presence of intra-cluster correlation in quantile regressions, we compute robust clustered standard errors at the university level following a recent development in the applied econometrics literature (Parente & Santos Silva, 2016).[9]

7.3.3 Explanatory Variables

As for our key explanatory variables, we are interested in testing the relationship between management practices, which support academic entrepreneurship, and the growth of academic spin-offs. We capture the quality of management practices drawing upon an existing methodology that has been used in manufacturing (Bloom et al., 2007; Bloom et al., 2012), health care (Bloom, et al., 2015b), schools (Bloom et al., 2015a), and higher education (McCormack et al., 2014). Notably, we

[8] To obtain real turnover, gross turnover has been deflated by adopting the ratio of current prices to chained-linked prices (reference year 2010) at the higher level of disaggregation, as provided by the Italian National Institute of Statistics (ISTAT) at the NACE rev. 2 2-digit industrial level.

[9] As further robustness check, we have also run the analysis by bootstrapping standard errors with 1000 replications. Results do not differ from those presented in the main text and are available from the authors upon request.

adapted the survey developed by McCormack et al. (2014) in their analysis of the effect of management practices on teaching and publication performance of UK universities. The focus is on management practices which belong to five main categories.

Our first category relates to operations aimed at supporting the creation and development of spin-offs. The respondents to our questionnaire were asked to rate the importance of different practices supporting the creation and development of academic spin-offs in the period 2010–2014. The respondents were asked to rank the importance of the items on a five-point Likert scale, ranging from ‘not important’ to ‘highly important’. The different practices were: (1) coaching; (2) mentoring; (3) awards and internal competition; (4) training support; (5) support in the development of a proof-of-concept; (5) support for patenting activity and (6) help with fund raising activity. We run factor analysis on the six different items to synthesize the information in common factors underlying ‘lean’ management practices. The three resulting predicted factors are used as our first set of explanatory variables in the econometric model. Previous literature assists in the interpretation of these three constructs (Bloom et al., 2014). The first factor contains a range of items that involve support operations relating to training, such as counselling activity for the academic spin-off founding team, but also specific on-the-job training activities. Accordingly, this factor is labelled *Support Operations Training*. The second group, *Support Operations Patent*, includes two items that relate to the patenting activities which are conducive to the creation and development of the spin-offs: support in the proof of concept and assistance in the process of filing. The third group comprises a single item which refers to fund raising activity. The corresponding variable is labelled *Support Operations Funding*.

Our second category of management practices captures the relevance of different targets/objectives for the spin-off firms. We use information about the management of targets/objectives as defined by the university TTO’s. We built this set of variables from responses to the following question contained in the survey: “How would you rate the level of importance for the following goals for the spin-offs your organisation has contributed to create?”. Respondents were asked to provide a score between one and five, with a higher score indicating a better performance. Four items were present: (i) growth; (ii) scientific excellence; (iii) employment creation, and (iv) technological excellence. Similarly to our first set of explanatory variables, we run factor analysis to reduce the information in common factors underlying target management practices. The two resulting predicted factors are again used as explanatory variables in the econometric model. Quite straightforwardly, we obtain two factors. The first one is mainly related to growth targets – item (i) and (iii) above – and is labelled *Target Growth.* The second group includes items (ii) and (iv) above and relates to scientific/technological objectives (*Target Scientific Excellence*).[10]

[10]We run a number of robustness checks to evaluate the robustness of results from factor analyses for the first two sets of explanatory variables (*support operations* and *target management*). First, we adopted different methods of factor extraction – principal components, iterated principal factors and

Our third key variable relates to the monitoring activities in place to track the performance of the academic spin-offs. Respondents were asked whether the performance of the spin-offs was regularly tracked and whether this was done using specific measures (e.g. balance sheet information, reports from the spin-off management team, etc.). *Monitoring Management* is a dummy variable which takes value one if the respondents answered positively to both questions and zero otherwise.

Fourth, we capture the existence of incentives management drawing on responses to the following question contained in the survey: "Do you have a reward system (e.g. rewarding or promoting high performers) for your employees linked to the achievement of targets/objectives set out for the spin-offs?". *Incentives Management* takes the value one if the organisation has a reward system for personnel, and zero otherwise.

Finally, we measure people management with the ability of the TTO to attract human capital from the private sector (Bloom et al., 2015a). As supporting the creation and development of academic spin-offs can potentially benefit from the combination of skills and competences from different organisational dimensions (e.g. private and public organisations), we expect the ability of the TTO to attract employees with private sector experience to be a good proxy for the ability of universities to hire talent with private sector experience. *Professional Management* is thus computed as the share of TTO employees with at least 2 years of experience in the private sector.

7.3.4 Controls

To account for other firm- and university-level attributes that might be associated with the growth of academic spin-offs, we considered some additional control variables.[11]

First, we control for a set of variables that are often included in growth rate regression models: the stock of investment in tangible (*Tangible Capital Stock*) and intangible (*Intangible Capital Stock*) assets. Investments and access to capital are recognised as important explanatory factors when explaining firms' growth (Hall,

maximum likelihood – which yield consistent results. We further test the robustness of the factor analyses by running them with a polychoric correlation matrix, which has been shown to be more appropriate with ordinal variables (Flora and Curran, 2004). Finally, we included in the regressions the average value of the items entering each factor instead of the predicted factor. The results are robust to all these specifications and are available from the authors upon request.

[11] We are unable to include fixed effects in our regressions as our core explanatory variables (management practices) are time invariant, nevertheless we believe that the rich set of variables described in this section would contribute to control for the influence of intra-firm strategies and capabilities.

1986).[12] *Tangible Capital Stock* (*Intangible Capital Stock*) is calculated as the yearly net acquisition of tangible (intangible) assets plus the amortisation (Grazzi et al., 2015).[13] Moreover, based on Gibrat's law and other works on firms' growth (e.g., Audretsch et al., 2012), we control for initial firm size measured as the turnover of the firm (*Turnover*). All these variables have been lagged by 1 year to minimise problems of reverse causality and log transformed (plus one).

Second, we included structural characteristics for the firms in our sample, such as firm age (*Age*), *Herfindahl-Hirschman index* as a popular measure of industry concentration which has been found to play a relevant role with respect to firms' performance (Kaniovski & Peneder, 2008) and *University Size* (the number of tenured professors per university).[14] This information was obtained from the data provided by Bureau van Dijk AIDA and the Italian Ministry of Education, Universities and Research (MIUR). In order to control for the scientific and technological sectorial base, we include controls for 37 industries (NACE rev.2 2 digit level). Finally, we include two different sets of dummy variables to control for geographical (NUTS 2 level) and time effects (period 2006–2014).[15]

Table 7.2 presents the descriptive statistics for the variables used in this study; Table 7.3 reports the correlation matrix of our variables. In general, correlation among the independent variables is low, and variance inflation factor range between 1.2 and 7.2 (well below the threshold value of 10) suggesting the absence of multicollinearity problems.

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[12] We do not have information on the amount of venture capital obtained by the firm. Although venture capital has been shown to explain spin-offs' growth in a large number of contexts, this does not necessarily apply to the Italian case where venture capitalists play a minor role. For example, Bolzani et al., (2014) show that VC-backed academic spin-offs in Italy have been around the 1% of the total over the period 2003–2013. Even more interestingly, the average nominal equity invested by VCs has been less than 1 million euros over the period 2010–2013.

[13] Investments are measured in millions of euros and deflated by adopting the ratio of current prices to chained-linked prices (reference year 2010) at the NACE rev. 2 2-digit industry level, as provided by the Italian National Institute of Statistics (ISTAT) The investments have later been transformed into stocks. We adopt the standard approach found in the relevant literature and calculate it using the following formula: $K_t = K_{t-1}(1-\delta) + P_t$ where K_{t-1} is the stock of capital at year $t-1$, δ is the depreciation rate assumed at 5%, and P_t is the investment in year t.

[14] *HH index* is the sum of the square of the turnover shares of firms operating in (NACE Rev.2) industries. University size is measured by the number of tenured professors per university because, owing to the data sources used, only they held relevance for spin-off establishment in our study (please refer to the definition of academic spin-off reported in footnote 2).

[15] We have also tried to include a number of controls at the TTO level (e.g. TTO's age and size) but they do not contribute to explain academic spin-offs' growth. Consequently, we do not include these variables in our estimates on the ground of parsimony.

Table 7.2 Descriptive statistics ($n = 3695$)

Variable	Mean	Std. Dev.	Min	Max
Turnover Growth	0.08	2.57	−13.81	13.81
Turnover	0.31	2.13	0	97.53
Support operations – training	2.13	0.82	0	3.75
Support operations – patent	2.19	0.75	0.5	3.5
Support operations – funding	1.72	0.97	0	4
Monitoring management	0.70	0.46	0	1
Target – growth	2.31	1.06	0	3.5
Target – scientific excellence	2.13	1.01	0	3.5
Incentives management	0.08	0.27	0	1
Professional management	31.34	33.12	0	100
Tangible capital stock	0.08	0.36	0	6.21
Intangible capital stock	0.12	0.45	0	7.44
Industrial concentration index	0.05	0.06	0.001	0.95
Age	5.28	2.73	2	14
University size	1165.77	783.52	58	4161

Descriptive statistics for tangible capital stock, intangible capital stock and turnover refer to the variables before natural log-transformation and are measured in million euros.

7.4 Results and Discussion

7.4.1 Core Findings

The main results are reported in Table 7.4 Model 1 presents the OLS estimates while Models 2 to 6 show results for different percentiles of the conditional growth rate distribution (10th, 25th, 50th, 75th and 90th percentiles).

Concerning "lean" operations management which support the creation and development of spin-offs, we observe a positive and significant effect of *Support Operations Training* ($\beta = 0.094$, $p < 0.1$) and *Support Operations Patent* ($\beta = 0.142$, $p < 0.01$) on spin-off's growth. Interestingly, when we take into consideration the effects at different points of the conditional growth rate distribution by adopting our quantile regression approach (Columns 2 to 6 of Table 7.4), we still observe a positive and significant effect of *Support Operations Training* ($\beta = 0.153$, $p < 0.01$; $\beta = 0.023$, $p < 0.1$) and *Support Operations Patent* ($\beta = 0.116$, $p < 0.01$; $\beta = 0.074$, $p < 0.01$), but only for low-growth companies which belong to the 10th and 25th percentiles.

Regarding the role of target management, Table 7.4 reports negative and significant coefficients of *Target Growth* for OLS estimates as well as all the percentiles in the conditional growth rate distribution. Our results seem to point to a controversial outcome: setting a growth goal for academic spin-offs leads to a negative effect on the actual ability of these companies to realise turnover growth.

As for incentives management, Table 7.4 provides good evidence of a positive relationship between reward systems for the achievement of specific objectives of

Table 7.3 Correlation table

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
[1]	Turnover	1											
[2]	Support operations – training	0.047	1										
[3]	Support operations – patent	−0.026	0.085	1									
[4]	Support operations – funding	0.017	0.171	0.296	1								
[5]	Monitoring management	0.031	−0.204	−0.004	0.005	1							
[6]	Target – growth	−0.021	0.144	0.173	−0.090	−0.101	1						
[7]	Target – scientific excellence	0.033	0.161	−0.258	−0.035	0.007	0.169	1					
[8]	Incentives management	−0.018	0.130	−0.073	−0.215	−0.121	−0.015	0.176	1				
[9]	Professional management	−0.001	−0.161	−0.167	0.106	−0.265	−0.364	0.250	0.201	1			
[10]	Tangible capital stock	0.541	0.091	0.026	0.029	−0.062	−0.001	0.036	−0.040	−0.011	1		
[11]	Intangible capital stock	0.062	0.041	0.099	0.058	−0.015	0.073	−0.006	−0.047	−0.064	0.454	1	
[12]	Industrial concentration index	−0.014	−0.048	0.037	0.042	0.013	0.028	0.016	−0.011	0.002	−0.014	0.004	1
[13]	Age	0.056	0.034	0.018	0.003	−0.047	0.079	−0.006	0.063	−0.112	0.155	0.148	−0.014

Table 7.4 The relationship between management practices and the growth of academic spin-offs

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Support operations – training	0.094*	0.153***	0.023*	−0.007	−0.013	0.036
	[0.052]	[0.049]	[0.014]	[0.013]	[0.032]	[0.067]
Support operations – patent	0.142***	0.116***	0.074***	0.013	0.033	0.074*
	[0.048]	[0.039]	[0.017]	[0.018]	[0.022]	[0.042]
Support operations – funding	−0.014	0.019	0.031	0.019*	0.031	0.006
	[0.037]	[0.031]	[0.023]	[0.011]	[0.026]	[0.039]
Monitoring management	−0.046	0.048	−0.047	−0.029	−0.035	−0.030
	[0.159]	[0.148]	[0.072]	[0.034]	[0.070]	[0.159]
Target – scientific excellence	0.064	0.072	0.016	0.006	0.023	0.044
	[0.043]	[0.049]	[0.017]	[0.012]	[0.026]	[0.034]
Target – growth	−0.095**	−0.126***	−0.074***	−0.035**	−0.045*	−0.105**
	[0.042]	[0.039]	[0.018]	[0.014]	[0.025]	[0.051]
Incentives management	0.291	0.528*	0.271**	0.133*	0.371***	0.665*
	[0.353]	[0.320]	[0.105]	[0.080]	[0.137]	[0.383]
Professional management	−0.004***	−0.005***	−0.003***	−0.002***	−0.003***	−0.005**
	[0.001]	[0.002]	[0.001]	[0.000]	[0.001]	[0.002]
Log tangible capital stock −1	1.389***	0.678***	0.269**	0.078	1.310***	2.241***
	[0.372]	[0.159]	[0.113]	[0.074]	[0.352]	[0.363]
Log intangible capital stock −1	−0.269	−0.151	−0.089	−0.057*	0.210	0.366*
	[0.316]	[0.168]	[0.142]	[0.032]	[0.169]	[0.193]
Ind concentration index −1	0.642	−0.172	0.159	0.220	0.178	0.490*
	[0.556]	[0.777]	[0.216]	[0.137]	[0.232]	[0.281]
Log age −1	−0.182***	−0.039	−0.087***	−0.132***	−0.087**	0.037
	[0.059]	[0.069]	[0.026]	[0.018]	[0.043]	[0.079]

(continued)

Table 7.4 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Log Univ size	0.033	−0.034	0.034	0.012	0.096***	0.141**
	[0.089]	[0.072]	[0.023]	[0.021]	[0.036]	[0.068]
Turnover −1	−0.294***	−0.067***	−0.032***	−0.013***	−0.417***	−0.735***
	[0.024]	[0.011]	[0.005]	[0.004]	[0.065]	[0.016]
Industry controls	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
Year controls	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
Geographical controls	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
N	3695.000	3695.000	3695.000	3695.000	3695.000	3695.000

Robust standard errors clustered at university level are reported in parenthesis.
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

the spin-offs and turnover growth across all the percentiles. Model 6 indicates that the highest effect of *Incentives Management* is to be found for high-growth companies ($\beta = 0.665$, $p < 0.1$).

Finally, as long as professional management is concerned, we find evidence of a negative relationship between the share of TTO's employees with at least 2 years of business experience and the conditional growth rate distribution. Models 1 to 6 always report a negative and significant coefficient of *professional Management*.

7.4.2 Robustness Checks

We check the stability of our results to two problems. First, there might be problems related to the misalignment of the time-frame for firm- and university-level information. While information referring to university management practices, which come from our survey, refers to the period 2010–2014, we are able to control for firm-level characteristics (included turnover growth) for a longer period (2006–2014). Although management practices tend to be persistent and to take much effort and time to change, we checked the robustness of our results to this problem by estimating our models for the reduced time period 2010–2014 which represents a perfect overlap between firm- and university-level information.[16] We also consider the likelihood that our results are driven by a low number of high or low performing spin-offs in some universities: universities with a reduced number of spin-offs are characterised by an extremely high (or low) average turnover growth over the period 2006–2010. In order to control for this, we consider the sample of universities which have ten spin-offs or more. This amounts to drop twelve universities and 68 spin-offs from our initial sample. Tables 7.5 and 7.6 provide evidence of the robustness of our main results with minor variations from our core findings.

7.4.3 Discussion

Our results bear a number of implications in regard to the role of university management practices that may influence academic spin-offs. First and foremost,

[16]The persistency of management practices for academic spin-offs has also been confirmed by introductory semi-structured interviews we had with 6 heads of TTOs before starting with the large-scale survey. Several interviewees stressed how the Italian university system has been historically characterised by a slow process of adaptation to the university-industry practices of other European countries and that the support and practices for academic spin-offs do not represent an exception to this general trend.

Table 7.5 The relationship between management practices and the growth of academic spin-offs – period 2010–2014

	(1)	(2)	(3)	(4)	(5)
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Support operations – training	0.048	0.013	−0.015	−0.024	0.084
	[0.062]	[0.013]	[0.012]	[0.034]	[0.054]
Support operations – patent	0.061	0.051***	0.005	0.031	0.073
	[0.062]	[0.017]	[0.016]	[0.029]	[0.055]
Support operations – funding	0.022	0.004	0.003	0.014	−0.026
	[0.037]	[0.014]	[0.012]	[0.026]	[0.041]
Monitoring management	−0.068	−0.047	−0.036	−0.108	−0.058
	[0.182]	[0.051]	[0.031]	[0.080]	[0.122]
Target – scientific excellence	−0.018	−0.003	0.017	0.029	0.027
	[0.048]	[0.014]	[0.013]	[0.025]	[0.043]
Target – growth	−0.065*	−0.046**	−0.029**	−0.056**	−0.138**
	[0.039]	[0.019]	[0.013]	[0.029]	[0.057]
Incentives management	0.198	0.198	0.082	0.407**	0.725***
	[0.483]	[0.124]	[0.078]	[0.199]	[0.237]
Professional management	−0.005**	−0.002***	−0.001***	−0.004***	−0.005***
	[0.002]	[0.001]	[0.000]	[0.001]	[0.002]
Log tangible capital stock −1	0.644***	0.306***	0.060	1.304***	2.236***
	[0.155]	[0.100]	[0.059]	[0.389]	[0.274]
Log intangible capital stock −1	0.122	−0.050	−0.016	0.259*	0.439**
	[0.304]	[0.102]	[0.037]	[0.155]	[0.196]
Ind concentration index −1	−0.074	−0.007	0.247*	0.271	0.537*
	[1.097]	[0.314]	[0.127]	[0.260]	[0.279]
Log age −1	−0.029	−0.078***	−0.105***	−0.056	0.062
	[0.071]	[0.029]	[0.017]	[0.041]	[0.088]
Log Univ size	0.048	0.021	0.002	0.084*	0.119**
	[0.086]	[0.036]	[0.020]	[0.048]	[0.057]
Turnover −1	−0.061***	−0.033***	−0.011***	−0.425***	−0.731***
	[0.011]	[0.004]	[0.004]	[0.063]	[0.024]
Industry controls	Inc.	Inc.	Inc.	Inc.	Inc.
Year controls	Inc.	Inc.	Inc.	Inc.	Inc.
Geographical controls	Inc.	Inc.	Inc.	Inc.	Inc.
N	2855.000	2855.000	2855.000	2855.000	2855.000

Robust standard errors clustered at university level are reported in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7.6 The effect of management practices on the growth of academic spin-offs – universities with 10 spin-offs or more

	(1)	(2)	(3)	(4)	(5)
	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile
Support operations – training	0.068	0.024*	0.003	0.002	0.055
	[0.070]	[0.013]	[0.013]	[0.032]	[0.069]
Support operations – patent	0.151***	0.052***	0.002	0.037	0.073
	[0.047]	[0.017]	[0.019]	[0.024]	[0.046]
Support operations – funding	0.062	0.036*	0.020	0.028	0.010
	[0.069]	[0.019]	[0.013]	[0.038]	[0.040]
Monitoring management	−0.741**	−0.107**	−0.018	0.010	0.079
	[0.325]	[0.054]	[0.058]	[0.120]	[0.245]
Target – scientific excellence	0.142***	0.025	0.035*	0.051*	0.038
	[0.035]	[0.016]	[0.018]	[0.029]	[0.032]
Target – growth	−0.284***	−0.072***	−0.028	−0.038	−0.108*
	[0.048]	[0.018]	[0.020]	[0.030]	[0.055]
Incentives management	−1.115	0.154	0.197*	0.511**	0.922*
	[0.732]	[0.104]	[0.105]	[0.211]	[0.553]
Professional management	−0.010***	−0.003***	−0.002**	−0.003**	−0.005**
	[0.002]	[0.001]	[0.001]	[0.001]	[0.002]
Log tangible capital stock −1	0.638***	0.234**	0.065	1.248***	2.236***
	[0.129]	[0.103]	[0.066]	[0.439]	[0.301]
Log intangible capital stock −1	−0.128	−0.041	−0.043	0.211	0.348*
	[0.193]	[0.135]	[0.037]	[0.164]	[0.190]
Ind concentration index −1	−0.002	−0.150	0.078	−0.272	0.136
	[0.956]	[0.512]	[0.209]	[0.537]	[0.915]
Log age −1	0.019	−0.093***	−0.135***	−0.096**	0.040
	[0.100]	[0.024]	[0.019]	[0.044]	[0.091]
Log Univ size	−0.417**	0.018	0.028	0.118*	0.185*
	[0.167]	[0.030]	[0.028]	[0.071]	[0.096]
Turnover −1	−0.064***	−0.029***	−0.014***	−0.403***	−0.733***
	[0.013]	[0.005]	[0.005]	[0.071]	[0.019]
Industry controls	Inc.	Inc.	Inc.	Inc.	Inc.
Year controls	Inc.	Inc.	Inc.	Inc.	Inc.
Geographical controls	Inc.	Inc.	Inc.	Inc.	Inc.
N	3394.000	3394.000	3394.000	3394.000	3394.000

Robust standard errors clustered at university level are reported in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

in line with the recent developments in the literature on the empirical economics of management (Bloom et al., 2014), we obtain evidence that university management practices contribute to explaining the variation in the growth of academic spin-offs. At the same time, our results suggest that the overall picture is far from unambiguous. While some types of management practices (*support operations* and *incentives*) show a positive correlation with the growth of academic spin-offs, other management practices (*target* and *professional management*) are negatively correlated. In subsequent paragraphs, we argue that the specific organisational context, namely, a public university system, can help to shed light on these contrasting results.

Out of the five possible different typologies of management practices, we find that the most relevant ones are *support operations* and *incentives management*. For the former, we show that the extent of the adoption of management practices to support *patent* and *training* is positively correlated to the growth of the spin-offs, although this positive correlation is significant for low-growth spin-offs only. This result resonates well with the historical reason that brought public universities to establish TTOs in the first place. TTO offices were designed to economise on a number of functional services within universities, particularly by pooling innovations and services across research units subject to economies of scale and learning, such as patenting (Macho-Stadler et al., 2007). This approach has been a key support for spin-offs, which bet their destiny on a patent and invest in patenting as their main strategic avenue (i.e., possibly to realise a profitable exit through acquisition).

As for incentive management, a positive and significant correlation is shown with growth, particularly for high-growth spin-offs. This result relates to the findings of the recent literature on management practices, which show that incentives are an effective way, even for public organisations (e.g., hospitals, schools, and universities), to react to external competition or institutional pressure (Bloom et al., 2015a, 2015b; McCormack et al., 2014). Similarly, incentives have been shown to be an important determinant of technology transfer in technology transfer literature (Friedman & Silberman, 2003). We contribute to this literature by showing that incentive management contributes to explaining the performance of academic spin-offs, as well.

Our result that professional management has a negative correlation with growth, with no remarkable differences being observed across the conditional growth distribution, points to a double-faceted selection process. On one hand, we interpret this result as evidence on the existence of an adverse selection process where universities are often unable to attract external talent. Notably, the presence of a standardised contract, the lack of flexibility in offering adequate benefits or a compensation package comparable to the private sector, as well as the hiring procedure can limit the attractiveness of public job posts for candidates from the private sector (Karl & Sutton, 1998; Buelens & Van den Broeck, 2007). On the other hand, even when universities manage to attract excellent employees from the private sector, problems can still arise. Notably, there could be a misalignment between the previous experience of the employee hired from the private sector and the real knowledge required to efficiently perform the job. Similarly, universities may be unable to create the conditions whereby the newly hired employee is able to perform due to the limited degrees of freedom or a lack of adequate flexibility.

Finally, the negative association between target setting and the performance of academic spin-offs resonates well with recent findings in management practices literature when applied to public administrations (Benassi & Rentocchini, 2017). A number of reasons explain the above result. First, the selection at entrance for academic spin-offs has been historically weak with the absence of appropriate support after the start-up phase (Siegel et al., 2007). Second, and more importantly, there is often a lack of credibility coming from setting growth objectives in universities, as TTOs are often unable to enforce the achievement of these goals with credible actions (e.g., credible threats or rewards). Furthermore, growth targets usually refer to the short-term, but setting stringent goals in the short-term can actually be detrimental to medium- or long-term growth, which is likely the main interest of academic spin-offs. This is particularly relevant in the valorisation of patents when they form a central intellectual asset for the spin-off (Djokovic & Souitaris, 2008). These last two points suggest that the existence of growth targets by universities can be mere 'ceremonial' commitments. Therefore, academic spin-offs are likely to systematically miss these short-term targets and instead aim for medium- or long-term growth targets.

7.5 Conclusions

Academic spin-offs are a possible backbone of universities' third mission and can play a key role in transferring knowledge to local contexts (Mathisen & Rasmussen, 2019; Benassi & Rentocchini, 2017). Recent works in the field of academic entrepreneurship have focused mainly on the antecedents of spin-off creation by universities and spin-off performance.

Our study can be instrumental in bridging these two areas of research. The analysis of internal processes might help explain under which conditions spin-offs originate and how they evolve over time. From this perspective, our study contributes to the research stream of academic entrepreneurship by using the management practices framework. We interpret management practices as an outcome of universities' decisions. We assume that, despite the fact that rules and regulations do constrain their autonomy, universities have degrees of freedom in structuring internal processes regarding spin-offs. We observed significant differences in how universities structure their processes: management practices are not all alike and their adoption is uneven.

We also find that not all management practices have the same effect. Some management practices show a counterintuitive relationship with spin-off growth: it is the case of the negative coefficient of growth target setting. This finding highlights the difficulty of importing practices that are 'developed' in other institutional settings. It is reasonable to assume that there is a fit issue, as universities are organisations facing new challenges. We believe that future research on different management practices and their impact on spin-off performance should help in designing more appropriate governance structures and coordination mechanisms for universities.

Our study has several limitations. First and foremost, it refers to Italy, whose institutional context is for several reasons distinct from those of other countries. We focused on public universities, by far the large majority of the Italian population. Private universities might leverage management practices for academic spin-offs more freely.

Second, our study covers a significant time interval as far as spin-off performance is concerned but does not offer comparable data and information on the adoption of management practices. We did not observe management practices from a longitudinal viewpoint, so we cannot completely rule out the possibility of reversed causality between observed results and specific management practices.

Third, management practices are not algorithms. They require interpretation and adaptation by competent decision-makers. In other words, more investigation is required to assess the interdependence between management practices and competence of decision-makers.

Finally, as hierarchy is not the usual coordination mode universities use, the enforcement of management practices might differ widely. Some universities might simply suggest which practices spin-offs should adopt; others might have a say and directly influence spin-offs. More evidence on the real adoption of management practices from a spin-offs point of view is required.

Despite these limitations, we are confident that our study has relevant policy implications for universities and policy makers. First, universities should be more aware of the management practices they adopt and how these practices fit into their internal organisation. Second, universities should focus on practices they can directly enforce. For example, training support depends on regulations set in place at the university level, whereas target setting is likely to be better enforced by the spin-off founding team. Third, launching spin-offs requires time and is not a one-shot activity. Universities can be equipped for providing services and assistance in the first stages, but too constrained in the following stages. Therefore, management practices supported in theory have low chances to be adopted in practice.

References

Audretsch, D. B., Hülsbeck, M., & Lehmann, E. E. (2012). Regional competitiveness, university spillovers, and entrepreneurial activity. *Small Business Economics, 39*(3), 587–601.

Benassi, M. (2014). *Exploring incubation performances and its determinants*. International Conference on Incubation and Regional Development, Toulouse, October 23th, 2014.

Benassi, M., & Rentocchini, F. (2017). Academic spin-offs and regional development: New insights for future research. *Ekonomiaz. Revista Vasca de Economía, 92*(02), 190–221.

Bercovitz, J. E., & Feldman, M. P. (2008). Academic entrepreneurs: Organizational change at the individual level. *Organization Science, 19*(1), 69–89.

Bertrand, M., & Schoar, A. (2003). Managing with style: The effect of managers on firm policies. *The Quarterly Journal of Economics, 118*(4), 1169–1208.

Bloom, N., Brynjolfsson, E., Foster, L., Jarmin, R., Patnaik, M., Saporta-Eksten, I., & Van Reenen, J. (2017). *What drives differences in management? (w23300)*. National Bureau of Economic Research.

Bloom, N., Genakos, C., Sadun, R., & Van Reenen, J. (2012). Management practices across firms and countries. *The Academy of Management Perspectives, 26*(1), 12–33.

Bloom, N., Lemos, R., Sadun, R., & Van Reenen, J. (2015a). Does Management Matter in Schools? *The Economic Journal, 125*, 647–674.

Bloom, N., Lemos, R., Sadun, R., Scur, D., & Van Reenen, J. (2014). Jeea-Fbbva lecture 2013: The new empirical economics of management. *Journal of the European Economic Association, 12*(4), 835–876.

Bloom, N., Sadun, R., & Van Reenen, J. (2007). *Americans do IT better: US multinationals and the productivity miracle (w13085)*. National Bureau of Economic Research.

Bloom, N., Propper, C., Seiler, S., & Van Reenen, J. (2015b). The impact of competition on management quality: Evidence from public hospitals. *The Review of Economic Studies, 82*(2), 457–489.

Bloom, N., & Van Reenen, J. (2006). *Measuring and explaining management practices across firms and countries (w12216)*. National Bureau of Economic Research.

Bloom, N., & Van Reenen, J. (2010). Why do management practices differ across firms and countries? *The Journal of Economic Perspectives, 24*(1), 203–224.

Bottazzi, G., & Secchi, A. (2003). Common properties and sectoral specificities in the dynamics of US manufacturing companies. *Review of Industrial Organization, 23*(3–4), 217–232.

Buchinsky, M. (1998). Recent advances in quantile regression models: a practical guideline for empirical research. *Journal of Human Resources, 33*(1), 88–126.

Buelens, M., & Van den Broeck, H. (2007). An analysis of differences in work motivation between public and private sector organizations. *Public Administration Review, 67*(1), 65–74.

Coad, A., & Rao, R. (2008). Innovation and firm growth in high-tech sectors: A quantile regression approach. *Research Policy, 37*(4), 633–648.

Cohen, W. M., Florida, R., Randazzese, L., & Walsh, J. (1998). Industry and the academy: Uneasy partners in the cause of technological advance. In R. Noll (Ed.), *Challenge to the research university* (pp. 171–200). Brookings Institution.

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

Degroof, J. J., & Roberts, E. B. (2004). Overcoming weak entrepreneurial infrastructures for academic spin-off ventures. *Journal of Technology Transfer, 29*(3–4), 327–352.

Delmar, F., Davidsson, P., & Gartner, W. B. (2003). Arriving at the high-growth firm. *Journal of Business Venturing, 18*(2), 189–216.

Di Gregorio, D., & Shane, S. (2003). Why do some universities generate more start-ups than others? *Research Policy, 32*(2), 209–227.

Djokovic, D., & Souitaris, V. (2008). Spinouts from academic institutions: A literature review with suggestions for further research. *The Journal of Technology Transfer, 33*(3), 225–247.

Flora, D. B., & Curran, P. J. (2004). An empirical evaluation of alternative methods of estimation for confirmatory factor analysis with ordinal data. *Psychological Methods, 9*(4), 466. Chicago.

Florida, R., & Cohen, W. M. (1999). Engine or infrastructure? The university role in economic development. In L. M. Branscomb, F. Kodama, & R. Florida (Eds.), *Industrializing knowledge: University–industry linkages in Japan and the United States* (pp. 589–610). MIT Press.

Friedman, J., & Silberman, J. (2003). University technology transfer: Do incentives, management, and location matter? *The Journal of Technology Transfer, 28*(1), 17–30.

Goedhuys, M., & Sleuwaegen, L. (2010). High-growth entrepreneurial firms in Africa: A quantile regression approach. *Small Business Economics, 34*(1), 31–51.

Grazzi, M., Jacoby, N., & Treibich, T. (2015). Persistance du comportement d'investissement dans le secteur manufacturier français. *Revue d'Économie Industrielle*, *150*, 51–79.

Hall, B. H. (1986). *The relationship between firm size and firm growth in the US manufacturing sector*. Chicago.
Kaniovski, S., & Peneder, M. (2008). Determinants of firm survival: A duration analysis using the generalized gamma distribution. *Empirica, 35*(1), 41–58.
Karl, K. A., & Sutton, C. L. (1998). Job values in today's workforce: A comparison of public and private sector employees. *Public Personnel Management, 27*(4), 515–527.
Kesidou, E., & Demirel, P. (2012). On the drivers of eco-innovations: Empirical evidence from the UK. *Research Policy, 41*(5), 862–870.
Likert, R. (1961). *New patterns of management*. McGraw Hill.
Lockett, A., Wright, M., & Franklin, S. (2003). Technology transfer and universities' spin-out strategies. *Small Business Economics, 20*, 185–200.
Lockett, A., Siegel, D., Wright, M., & Ensley, M. D. (2005). The creation of spin-off firms at public research institutions: Management and policy implications. *Research Policy, 34*(7), 981–993.
Louis, K. S., Blumenthal, D., Gluck, M. E., & Stoto, M. A. (1989). Entrepreneurs in academe: An exploration of behaviors among life scientists. *Administrative Science Quarterly, 34*, 110–131.
Macho-Stadler, I., Pérez-Castrillo, D., & Veugelers, R. (2007). Licensing of university inventions: The role of a technology transfer office. *International Journal of Industrial Organization, 25*(3), 483–510.
March, J. G. (1999). *The pursuit of organizational intelligence*. Blackwell Publishers.
Markman, G., Phan, P., Balkin, D., & Gianiodis, P. (2004). Entrepreneurship from the ivory tower: Do incentive systems matter? *Journal of Technology Transfer, 26*(3), 233–245.
Mathisen, M. T., & Rasmussen, E. (2019). The development, growth, and performance of university spin-offs: A critical review. *The Journal of Technology Transfer, 44*(6), 1891–1938.
McCormack, J., Propper, C., & Smith, S. (2014). Herding cats? Management and university performance. *The Economic Journal, 124*(578), F534–F564.
Merton, R. K. (1973). *The sociology of science: Theoretical and empirical investigations*. University of Chicago Press.
Miranda, F. J., Chamorro, A., & Rubio, S. (2018). Re-thinking university spin-off: A critical literature review and a research agenda. *The Journal of Technology Transfer, 43*(4), 1007–1038.
Muscio, A., Quaglione, D., & Ramaciotti, L. (2016). The effects of university rules on spinoff creation: The case of academia in Italy. *Research Policy, 45*(7), 1386–1396.
O'Shea, R. P., Allen, T. J., Chevalier, A., & Roche, F. (2005). Entrepreneurial orientation, technology transfer and spinoff performance of US universities. *Research Policy, 34*(7), 994–1009.
Parente, P. M., & Santos Silva, J. (2016). Quantile regression with clustered data. *Journal of Econometric Methods, 5*(1), 1–15.
Patzelt, H., & Shepherd, D. A. (2009). Strategic entrepreneurship at universities: Academic entrepreneurs' assessment of policy programs. *Entrepreneurship Theory and Practice, 33*(1), 319–340. Chicago.
Pazos, D. R., López, S. F., González, L. O., & Sandiás, A. R. (2012). A resource-based view of university spin-off activity: New evidence from the Spanish case. *Revista Europea de Dirección y Economía de la Empresa, 21*(3), 255–265.
Ramacciotti, L., & Daniele, C. (2015). Protagonisti dell'ecosistema dell'innovazione? *XII Rapporto Netval sulla Valorizzazione della Ricerca Pubblica Italiana*, ISBN: 978-88-6550-459-8.
Rasmussen, E., Mosey, S., & Wright, M. (2011). The evolution of entrepreneurial competencies: A longitudinal study of university spin-off venture emergence. *Journal of Management Studies, 48*(6), 1314–1345.
Reitan, B. (1997). Fostering technical entrepreneurship in research communities: Granting scholarships to would be entrepreneurs. *Technovation, 17*(6), 287–296.
Rothaermel, F. T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change, 16*(4), 691–791.
Sauermann, H., & Stephan, P. (2012). Conflicting logics? A multidimensional view of industrial and academic science. *Organization Science, 24*, 889–909.

Schmitz, A., Urbano, D., Dandolini, G. A., de Souza, J. A., & Guerrero, M. (2017). Innovation and entrepreneurship in the academic setting: A systematic literature review. *International Entrepreneurship and Management Journal, 13*(2), 369–395.

Siegel, D. S., Wright, M., & Lockett, A. (2007). The rise of entrepreneurial activity at universities: Organizational and societal implication. *Industrial and Corporate Change, 16*, 489–504.

Soetanto, D., & Jack, S. (2016). The impact of university-based incubation support on the innovation strategy of academic spin-offs. *Technovation, 50–51*, 25–40.

Stinchcombe, A. L. (1965). Social structure and organizations. In J. G. March (Ed.), *Handbook of organizations* (Vol. 44(2), pp. 142–193). Routledge.

Vinig, G. T., & Van Rijsbergen, P. J. (2012). Determinants of university technology transfer—A comparative study of US, European and Australian Universitie. In A. Malach-Pines (Ed.), *Handbook of research on high technology entrepreneurship*. Edward Elgar.

Zhang, J. (2009). The performance of university spin-offs: An exploratory analysis using venture capital data. *The Journal of Technology Transfer, 34*(3), 255–285.

Chapter 8
Public Research Organizations and Technology Transfer: Flexibility, Spatial Organization and Specialization of Research Units

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Abstract The aim of the present work is to understand whether the institutional dynamics of Public Research Organizations (in particular, the flexible structure of research units and their physical proximity to firms, as well as their research specialization) have a positive impact on Technology Transfer, helping to create and maintain collaborations with firms. The main subject of the research are large PROs, i.e., research bodies characterized by a wide coverage of scientific fields and by the presence of a geographically distributed research network. In order to address our research question, the paper exploits the results of a multiple case study analysis performed on the Institutes of the CNR, the National Research Council of Italy. The results show the positive impact on technology transfer of the internal organization and flexible structure of large PROs, as well as the positive externalities of research units localization across different proximity dimensions. The conclusions of our work offer policy suggestions and cues for future research.

Keywords Large Public Research Organization · Italy · Technology transfer · Case study · Interviews

8.1 Introduction

The aim of the present work is to understand if and how some specific institutional dynamics of Public Research Organizations (PROs from now on) positively impact on their technology transfer (TT from now on) activities. We try to answer the following research question: how do the institutional dynamics typical of PROs

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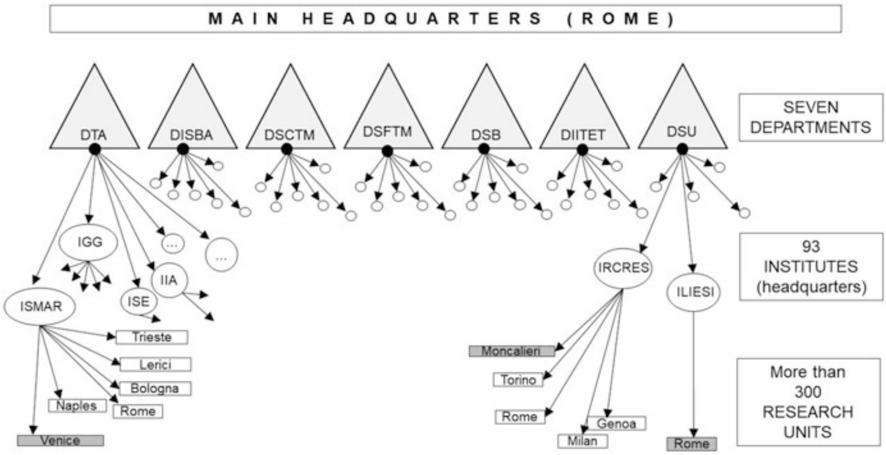

Fig. 8.1 Structure of CNR scientific network

influence their cooperation with firms for TT, stimulating (or discouraging) firms in cooperating with them? The theoretical contribution of this paper lies in the study of the effects of the organization of PROs and of research bodies in general on TT, thus deepening the analysis of the drivers of research-industry interactions.

Specifically, as the experimental section shows, our research mainly deals with the effects on large PROs of the flexible structure of research units and of their spatial organization, close to industrial environments and firms. We define large PROs as those "umbrella organizations" encompassing the complete spectrum of human knowledge in their research activities. Examples at European level include the Max Planck Society and the Fraunhofer Society in Germany, the CNRS in France, the CSIC in Spain and the CNR in Italy (Martínez et al., 2013). We regard them as different from "small" PROs, that is, those research organizations that focus on one specific topic and usually have either a single or very few physical sites.[1] Large PROs, on the contrary, display the specific feature of being arranged as a country-wide *research network*, organized into Institutes of variable size; these are often encompassing several research units, that can also be located in different regions of the Country, and sometimes these units are hosted by other Academic institutions (see Fig. 8.1 – Structure of CNR scientific network). The results of this study apply mainly to large PROs; nevertheless, also small PROs may exhibit some of the dynamics described here.

Empirically, the paper relies on the outcomes of a case study analysis performed on the CNR (Consiglio Nazionale delle Ricerche, the National Research Council of Italy), the largest Public Research Organization of Italy, based on a large quantity of

[1] Among the large number of Italian (small) PROs, we cite here, as examples, the "Anton Dohrn" Zoological Station, the Italian Institute for Germanic Studies and the "Enrico Fermi" Historical Museum of Physics.

information and data on its relations with firms. The results show that the institutional flexibility and networked, relational structure of the CNR's research units affords researchers personal operational freedom and fosters higher degrees of specialization in the choice of personal research paths, since researchers can have more opportunities to develop niche and particularly qualified research topics and practices. This attracts firms in search of solutions to specific industrial problems. A second relevant dynamic emerging from our results is the diffused spatial organization of the units belonging to the CNR's research network, partly enabled by the units' internal flexibility itself. This allows close physical proximity to firms, thus promoting stronger cooperation. Indeed, in many cases, the CNR's research units operate within a context of proximity to firms, which enables continuous mutual interchanges. The ability to establish human relations further supports these dynamics, enhancing trust between firms and researchers.

This work is organized as follows. Section 8.2 presents the theoretical framework, while Sect. 8.3 describes the specific case study on the CNR. Section 8.4 introduces the adopted methodology, while Sect. 8.5 illustrates its results. The last section, Sect. 8.6, comments on the results and provides some conclusions and answers.

8.2 Theoretical Framework

This section discusses the literature on the impact of the organizational and institutional dynamics of research bodies (PROs and universities) on TT and the factors that may enhance TT cooperation, such as, for instance, the different dimensions of proximity. These dimensions are then matched with the constructs we define starting from our specific case study. Our review deals mainly with works about university-industry collaborations (U-I from now on) since, to the best of our knowledge, very few studies have specifically tackled the TT activities of PROs.

Researchers have studied a large number of organizational and institutional dynamics, more or less related to those investigated in the present work. Nevertheless, some notions that are not considered in the experimental section are introduced here for the sake of completeness. This theoretical section also aims to show that, in the context of the study around the forces that drive firms and research institutes to cooperate in TT activities, the topic we discuss is still underexplored.

Rybnicek and Königsgruber (2019) provide a thorough review of the literature on *success* factors in U-I collaborations. They also derive some implications for practitioners and identify some often-overlooked aspects that might interfere with successful cooperation, among which differences in collaboration phase, scale, organizational level and discipline. In detail, when discussing the organizational level, the authors stress the importance of individual leaders in fostering communication and trust.

An approach to research-industry collaborations that is particularly relevant to the context of the present work is that of Bodas Freitas and Verspagen (2017). In their analysis of Dutch collaborative projects, they identify, among others, exogenous factors that stimulate collaboration, i.e., alignment of motivations between the two parties and complementation from the two sides. Compared with their approach, the present paper is focused instead on testing how the internal dynamics of research institutions – first of all internal flexibility of research units, then the research specialization deriving from this dynamic, and lastly their spatial organization – influence their opportunities to establish collaborations, rather than simple motivational factors.

On the research side, a large sample of physics and engineering faculties in the UK shows that the main motivation for engaging in collaborations with firms has to do with research-related reasons, rather than commercialization (D'Este & Perkmann, 2011).

Rolfo and Finardi (2014) highlight internal institutional dynamics in their comparative analysis of "third stream" activities performed by two universities (generalist vs. technical). Here, differences in research/teaching subjects prove relevant in terms of attitudes and ability to collaborate in knowledge transfer, regardless of academic role or position in the technical university. Nevertheless, the factors that shape U-I collaborations are numerous, like for instance those discussed by Davids and Frenken (2018). At the theoretical level, they identify several proximity dimensions[2]: geographical, cognitive, social, institutional and organizational. Their single case study aims to integrate these dimensions with the different types of knowledge base present at different stages of product development. Their results stress the importance of firm departments being able to operate under different *institutional logics* and norms, depending on their characteristics. Proximity dimensions are also at the core of the paper by Steinmo and Rasmussen (2016), one of the few works studying cooperation between firms and PROs. Its authors discuss how the different dimensions of proximity—geographical, cognitive, organizational and social—evolve in facilitating cooperation between firms and PROs. The dimensions that are at play in the establishment of collaborations change during their development and morph into other ones; additionally, they are different depending on the types of firms (engineering-based or science-based).

The dimensions highlighted by the two above works match with those we identify. Internal flexibility of research units is the specific organizational and social idiosyncrasy we highlight. Geographical proximity is connected directly to our concept of spatial organization of the research network. Lastly specialization of researchers is the path to put in action cognitive proximity. These facts are also true for other contributions we are discussing below.

Geographical and spatial proximity are the most frequently analysed dimensions. D'Este et al. (2013) show their influence in making collaborations more likely. Fuentes and Dutrénit (2016) choose to study geographical proximity as they differentiate between various knowledge channels exploited for transferring technology.

[2]Though the concept of proximity has been used by economists since the 19th century, the multidimensional approach was developed by the French economic geographers (see Gilly & Torre, 2000; Pecqueur & Zimmermann, 2004).

Their results derive from an analysis of Mexican firms, universities and PROs. (Small) firm dimension plays an important role in deciding to collaborate with PROs. Proximity is crucial in cooperation between industry and research bodies, notwithstanding the fact that it interacts with other factors, such as absorptive capacity and types of knowledge channels.

The effects of regional geography on contract research—also combined with cognitive distance—are the main topics studied by Spithoven et al. (2019). Their results show that geographical distance must be considered together with other regional features in assessing the likelihood of contract collaborations. At the same time, cognitive distance does not alter their findings on the effects of geographical distance and regional impacts. In fact, as also argued by Capello and Caragliu (2016), spatial proximity is only one of the dimensions of the space where economic interactions take place, and it should be explored in combination with social, cognitive, and technological proximity in order to study their joint influence on scientific cooperation.

Besides prior collaboration *ties* and closeness in terms of *geography*, a key aspect is that of technological *similarity*. An analysis by Petruzzelli (2011) shows that a certain degree of similarity is essential for successful collaboration. Nevertheless, *too much* similarity might prove detrimental, due to the need for complementarity between partners.

The effects of cognitive distance are explicitly addressed by Muscio and Pozzali (2013). Their investigation starts from a survey of almost 200 Italian university departments and aims to assess how norms, mindsets and values existing within universities affect their communication with firms. Cognitive distance is *not* a barrier to collaboration but it does hinder its frequency, and it might also prevent the establishment of continuous university-industry relations.

Summing up, we have provided an overview of the debate around the impact of organizational and institutional dynamics on TT and the external factors affecting it, such as proximity dimensions. A key problem lies in the fact that the literature discussing PROs is very scarce, so that we must rely on studies analysing university TT. Among the various proximity dimensions, spatial organization (in terms of proximity and geographical distance) is probably the most widely discussed topic, as its effects can be relevant in making collaborations more likely. However, other proximity dimensions, as well as the internal dynamics of research bodies, are considered equally or even more important by the available literature. Among them, the present study places particular emphasis on the organization of research units (in terms of organizational flexibility and freedom of research motivation, leading to specialization). Thus the dimensions highlighted by literature act in our case study through specific idiosyncrasies of PROs, that we are exploring in the following experimental section.

8.3 Case Study

While the establishment of the first universities dates back to the Middle Ages, PROs originated in more recent times. For instance, the U.K. National Physical Laboratory was founded only at the beginning of the 1900s (1902). The same happened in Germany with the Kaiser Wilhelm Gesellschaft (1911), which then became the Max Planck Society. During World War I, the massive military effort required the engagement of scientists in every nation involved in the war. At the end of the conflict, the failed attempts to create an International Council of Research led countries to look for national arrangements. Thus, in Italy Prof. Vito Volterra committed himself to creating the CNR in 1923, of which he became the first President (Tomassini, 2001; Science, 1928; Science, 1929). France and Spain followed only in 1939, with the creation of the CNRS and the CSIC, respectively.

From its beginning, the efforts of the CNR converged around the establishment of large laboratory facilities. This trend continued after World War II, so that the CNR was characterized by the presence of stable research groups, able to work systematically on the main topics of scientific progress and to conduct research up to the phases closer to industrial concern, since collaborations with firms were pursued from very early on.

Nowadays, the CNR is Italy's largest Public Research Organization and its activities cover research in every scientific domain, as well as "third mission" activities (Finardi & Rolfo, 2016).[3] Its main seat in Rome provides all the general services to its scientific network, which is divided into 7 Departments: Engineering, Bio-food Sciences, Earth and Environmental Sciences, Chemistry and Materials Sciences, Physical Sciences, Biomedical Sciences, Social Sciences and Cultural Heritage. Each department comprises some of the over 90 CNR research Institutes.

As of end of 2018, the staff of the CNR numbered more than 8500 people. Of these, 53% were researchers, 9% were technologists, 28% were technicians and 10% were administrative staff. It is also important to note that, until the end of 2018, 18% of the personnel were hired with short-term contracts.[4] In addition, there were around 2000 Post-docs, also hired with temporary contracts (known as "Assegno di ricerca" in Italian). The present study was performed in 2014 and 2015, as part of a research project financed by an Italian Government Consultancy Body.

The organization of the CNR's scientific network is a structural characteristic that is very specific to large PROs, thus deserving special attention prior to entering the experimental section. In fact, much like other European PROs, the CNR is organized according to a country-wide, dispersed network of Institutes. It is also worth

[3] As mentioned above, although the CNR is Italy's largest PRO and the only PRO active in all research fields, it is *not* the only non-university PRO in the country.

[4] Starting from the end of 2018, almost 1800 personnel, formerly hired with short term contracts and as post-docs, have become tenured thanks to specific legislation. The success of this process (still continuing to date for the remaining unstable workers, known as "precari") is mainly due to the action of a spontaneous internal movement of employees, the "Precari Uniti CNR".

highlighting that nearly all its Institutes are divided into different branches: besides the main office, there are several smaller research units (at present, labelled “Secondary Branches” by the CNR), usually scattered across the country. This is why many research units feature relatively small groups of researchers. Figure 8.1 presents a schematic rendering of CNR scientific network.

8.4 Methodology

The present work is based on a case study methodology. The core material derives from a series of interviews with key players involved in research collaborations between a firm and one of the CNR’s research Institutes. In addition, other complementary data of different types are also taken into account. Table 8.1 presents an overview of the data sources and types, as well as how they are used in the analysis.

According to Yin (2009), case study research has a distinct advantage “when a ‘how’ or ‘why’ question is being asked about a contemporary set of events, over which the investigator has little or no control” (p. 13). Thus, the case study methodology, based on interviews and other sets of data, seems a suitable choice in order to investigate a specific topic. In our work, we adopt a single-case, embedded study tactic (Yin, 2009, p. 34). In fact, in order to build our case study,

Table 8.1 Summary of data sources

Data source	Type of data	Use in the analysis
Semi-structured interviews	Interviewees: Researchers of CNR Institutes involved in collaborations (15 interviews) Researchers or managers of collaborating firms Period: June 2014 – December 2015 (total of 30 interviews, from 60 to 90 minutes each)	Main analysis Description of the case study
Data on CNR-firms contracts	Administrative data, obtained from the CNR central administration	Choice of firm-institute pairs Assessment of the quantity of CNR research contracts
CNR official website	Data on the CNR: numbers of personnel and balance sheet data. Data on the location of Institutes and research units	Description of the case study Description of the case selection methodology Assessment of the location of Institutes and research units
AIDA – Bureau Van Dijk®	Descriptive data on firms	Description of the case study
Scopus®	Bibliometric data	Assessment of the interpretation of data from the interviews

we performed 30 interviews with representatives of both the CNR Institutes and the firms involved in the collaboration projects considered. This allowed us to obtain a large and comprehensive amount of data, which made it possible to fully investigate the case and to adequately answer the research questions. Moreover, such a case study design might be of more general interest, in that it might prove useful in the analysis of other similar large PROs. From this point of view, it is relevant to refer to the discussion initiated by Eisenhardt (1989) on the building of theories from case study research. Eisenhardt describes a process of theory building that we have followed, adapting it to the specificities of our work.

8.4.1 Case Selection

The first step in our work methodology was the selection of the firm-institute pairs, which was made by using two different tools. The first was the list of research contracts between the CNR Institutes and firms, supplied by the CNR central administration. The number of such contracts is rather large. A quick analysis shows its magnitude: the list of all the contracts *beginning* in 2011 (from January 1st to December 31st), cleaned of spurious data, contains almost 1100 different contracts with nearly 700 different entities. A preliminary selection of cases was performed starting from this list, and then a second tool was employed, i.e., the help and knowledge of the Departments' Directors. They collaborated in selecting the cases relevant to our research from among those involving the Institutes under their responsibility, following two main conditions:

- Continuity of Institute-firm relations over time: the selected research collaborations had to have lasted for a minimum of 5 years.
- Relevance in both technological and economic terms.

That is, the collaborations actually chosen were scientifically/technologically high-profile projects *and* had the aim of leading to innovation in terms of new products, processes or services. Thus, instances of long-lasting cooperation with low innovative scope (such as those involving simple testing activities) were discarded, as were important but isolated initiatives. On the contrary, we focused on relations oriented toward both the development of products or services of the firms and the improvement of the scientific content of research activities. All the cases studied here are cooperation experiences repeated over time, also under different forms, some of them with a timespan of more than 20 years.

Besides the two main conditions mentioned above, we also considered other determinants. The single cases were in fact chosen taking all seven CNR Departments into account and trying to include firms of different sizes and belonging to different NACE sectors. Moreover, the firms and Institutes analysed represent the various geographical areas of the country (Northern, Central and Southern Italy). Our study was conducted on 15 firms and 13 Institutes; two Institutes were

Table 8.2 Summary of the interviewed Institutes

CNR Department	No.	Geog. area	No. of branches	Personnel
Engineering, ICT, Energy and Transportation Technologies	1	N	6	≈100 (70% researchers)
	2	N	3	>100 (60% researchers)
	3	N	6	>100 (50% researchers)
Bio-agro-food Sciences	4	C	4	>100 (46% researchers)
	5	S	4	<100 (53% researchers)
Earth and Environment Sciences and Technologies	6	C	4	<100 (44% researchers)
	7	N	7	>100 (55% researchers)
	8	C	4	<100 (63% researchers)
Chemistry and Materials Sciences	9	S	2	< 50 (89% researchers)
	10a	N	1	<100 (65% researchers)
	10b	N	1	<100 (65% researchers)
Social Sciences and Cultural Heritage	11	S	4	<100
Physical Sciences and Technologies of Matter	12	S	7	>100 (60% researchers)
Biomedical Sciences	13a	C	5	>100 (50% researchers)
	13b	C	5	>100 (50% researchers)

considered twice, for a total of 15 interviews. Tables 8.2 and 8.3 summarize the characteristics of the interviewed Institutes and firms respectively. All the material was anonymized for the sake of privacy. The case selection performed was in line with the statements of Eisenhardt (1989), as we identified cases according to the theoretical sampling, trying to "choose cases which are likely to replicate or extend the emergent theory" (p. 537).

Table 8.3 Summary of the interviewed firms

N.	Geog. area	Turnover (M €)	Employment	NACE section	% export/ turnover	% R&D expenses/ turnover
1	N	400	626	C-Manufacturing	50%	0.75%
2	N	158	511	C-Manufacturing	80%	7%
3	S	30	217	C-Manufacturing	50%	14%
4	N	3000	8000	C-Manufacturing	50–60%	0.86%
5	N	136	350	C-Manufacturing	20%	5%
6	N	126,000	75,000	B-Mining and Quarrying	n/a	0.16%
7	N	44	387	M-Professional, scientific and technical activities	50%	15%
8	C	24	105	M-Professional, scientific and technical activities	n/a	n/a
9	N	46	225	C-Manufacturing	n/a	n/a
10a	N	48	170	C-Manufacturing	75%	15%
10b	C	90	274	C-Manufacturing	n/a	n/a
11	S	700	6000	J-Information & Communication	12%	3.5%
12	S	1422	9464	M-Professional, scientific and technical activities	80%	20-22%
13a	C	260	1100	C-Manufacturing	60–70%	4,5%
13b	C	0.35	10	M-Professional, scientific and technical activities	n/a	100%

8.4.2 Data Collection

Once the cases were selected, data collection was performed via semi-structured interviews (either face to face or via teleconference, depending mainly on the location of the interviewees) with *both* a researcher from the institute (generally the researcher who was mostly involved in the collaboration with the firm) *and* a representative of the firm (usually a project manager or R&D unit leader). The two questionnaires were similar and featured the same points, grouped under three main blocks of questions (besides general information on the interviewed body, i.e., firm or Institute), though individual questions were obviously adapted to each of the two cases. The three blocks of questions were labelled as:

- Channels and frequency of the interaction;
- Characteristics of the interaction;
- Assessment of the interaction and follow-up.

This methodology allowed us to compare the two points of view and to gather comprehensive evidence on the same experience. The interviews were recorded and then transcribed, carefully integrating the interviewers' notes and reporting the precise statements of the interviewees.

8.4.3 Data Analysis

Once the interviews were concluded and the resulting materials were collected, the most relevant information derived from them was arranged and systematized. To this end, we mainly followed the methodology indicated by Eisenhardt (1989), as we first performed a within-case analysis, examining the "detailed case study write-ups for each site [. . .] to become intimately familiar with each case as a stand-alone entity" (p. 540, *passim*). Then we began searching for cross-case patterns, by relying on Eisenhardt's suggestion "to select categories or dimensions, and then to look for within group similarities coupled with intergroup differences" (p. 540). Once the data were suitably organized, we tackled the next step of shaping our hypotheses by means of an iterative process (p. 541).

The following section presents the results of our analysis of the case study material. Several word-for-word citations from the interviews are included in order to offer immediate evidence of our findings.

8.5 Results

The interviews highlight some characteristics of the CNR-industry collaborations. In all the cases, the CNR researchers provide a positive evaluation of the projects, which help the Institutes widen their networks through contacts with firms and allow the empirical testing of theories in a "real" context and the discovery of market and production dynamics. The firm representatives give an equally positive evaluation, stating that the CNR researchers can translate needs into solutions, display a practical/firm-like attitude, and are collaborative, proactive, flexible and able to test concepts in the field. They also underline that the human traits of the CNR researchers often contribute to building a "technically-scientifically stimulating" environment. Human relations, they say, are based on trust and functional to the success and continuation of the collaborations, while the researchers describe themselves as being highly "flexible".

> An extremely meaningful point, which has made the project successful, has been the contribution of the people, their competence and availability. Besides the technical side, there has been a human side, not only in terms of empathy but mostly in terms of the ability to provide technical-scientific stimulus [Firm # 4].

> We have been able to offer two things: on the one hand some scientific ability, on the other hand incredible flexibility compared to universities or other research bodies, as we have adapted to their requests [Institute # 10b].

In addition to this general description of firm-research interactions, the interviews highlight other, more specific points that have attracted out attention. The interviewees, in particular those from the firms, remark on some aspects, which they describe as relevant drivers of TT interaction, that are specific to large PROs. Indeed, what the interviewees notice are the consequence of organizational dynamics typical of the research units and scientific networks of large PROs.

8.5.1 Flexible Internal Organization of Research Units

The first of these specific features is the structure of scientific and personal relations within the different Institutes and research units, coupled with the lack of institutionalized teaching activities. In many cases, the research units of the CNR (both main and secondary branches) display an internal relational structure that is more network-like than that of generic research labs found in (Italian) university departments. The latter usually have a hierarchical structure: a full professor leads the lab team, formed by one or more associate professors, university researchers, post-docs, Ph.D. students and undergraduate students. The size of the research lab mostly depends on the fund-raising abilities of the professors, as well as on the scientific quality and political influence of the full professor (and, partly, of the associates) leading the group.

Conversely, the CNR research units have no undergraduate students and fewer Ph.D. students, and their organization is different. Excluding the administrative and technical personnel, the CNR researchers are divided into three tiers. The same structure also applies to the technologists, whose duties are (formally) related to technical and technological operations strictly connected to research activities. These positions are different in terms of salary and, at least on paper, of responsibilities. What is also important to note here is the fact that career opportunities for researchers and technologists are rather scarce due to a variety of reasons. That said, it is fairly common for 3rd tier researchers (or technologists) to be responsible for research facilities, such as large instruments or laboratories, and to manage research projects and lead teams purposely created to that end, which may also include 2nd and 1st tier colleagues. To this picture one must add the presence of CNR research Associates. In fact, university professors, researchers and research technicians, both in service and retired, researchers and technologists from public or private research centres, as well as former research personnel of the CNR, can make an application in order to become research Associates. This status does not entail any economic gains, but it allows them to participate, in various capacities, in the research activities of an Institute, to have a personal office space and to enjoy other benefits.

The sum of all these structural dynamics and distinctive traits of PROs results in the fact that many research units are characterized by more informal relations among peers. Research groups can thus "recombine" to deal with specific research topics or financed projects according to a "free-flowing" model, rather than be constrained by the "pyramidal" hierarchy of a university research lab. In some cases, 2nd tier First Researchers have even been appointed as institute Directors. Hence, it is relevant to stress the non-hierarchical and free-flowing internal structure of Institutes and Research units. This internal dynamic, which is a specific idiosyncrasy of LPROs, is related with the organizational dimension of proximity between LPROs and firms: flexibility and recombination allow LPROs to better adapt to firm requirements. Steinmo and Rasmussen (2016) in fact discussing proximity affirm that "Organizational proximity refers to shared relations within or between organizations, and it is advantageous for innovation networks" (p. 1251). Organizational proximity can be a relevant facilitator of cooperation.

> The CNR Institutes fit better with the business mindset compared with the universities, where the pace of research work is strongly affected by academic management and teaching duties [Firm # 11].

> The benefits of cooperating with the CNR Institutes are of two kinds: on the one hand, the acquisition of specialized competences and analytical methodologies; on the other, the use of professional scientific equipment [Firm # 7].

> The fact that the same knowledge has been leveraged for more than one application and collaboration is not a negative aspect, but instead it demonstrates greater ability and higher levels of specialization and reliability [Firm # 2].

This dynamic of flexible and recombining tiers is functional to a specific configuration of scientific activities. In fact it offers the chance to perform research with more freedom, developing original research paths with both next-door colleagues and third parties outside the Institute. Generally, as their agenda is not dictated by the needs of teaching or by hierarchical settings, researchers are allowed to pursue their own research projects, even for a very long time, regardless of whether these are driven by curiosity, by the drive to publish, or by opportunities to attract funding or establish collaborations. As a consequence, those researchers that are more skilled and proactive can attain a very high level of specialization in a long timeframe if they are able to profitably allocate their working time. In many cases, the only constraint is the need to complete research projects, be they either competitive or deriving from tenders, consultancies to public bodies, or industrial cooperation.

8.5.2 Specialization on Research Subjects of Research Units

Many interviewees focus on the direct consequences of this dynamic. Several statements made by the industrial partners during the interviews highlight the excellent reputation and knowledge of the CNR researchers *in very specific research topics*. This is perceived as a key driver toward collaboration with the CNR by those firms seeking solutions to address less common industrial needs. The chance to cooperate with researchers who are highly skilled in the specific research topic that may solve the firm's problem is seen as crucial by the industry representatives. This specific idiosyncrasy of CNR research units makes it possible to put in action cognitive proximity in their cooperation with firms.

From this point of view, the most interesting collaborations are probably case studies number 5, 6 and 9. Case study number 5 concerns a collaboration between a CNR institute of the Bio-agro-food Department and a company involved in the production of bioplastics. The aim of the project was to improve the cultivation of a specific vegetable species in order to obtain raw materials for the production line *and* to implement phytoremediation in a heavily polluted area.

> We got the name of Mr. [name of the researcher]. He is the Italian researcher who has been working on [topic] for the longest time. We thus asked Prof. [foreign researcher], who was working on this topic, and he confirmed that Mr. [name of the researcher] possesses both agricultural and biochemistry competences [Firm # 5].

> Actually, we have been working a lot on [topic] in the last 10-15 years and, when we were first contacted by [firm] we were the main knowledge centre on this topic at the global level [Institute # 5].

Case number 6 is somewhat similar to the previous one, since it involved an institute of the Department of Earth and Environmental Sciences and Technologies and a large industrial group working in the energy field. This collaboration too tackled the problem of phytoremediation in a former industrial area. The CNR researchers had already collaborated with the group and were contacted again because of their great expertise.

> The choice was easy due to the excellent reputation of Mr. [name of the researcher] in relation to the topic of [topic]. So, our first contact came from the need to find people with specific scientific skills, complementary to our skills, as well as highly skilled in the development of this specific technology. [...] Among the elements that prompted the collaboration were previous relations with the institute and the researchers' strong reputation in the specific field [Firm # 6].

> Working with colleagues who consider scientific development and not only practical applications makes things particularly interesting [. . .]. We have an extremely productive relation on the scientific side, as their activities are complementary to our activities [Institute # 6].

Collaboration number 9, instead, was established between an institute of the Department of Chemistry and Materials Sciences and a firm, belonging to a larger group, that works in a highly specialized manufacturing field involving the use of high-tech materials. The partnership has lasted for decades due to the researchers' outstanding expertise in a very specific topic that exactly matches the needs of one of the firm's production lines. The collaboration has involved mutual problem solving, exchanges of personnel, and continuous joint efforts thanks to strong interpersonal relations.

> The researchers from [name of the Institute] have an excellent level of knowledge, and are one of the reference centres on the topic at the global level [Firm # 9].

> [The researchers] are very much oriented toward problem-solving and a type of collaboration that is not only formal, but also personal. In this way, relations are materially, and not just artificially, easier. The human side is integrated with the professional side, building a winning propensity to collaboration [Firm # 9].

In order to explore this topic further, we performed a simple but effective bibliometric exercise. On a bibliometric platform, we selected the publications of the three researchers involved in the cases described above.[5] Then, we used the "Refine Results" mask to identify up to 5 keywords (or groups of matching keywords) closely linked to the topic of the collaboration and the specialization mentioned during the interviews. Our aim was to test whether a small number of keywords was able to intercept the majority of publications by these authors, thus showing a very specific research interest. The results indicate that 63% of the publications are covered by 5 groups of keywords in the first case; 70% of the publications are covered by two (interrelated) groups of keywords, plus a single one, in the second case; lastly, 70% of the publications are covered by one keyword, plus four of its combinations with other words, in the third case.[6] This evidence points to the fact that the researchers have a rather high level of specialization in narrow topics, which are tackled over a long period of time.

8.5.3 Effects of Spatial Organization of Research Units

The interviewees also underline the effects of another specific organizational characteristic of large PROs. As described above, the CNR research units are geographically dispersed across Italy. Moreover, many of them are located outside the CNR research campuses. These are not the majority, but their number is rather large. More than 70 research units are hosted by university departments, and another 5 by large university laboratory facilities. Besides these academic venues, other locations deserve attention in the present context. Indeed, some research units operate in places such as Technology Parks, research centres of different kinds, university campuses and hospitals, or even inside firm plants. Appendix 1 describes a selection of the most relevant cases. This geographical organization of CNR units is a key driver to enable spatial proximity. As the theoretical framework shows, geographical and spatial proximity are among the most widely analysed proximity dimensions in literature. Geographical proximity, as D'Este et al. (2013) affirm, makes research partnership more likely. In our case proximity is put in action in a rather specific way, thanks to the structure of CNR research network, as well as of the single research units.

[5]The bibliometric exercise was performed on Scopus® (https://www.scopus.com, link visited in June 2019). The names of the researchers were selected using the "Author" search mask.

[6]Results are not presented explicitly for sake of anonymity.

The presence of CNR units or labs located next to, or even inside, firms is seen by the interviewees as having major positive effects on TT through spatial proximity. This is made possible thanks to the CNR's dispersed research network. Nevertheless, also the above-mentioned *internal* structure of research units, which affords greater flexibility and thus specific organizational (and consequently cognitive) proximity in terms of research cooperation, is important, since it facilitates reorganization and, possibly, staff reallocation in order to collaborate with external entities. It is also worth noting that a rather simple system of administrative authorizations allows researchers to change their work location, or even their Institute. This can be done mainly according to their research interests and specialization acquired during their professional service at the CNR.

From this point of view, the most relevant collaborations are number 12 and number 13b. The first involves a large industrial group working in the field of microelectronics and an institute belonging to the Department of Physical Sciences. The collaboration has lasted since the foundation of the Institute, whose main branch has always been physically located on the premises of the industrial group. This has created a breeding ground for continuous collaboration, while also offering the opportunity to share expensive equipment and facilities.

> Being located in the same place is a fundamental aspect of the collaboration [Firm # 12].

> I would define our collaboration activities as "spin-in": the CNR laboratories can introduce more radical innovations in the firm thanks to target-free research activities, which can be integrated into process and product innovation processes [Institute # 12].

Also, the researchers from this firm emphasize the high level of specialization of the CNR researchers, already mentioned above:

> Our collaboration with the CNR institute allows us to support basic research, useful to develop radical innovations. We would not be able to achieve internally the very high level of specialized scientific competences of the CNR researchers [Firm # 12].

The second collaboration, i.e., 13b, concerns a small start-up working in the field of biochemistry and biomedical research and a unit of a CNR institute belonging to the Department of Biomedical Sciences. Both entities were located inside an enterprise incubator, set up by a local bank foundation. This has allowed first to deepen mutual knowledge and then to set up a continuous side-by-side collaboration. Such a strategic location has also represented a chance for the institute to entertain short, but fruitful, relations with other firms and start-ups.

> Credit is due to the venue where we operate, a regional incubator hosting firms and research centres, which fosters the creation of relations. [. . .] It is important to set up labs providing either research or hi-tech services within a public-private facility, where firms bring their skills into play and research centres their flexibility [Firm # 13b].

> This unit is located within a technological cluster that also manages an enterprise incubator hosting former spin-offs. We are the only public entity, so firms see us as a point of reference. [. . .] I would suggest having more and more Institutes located in technological industrial poles, instead of having them in isolated facilities. This would make it possible to help those firms that often lack enough resources for research [Institute # 13b].

Other CNR researchers underline the strategic importance of this kind of arrangement for their research and collaboration needs:

> The advantage of a joint lab with a firm is also the chance to use their channels for buying materials, thus strongly accelerating timing [Institute # 8].

> Joint labs could be a tool to develop long-term collaborations [Institute # 10b].

It is also important to remark that research units can be located in contexts, such as industrial districts or clusters, where the expertise of a specific institute can be exploited by firms through TT collaborations. There are many examples of this pattern. For instance, the main location of the Institute of Ceramics Science and Technology is within the ceramic industry cluster of the Emilia-Romagna Region. Two sections of the Institute of Industrial Technologies and Automation are located respectively in in the textile industry cluster of the Piedmont region (working on the chemistry of fabrics) and in Puglia's aerospace district (working on aerospace mechatronics). Furthermore, a small, specialized lab of the same institute is located in the shoe production district of southern Lombardy. Lastly, a section of the Institute for Advanced Energy Technologies is strictly connected with the shipyard industrial cluster of northern Sicily. These facts contribute to enhance the chance to obtain spatial proximity for CNR research units.

8.6 Conclusions

The aim of the present work was to shed light on if and how the institutional dynamics that are typical of PROs, and more specifically of large PROs, stimulate firms to collaborate with them. We also had the specific target of analysing the effects of internal organization and spatial arrangement of research units. To answer our research question, we used evidence gathered through an extensive case study on the Institutes of the CNR, the National Research Council of Italy, which was based on a large number of interviews. We analysed the body of information obtained, selecting and organizing the most relevant statements, in order to understand if and how the scientific and personal relations within the different Institutes and research units, as well as their location, have an impact on industrial collaborations. The location of research units and their internal structure of human and professional relations are rather typical of large, umbrella-type PROs and, to a more limited extent, of smaller PROs too, while they are less common in other contexts, such as university departments.

The outcomes of our case study suggest that there are institutional dynamics in PROs, in particular large ones, that positively influence cooperation between research institutions and firms for TT. These dynamics concern the flexible internal professional structure of research units and their spatial organization, in terms of both geography and environment. These dynamics directly enable respectively organizational proximity, cognitive proximity and geographical proximity presented in the theoretical framework.

Some policy implications and recommendations can be drawn from our investigation. The first aspect has to do with the importance of establishing, maintaining and possibly enhancing a mixed system of research, involving both universities and PROs (either smaller ones or larger, networked "umbrella" organizations), since the activities of the two groups do not overlap. Our results actually show that the difference does not lie merely in PROs being "research-without-teaching" organizations. On the contrary, it is true that research performed at PROs has its own characteristics, which in turn depend on their specific organizational and institutional dynamics. An accessory topic, also brought up by some of the interviewees, regards how research in PROs may be evaluated. It is in fact clear that the instruments used to evaluate university professors may not fit the evaluation of researchers and technologists in PROs.

A second implication lies in the importance of performing target-free research in PROs, in view of possible collaborations focusing on TT. Although recent reforms in Italy have tried to steer PROs, and especially the CNR, toward very applied research activities, target-free research continues to be steadily pursued, also thanks to the dynamics highlighted in our study. This, as some of our cases show, can prove fundamental when firms need to address broader problems, rather than very specific and limited technological issues.

In addition, a third point adds evidence to past research dealing with the topic of proximity. Indeed, our experimental results show that physical proximity, deriving from spatial organization, plays a positive role in fostering TT. In detail, this outcome can be ascribed to organizational structure, and is thus intertwined with structural flexibility and human traits. In some cases, research units are embedded in an industrial context that is strictly connected with their research activities. This may allow them to act as "knowledge reservoirs", preserving, developing (sometimes in new forms) and then distributing the knowledge of the industrial ecosystem to which they belong.

As for relational proximity, some may conclude that the flexible structure of the CNR's research units could allow for multiple appointments of researchers at other research institutions (either public or private) or firms. Nevertheless, this would be impossible, given the civil servant status of researchers and technologists. On the other hand, the presence of research associates, described above among the "flexible features" of the CNR, could be exploited in this regard. University professors, former CNR personnel and researchers of other public and private institutions can become CNR research associates under various arrangements. This offers a wide range of opportunities to reinforce collaborations, and its application should be fostered and possibly replicated.

Finally, our theoretical framework shows that TT activities in PROs have so far been an underdeveloped research stream, counting a limited number of contributions compared to studies on universities. The results highlighted by the present work confirm the relevance of this topic and suggest that it deserves further development.

Appendix 1: Location of Research Units Relevant to TT Opportunities[7]

More than 70 CNR research units are accommodated by university departments, and many others are located outside the CNR research areas. Some units are hosted by other public research bodies (such as ENEA, the National Agency for New Technologies, or the European Synchrotron Radiation Facility in Grenoble) or by public or private hospitals, while seven research units operate in technology parks. Among these, three units (including the main branch of one of the Institutes) are located within the AREA Science Park in Trieste, a lively innovation hub.

Some CNR research units are also found at the facilities of Foundations devoted to research and innovation, a key location in terms of chances of contacts with firms. For instance, CNR units are present at Fondazione Bruno Kessler (FBK), a not-for-profit public interest research entity. Another relevant case is that of a Research Unit of the Physiology Institute inside a Technology Park, which was established by a mixed public-private capital foundation together with several firms. A similar facility hosts a unit of the Optics Institute.

University campuses can be a major location in order to foster industrial collaboration. Seven research units operate within the scientific campus of the University of Salento, near Lecce, next to the local "Hi-Tech Technology District" (a mixed public-private capital TT venture). Even more interesting is the case of the Lecco campus of the Polytechnic of Milan, where six research units work in a context of collaboration with the local industrial organization, which explicitly promotes cooperation between researchers and firms.

Other research units are located close to or even inside the buildings of private companies. For instance, in Milan two research units are found inside a private research centre belonging to a hospital group. Finally, two units of one of the CNR Institutes are located on the premises of a firm working in the same technology field.

References

Capello, R., & Caragliu, A. (2016). Proximities and the intensity of scientific relations: Synergies and nonlinearities. *International Regional Science Review, 41*(1), 7–44. https://doi.org/10.1177/0160017615626985

Davids, M., & Frenken, K. (2018). Proximity, knowledge base and the innovation process: Towards an integrated framework. *Regional Studies, 52*(1), 23–34. https://doi.org/10.1080/00343404.2017.1287349

D'Este, P., Guy, F., & Iammarino, S. (2013). Shaping the formation of university–industry research collaborations: What type of proximity does really matter? *Journal of Economic Geography, 13*(4), 537–558. https://doi.org/10.1093/jeg/lbs010

[7]The information was retrieved via CNR and Institutes websites.

D'Este, P., & Perkmann, M. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. *The Journal of Technology Transfer, 36*(3), 316–339. https://doi.org/10.1007/s10961-010-9153-z

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

Finardi, U., & Rolfo, S. (2016). Spin-off creation in a national research institution: Technological and industrial implications. In D. Audretsch, E. Lehmann, M. Meoli, & S. Vismara (Eds.), *University evolution, entrepreneurial activity and regional competitiveness* (pp. 97–125). Springer International Publishing. https://doi.org/10.1007/978-3-319-17713-7_5

Freitas, I. M. B., & Verspagen, B. (2017). The motivations, institutions and organization of university-industry collaborations in the Netherlands. *Journal of Evolutionary Economics, 27*(3), 379–412. https://doi.org/10.1007/s00191-017-0495-7

Fuentes, C. D., & Dutrénit, G. (2016). Geographic proximity and university–industry interaction: The case of Mexico. *The Journal of Technology Transfer, 41*(2), 329–348. https://doi.org/10.1007/s10961-014-9364-9

Gilly, J.-P., & Torre, A. (Eds.). (2000). *Dynamiques de proximité*. L'Harmattan. isbn:978-2-7384-9169-5.

Martínez, C., Azagra-Caro, J. M., & Maraut, S. (2013). Academic inventors, scientific impact and the institutionalisation of Pasteur's Quadrant in Spain. *Industry and Innovation, 20*(5), 438–455.

Muscio, A., & Pozzali, A. (2013). The effects of cognitive distance in university-industry collaborations: Some evidence from Italian universities. *The Journal of Technology Transfer, 38*(4), 486–508. https://doi.org/10.1007/s10961-012-9262-y

Pecqueur, B., & Zimmermann, J.-B. (Eds.). (2004). *Economie de proximité*. Hermès et Lavoisier. isbn:978-2-7462-0855-1.

Petruzzelli, A. M. (2011). The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation, 31*(7), 309–319. https://doi.org/10.1016/j.technovation.2011.01.008

Rolfo, S., & Finardi, U. (2014). University Third mission in Italy: Organization, faculty attitude and academic specialization. *The Journal of Technology Transfer, 39*(3), 472–486. https://doi.org/10.1007/s10961-012-9284-5

Rybnicek, R., & Königsgruber, R. (2019). What makes industry–university collaboration succeed? A systematic review of the literature. *Journal of Business Economics, 89*(2), 221–250. https://doi.org/10.1007/s11573-018-0916-6

Spithoven, A., Vlegels, J., & Ysebaert, W. (2019). Commercializing academic research: A social network approach exploring the role of regions and distance. *The Journal of Technology Transfer, 46*(4), 1196–1231. https://doi.org/10.1007/s10961-019-09740-1

Steinmo, M., & Rasmussen, E. (2016). How firms collaborate with public research organizations: The evolution of proximity dimensions in successful innovation projects. *Journal of Business Research, 69*(3), 1250–1259. https://doi.org/10.1016/j.jbusres.2015.09.006

Science. (1928). The National Research Council of Italy. *Science, 67*(1731), 233–234.

Science. (1929). The National Research Council of Italy. *Science, 69*(1784), 263–263.

Tomassini, L. (2001). Le origini. In R. Simili & G. Paoloni (Eds.), *Per una storia del Consiglio Nazionale delle Ricerche* (Vol. 1). Laterza.

Yin, R. K. (2009). *Case study research. Design and methods*. Sage Publications. isbn:978-1-4129-6099-1.

Part III
Gender, Youth and Mobility in Academic Entrepreneurship

Chapter 9
Every Woman Is a Vessel: An Exploratory Study on Gender and Academic Entrepreneurship in a Nascent Technology Transfer System

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Abstract Previous research shows that women are under-represented among academic entrepreneurs, indicating a gender gap in this field. Using a case-oriented approach combining interview analysis and fuzzy-set analysis, we explore potential barriers to women's engagement in academic entrepreneurship as perceived by both the researchers and the heads of technology transfer offices (TTOs). The inclusion of the latter group foreshadows the relevance of different actors who can influence the gender gap in academic entrepreneurship settings. We thus contribute to the body of knowledge about female academic entrepreneurship. The potential barriers are modelled as internal and external. We reveal that internal barriers (e.g., work-family balance and ambition) are perceived as more crucial than external barriers by both groups of respondents. However, TTOs and researchers seem to partially disagree about those barriers, which may impact the effectiveness of mechanisms implemented to mitigate the gender gap in academic entrepreneurship. Moreover, although both TTOs and researchers recognise the gender gap, neither party identified TTOs as responsible for reducing the associated disparities. Our fuzzy-set analysis, performed to explore the causal relationships between different gender gap conditions and female academic entrepreneurial activity, reveals two combinations of barriers underlying women's low engagement in academic entrepreneurship.

Keywords Female entrepreneurship · Academic entrepreneurship · Technology transfer · Gender gap · Patents

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9.1 Introduction

Women's engagement in academic entrepreneurship is taking place in the era of an entrepreneurial turn (Foss & Gibson, 2015). However, the issue of female academic entrepreneurship and the gender gap was long limited to feminist studies. Areas like innovation, technology, and entrepreneurship were traditionally characterised by gender blindness, emphasising that science and innovation operate on meritocratic principles for which only results and contributions matter (Ranga & Etzkowitz, 2010). Nonetheless, a change is happening. Alsos et al. (2016: 11) claim that 'gender and innovation is an emerging field of research' that has 'quickly gained a strong and influential foothold'. The same sentiment is mirrored in the entrepreneurship literature (Brush et al., 2019; Foss et al., 2019).

As universities are becoming increasingly entrepreneurial, we are presented with somewhat conflicting evidence on the extent of the gender gap in academia (e.g., compare Milli et al., 2016 with Colyvas et al., 2012) even in larger and more explored systems, such as the United States. However, the transition to more entrepreneurial universities is even more ill-informed in less-developed nascent systems, which can face unique setbacks. Thus, strategies to recognise and mitigate gender gap barriers are particularly important in small nascent systems.

To shed light on the barriers underlying the gender gap in academic entrepreneurship, we provide a literature-based model of internal (i.e., work-family balance, risk-taking, ambition, experience) and external (i.e., lack of presence, access to finance, peer effect, gender-differentiated TTO support, networking) barriers, drawing on the gender, entrepreneurship, and innovation literature.

Utilising a case-oriented approach and combining interview data from TTOs and university researchers, we elucidate the barriers to female academic entrepreneurship as recognised by university researchers and heads of TTOs. We thus answer the call for more research on other actors in academic entrepreneurship, especially brokers, and try to move beyond 'consistently recommending "fixing women"' by 'isolating and individualising' perceived problems (Foss et al., 2019: 409–410).

We discover that both TTOs and researchers give more attention to the internal barriers to women's engagement. However, we also uncover some differences between the perceptions of the providers of academic commercialisation support and the perceptions of users of said support (researchers). This mismatch can have important policy consequences as it may contribute to nascent technology transfer systems' slower progress in overcoming the gender gap in academic entrepreneurship compared to their more developed counterparts.

A common limitation of research exploring nascent systems in small countries, such as in the case of our research setting, is the use of small samples that prevent more advanced analysis. Although we interviewed the heads of the majority of Slovenian TTOs, our sample was small. Thus, to overcome this limitation, we used fuzzy-set qualitative comparative analysis (fsQCA), which enables the analysis of small samples but still allows for generalisation (Ragin, 2008). We also answer the call by Henry et al. (2016: 217) to further 'develop the methodological repertoire' in gender entrepreneurship studies, including that related to case studies. fsQCA allowed us to explore the different conditions (i.e., combinations of barriers) leading to women's lower engagement in academic entrepreneurship.

As an original contribution, we show which combinations of barriers underlie women's lack of engagement in academic entrepreneurship in nascent systems. We contribute to extant gender and (academic) entrepreneurship theory by highlighting the importance of internal and external barriers of the gendered academic entrepreneurship and the nuanced perceptions of these barriers by two important groups of actors, i.e., the TTOs and researchers. We also further our understanding of how these barriers can affect the outcomes of academic entrepreneurship by introducing the fsQCA methodology to explore gender issues in nascent systems.

9.2 Female Academic Entrepreneurship: Towards a Conceptual Framework

There are inherent restrictions in innovation and entrepreneurship research when focusing on gender issues. First, similar to other economic studies, gender has primarily been included only as a dummy variable, and still today, there is a 'proliferation of large-scale empirical studies', with limited interpretative value (Henry, C. et al., 2016). Second, the restrictions are connected to prevailing meritocratic ideals in terms of individuals' participation in scientific activities, with little room for individual-level innovation and entrepreneurship research, let alone a focus on gender disparities. This is underlined by the prevalence of studies on the team, institutional, and organisational levels (Modic & Yoshioka-Kobayashi, 2020; Ranga & Etzkowitz, 2010).

However, gender issues are gaining prominence outside the field of gender studies, confirming what Alsos et al. (2016) and Foss et al. (2019) have pointed out: there is budding interest in gender issues in innovation and entrepreneurship studies. In terms of technology transfer and, in particular, female academic entrepreneurship, research points out that female academics show a significantly lower propensity to start ventures than men do (Ebersberger & Pirhofer, 2011; Pitchbook, 2018). Also in terms of other channels of technology transfer, women seem to be less present than men are; e.g., women are less likely to be included as inventors in patent activity in comparison to men (Frietsch et al., 2009; Milli et al., 2016). There is evidence that most women inventors with patents come from academia (Martínez et al., 2016), yet this is poorly researched in nascent systems.

Exploring nascent systems is also interesting in terms of the structural vs culturalist viewpoint. The structural approach, which asserts that similarities are to be expected across countries with similar structures (e.g., levels of industrialisation, occupational systems), is opposed by culturalist theory, which argues that dissimilarities are to be expected as a result of intrinsic country-specific characteristics; that is, culture modifies the effect of a country's social structure on individuals (Gauthier, 2000; Paisey & Paisey, 2010). Previous research indicates that more developed technology transfer systems might follow similar patterns (e.g., Grimpe & Fier, 2010), but it is unclear which effect prevails in nascent systems. Identifying gender gaps and the barriers to female entrepreneurship in a system, such as the Slovenian one, whose institutional set up shares many similarities to other nascent systems, e.g., the Hungarian one (Novotny, 2017), can shed more light on this.

We focus on the barriers to female academic entrepreneurship and have classified the barriers in two types according to the source: external and internal. This also allows us to contrast the 'deficit' and 'difference' models, according to Corley (2005). External barriers are related to the environment and range from systemic to peer-level factors. Barriers classified as internal are related to the individuals themselves. Therein, according to the literature, a range of demographic and economic factors and barriers act as either drivers or inhibitors of entrepreneurial behaviour (Loscocco & Bird, 2012). In addition to the barriers presented in the entrepreneurship literature, we also take into account barriers from the psychology and sociology literature, which have often been seen as being relevant as female academic entrepreneurship engagement deterrents (Brush et al., 2019). Corley (2005) contrasted the 'deficit model', which sees female scientists as less productive than male scientists because they have fewer opportunities than men do, with the 'difference model', which views female scientists as less productive than male scientists because the two genders are 'different'. The external barriers reflect the 'deficit' model, and the internal barriers reflect the 'difference' model.

While focusing on barriers, we take into account two important actors in the academic entrepreneurship ecosystem: researchers who engage in academic entrepreneurship and TTOs. The latter relate to the meso-level in the 5 M framework, proposed by Brush et al. (2019) to study female entrepreneurship since they claim the gatekeepers of resources (such as TTOs) matter. In systems without professor privilege, science commercialisation begins when researchers disclose a technology to a university's TTO. After disclosure, the majority of the decision-making process is left up to the TTO. Goel et al. (2015) conceptualised TTOs as one of the main bottlenecks to successful science commercialisation. TTOs can also have diverse recognition of barriers to successful commercialisation and female engagement therein than researchers do. Having a strong position, but diverse perceptions, can have important consequences for the academic entrepreneurship ecosystem and for decreasing the gender gap therein (Fig. 9.1).

We hence also draw attention to the fact that entrepreneurs often rely on subjective perceptions rather than on objective expectations of success when pursuing entrepreneurial opportunities (Arenius & Minniti, 2005; Minniti, 2009). We argue the same is true for staff at TTOs, based on indices from previous research (Shane et al., 2015). In regards to female entrepreneurship, evidence suggests that subjective perceptions also contribute to explaining differences between the participation of men and women (Minniti, 2009). Different groups can thus have diverse perceptions. Acknowledging the role of subjective perceptions has influenced our research design. Hence, we not only focused on specific 'perceptual variables' (Arenius & Minniti, 2005) but, as a broader approach, we also studied the barriers to women's

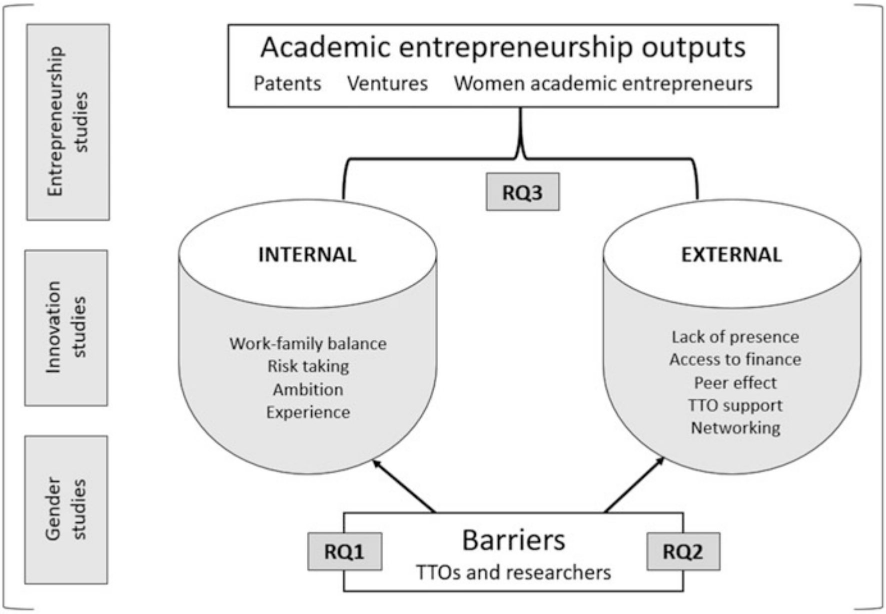

Fig. 9.1 Conceptual framework

engagement in academic entrepreneurship as perceived by individual researchers as well as heads of TTOs.

We thus explore the internal and external barriers to female engagement in academic entrepreneurship recognised by TTO staff (RQ1) compared with those recognised by researchers (RQ2). We then proceed by scrutinising which combinations of barriers are (relevant) causes for women's low engagement in academic entrepreneurship (RQ3).

9.3 Operationalisation of Selected Barriers

We adopt a dichotomous view of the barriers to women's engagement in academic entrepreneurship, dividing them into *internal and external barriers*, which allows us to capture both the deficit model and the difference model proposed by Corley (2005).

In terms of internal barriers, we first take into account potential gender differences in work-family balance. The effect of women's family roles on their scientific careers has been extensively studied. For example, Shauman and Xie (1996) hypothesised that having children results in reduced career mobility for women scientists. In contrast, Sullivan and Meek (2012) argued that entrepreneurship provides flexibility, enabling women to manage their work-family balance better.

Second, we take into account gender differences in risk-taking (e.g., see Loscocco & Bird, 2012 and literature therein), for which risk aversion due to fear of failure seems to be more pronounced among women than men (Arenius & Minniti, 2005). Third, we focus on women's presumed lack of ambition in terms of research commercialisation (Abreu & Grinevich, 2017; Ebersberger & Pirhofer, 2011). For instance, Abreu and Grinevich (2017) discovered that women feel more ambivalent about research commercialisation than men do, which correlates to lower rates of spin-out activity among women. Fourth, research often emphasises that researchers' age and experience as well as TTO's age, reflecting their experience (e.g., Colyvas et al., 2012; Friedman & Silberman, 2003) matter in science commercialisation.

Focusing on external barriers, first, we account for a lack womens' interest in academic entrepreneurship (Colyvas et al., 2012; Rosa & Dawson, 2006), either due to self-selection (Abreu & Grinevich, 2017), male-dominated fields being more often seen as a context for inventive activities (Wajcman, 2010) or to womens' lower perceptions of the impact of their research on industrial beneficiaries (Azagra-Caro & Llopis, 2018). Second, one of the most important elements for an academic entrepreneurial endeavour to succeed is access to finance. Although there is evidence that women experience less overt discrimination in gaining access to funding than previously thought (e.g., Brush et al., 2014), research also shows that men tend to have better access to capital for start-ups (Robb & Coleman, 2009; Brooks et al., 2014). Third, we focus on perceptions of the value of women's innovation skills and peer effects. In some contexts, women's innovations are perceived as lesser than their male counterparts' innovations (Alsos et al., 2016). Furthermore, peers may be perpetuating these ideas, with Goel et al. (2015) theorising that perhaps women remain occupied with the administrative work and thus have fewer opportunities to conduct research that generates entrepreneurial interest. Fourth, we consider the role of TTO's support service, for which a TTO's actions should be seen as a part of a collaborative community with the potential to affect many facets of academic entrepreneurship outcomes, including those connected to gender participation. Shane et al. (2015) discovered that randomly assigning a female faculty member to an invention disclosure discouraged a TTO from forming a spin-off company. TTO staff may be more willing to support male inventors than female inventors. Fifth, we acknowledge that academic entrepreneurship is greater among academics with wide-ranging networks, but women could have less access to networks that provide social resources (Stephan & El-Ganainy, 2007; Bird, 2011).

In terms of outputs, to test our model, we include three outputs that most accurately capture the main characteristics of female academic entrepreneurship. Specifically, we take into account two factual indicators – patents and academic ventures – and one indicator that is in itself a perceptual variable – female academic entrepreneurs (Arenius & Minniti, 2005); the latter is an operational necessity due to the lack of statistical data on women entrepreneurs in academia.

9.4 Research Set-Up, Methodology and Data

The nascent Slovenian system presents an interesting research set-up: spin-out companies are not listed among main the outputs of TTOs operations; however, TTOs publicly acknowledge them (Suhadolnik, 2018). A rather specific legal regulation related to the definition of university start-ups that needs to be taken into account in nascent systems in which legal regulations prevents public research organisations (PROs), including universities, to have ownership shares in academic start-ups. This has prompted a more open definition of academic start-ups in order to capture all relevant start-ups. We define an academic start-up as a business endeavour initiated by an academic researcher or a researcher from a PRO on the basis of publicly funded intellectual property. This allowed us to also tap into *hidden technology transfer*, i.e., technology transfer outside the formal system (Fini et al., 2010), which is needed if we want to gain a clearer picture of the true extent of academic entrepreneurship in similar institutional set-ups and the potential gender gap therein.

Slovenian research has remained silent on potential gender gaps in academic entrepreneurship, although gender issues play a prominent role in Slovenian society, and there have been several research endeavours connected to women entrepreneurs in Slovenia (e.g., Modic et al., 2015). Nevertheless, only a few have also encompassed academic entrepreneurship (e.g., Adam et al., 2014) and did not focus on women in particular. However, Slovenia is among the most advanced countries in the European Union according to some gender statistics (Eurostat, 2019). The first TTO in Slovenia was established in 1996. Ruzzier et al. (2011) claimed that until 2009, PROs managed to form a formal spin-off or spin-out company, indicating that the PROs' start-up tradition is young. However, some universities have formed successful start-ups, several of which remain in close contact with their PROs. The Slovenian government has provided financial support to TTOs continuously since 2009; including for the National Consortium of PROs for Technology Transfer (TTO Consortium). The TTO Consortium currently consists of eight members, producing the majority of all technology transfer outputs in Slovenia.

Due to the mostly anecdotal evidence relating to the nascent technology transfer system under scrutiny, we first had to conduct a short preliminary patent analysis, before pursuing a multiple-case approach. The analysis explores the presence of women in patenting and women's patent potentials. With a multiple case study, multiple cases are explored to understand differences and similarities between the cases (or types of cases), which can then be used to analyse the data both within and across situations and to reveal contrasting or similar results in individual cases (or types of cases) (Yin, 2014; Gustafsson, 2017).

We conducted semi-structured interviews with the heads of Slovenian TTOs to answer RQ1. We invited all eight TTOs that are members of the TTO Consortium to participate. All but one responded positively. Through the interviews, we analysed barriers that prevent female researchers from coping with the challenges of entrepreneurship. The interview guide consisted of open questions and a four-point Likert scale to allow the respondents to rank the predicted influence of individual barriers.

Furthermore, we conducted eight interviews with female and male researchers to answer RQ2. We included male researchers to provide diversity and account for factors that have equal or divergent intensity for both genders. The researchers came from different fields (e.g., informatics, electro-engineering, chemistry) to account for differences related to their field of work. Researchers engaged in entrepreneurship were connected to six different TTO-facilitated technologies. We also included female entrepreneurs from the only two Slovenian academic ventures with predominantly female founders.

We used the fuzzy set qualitative comparative analysis (fsQCA), which enables the analysis of small-N samples, to shed light on RQ3. With carefully selected cases, including those of general importance in relation to the research problem, the method allows for reasonable generalisation. FsQCA is a recent and rapidly developing method in comparative social research (Ragin, 2008; Modic & Rončević, 2018). The underlying assumption of fsQCA is that patterns of attributes exhibit different features and lead to different outcomes depending on how they are arranged. In addition, fsQCA assumes that contextuality, i.e., how attributes within cases are arranged (present/absent conditions) and interacted, determines outcomes rather than the net effect of all attributes. To achieve this, the fsQCA was developed using the functions and rules of Boolean algebra. We constructed an original dataset from the interviews to determine which combinations of barriers hinder women's engagement in academic entrepreneurship.

We took into account several factors based on theory and previous research to operationalise both types of barriers and provide answers to our research questions. Our operationalisation of the barriers is in Table 9.1. Anchor values were assigned to each of the variables using a joint calibration approach[1] and are available in Appendix 1. After the calibration, we merged the individual internal and external barriers into two super groups and tested them against the joint output to test the robustness of our data and proposed model. The calculations were done using Boolean algebra and its addition rule. The purpose is to test the robustness of our data and the proposed model.

Each of the variables in our model obtained a score, which we then translated to a fuzzy-set value between 0 (indicating the complete absence of the variable) and 1 (indicating the complete presence of the variable). This was done as follows: 1 corresponded to 0 in the fuzzy set; 2 corresponded to 0.334; 3 corresponded to 0.667; 4 corresponded to 1 (see also Table 9.1). For example, the specific interviewee age groups were assigned fuzzy-set values as follows: 20–30 years corresponded to 0 in the fuzzy set; 31–40 years corresponded to 0.334;

[1] In this approach, anchor values are determined by joint discussion and agreement among all authors to ensure the values correspond with theory and data and to avoid individual bias. Similar approaches have proven successful in prior research (e.g., Modic & Rončević, 2018).

Table 9.1 Operationalisations of internal and external barriers with anchors

		Descriptions of barriers	
	Fuzzy sets	[Anchors researchers]	[Anchors TTOs]
INTERNAL	INT1: Work-family balance	Description: Women choose to pursue academic entrepreneurship more rarely than men do due to their family obligations.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
	INT2: Risk-taking tendencies	Description: Women choose to pursue academic entrepreneurship more rarely than men do because employment in a public research organisation is more stable.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
	INT3: Ambition	Description: Men are more ambitious than women are.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
	INT4: Experience[a]	Description: Age of researcher	Description: Age of TTO
		[20–30 years = 0; 31–40 years = 0.334; 41–50 years = 0.5; 51–60 years = 0.667; 61–70 years = 1]	[0–1 years = 0; 2–-5 years = 0.334; 6–-8 years = 0.5; 9–-12 years = 0.667; 13+ years = 1]
EXTERNAL	EXT1: Lack of presence	Description: Women are creative in areas that are interesting for entrepreneurship.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
	EXT2: Access to finance	Description: Women have more problems acquiring start-up capital for an academic venture.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
	EXT3: Peer effect	Description: Women are allocated more administrative work (routine, non-creative) compared to their male colleagues.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
	EXT4: Gender differentiated TTO support	Description: TTOs support differentiates between genders.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
	EXT5: Networking	Description: Women in academia have weaker social networks than men do.	
		[1 = 0; 2 = 0.334; 3 = 0.667; 4 = 1]	
OUTPUTS	OUT1: Patents[a]	Description: Researchers' number of patents weighted by age.	Description: Number of patents in the last year per FTE.
		[Less than 0.5 = 0; 0.5 to less than 1 = 0.334; 1 to less than 1.25 = 0.334; 1.25 to less than 1.5 = 0.667; 1.5+ = 1]	[Less than 0.5 = 0; 0.5 to less than 1 = 0.334; 1 and less than 1.33 = 0.5; 1.33 and less than 3 = 0.667; 3 and more = 1]
	OUT2: Ventures[a]	Description: Extent of collaboration in an academic venture.	Description: Number of academic ventures normalised by TTOs' age.
		[No venture and no intention of establishing one = 0; there was never any significant	[Less than 0.1 = 0; 0.1 and less than 0.33 = 0.334; 0.33 and less than 0.34 = 0.5; 0.34

(continued)

Table 9.1 (continued)

		Descriptions of barriers	
	Fuzzy sets	[Anchors researchers]	[Anchors TTOs]
		realisation of collaboration = 0.334; the venture is active = 0.5; academic venture has more than 20 employees = 1]	and less than 0.5 = 0.667; 0.5 and more =1]
	OUT3: Female academic entrepreneurs	Description: Women are academic entrepreneurs less often than men.	Description: Women are encountered as academic entrepreneurs less often than men.
		[Less than 5% = 0; 5–10% = 0.334; 10–50% = 0.667; more than 50% = 1]	

[a]Factual variables

41–50 years corresponded to 0.5; 51–60 years to 0.667; and 61–70 years to 1. None of the interviewees was below 20 years of age or above 70 years of age.

In terms of outputs, data for OUT1 were gained by calculating the number of patents weighted by the researchers' age and the number of patents in the previous year by full-time employment equivalent for TTOs. Data for OUT2 were gained by calculating researchers' extent of collaboration in an academic venture and the number of academic ventures normalised by the TTOs' age. Lastly, OUT3 was created on the basis of both researchers' and TTO representatives' perceptions regarding the extent of women's engagement in academic ventures encapsulated in their Likert scale evaluation.

To be able to test the robustness of the proposed model, we created two expressions on the internal and external barriers. We applied the Boolean function of 'OR' to both calculations, as follows: for internal barriers, allINT, including work-family balance, risk-taking, ambition, and lack of experience, and for allEXT, including women's lack of presence in specific fields, access to finance, networks, gender-differentiated support by TTO, and peer effect. The formulas allINT = fuzzyor (INT1,INT2,INT3,~INT4[2]) and allEXT = fuzzyor(EXT1,EXT2,EXT3,EXT4, EXT5), respectively, were used. Following the same logic, the allOUTPUT variable, we used a multiplication approach (i.e., Boolean Algebra 'AND' function) combining the normalised numbers of patents, ventures, and women in academic entrepreneurship: allOUTPUT = fuzzyand(OUT1,OUT2,OUT3).

Since we were interested in the absence of women's engagement in academic entrepreneurship, we applied Boolean negation to the allOUTPUT variable as follows: ~allOUTPUT = fuzzyneg(allOUTPUT). To test the robustness of the

[2]The INT4 barrier was operationalised as the researcher's age and the TTO's age (years of existence). The barrier, in this case, is a lack of experience resulting from the younger age; therefore, we re-calculated the barrier and included it in the analysis as 'absence of experience'. We used ~INT4 = fuzzyneg(INT4).

model, we elaborated the expression ~allOUTPUT = f(allINT, allEXT). We applied the Boolean Truth Table with a consistency cut-off at 0.80[3] and Quine-McCluskey algorithm to the expression.

9.5 Results

9.5.1 *Preliminary Analysis: Patents and Start-Ups by Women in the Selected Nascent System*

To provide context for our research setting, we first tested the claims of Martínez et al. (2016) that most women inventors with patents come from academia. In May 2019, we analysed all 261 patents granted in 2018, as reported in the Slovenian patent database (SIPO.DS). Based on a fractional count, the majority of patents (60.3%) belong to companies, 29.1% to individual inventors (among them only 12.2% are women), and 10.5% to universities or research institutes.

These 261 patents have 620 inventors; among them, 14.4% have women inventors listed. However, if only academic inventors (i.e., patents belonging to universities and institutes) are considered, the share of women is much larger (34.1%), which is consistent with the findings of Martínez et al. (2016). Since women inventors in academia represent more than 50% of all women inventors, we can assume that the typical female inventor is employed at a higher education institution or PRO (see Table 9.2).

Next, we looked at the gender balance based on patents with more and less (commercial) potential. We took into account whether the patent application process started in Slovenia with a less demanding patenting process or it started or continued in a (more demanding) international patenting process. This approach enabled us to differentiate patents with more and less potential as the latter (patents going through an international process) undergo more rigorous examination and have broader geographical coverage and higher applicant costs. Table 9.3 shows that the share

Table 9.2 Inventors and academic inventors

	All inventors		Academic inventors	
	Number	Percentage	Number	Percentage
Women	89	**14.4**	45	**34.1**
Men	531	85.6	87	65.9
Sum	620	100	132	100

[3]Consistency measures the degree to which the term and the term solution are subsets of the outcome (Ragin, 2008). We followed the idea of reporting positive experience the cut-off is set at 0.70 (Schneider & Wageman, 2007). We set the cut-off even more strictly, at 0.8, to ensure higher levels of degree to which cases in the dataset are members of the proposed solution. Similarly, the coverage threshold, representing the degree of the outcome being explained by the proposed solution, is also set to 0.8.

Table 9.3 Inventors broken down by patent potential

	Domestic patents (223)		Patents with international examination (38)		Academic patents with international examination (4)	
	Number	Percentage	Number	Percentage	Number	Percentage
Women	60	**11.8**	29	**25.7**	7	**41.2**
Men	447	88.2	84	74.3	10	58.8
Sum	507	100	113	100	17	100

of women inventors is much higher for patents with more potential, especially when the (co-)owner is a PRO.

We also conducted an initial review of the PROs' start-ups, deriving the information from the TTOs' websites and articles related to academic start-ups in Slovenia. The review revealed 24 currently acknowledged spin-outs in Slovenia connected to the consortium of TTOs (May 2019). The majority of the spin-outs' founders are men; in only two cases did the initiative for establishing an academic company come exclusively from women.

9.5.2 *Interview Analysis*

The majority of TTOs, who vary significantly in terms of experience, reported that in the last year, women researchers applied for fewer patents than men did, even though the number of male and female researchers in these TTOs was mostly similar. Four out of the seven TTOs reported having spin-outs and establishing measures to promote academic entrepreneurship. The majority of the TTO representatives noted that women rarely participate in academic entrepreneurship. However, no TTO reported measures to encourage women's participation in entrepreneurship, although one respondent explicitly outlined the need for more support for women who are having issues with work-family balance. Overall, respondents think TTOs' support should be equally accessible to both genders. There was little convergence in terms of external barriers to women engagement in academic entrepreneurship. While some stated that women have more difficulties dealing with risks in entrepreneurship and may consider working in a PRO to be a safer option, others claimed that both genders face these risks equally and that employment in a PRO is not 'safe' anymore. The majority also believed that women face equal difficulties in obtaining start-up funding as men do and that their professional networks are comparable. In contrast, the majority of TTO representatives recognised that women researchers engage in administrative and other 'less valuable' work more frequently than their male colleagues do.

Our interviews with researchers pointed out that for the internal barriers, family and lack of ambition are seen as most problematic. However, the researchers did not see that TTOs encourage male researchers more, that women are less creative in areas of interest for academic entrepreneurship, or that women are burdened with more administrative work. They also did not believe that women's inventions are less respected in society. Indeed, one of the researchers commented, *'It looks like women are rare, but when they do something, there is a higher probability they will do it well and thoughtfully'*. Some emphasised that *'women are less trusted in the business environment'* while others claimed that society recognises the benefits of female business owners. Another researcher believed that traditional patterns still prevail both in society in general and in academia. Men are traditionally seen as leaders and women as supporters, which is also evident in other more mature systems, such as the United Kingdom, where the respondent was working at the time of the study. This individual, along with a female researcher who was working in the United States, also pointed out the very different financial opportunities available for start-ups in mature technology systems in comparison to nascent systems. Appointing a female start-up leader in traditional environments can even have a negative effect on entire start-up teams. Another researcher believed the main reason for the absence of women in academic entrepreneurship is women's higher social responsibility: they are afraid of bankruptcy and the negative effects it has on employees.

Both types of respondents (TTOs and researchers) observed that women rarely participate in academic entrepreneurship. In terms of internal barriers, both types of respondents recognised the decision to have a family as an obstacle to female academic entrepreneurship, while they disagreed about which of the two genders might be more ambitious. In terms of external factors, the TTO representatives recognised that women engage in 'less valuable' work more frequently than their male colleagues do, seeing this as a serious barrier to their engagement in academic entrepreneurship. Interestingly, the majority of the researchers did not share this view, with some even arguing that women can develop trustworthy networks by serving as administrative project leaders. In addition, the TTO representatives did not believe that their organisations play a particular role in supporting female academic entrepreneurship, a view shared by the researchers, who also did not perceive that TTOs encourage one gender more than the other.

We thus provide answers to RQ1 and RQ2, while detecting some differences among the TTO representatives' and the researchers' perceptions of important barriers.

9.5.3 Fuzzy-Set Analysis

We proceeded with the fuzzy-set analysis to answer RQ3. In our research context, the notion of relevance is defined as seeking correlations between the proposed barriers and lower levels of women's engagement in academic entrepreneurship.

The results indicate that both sets of barriers, i.e., internal and external, are important and contribute towards the proposed outcome. The solution's consistency is 0.823944, and its coverage value is 0.87405. We can thus reliably conclude that the absence of female academic entrepreneurship is conditioned upon a combination of the presence of internal barriers (lack of work-family balance, lack of risk-taking, lack of ambition, and lack of experience) and the absence of external barriers (lack of presence, difficulties accessing funding, negative peer effect, lack of gender-differentiated support for women by TTO, weaker networks). In other words, the presence of internal barriers, together with the absence of external barriers, represents *a sufficient condition*[4] for the absence of female academic entrepreneurship. This finding is in line with the results from our qualitative analysis.

After finding a set of barriers that resulted in sufficiency for the absence of women's engagement in academic entrepreneurship, we initiated the test of necessity. To perform this test, we first computed a new variable for both internal and external barriers using the following formula: solution = allINT*~allEXT. The new variable was tested in terms of the *necessity* for the analysed absence of women's engagement in academic entrepreneurship. Applying the same threshold as above, the values for consistency and coverage result to be 0.876405 and 0.823944. To conclude, the presence of internal barriers, along with the absence of external barriers, is a *necessary condition*[5] for the absence of women's engagement in academic entrepreneurship. In our case, the presence of internal barriers along with the absence of external factors leads to an absence of women in academic entrepreneurship.

After analysing the whole model, we analysed the impact of individual barriers. Based on the results for the whole model, we were able to outline two potential internal barriers and one external barrier that might be more relevant than the others: work-family balance (INT1), ambition (INT3) and gender-differentiated support by TTO (EXT4).

Two combinations of barriers were elaborated and tested, forming a sufficient condition for the absence of women's engagement in academic entrepreneurship. In Table 9.4, we show our application and the above-mentioned results of the Quine-McCluskey algorithm using the formula ~allOUTPUT = f(INT1, INT3, EXT4). The result proved the joint consistency at 0.812805 and coverage at 0.811891.

Based on a Boolean Truth Table analysis as standard analysis in fsQCA, we can reliably conclude that two paths lead towards women deciding not to engage in academic entrepreneurship. The first path combines work-life balance, together with the absence of gender-differentiated support by TTO. The second path includes a lack of ambition among women and the absence of gender-differentiated support by TTO.

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[4]A sufficient presence of a condition (or combination of conditions) is enough for the output to occur. Since the inclusion interpretation is sometimes more theoretically relevant than the correlation interpretation, the sufficiency check is part of standard fuzzy-set analysis. The calculation method is parallel to the Kolmogorov-Smirnoff test (Smithson, 2005).

[5]The test of necessity gives information about conditions that need to be present for the output to occur. Analysis of necessity is an analysis of correlation. The calculation method is parallel to Chi square tests in discrete membership of sets (Smithson, 2005).

Table 9.4 Complex solution using the Quine-McCluskey algorithm

Model: ~allOUTPUT = f(INT1, INT3, EXT4)			
Algorithm Quine-McCluskey			
Frequency cut-off: 14			
Consistency cut-off: 0.908414			
	Raw coverage	Unique coverage	Consistency
INT1*~EXT4	0.686423	0.218352	0.879544
INT3*~EXT4	0.593539	0.125468	0.808959
Solution coverage	0.811891		
Solution coverage	0.812805		

The fuzzy-set analysis offered a response to RQ3. We were able to detect two combinations of barriers that can lead to the absence of women's engagement in academic entrepreneurship.

9.6 Discussion and Implications

Why is encouraging women's engagement in academic entrepreneurship so important? As our research has confirmed, women are rare in entrepreneurship and patent development, but we find indications that, regarding patents, women can achieve even better results than their male counterparts can. There are also indications that women can make very valuable contributions to academic entrepreneurship (Suhadolnik, 2018). Promoting the participation of female scientists in academic entrepreneurship can also lead to outcomes that pursue different goals and address different markets.

Women's lower participation in academic entrepreneurship thus remains an interesting topic. However, the small sizes of samples, especially in nascent systems, is limiting research to case studies and thus preventing researchers from drawing general conclusions. In these circumstances, it can be challenging to cover sufficient number of cases to satisfy doubts about representation, generalisation, and validity (Goedegebuure & van Vught, 1996) without a proper methodological approach. Using methods like fuzzy-set analysis can mitigate these issues, but further methodological discussions on appropriate small-sample analysis approaches are needed. The call for qualitative research needs to be, in our opinion, supplemented with a call for the diligent application of quantitative methods on qualitative data. We answer this call by applying an innovative approach wherein the case-oriented approach is upgraded with fuzzy-set analysis, revealing new dimensions to collected data and providing medium-level generalisation (Modic & Rončević, 2018).

Our research highlights a nascent system perspective, which may also be a limitation of the study. Arguments provided by the structural approach point out similarities, while the culturalist approach points out dissimilarities among systems. These different approaches lead us to believe that, without further research, we still stand on the precipice of knowing whether we will find similar results in terms of academic entrepreneurship and the gender gap across systems that share a similar framework. We suggest further comparative studies to explore the similarities and differences between nascent, catching-up, and mature technology systems and the role of women therein. Due to different regulative settings, researchers need to adapt their research designs to ensure they capture all relevant academic ventures and thus any hidden technology transfer (Fini et al., 2010).

Unsurprisingly, according to our research, both TTOs and researchers perceive a gender gap in academic entrepreneurship inside the nascent Slovenian system. The gender structure in Slovenia, where women are more interested in the social sciences, life sciences, and humanities and men are more interested in technical sciences (University of Ljubljana, 2018), only partially explains this gender gap since women rarely set up academic enterprises even in PROs, which have approximately equal numbers of researchers of both genders. Other significant barriers must exist.

Our study reveals three interesting issues. First, we found distinctions between the perceptions of barriers by TTOs and researchers. Second, neither group recognised TTOs' potential to remedy women's low participation in academic entrepreneurship.

In line with the inability to recognise gender issues as an important issue to be addressed, our fuzzy-set analysis reveals two sets of barriers leading to women's lack of engagement in academic entrepreneurship: (1) lack of work-family balance and lack of gender-differentiated TTO support and (2) lack of ambition and lack of gender-differentiated TTO support.

Both sets of respondents paid more attention to the internal barriers that may influence women's lower participation in academic entrepreneurship, than to the external barriers. This tendency seems to be consistent with the contemporary individualistic view that each person (not society), is solely responsible for their success – a difference model viewpoint, yet as seen from the fuzzy-set, these are combined with external barriers, pointing out to the deficit model. The TTO representatives and researchers generally agreed that among internal barriers, the main problem is the work-family balance for women, while the researchers also pointed out that men are more ambitious than women are. We can see the reasons for these perceptions in traditional cultural patterns that are still very alive in formal (de jure) gender-equal societies. Regarding external barriers, on average, respondents believed both genders have equal networks and access to finance.

Internal factors can be hard to overcome without strong public action. Thus, women's low engagement in academic entrepreneurship can be improved by special efforts or programmes within PROs focused on helping female researchers innovate and engage in entrepreneurship. For this task, TTOs or university management have to create policies to deal with gender issues and clearly define the managerial and operational implications of the gender-differentiated approach. Thus, experimental policy initiatives might be the first step to overcoming the barriers to women's engagement in academic entrepreneurship. However, special care must be given to balancing the influx of potential users with the capabilities of support organisations (e.g., TTOs). Nevertheless, in countries where TTO offices or other actors have strong cooperative platforms at their disposal, this issue might be mitigated.

Also, when designing support mechanisms, one needs to acknowledge that TTOs do not always perceive the same barriers as researchers do. Consequently, they might set up support mechanisms that address non-key marginal issues and disregard other barriers researchers experience. A co-development of gender initiatives with (male and female) researchers can mitigate this. It would be beneficial that this co-development also encompasses the initiative's design phase.

Lastly, most research on women in science and technology transfer is dedicated to barriers, but there is a gap in our understanding of the (natural or constructed) advantages that can position women researchers in certain niche areas. However, understanding the advantages next to the barriers can have the potential to aid in understanding how to construct either teams or policy support mechanisms better. Women are praised for their strong empathy and ability to provide practical everyday solutions, yet we know little about how these qualities can be harnessed to achieve better overall technology transfer results. A holistic understanding of advantages and barriers is also an opportunity for work in technology transfer and academic entrepreneurship to provide inputs to other fields dealing with women's contributions.

Appendix 1: Fuzzy-Set Matrix

Fuzzy set	OUT1	OUT2	OUT3	INT1	INT2	INT3	INT4	EXT1	EXT2	EXT3	EXT4	EXT5
RESP1	0.667	0.334	1	0	0	1	0.667	0	0	0	0	0.334
RESP2	0.334	0.5	0.334	0.667	0	0	0.5	0.334	0.667	0.667	0.334	0
RESP3	0.334	0	0.667	0.5	0	0.334	0.334	1	0.5	1	0	0
RESP4	0.5	0	0.5	0.667	0.334	0	0.5	0	0	0	0	0
RESP5	1	0.334	0.667	0.667	0	0.667	1	0.667	0.5	0	0	0
RESP6	0.667	0.667	0.5	0.667	0	1	0.667	0	0	0.334	0	0.667
RESP7	0.334	0.334	0.334	0.667	0.334	0.334	0.5	0	0.5	0.5	0.5	0.667
RESP8	0.667	1	0.667	0.667	0.334	0.5	0.667	0.667	0	0.334	0	0
RESP9	0.667	0	0.667	0	1	0.667	0.5	0.334	0.334	0	0	0.667
RESP10	0.5	0	0	1	0.667	0.667	0.334	0.667	0.667	1	0	1
RESP11	0.334	1	0.5	0.667	0.667	1	0.334	0	0.334	0	0	0
RESP12	0.334	0	0.667	0.667	0.667	0.5	1	0.334	0	0.667	0	0
RESP13	0	0.334	1	0.667	0.667	0.5	0.667	0.334	0	0.334	0	0
RESP14	1	0.5	1	1	0.667	0.667	0.667	0	0.667	0.334	0	0.334

References

Abreu, M., & Grinevich, V. (2017). Gender patterns in academic entrepreneurship. *The Journal of Technology Transfer, 42*(4), 763–794.

Adam, F., Gojkovič, U., Hafner, A., et al. (2014). *High-technology enterprises – influence of organisational culture and social networks on knowledge transfer (in Slovenian)*. IRSA.

Alsos, G. A., Hytti, U., & Ljunggren, E. (2016). Gender and innovation – an introduction. In *Research handbook on gender and innovation*. Edward Elgar Publishing.

Arenius, P., & Minniti, M. (2005). Perceptual variables and nascent entrepreneurship. *Small Business Economics, 24*, 233–247.

Azagra-Caro, J. M., & Llopis, O. (2018). Who do you care about? Scientists' personality traits and perceived impact on beneficiaries. *R&D Management, 48*(5), 566–579.

Bird, S. R. (2011). Unsettling universities' incongruous, gendered bureaucratic structures: A case-study approach. *Gender, Work and Organization, 18*(2), 202–239.

Brooks, A. W., Huang, L., Kearney, S. W., & Murray, F. E. (2014). Investors prefer entrepreneurial ventures pitched by attractive men. *Proceedings of the National Academy of Sciences of the United States of America, 111*(12), 4427–4431.

Brush, C., Green, P., Balachandra, L., & Davis, A. E. (2014). *Diana report women entrepreneurs 2014: Bridging the gender gap in venture capital*. Babson College.

Brush, C., Edelman, L. F., Manolova, T., & Welter, F. (2019). A gendered look at entrepreneurship ecosystems. *Small Business Economics, 53*(2), 393–408.

Colyvas, J. A., Snellman, K., Bercovitz, J., & Feldman, M. P. (2012). Disentangling effort and performance: A renewed look at gender differences in commercializing medical school research. *Journal of Technology Transfer*, 1–12.

Corley, E. A. (2005). How do career strategies, gender, and work environment affect faculty productivity levels in university-based science centers? *Review of Policy Research, 22*(5), 637–655.

Ebersberger, B., & Pirhofer, C. (2011). Gender, management education and the willingness for academic entrepreneurship. *Applied Economics Letters, 18*(9), 841–844.

Eurostat. (2019). *Gender statistics*. Available from: https://ec.europa.eu/eurostat/statistics-explained/pdfscache/22925.pdf. Accessed: 14.5.2019.

Fini, R., Lacetera, N., & Shane, S. (2010). Inside or outside the IP system? Business creation in academia. *Research Policy, 39*(8), 1060–1069.

Foss, L., & Gibson, D. V. (2015). *The entrepreneurial university: Context and institutional change*. The Entrepreneurial University.

Foss, L., Henry, C., Ahl, H., & Mikalsen, G. H. (2019). Women's entrepreneurship policy research: A 30-year review of the evidence. *Small Business Economics, 53*(2), 409–429.

Friedman, J., & Silberman, J. (2003). University technology transfer: Do incentives, management, and location matter? *The Journal of Technology Transfer, 28*(1), 17–30.

Frietsch, R., Haller, I., Funken-Vrohlings, M., & Grupp, H. (2009). Gender-specific patterns in patenting and publishing. *Research Policy, 38*, 590–599.

Gauthier, L. R. (2000). The role of questioning: Beyond comprehension's front door. *Reading Horizons: A Journal of Literacy and Language Arts, 40*, 239–252.

Goedegebuure, L., & van Vught, F. (1996). Comparative higher education studies: The perspective from the policy sciences. *Higher Education, 32*, 371–394.

Goel, R. K., Göktepe-Hultén, D., & Ram, R. (2015). Academics' entrepreneurship propensities and gender differences. *The Journal of Technology Transfer, 40*(1), 161–177.

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

Gustafsson, J. (2017). *Single case studies vs. multiple case studies: A comparative study.* Available at: http://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf

Henry, C., Foss, L., & Ahl, H. (2016). Gender and entrepreneurship research: A review of methodological approaches. *International Small Business Journal, 34*(3), 217–241.
Loscocco, K., & Bird, S. R. (2012). Gendered paths: Why women lag behind men in small business success. *Work and Occupations, 39*(2), 183–219.
Martínez, G. L., Raffo, J., & Saito, K. (2016). *Identifying the gender of PCT inventors. Economic Research Working Paper No. 33*. WIPO.
Milli, J., Gault, B., Williams-Baron, E. X., & Berlan, B. (2016). *The gender patenting gap*. Institute for Women's Policy Research.
Minniti, M. (2009). Gender Issues in Entrepreneurship. *Foundations and Trends in Entrepreneurship, 5*(7-8), 497–621.
Modic, D., & Rončević, B. (2018). Social topography for sustainable innovation policy: Putting institutions, social networks and cognitive frames in their place. *Comparative Sociology, 17*(2018), 100–127.
Modic, D., & Yoshioka-Kobayashi, T. (2020). Individual-level determinants of academic patent licensing to start-ups: Impacts of principal investigators' embeddedness in the industry. In A. Novotny, T. Clausen, E. Rasmussen, & J. Wiklund (Eds.), *Research handbook on start-up incubation ecosystems*. Edward Elgar Publishing.
Modic, D., Novak, M., Prijon, L., & Miller, J. L. (2015). *Let the best (wo)man decide: Gender equality in economic decision making in SME's*. Report on a US Embassy NGO small grant sponsored initiative. Ljubljana: Prudentia Institute.
Novotny, A. (2017). The heterogeneity of the academic profession: The effect of occupational variables on university scientists' participation in research commercialization. *Minerva, 55*(4), 485–508.
Paisey, C., & Paisey, N. J. (2010). Comparative research: An opportunity for accounting researchers to learn from other professions. *Journal of Accounting & Organizational Change, 6*, 180–199.
Pitchbook. (2018). *The top 50 universities producing VC-backed entrepreneurs report*. Available at: https://files.pitchbook.com/website/files/pdf/PitchBook_Universities_Report_2017-2018_Edition.pdf. Accessed: 30.5.2019.
Ragin, C. (2008). *Redesigning social inquiry: Fuzzy sets and beyond*. University of Chicago Press.
Ranga, M., & Etzkowitz, H. (2010). Athena in the world of techne: The gender dimension of technology, innovation and entrepreneurship. *Journal of Technology Management & Innovation, 5*(1), 1–12.
Robb, A. M., & Coleman, S. (2009). *Characteristics of new firms: A comparison by gender*. Ewing Marion Kauffman Foundation.
Rosa, P., & Dawson, A. (2006). Gender and the commercialization of university science: Academic founders of spinout companies. *Entrepreneurship and Regional Development, 18*(4), 341–366.
Ruzzier, M., Antončič, B., Zirnstein, E., et al. (2011). *Slovenian researchers at the cross-roads (in Slovenian)*. Univerza na Primorskem.
Schneider, C. Q., & Wagemann, C. (2007). *Qualitative comparative analysis (QCA) und fuzzy sets: Ein lehrbuch für anwender und jene, die es werden wollen*. Barbara Budrich.
Shane, S., Dolmans, S. A. M., Jankowski, J., et al. (2015). Academic entrepreneurship: Which inventors do technology licensing officers prefer for spinoffs? *Journal of Technology Transfer, 40*, 273–292.
Shauman, K. A., & Xie, Y. (1996). Geographic mobility of scientists: Sex differences and family constraints. *Demography, 33*(4), 445–468.
Smithson, M. (2005). Fuzzy set inclusion: Linking fuzzy set methods with mainstream techniques. *Sociological Methods & Research, 33*(4), 431–461.
Stephan, P. E., & El-Ganainy, A. (2007). The entrepreneurial puzzle: Explaining the gender gap. *Journal of Technology Transfer, 32*, 475–487.
Suhadolnik, G. (2018). Do our universities and institutes give birth to start-ups and why not? (English title). *Manager, 1*(6), 2018.

Sullivan, D. M., & Meek, W. R. (2012). Gender and entrepreneurship: A review and process model. *Journal of Managerial Psychology, 27*(5), 428–458.

University of Ljubljana. (2018). *Analysis of application and enrolment for the academic year 2017/2018 (English title)*. Available at: http://www.mizs.gov.si/fileadmin/mizs.gov.si/pageuploads/Visoko_solstvo/Statistika_in_analize/Analize_vpisa_arhiv/analiza_2017_2018.pdf. Accessed: 17.6.2019.

Wajcman, J. (2010). Feminist theories of technology. *Cambridge Journal of Economics, 34*(1), 143–152.

Yin, R. K. (2014). *Case study research: Design and methods*. Sage.

Chapter 10
The Effects of the Academic Environment on PhD Entrepreneurship: New Insights from Survey Data

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Abstract This paper investigates PhD entrepreneurship. We focus on the university factors most closely associated to: (1) students' success in starting a business venture; (2) students' startup intention; (3) students' abandoning the entrepreneurial idea. The empirical analysis is based on data from a questionnaire survey, administered in 2016 in Italy. We focus on four factors related to the university entrepreneurial environment: (1) university entrepreneurship policy frameworks; (2) PhD orientation to business problems; (3) entrepreneurship training; (4) PhD lab reputation. We find that the academic environment can have a fundamental impact on students' decisions to start new ventures and on their entrepreneurial attitude.

Keywords Student entrepreneurship · Entrepreneurial university · Start-up · PhDs · Firm creation

10.1 Introduction

As knowledge has become recognized increasingly as an engine of economic growth, governments in many countries have been encouraging universities to contribute directly to economic development via knowledge transfer (Powers & McDougall, 2005). Although the transfer of knowledge from academia to society is not a new phenomenon (Geuna & Muscio, 2009; Wright et al., 2007; Rothaermel

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et al., 2007), university third-mission activities and university–industry linkages have become progressively ‘institutionalized’ over the last 30 years (Gibbons et al., 1994; Etzkowitz & Leydesdorff, 2000).

University-industry interactions can take various forms, including patenting, licensing and spin-off creation (Agrawal & Henderson, 2002; Bekkers & Bodas Freitas, 2008; Cohen et al., 2002; Muscio & Pozzali, 2013; Philpott et al., 2011), and recent scholarly debate has highlighted the rise of academic entrepreneurialism (Dooley & Kenny, 2015; Wright et al., 2007; Siegel et al., 2003). Increasing numbers of academics are choosing (and being encouraged) to engage in entrepreneurial activities, and the commercialization of university research via academic spin-offs is growing steadily (Thursby & Thursby, 2007). However, the literature focuses almost exclusively on entrepreneurialism by university faculty and academic staff and tends to ignore student entrepreneurship (Åstebro & Bazzazian, 2011; Åstebro et al., 2012; Shah & Pahnke, 2014). In particular, there is a lack of empirical evidence on entrepreneurship by doctoral students (hereafter *PhD entrepreneurship*) (Bienkowska et al., 2016). This is in part because students’ (as opposed to university faculty) entrepreneurial activities are based, less frequently, on university Intellectual Property (IP). Typically, student startups are not recorded as “university spin-offs” unless the venture involves a university faculty member.

Nevertheless, PhD entrepreneurship is effective for fulfilling the university third mission (Etzkowitz, 2017; Etzkowitz et al., 2000; Philpott et al., 2011). PhD entrepreneurship involves the establishment of knowledge-intensive start-ups, provides high-skilled jobs, reinforces regional economic structure and helps to legitimate the role of the university in the regional economy. Moreover, PhD students can be incentivized to start a venture business due to the lack of a stable academic position and a more risk-taking attitude compared to tenured faculty members. PhD entrepreneurship responds to policy debate which questions the over-production of PhD graduates (Stephan, 2012). A large part of the investment in PhD programmes is based on the assumption that PhD graduates will continue in academia and engage in research and education, providing a fair return for public funding. However, studies of PhD graduates’ employment outcomes show that taking up an academic position is not the main outcome (Conti & Visentin, 2015). We are observing a transformation to universities’ goals and doctoral education programmes and a greater emphasis on new business creation by students (Muscio et al., 2013).

In this study, we investigate how both university-and student-level factors are associated to PhD students’ entrepreneurial activity. We study the entrepreneurial environment surrounding PhD students situated in Italian academic institutions and analyse its influence on students’ success or failure at venture business creation and the startup intention. First, our analysis of students’ entrepreneurial environment provides immediate policy and managerial implications for research institutions that want to promote entrepreneurship. Second, little research has been done on the relation between environmental factors and students’ personal characteristics (Pruett et al., 2009). Although there is a stream of work on how universities can support academic entrepreneurship generally (Philpott et al., 2011; Ramaciotti et al., 2017), few studies investigate how the university environment affects the decision to start a new business, particularly by PhD students who are in the unique position of being simultaneously a student and a young professional.

In what follows, we formulate some hypotheses and test them using the data collected from the responses to a questionnaire survey of doctoral students enrolled in PhD programmes between 2008 and 2014.

10.2 PhD Entrepreneurship: Theoretical Insights

Universities are under political pressure to integrate with industry and society, and the so-called 'entrepreneurial university' model emphasizes new business creation and knowledge spillovers (Branscomb et al., 1999; Ghio et al., 2015). Academic entrepreneurship involves multiple stakeholders such as faculty at different levels, post-doctoral fellows and students. There are many reasons why these individuals choose to focus on venture creation: greater availability of entrepreneurial and technological opportunities, lower availability of academic jobs, better information on the steps to market and access to entrepreneurship programmes. Scholarly debate on academic entrepreneurship has been overly focused on the university third mission and university–industry linkages (Siegel & Wright, 2015) and overlooks new forms of entrepreneurial activities, including PhD entrepreneurship.

For various reasons, PhD entrepreneurship deserves special attention. PhD students, potentially, may be more able to overcome the barriers to new venture creation. Unlike academic staff, they are often better positioned to gain access to the required commercial competences and assets, and they do not need to undergo 'genetic mutation' to become entrepreneurs (Colombo & Piva, 2012). During their early academic experience, PhD students compared to graduates and faculty members can exploit business ideas with higher technological/knowledge content. Despite the paucity of scholarly debate on PhD entrepreneurship, many universities are encouraging student entrepreneurship (Åstebro et al., 2012; Conti & Visentin, 2015).

We investigate the entrepreneurial climate in universities and what characterizes PhD curricula and research training. The succeeding sections discuss the theoretical underpinnings.

10.2.1 The University Entrepreneurship Policy Framework

Students' entrepreneurial intentions and entrepreneurial activities are influenced by the social context (Bercovitz & Feldman, 2008; Clarysse et al., 2011; Stuart & Ding, 2006; Guerrero et al., 2018). For example, academics' proximity to academic entrepreneurs increases the probability of also engaging in entrepreneurial activities (Muscio & Ramaciotti, 2019; Stuart & Ding, 2006). Academic spin-offs keep tighter links to universities than other young innovative firms (Azagra-Caro et al., 2012) and, in addition, the number of the institution's spin-offs has a positive influence on the entrepreneurial attitude of academics (Clarysse et al., 2011; Muscio & Ramaciotti, 2019). These results suggest that a local environment that is nurturing entrepreneurship is crucial.

Although not all academic institutions are engaged actively in entrepreneurship (Muscio et al., 2016; Wright et al., 2007), some have adopted infrastructures that include entrepreneurship education and support, which create an environment favourable to entrepreneurial activity and encourage students to become entrepreneurs (Barbero et al., 2014; Guerrero et al., 2018; McAdam & McAdam, 2008). For example, incubation services provide students with a common working space, professional office facilities, business mentors and networking opportunities (Jansen et al., 2015; Souitaris et al., 2007). Van Rijnsoever et al. (2017) suggest, also, that incubators have a positive effect on financial aspects, for instance, by attracting start-up funding and promoting engagement with financial institutions and investors.

Another instrument that universities can put in place to support entrepreneurship comes in the form of clear rules and guidance to regulate startup activities (Caldera & Debande, 2010; Rasmussen et al., 2014). By providing a supportive context for entrepreneurial activities, rules and guidelines increase the propensity for student entrepreneurialism (Hoppe, 2016; Walter et al., 2013; Kuratko, 2005; Lockett et al., 2003). Rules and guidelines provide a framework for the startup process, regulate entrepreneurs' monetary incentives and mitigate entrepreneurial risks (Muscio et al., 2016). Also, academic rules/guidelines can contribute to clarifying the institutions' strategic orientation to entrepreneurship (Phan & Siegel, 2006; Rasmussen & Borch, 2010; Van Looy et al., 2011). They can facilitate the preparation and approval of business plans, limit potential conflicts between parent institution and entrepreneur, and provide incentives to those considering becoming an entrepreneur (Muscio et al., 2016; Rasmussen & Borch, 2010). Therefore, we argue that:

Hypothesis 1 PhD students affiliated to institutions with policies to promote and support entrepreneurial initiatives are more likely to become entrepreneurs.

10.2.2 Entrepreneurship Training

Another important factor that is particularly relevant to PhD students compared to academic staff, is access to entrepreneurship courses and training. In many countries, entrepreneurship training for doctoral students has become a significant topic in education policy (Bienkowska & Klofsten, 2012; Thune, 2009). Although personal characteristics may be important drivers of student start-up activity (Guerrero et al., 2018), the student's attitude to entrepreneurship will be influenced by access to appropriate entrepreneurship education programmes (Harris & Gibson, 2008).

Entrepreneurship is becoming a prominent field in university education and several studies show that such programmes can foster an entrepreneurial attitude in students (Blackford et al., 2009; Maresch et al., 2016; Mitra & Matlay, 2004;

Sanchez, 2011; Souitaris et al., 2007; Stamboulis & Barlas, 2014; Vanevenhoven & Liguori, 2013). Some authors suggest that, to improve the business skills of potential entrepreneurs, academic institutions should offer entrepreneurship courses (Åstebro et al., 2012; Storey & Tether, 1998). Entrepreneurship training strengthens the student's intention to establish a new business, enhancing the ability to assess individual aptitude (Oosterbeek et al., 2010) to create an academic spinoff in particular (Rasmussen & Borch, 2010; Rasmussen et al., 2014). Therefore, we posit:

Hypothesis 2 PhD students who take entrepreneurship courses are more likely to become entrepreneurs.

10.2.3 Orientation of PhD Programmes Towards Business Problems

When new ventures derive from research-driven ideas, it can be difficult to match the results of academic research to market opportunities, and experience of working in an industrial context can greatly enhance the entrepreneurial process and reduce the level of uncertainty about the application of research (Smith et al., 2009). It follows that research activities with applications in industry should spark entrepreneurialism in PhD students (Abreu & Grinevich, 2013). If the PhD research is focused on the solution to business problems, the researcher (research team) will be likely to interact with companies, whose involvement can have a positive impact on the student's choice to start his or her own firm (Dooley & Kenny, 2015). The literature shows that research oriented to resolving business problems is associated positively to the frequency of university-industry partnerships and academics' entrepreneurial intentions (Calderini et al., 2007; Muscio & Pozzali, 2013; Landry et al., 2006; Krabel & Mueller, 2009).

Since students tend to lack business sector experience, exposure to industry problems and the interaction with firms can provide opportunities to identify industrial applications for the results of their doctoral research and steer them towards an entrepreneurial career (Muscio & Ramaciotti, 2019). Students' interactions with business can offer learning opportunities that academic institutions might be unable to provide (Lester & Costley, 2010; Kessels & Kwakman, 2007; Slaughter et al., 2002), expose them to more applied research (Geisler & Rubenstein, 1989) and increase the integration of complementary forms of knowledge (Thune & Støren, 2015). Therefore, students' efforts to solve real-world business problems can result in networking relationships and provide the capabilities needed to become an entrepreneur (D'Este et al., 2012; Wright et al., 2004). Therefore, we argue:

Hypothesis 3 PhD students who engage in problem-oriented research are more likely to become entrepreneurs.

Further, we argue that this effect should depend on the scientific quality of the research environment. PhD research training is embedded in the local context of a research lab or a small group of scientists led by the PhD supervisor, and the quality of the science that the student can draw on can differ significantly among labs.

The scientific quality of the local environment depends on several factors including the PhD supervisor, who guides the student's research project, and points to interesting research areas and suitable methodologies (Delamont & Atkinson, 2001; Laudel, 2001; Shibayama et al., 2015). Scientific quality is constrained, also, by resources, which determine, for example, how certain research tasks can be performed, the access to equipment and materials and the opportunities for conference participation and publication. Scientific quality is influenced, also, by the time the PhD student can devote to research; many engage in teaching and other activities.

The prior literature identifies a positive link between scientific quality and academic entrepreneurship. That is, that universities that perform high-quality research tend to attract private funding (European Commission, 2010). Research labs led by star scientists tend to engage in a higher level of knowledge transfer activities (D'Este et al., 2012; Olmos-Peñuela et al., 2014; Lowe & Gonzalez-Brambila, 2007; Zucker & Darby, 1996). There can also be signalling effects (Spence, 1973). Commercial investors in academic ideas prefer to support start-ups that involve high-skilled human capital (Ramaciotti et al., 2017). Universities with a high research ranking tend to have more frequent interactions with industry (McCormack et al., 2014; Muscio et al., 2013).

These results imply that a high-quality research environment can reinforce the link between problem-oriented PhD research and entrepreneurial activities. Through working in such an environment, problem-oriented research can produce practically meaningful results which facilitate PhD students' entrepreneurial activities. Therefore, we argue:

Hypothesis 4 The scientific quality of the research training lab is positively associated to the likelihood of the PhD student becoming an entrepreneur.

10.3 Empirical Design

10.3.1 Data and Methodology

This empirical analysis is based on data from a questionnaire survey, administered between end 2014 and beginning of 2015, to Italian doctorate students enrolled in a PhD course in the period 2008–2014. The authors designed the questionnaire and the survey was managed by CINECA, an Italian consortium of universities, research institutions and the Ministry of Education and Research (MIUR). The questionnaire asked students to evaluate their PhD course and institution, and their entrepreneurial activity and occupational status, and asked some general questions about personal characteristics. CINECA sent the questionnaire to a balanced sample of 23,500 individuals, which represented 50% of the population of doctoral students enrolled in PhD courses in the period 2008–2014. All responses were verified by the Italian

National institute of Statistics (ISTAT), which, in the case of very low response rates, did not disclose data on certain PhD courses in order to guarantee data anonymity. A total of 8755 completed questionnaires was achieved, a response rate of 37.25%. For the purposes of our analysis, we dropped cases where scientific area of the PhD programme was missing. Department and university-level variables such as research rating and size were provided by MIUR. Information on university policies, such as startup regulations, was obtained from institutions' websites.

Table 10.1 presents the responses by scientific field and university size, and the population of PhD graduates estimated by ISTAT. ISTAT publishes these data in its yearly reports on the employment conditions of PhD graduates in Italy.[1] In its 2015 report ISTAT identified 22,469 graduates belonging to two cohorts: 2008 and 2010. We compared the distribution of responses, by scientific area, obtained from our survey and by ISTAT. The estimated difference between our sample and the ISTAT sample was always below the 5% threshold, demonstrating the good representativeness of our sample (Table 10.1). The two scientific areas accounting for the majority of students are Medicine and Engineering. Students are also concentrated in larger academic institutions.

The responses show that 69.1% of students enrolled in a PhD programme completed their PhD studies during the period considered. Of these, 72.8% were employed, 6.4% had been involved in entrepreneurial ventures, 5.5% were involved in businesses that were still active at the time of the survey.

Table 10.2 presents information on the variables used in the econometric analysis. A set of logit and ordered logit regressions was run to test the research hypotheses: the main model presented in Eq. (10.1) estimates whether or not the university entrepreneurial environment is associated to the probability that students will take the decision to become an entrepreneur.

$$\Pr\left(y_{ij} = 1\right) = \alpha + \beta_1 x_j + \beta_2 \gamma_{ij} + \beta_3 \delta_j + \epsilon_{ij} \tag{10.1}$$

The dichotomous dependent variable y_{ij} is equal to 1 if student i, attending university j, started a business that was still active (or contributed to its establishment) at the time of survey, and 0 otherwise. Two other sets of models test the research hypotheses in the two scientific areas of Social Sciences and Humanities (SSH) and Life and Hard Sciences (LHS), which show different scientific behaviour (Bonaccorsi et al., 2017).

We ran two additional models as robustness checks. The first one tests the aforementioned specification on the probability that students with entrepreneurial intentions will abandon the idea to become entrepreneurs. In this model the dichotomous dependent variable y_{ij}, is equal to 1 if student i, attending university j, abandoned the entrepreneurial idea, and 0 otherwise. The second robustness check is estimated with a third model investigating whether the university entrepreneurial environment is associated to the students' entrepreneurial intentions. In this case, the

[1] https://www.istat.it/it/archivio/8555

Table 10.1 Distribution of responses

		University size								
SSD	Scientific area	Small	Medium	Large	Mega	Total	Per cent	ISTAT pop.	Per cent	Difference
1	Mathematics & Computer Science	46	26	233	245	550	6.28	517	3.17	3.11
2	Physics	29	13	200	199	441	5.04	745	4.56	0.48
3	Chemistry	20	29	182	310	541	6.18	899	5.51	0.67
4	Geology	33	19	160	140	352	4.02	399	2.44	1.58
5	Biology	66	51	315	426	858	9.80	1598	9.79	0.01
6	Medicine	32	107	550	588	1277	14.59	2420	14.83	−0.24
7	Agriculture & Veterinary	29	87	104	300	520	5.94	1071	6.56	−0.62
8	Civil Engineering & Architecture	84	53	338	306	781	8.92	1172	7.18	1.74
9	Engineering	18	106	519	411	1054	12.04	1963	12.03	0.01
10	Humanities	34	65	290	412	801	9.15	1402	8.59	0.56
11	Sociology, Philosophy and Psychology	19	68	237	299	623	7.12	1480	9.07	−1.95
12	Law	5	33	117	113	268	3.06	1171	7.17	−4.11
13	Economics and Statistics	16	31	166	161	374	4.27	925	5.67	−1.40
14	Political Sciences	11	31	114	159	315	3.60	560	3.43	0.17
	Total	442	719	3525	4069	8755	100.00	16,322	100.00	

Table 10.2 Data definition

Variable	Description	Source
Dependent variables		
Active startup	Dummy variable taking value 1 if the student established or contributed to the establishment of a still active business start-up and 0 otherwise.	Questionnaire
Abandoned idea	Dummy variable taking value 1 if the student abandoned the idea of start-up and 0 otherwise.	Questionnaire
Startup intention	Scalar variable ranging from 1 if the student has absolutely no intention to start-up and 6 if she/he very interested in starting a business.	Questionnaire
Research hypotheses testing		
Startup regulation	Dummy variable taking value 1 if the university in 2006 had a dedicated set of rules for spinoff and startup creation, and 0 otherwise.	University website
Incubator	Dummy variable taking value 1 if the university hosted a business incubator, and 0 otherwise.	PniCube website
Entrepreneurship courses	Dummy variable taking value 1 if the student attended entrepreneurship courses during her/his PhD and 0 otherwise.	Questionnaire
Business-oriented research	Scalar variable ranging from 6 if the student claims that her/his PhD research was oriented towards immediate application in a business context and 1 if she/he absolutely does not believe so.	Questionnaire
Lab environment	One factor obtained from exploratory factor analysis on a set on nine questions investigating students' opinion about the Ph.D. environment they engaged with.[a]	Questionnaire
Student-level control factors		
PhD completion	Dummy variable taking value 1 if the student completed her/his PhD studies and 0 otherwise.	Questionnaire
Year of birth	Year of birth of the student.	Questionnaire
Male gender	Dummy variable taking value 1 if the student is a male and 0 otherwise.	Questionnaire
Academic position	Dummy variable taking value 1 if the student holds an academic position.	Questionnaire
Post lauream work experience	Dummy variable taking value 1 if the student did not start the Ph.D. immediately after previous university degrees to gain some work experience and 0 otherwise.	Questionnaire
Risk preference	Scalar variable ranging from 1 if the student claims that she/he is more willing to invest in technologies, projects or products that involve low risk and certain, low gains and 5 if she/he is more willing to invest in risky projects that involve high gains.	Questionnaire

(continued)

Table 10.2 (continued)

Variable	Description	Source
University-level control factors		
Research rating	Research rating published by MIUR in 2014, based on the evaluation of research output carried out over the period 2004–2010. This composite indicator takes into account peer review evaluations of research activity carried out at academic institutions (patents, impact factor of journal articles, etc.).	MIUR
University size	Size of the academic institution. University size is expressed in terms of number of students: 1 small (<10,000); 2 medium (10,000–15,000); 3 large (15,000–40,000); 4 mega (>40,000).	MIUR

[a]Questions: Competence of the supervisor; Time dedicated to research activity; Availability of equipment and res. Infrastructure; Availability of financial resources; Degree of independence/autonomy of res. subjects; Extension/quality of the international res. network; Degree of international experience; Quality of the research team; Access to labour market

dependent variable y_{ij} takes scalar values ordered progressively, ranging from 1 if the student had absolutely no intention to start-up and 6 if, on the opposite, she/he very interested in starting a business. Accordingly, we chose the following ordered logit model for the analysis:

$$\Pr\left(y_{ij} = \mathrm{z}\right) = \alpha + \beta_1 x_j + \beta_2 \gamma_{ij} + \beta_3 \delta_j + \epsilon_{ij} \tag{10.2}$$

with z ranging from 1 to 6. It must be noted that in this case we run the econometric model on a sub-sample of students that did not already start a company at the time of the survey. Therefore, we considered those students that might have been willing to become entrepreneurs but that had not yet pursued this career option.

Both models (10.1) and (10.2) include on the right-hand side: some indicators x measuring the entrepreneurial environment accessible at the university; some variables γ control for student characteristics; finally, some variables δ control for institutional characteristics. ϵ denotes the error term. The control variables were chosen on the basis of the literature student start-up activity (Åstebro et al., 2012; Muscio & Ramaciotti, 2019; Krabel & Mueller, 2009). This literature identifies individual factors influencing the individual propensity to establish a firm (e.g., Abreu & Grinevich, 2013; Landry et al., 2006), as well as university-level control factors measuring institutional research performance and size. As regional economic characteristics play a relevant role in start-up creation (Feldman, 2001), all models include province-level (NUTS3) geographical dummies. Year dummies and dummies for the PhD scientific area are also included when necessary.

The definition of the variables included in the regressions are presented in Table 10.2, while the descriptive statistics are in Table 10.3 and the correlation matrix in Table 10.4.

Table 10.3 Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Dependent variables					
Active startup	9049	0.055	0.228	0.000	1.000
Abandoned idea	7178	0.412	0.492	0.000	1.000
Startup intention	6308	3.863	1.719	1.000	6.000
Research hypotheses testing					
Startup regulation	9062	0.638	0.481	0.000	1.000
Incubator	9062	0.808	0.394	0.000	1.000
Entrepreneurship courses	9062	0.071	0.257	0.000	1.000
Business-oriented research	8596	1.964	1.460	1.000	6.000
Lab environment (factor = 1)	8026	0.000	0.933	−2.765	1.900
Student-level control factors					
PhD completion	9062	0.581	0.493	0.000	1.000
Year of birth	9062	1981	5.498	1950.000	1990.000
Male gender	9062	0.500	0.500	0.000	1.000
Academic position	9062	0.616	0.486	0.000	1.000
Post lauream work experience	8661	0.444	0.497	0.000	1.000
Risk preference	6689	2.805	0.759	1.000	5.000
University-level control factors					
Research rating	9062	1.000	0.234	0.000	2.080
University size	8755	3.282	0.818	1.000	4.000

10.4 Results

Table 10.5 presents the results of the regressions. The results of the variance inflation factor test confirm that our estimates do not suffer from multicollinearity.[2]

With reference to the effects of the variables of interest, we find that the entrepreneurial environment available at the parent institution university-level and PhD course factors are positively associated to student entrepreneurship. Confirming empirical work on academic entrepreneurship, we find that creating a favourable environment for the entrepreneurial process at the university, is positively associated to the probability that doctoral graduates will create their own firms. In order to test Hypothesis 1, we use a dummy variable indicating whether the parent institution introduced some guidelines and rules in support of start-up and spin-off creation and a dummy variable accounting for a business incubator at the parent university. Universities usually define these rules in an attempt to better frame academic entrepreneurial initiatives (Caldera & Debande, 2010), defining aspects such as monetary incentives for startup creation and norms reducing the entrepreneurial risk (see Muscio et al., 2016). For the purpose of this paper, these rules can be considered as a proxy of the academic entrepreneurial orientation, highlighting the

[2]The variance inflation factor test was always below 10.

Table 10.4 Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Startup regulation	1.000												
2	Incubator	−0.042	1.000											
3	Entrepreneurship courses	−0.018	0.001	1.000										
4	Business-oriented PH.D. research	0.029	0.003	0.115	1.000									
5	Lab environment (factor = 1)	0.015	0.002	−0.021	0.152	1.000								
6	PhD completion	−0.033	−0.023	0.008	−0.044	−0.060	1.000							
7	Year of birth	0.031	−0.030	0.006	0.013	0.045	−0.308	1.000						
8	Male gender	−0.010	−0.003	0.011	0.094	0.040	0.014	−0.051	1.000					
9	Academic position	−0.004	0.001	−0.005	0.033	0.157	0.203	0.044	0.002	1.000				
10	Post lauream work experience	−0.021	0.022	0.030	0.032	−0.025	−0.005	−0.363	−0.031	−0.049	1.000			
11	Risk preference	−0.009	0.015	0.049	0.084	0.024	0.003	−0.020	0.150	0.010	−0.015	1.000		
12	Research rating	0.084	−0.058	−0.009	−0.025	0.008	−0.028	0.072	−0.019	0.063	0.012	−0.025	1.000	
13	University size	0.076	0.411	−0.020	−0.034	−0.054	−0.079	0.056	−0.009	−0.005	−0.014	−0.024	0.1678	1.000

Table 10.5 Logit and ordered logit regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variables	Active	Active	LHS active	SSH active	Abandoned	LHS abandoned	SSH abandoned	Intention	LHS intention	SSH intention
Startup regulation	0.251**	0.256**	0.312**	0.11	0.047	0.129*	−0.198+	0.025	−0.002	0.143
	[0.084]	[0.084]	[0.102]	[0.190]	[0.052]	[0.061]	[0.111]	[0.045]	[0.053]	[0.097]
Incubator	0.442**	0.443**	0.584**	0.081	−0.068	−0.108	0.009	0.03	0.045	−0.012
	[0.107]	[0.107]	[0.129]	[0.234]	[0.068]	[0.079]	[0.147]	[0.059]	[0.069]	[0.124]
Entrepreneurship courses	0.883**	0.889**	0.960**	0.873**	−0.447**	−0.478**	−0.245	0.354**	0.414**	0.014
	[0.080]	[0.081]	[0.092]	[0.217]	[0.074]	[0.083]	[0.179]	[0.063]	[0.072]	[0.145]
Business-oriented research	0.109**	0.108**	0.111**	0.162**	−0.079**	−0.081**	−0.114**	0.072**	0.058**	0.125**
	[0.019]	[0.020]	[0.022]	[0.047]	[0.014]	[0.015]	[0.035]	[0.013]	[0.013]	[0.030]
Lab environment	−0.124**	−0.233**	−0.266**	−0.265*	−0.079*	−0.085*	0.003	−0.080**	−0.093*	−0.053
	[0.033]	[0.055]	[0.065]	[0.123]	[0.035]	[0.041]	[0.074]	[0.031]	[0.036]	[0.066]
Business-oriented research * Lab environment		0.047*	0.051*	0.084+	−0.012	−0.007	−0.063+	0.024*	0.024+	0.015
		[0.019]	[0.021]	[0.051]	[0.014]	[0.016]	[0.036]	[0.012]	[0.014]	[0.031]
PhD completion	0.253+	0.249+	−0.028	1.435**	−0.005	−0.045	0.053	0.026	0.075	−0.282
	[0.150]	[0.150]	[0.173]	[0.442]	[0.087]	[0.098]	[0.203]	[0.074]	[0.083]	[0.182]
Year of birth	−0.016*	−0.015*	−0.019*	−0.009	−0.026**	−0.029**	−0.029**	0.001	−0.004	0.013+
	[0.006]	[0.006]	[0.008]	[0.013]	[0.005]	[0.005]	[0.009]	[0.004]	[0.005]	[0.008]
Male gender	0.265**	0.264**	0.342**	0.058	−0.209**	−0.274**	−0.076	0.094**	0.100*	0.038
	[0.065]	[0.066]	[0.076]	[0.149]	[0.041]	[0.045]	[0.088]	[0.035]	[0.040]	[0.075]
Academic position	−0.253**	−0.252**	−0.250**	−0.444**	−0.024	−0.019	−0.034	−0.065+	−0.042	−0.181*
	[0.065]	[0.066]	[0.076]	[0.164]	[0.043]	[0.050]	[0.094]	[0.038]	[0.044]	[0.080]
Post lauream work experience	0.135*	0.137*	0.109	0.191	−0.119**	−0.075	−0.276**	0.000	0.006	−0.023
	[0.067]	[0.067]	[0.077]	[0.171]	[0.043]	[0.048]	[0.098]	[0.037]	[0.042]	[0.083]

(continued)

Table 10.5 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Risk attitude	0.149**	0.145**	0.158**	0.118	−0.178**	−0.144**	−0.293**	0.287**	0.284**	0.307**
	[0.042]	[0.042]	[0.049]	[0.100]	[0.026]	[0.030]	[0.058]	[0.023]	[0.027]	[0.050]
University research rating	0.098	0.102	0.045	0.397	0.014	0.049	−0.015	−0.121	−0.157	−0.029
	[0.152]	[0.153]	[0.180]	[0.339]	[0.098]	[0.112]	[0.227]	[0.087]	[0.099]	[0.199]
University size	−0.252**	−0.252**	−0.244**	−0.234*	0.02	0.033	−0.034	−0.005	−0.007	−0.071
	[0.049]	[0.049]	[0.057]	[0.117]	[0.033]	[0.038]	[0.080]	[0.029]	[0.033]	[0.072]
Year dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Area dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Province dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Constant	26.333*	26.047*	36.537*	14.097	54.225**	58.635**	58.267**			
	[12.642]	[12.683]	[15.153]	[26.593]	[9.294]	[10.798]	[17.432]			
Observations	5135	5135	3877	964	4740	3689	1005	4041	3115	926
Pseudo R-squared	0.185	0.187	0.197	0.253	0.0758	0.0765	0.0964	0.0370	0.0366	0.0685

Standard errors in brackets. **$p < 0.01$, *$p < 0.05$, +$p < 0.1$.

inclusion of firms' startup in the cultural framework of institutions. In line with previous empirical works (Caldera & Debande, 2010; Muscio et al., 2016; Muscio & Ramaciotti, 2019), we find that the adoption of university regulations on entrepreneurship is positively associated to PhDs' decision to become entrepreneurs. These results extend previous findings on spin-off activity concerning the relevance of academic rules in supporting PhD startups (Lockett et al., 2003). We also find that these rules have no significant effect on either students evaluating or abandoning the idea to become entrepreneurs. These results are confirmed also by the second proxy of the entrepreneurial environment: we find that the availability of a business incubator at the parent university supports business creation is not significantly associated to students' intention or abandonment of the idea to establish a firm. This is probably because only those students that really needed the business incubation services engaged with it, whilst in the other two cases they did not.

Moving to student-level indicators testing the remaining hypotheses, we find that, supporting Hypothesis 2, entrepreneurship education is positively associated to students' choice to become entrepreneurs. These results are in line with investigations on the effect of entrepreneurial courses on students' future careers, confirming that, even in the case of PhDs, courses on entrepreneurship positively affect the entrepreneurial activity (Muscio & Ramaciotti, 2019) and intentions of students (Souitaris et al., 2007; Von Graevenitz et al., 2010). Conversely, we find that those students that attended the course are less likely to abandon the idea to become entrepreneurs.

Confirming Hypothesis 3, we find that those students that choose to dedicate their PhD studies to research that addresses business needs will be more likely to (or be willing to) become entrepreneurs. As suggested by Abreu and Grinevich (2013), research which is more easily applied to an industrial context is more likely to stimulate entrepreneurial ideas in academia. Therefore, carrying out research, which is applied to a business context, raises the probability of finding research results that can be relevant for the market, increases the probability of students' deciding to create a start-up.

Finally, concerning Hypothesis 4, as noted above, academic entrepreneurial activities are embedded, in institutional contexts (Autio et al., 2014; Welter, 2011), and breed from students' interaction with other researchers in given spaces (Bergmann et al., 2016). In this respect, university laboratories represent complex contexts where scientific research as well as research training and career building is carried out. Some authors (De Jong & Den Hartog, 2007; Olmos-Peñuela et al., 2014) argue that lab directors can influence lab members setting research priorities, steering research activities, mobilising organisational tasks and reallocating resources. Some papers suggest that the training that students receive in academic labs and their inter-personal relationship with peers and supervisors can determine their future prospects and employment outcomes (Miller et al., 2005; Shibayama, 2019). In this respect, we find that, while students' access to what they believe is a good quality PhD lab is negatively associated to entrepreneurial activity. Nonetheless, by testing the interaction effect of business-oriented research and lab environment, we also find that accessing good PhD labs positively moderates entrepreneurial activity and intention. Therefore, while access to good supervisors and good facilities might push students to pursue an academic career or to look for good research jobs, the availability of a high-quality PhD environment is boosting the effects of carrying out business-oriented research on the probability that they will become entrepreneurs or develop the intention to do so.

The individual level control variables confirm the results obtained by other researchers studying the determinants of academic spin-off creation (Krabel & Mueller, 2009). First, we find that the age effect is negatively significant, indicating that younger students will be more likely to pursue the choice to become entrepreneurs as an employment outcome. We also find that men have a higher probability than women of becoming entrepreneurs. Partially confirming the aforementioned arguments supporting Hypothesis 4, having a job in academia is negatively associated to both entrepreneurship and entrepreneurial intention. These results are confirmed by other studies showing that, in the early stages of an academic career, researchers tend to focus on research-based activities such as publications (Bercovitz & Feldman, 2008). Finally, as noted in Arenius and Minniti (2005), students' start-up activity will be driven by their risk attitude. Confirming this, we find that positive risk attitude is associated to startup activity and intention, while more risk-averse students will be more likely to abandon the idea of starting a company. Similarly, confirming Guerrero et al. (2018), earning previous work experience facilitates business creation while it is negative associated to the abandonment of the idea of business creation.

Moving to university control variables, our results show that entrepreneurial activities are more vibrant in smaller universities. Confirming the findings of other papers on spin-offs (Landry et al., 2006; Ramaciotti & Rizzo, 2015), university research performance does not affect start-up generation.

As the scientific activity and behaviour of scholars in the SSH might differ from those specialising in the LHS because of intrinsic or extrinsic factors (Bonaccorsi et al., 2017), we test the two models on two sub-samples of data including students that studied in these two areas. In general, the results for the hard sciences and the soft sciences largely confirm those obtained at the aggregate level, with the only exception of entrepreneurial intention in the SSH, where among the factors considered, only research oriented to business needs seem to be positively associated to students' intentions.

10.5 Conclusions

This paper investigated the effects of PhD students' access to the academic environment on their entrepreneurial activity. While the scientific literature and technology transfer policy alike have so far have paid little attention to PhD entrepreneurship, the findings from our study make a case for promotion of an entrepreneurial university model that is broader in scope than the models currently in place in many US and European institutions.

We shed light on the characteristics of the student's home institution associated to business creation by young, research-skilled individuals, focusing on four factors: (1) the availability of a university entrepreneurship policy framework; (2) PhD orientation towards business problems; (3) entrepreneurship training; (4) standing of the PhD lab. Our results confirm that academic institutions can play a fundamental role in influencing the entrepreneurial behaviour of their students and their commitment to offering an environment that nurtures entrepreneurship can also make a difference in terms of pursuing the third mission.

The empirical results presented here have some relevant policy and managerial implications. First of all, the definition and promotion of clear policy initiatives in support of academic entrepreneurship, such as the creation of clear academic rules for potential entrepreneurs and the establishment of a business incubator will make a difference in changing students' attitude towards new firm creation.

Secondly, our results show that the design of PhD programmes is most likely to influence PhD entrepreneurship. Students' engagement in business-oriented applied research activities and their participation in entrepreneurship courses, will have a tangible impact on the probability that they will choose to become entrepreneurs. Moreover, we find that students' access to better research laboratories will influence positively the effects of business-oriented research on their entrepreneurial activities. Therefore, supporting the creation of an entrepreneur-friendly PhD environment, could increase the institutional capability to generate a tangible impact on local communities while also offering better work opportunities for students.

Despite these relevant implications, this study faces some important limitations. First of all, the use of cross-sectional data implies some caution in identifying any cause-effect relationship (Muscio & Ramaciotti, 2018). Unfortunately, the use of single-call questionnaire data, which exposes to some risks of reverse causality, which in our case should be balanced by the high response rate and good representativeness of the sample. Secondly, as we run an individual level study, we cannot draw any conclusion in terms of institutional performance. This brings us to future developments of this type of studies, which could be extended exploring university-level factors influencing academic performance in terms of PhD startup activity.

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References

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

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

Arenius, P., & Minniti, M. (2005). Perceptual variables and nascent entrepreneurship. *Small Business Economics, 24*(3), 732–755.

Åstebro, T., & Bazzazian, N. (2011). Universities, entrepreneurship and local economic development. In M. Fritsch (Ed.), *Handbook of research on entrepreneurship and regional development*. Edward Elgar.

Åstebro, T., Bazzazian, N., & Braguinsky, S. (2012). Startups by recent university graduates and their faculty: Implications for university entrepreneurship policy. *Research Policy, 41*(4), 663–677.

Autio, E., Kenney, M., Mustar, P., Siegel, D. S., & Wright, M. (2014). Entrepreneurial innovation: The importance of context. *Research Policy, 43*(7), 1097–1108.

Azagra-Caro, J. M., Mas-Verdú, F., & Martinez-Gomez, V. (2012). Forget R&D–pay my coach: Young innovative companies and their relations with universities. In *Technology transfer in a global economy* (pp. 13–34). Springer.

Barbero, J., Casillas, J., & Wright, M. (2014). Do different types of incubators produce different types of innovations? *Journal of Technology Transfer, 39*, 151–168.

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

Bercovitz, J., & Feldman, M. (2008). Academic entrepreneurs: Organizational change at the individual level. *Organization Science, 19*, 69–89.

Bergmann, H., Hundt, C., & Sternberg, R. (2016). What makes student entrepreneurs? On the relevance (and irrelevance) of the university and the regional context for student start-ups. *Small Business Economics, 47*, 53–76.

Bienkowska, D., & Klofsten, M. (2012). Creating entrepreneurial networks: Academic entrepreneurship, mobility and collaboration during PhD education. *Higher Education, 64*, 207–222.

Bienkowska, D., Klofsten, M., & Rasmussen, E. (2016). PhD students in the entrepreneurial university – perceived support for academic entrepreneurship. *European Journal of Education, 51*, 56–72.

Blackford, B. J., Sebora, T. C., & Whitehill, T. (2009). The effects of collegiate entrepreneurship education on post-graduation startup of new ventures: A first look. *International Review of Entrepreneurship, 7*(3), 1–26.

Bonaccorsi, A., Daraio, C., Fantoni, S., Folli, V., Leonetti, M., & Ruocco, G. (2017). Do social sciences and humanities behave like life and hard sciences? *Scientometrics, 112*(1), 607–653.

Branscomb, L. M., Kodama, F., & Richard, F. (1999). *Industrializing knowledge: University–industry linkages in Japan and the United States*. MIT Press.

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

Calderini, M., Franzoni, C., & Vezzulli, A. (2007). If star scientists do not patent: The effect of productivity, basicness and impact on the decision to patent in the academic world. *Research Policy, 36*, 303–319.

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

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

Colombo, M. G., & Piva, E. (2012). Firms' genetic characteristics and competence-enlarging strategies: A comparison between academic and non-academic high-tech start-ups. *Research Policy, 41*, 79–92.

Conti, A., & Visentin, F. (2015). A revealed preference analysis of PhD students' choices over employment outcomes. *Research Policy, 44*, 1931–1947.

D'Este, P., Mahdi, S., Neely, A., & Rentocchini, F. (2012). Inventors and entrepreneurs in academia: What types of skills and experience matter? *Technovation, 32*(5), 293–303.

De Jong, J. P. J., & Den Hartog, D. N. (2007). How leaders influence employees' innovative behaviour. *European Journal of Innovation Management, 10*, 41–64.

Delamont S., & Atkinson P. (2001). Editorial. *Qualitative Research, 1*(3), 275–277.

Dooley, L., & Kenny, B. (2015). Research collaboration and commercialization: The PhD candidate perspective. *Industry and Higher Education, 29*, 93–110.

Etzkowitz, H. (2017). Innovation lodestar: The entrepreneurial university in a stellar knowledge firmament. *Technological Forecasting and Social Change, 123*(4), 122–129.

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

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

European Commission. (2010). *Monitoring industrial research: The 2010 EU Industrial R&D Investment Scoreboard*. Seville.

Feldman, M. (2001). The entrepreneurial event revisited: Firm formation in a regional context. *Industrial and Corporate Change, 10*(4), 861–891.

Geisler, E., & Rubenstein, A. H. (1989). University-industry relations: A review of major issues. In A. N. Link & G. Tassey (Eds.), *Cooperative research and development: The industry-university-government relationship* (pp. 43–62). Kluwer Academic.

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

Ghio, N., Guerini, M., Lehmann, E. E., & Rossi-Lamastra, C. (2015). The emergence of the knowledge spillover theory of entrepreneurship. *Small Business Economics, 44*, 1–18.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. Sage Publications.

Guerrero, M., Urbano, D., Cunningham, J. A., & Gajón, E. (2018). Determinants of graduates' start-ups creation across a multi-campus entrepreneurial university: The case of Monterrey Institute of Technology and Higher Education. *Journal of Small Business Management, 56*, 150–178.

Harris, M., & Gibson, S. G. (2008). Examining the entrepreneurial attitudes of US business students. *Education and Training, 4*(1), 35–50.

Hoppe, M. (2016). Policy and entrepreneurship education. *Small Business Economics, 46*, 13–29.

Jansen, S., van de Zande, T., Brinkkemper, S., Stam, E., & Varma, V. (2015). How education, stimulation, and incubation encourage student entrepreneurship: Observations from MIT, IIIT, and Utrecht University. *International Journal of Management Education, 13*, 170–181.

Kessels, J., & Kwakman, K. (2007). Interface: Establishing knowledge networks between higher vocational education and business. *Higher Education, 54*(5), 689–703.

Krabel, S., & Mueller, P. (2009). What drives scientists to start their own company? An empirical investigation of Max Planck Society scientists. *Research Policy, 38*, 947–956.

Kuratko, D. F. (2005). The emergence of entrepreneurship education: Development, trends, and challenges. *Entrepreneurship Theory and Practice, 29*(5), 577–597.

Landry, R., Amara, N., & Rherrad, I. (2006). Why are some university researchers more likely to create spin-offs than others? Evidence from Canadian universities. *Research Policy, 35*, 1599–1615.

Laudel, G. (2001). Collaboration, creativity and rewards: why and how scientists collaborate. *International Journal of Technology Management, 22*, 762–781.

Lester, S., & Costley, C. (2010). Work-based learning at higher education level: Value, practice and critique. *Studies in Higher Education, 35*(5), 561–575.

Lockett, A., Wright, M., & Franklin, S. J. (2003). Technology transfer and universities' spin-out strategies. *Small Business Economics, 20*(2), 185–200.

Lowe, R. A., & Gonzalez-Brambila, C. (2007). Faculty entrepreneurs and research productivity. *The Journal of Technology Transfer, 32*, 173–194.

Maresch, D., Harms, R., Kailer, N., & Wimmer-Wurm, B. (2016). The impact of entrepreneurship education on the entrepreneurial intention of students in science and engineering versus business studies university programs. *Technological Forecasting and Social Change, 104*, 172–179.

McAdam, M., & McAdam, R. (2008). High tech start-ups in University Science Park incubators: The relationship between the start-up's lifecycle progression and use of the incubator's resources. *Technovation, 28*, 277–290.

McCormack, J., Propper, C., & Smith, S. (2014). Herding cats? Management and university performance. *Economic Journal, 124*, 534–564.

Miller, C. C., Glick, W. H., & Cardinal, L. B. (2005). The allocation of prestigious positions in organizational science: Accumulative advantage, sponsored mobility, and contest mobility. *Journal of Organizational Behavior, 26*, 489–516.

Mitra, J., & Matlay, H. (2004). Entrepreneurial and vocational education and training: Lessons from eastern and central Europe. *Industry and Higher Education, 18*(1), 53–69.

Muscio, A., & Pozzali, A. (2013). The effects of cognitive distance in university-industry collaborations: Some evidence from Italian universities. *The Journal of Technology Transfer, 38*, 486–508.

Muscio, A., & Ramaciotti, L. (2018). Dataset from a qualitative survey on Ph.D. entrepreneurship in Italy. *Data in Brief, 18*, 1272–1276.

Muscio, A., & Ramaciotti, L. (2019). How does academia influence Ph.D. entrepreneurship? New insights on the entrepreneurial university. *Technovation, 82–83*, 16–24.

Muscio, A., Quaglione, D., & Vallanti, G. (2013). Does government funding complement or substitute private research funding to universities? *Research Policy, 42*, 63–75.

Muscio, A., Quaglione, D., & Ramaciotti, L. (2016). The effects of university rules on spinoff creation: The case of academia in Italy. *Research Policy, 45*, 1386–1396.

Olmos-Peñuela, J., Castro-Martínez, E., D'Este, P., & D'Este, P. (2014). Knowledge transfer activities in social sciences and humanities: Explaining the interactions of research groups with non-academic agents. *Research Policy, 43*, 696–706.

Oosterbeek, H., van Praag, M., & Ijsselstein, A. (2010). The impact of entrepreneurship education on entrepreneurial skills and motivation. *European Economic Review, 54*(3), 442–454.

Phan, P. H., & Siegel, D. S. (2006). The effectiveness of university technology transfer. *Foundations and Trends in Entrepreneurship, 2*, 77–144.

Philpott, K., Dooley, L., O'Reilly, C., & Lupton, G. (2011). The entrepreneurial university: Examining the underlying academic tensions. *Technovation, 31*, 161–170.

Powers, J. B., & McDougall, P. (2005). Policy orientation effects on performance with licensing to start-ups and small companies. *Research Policy, 34*, 1028–1042.

Pruett, M., Shinnar, R., Toney, B., Francisco, L., & Fox, J. (2009). Explaining entrepreneurial intentions of university students: a cross cultural study. *International Journal of Entrepreneurial Behavior & Research, 15*(6), 1355–2554.

Ramaciotti, L., & Rizzo, U. (2015). The determinants of academic spin-offs creation by Italian universities. *R&D Management, 45*(5), 501–514.

Ramaciotti, L., Muscio, A., & Rizzo, U. (2017). The impact of hard and soft policy measures on new technology-based firms. *Regional Studies, 51*(4), 629–642.

Rasmussen, E., & Borch, O. J. (2010). University capabilities in facilitating entrepreneurship: A longitudinal study of spin-off ventures at mid-range universities. *Research Policy, 39*, 602–612.

Rasmussen, E., Mosey, S., & Wright, M. (2014). The influence of university departments on the evolution of entrepreneurial competencies in spin-off ventures. *Research Policy, 43*, 92–106.

Rothaermel, F. T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change, 16*, 691–791.

Sanchez, J. (2011). University training for entrepreneurial competencies: Its impact on intention of venture creation. *International Entrepreneurship Management Journal, 7*, 239–254.

Shah, S. K., & Pahnke, E. C. (2014). Parting the ivory curtain: Understanding how universities support a diverse set of startups. *Journal of Technology Transfer, 39*, 780–792.

Shibayama, S. (2019). Sustainable development of science and scientists: Academic training in life science labs. *Research Policy, 48*, 676–692.

Shibayama, S., Baba, Y., & Walsh, J. P. (2015). Organizational design of university laboratories: Task allocation and lab performance in Japanese bioscience laboratories. *Research Policy, 44*, 610–622.

Siegel, D. S., & Wright, M. (2015). Academic entrepreneurship: Time for a rethink? *British Journal of Management, 26*, 582–595.

Siegel, D. S., Waldman, D. A., & Link, A. N. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. *Research Policy, 32*, 27–48.

Slaughter, S., Campbell, T., Holleman, M., & Morgan, E. (2002). The "traffic" in graduate students: Graduate students as tokens of exchange between academe and industry. *Science, Technology and Human Values, 27*(2), 282–312.

Smith, B. R., Matthews, C. H., & Schenkel, M. T. (2009). Differences in entrepreneurial opportunities: The role of tacitness and codification in opportunity identification. *Journal of Small Business Management, 47*(1), 38–57.

Souitaris, V., Zerbinati, S., & Al-Laham, A. (2007). Do entrepreneurship programmes raise entrepreneurial intention of science and engineering students? The effect of learning, inspiration and resources. *Journal of Business Venturing, 22*, 566–591.

Spence, M. (1973). Job market signalling. *The Quarterly Journal of Economics, 87*(3), 355–374.

Stamboulis, Y., & Barlas, A. (2014). Entrepreneurship education impact on student attitudes. *The International Journal of Management Education, 12*, 365–373.

Stephan, P. E. (2012). *How economics shapes science*. Harvard University Press.

Storey, D., & Tether, B. (1998). New technology-based firms in the European Union: An introduction. *Research Policy, 26*, 933–946.

Stuart, T. E., & Ding, W. W. (2006). When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences. *American Journal of Sociology, 112*(1), 97–144.

Thune, T. (2009). Doctoral students on the university-industry doctoral interface: A review of the literature. *Higher Education, 58*, 637–651.

Thune, T., & Støren, L. A. (2015). Study and labour market effects of graduate students' interaction with work organisations during education. *Education + Training, 57*, 702–722.

Thursby, J. G., & Thursby, M. C. (2007). University licensing. *Oxford Review of Economic Policy, 23*(4), 620–639.

Van Looy, B., Landoni, P., Callaert, J., van Pottelsberghe, B., Sapsalis, E., & Debackere, K. (2011). Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. *Research Policy, 40*, 553–564.

Vanevenhoven, J., & Liguori, E. (2013). The impact of entrepreneurship education: Introducing the entrepreneurship education project. *Journal of Small Business Management, 51*(3), 315–328.

Van Rijnsoever, F. J., van Weele, M. A., & Eveleens, C. P. (2017). Network brokers or hit makers? Analyzing the influence of incubation on start-up investments. *International Entrepreneurship and Management Journal, 13*, 605–629.

Von Graevenitz, G., Harhoff, D., & Weber, R. (2010). The effects of entrepreneurship education. *Journal of Economic Behavior and Organization, 76*, 90–112.

Walter, S. G., Parboteeah, K. P., & Walter, A. (2013). University departments and self-employment intentions of business students: A cross-level analysis. *Entrepreneurship Theory and Practice, 37*, 175–200.

Welter, F. (2011). Contextualizing entrepreneurship-conceptual challenges and ways forward. *Entrepreneurship Theory and Practice, 35*(1), 165–184.

Wright, M., Vohora, A., & Lockett, A. (2004). The formation of high-tech university spinouts: The role of joint ventures and venture capital investors. *The Journal of Technology Transfer, 29*, 287–310.

Wright, M., Clarysse, B., Mustar, P., & Lockett, A. (2007). *Academic entrepreneurship in Europe*. Edward Elgar.

Zucker, L. G., & Darby, M. (1996). Star Scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences of the United States of America, 93,* 12709–12716.

Chapter 11
International Academic Mobility and Entrepreneurial Opportunity Identification: A Resource-Based View

Kevin De Moortel, Thomas Crispeels, Jinyu Xie, and Qiaosong Jing

Abstract While studies find support that international academic mobility stimulates academic entrepreneurship, we lack understanding on the relation between these two increasingly relevant phenomena. We draw upon the resource-based view to disentangle this underexplored relation and theorize that international academic mobility augments the academics' identification of entrepreneurial opportunities through the accumulation and processing of external and heterogenous knowledge and that an academic's interpersonal social network acts as a mechanism through which such knowledge is transferred.

Keywords International academic mobility · Entrepreneurial opportunity identification · Resource-based view · Knowledge · Interpersonal networks

11.1 Introduction

Knowledge transfer includes all activities related to the transfer of knowledge and capabilities developed inside universities to non-academic environments and is globally considered the third mission of universities (Philpott et al., 2011; Molas-Gallart et al., 2002). Knowledge transfer activities can be of formal and informal nature and include contract research, staff exchanges, scientific publications, consultancy services, student internships, sharing facilities, and licensing of intellectual property (Ankrah & Al-Tabbaa, 2015; Perkmann et al., 2013; Bekkers & Bodas Freitas, 2008). Amongst the formal activities, commercialization of academic knowledge, which includes the licensing of protected inventions and academic

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entrepreneurship, has increasingly received attention both from scholars and practitioners (Perkmann et al., 2013; D'Este et al., 2012). *Academic entrepreneurship* refers to the development of new products and creation of companies, i.e. spin-offs, by academics to market their research knowledge and inventions (Shane, 2004).

Globalization and internationalization drastically change the higher education sector in the 21st century (Knight, 2004; Audretsch et al., 2015). Academics increasingly move across international borders for different durations and reasons (Rostan & Höhle, 2014; IOM, 2004). We refer to these physical movements – as opposed to any virtual connections – as *international academic mobility*. Many countries have developed policies and programs to support temporary international mobility by students and faculty (Wang et al., 2018). For example, in Europe, the Erasmus Program and the European Research Area increase the opportunity for students and academics to be internationally mobile (Maggioni & Uberti, 2009; Ackers et al., 2007).

Studies on how international academic mobility relates to academic entrepreneurship are scarce and different operationalizations of mobility and entrepreneurship are used, which hampers the comparison and aggregation of the empirical results. Nevertheless, these studies collect crucial insights on career development, incentive systems, and university or government policies towards entrepreneurship (Wright, 2014). We draw upon the resource-based view to disentangle the underexplored relation between temporary international academic mobility and the identification of entrepreneurial opportunities.

11.2 Theoretical Background: The Resource-Based View

In the process to become an entrepreneur, a distinction is made between sources of opportunities, i.e. opportunity identification, and actual enactment upon these opportunities, i.e. opportunity exploitation (D'Este et al., 2012; Shane & Venkataraman, 2000). Scholars are aware that, in order to fully grasp academic entrepreneurship, one should especially consider the perspective of the individual academic and the factors that drive his or her transition to engage in the entrepreneurial process, i.e. the factors that contribute to opportunity identification (Goethner et al., 2012; O'Shea et al., 2004; Eckhardt & Shane, 2003).

Such awareness brought along contributions on the motivations and intentions of academics to engage in entrepreneurship from different theoretical perspectives (Edler et al., 2011). For example, Siegel et al. (2003) consider the organizational context to encourage, enable or constrain an academic's engagement, while Bozeman et al. (2001) draw upon a scientific and technical human capital approach. Still others refer to psychological theories, like the theory of planned behaviour, (e.g. Goethner et al., 2012; Krueger & Dickson, 1994) or social network theories (e.g. Rasmussen et al., 2015) to understand why academics engage in entrepreneurship. These different theoretical perspectives rely upon different enabling factors for opportunity identification, e.g. personal traits, organizational support, or support

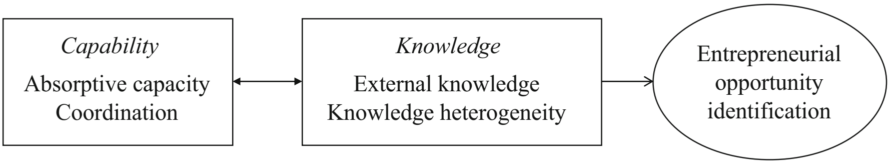

Fig. 11.1 Resource accumulation and process influencing the identification of entrepreneurial opportunities. (source: own elaboration)

from personal networks (Yasuda, 2016), yet have in common that they focus on how individual characteristics and their environment influence their intention to engage in entrepreneurship (Edler et al., 2011).

We consider the resource-based view which states that academics are enabled to engage in the entrepreneurial process by the resources at their disposal (van Rijnsoever et al., 2008; Barney, 1991). The identification of opportunities is typically dependent on the individual's own resource base (van Rijnsoever et al., 2008; Shane, 2002) and, in particular, on specific resources, i.e. knowledge and capabilities (Fig. 11.1), that facilitate the identification of opportunities (Alvarez & Busenitz, 2001; Barney, 2001).

Scholars have reached consensus that, in entrepreneurship, the key resource at stake is knowledge (Hayter, 2016; De Boer et al., 1999). Knowledge accumulation over time creates a knowledge base that allows someone to identify certain opportunities (Venkataraman, 1997). People possess different knowledge bases amongst each other and over time as knowledge is accumulated through people's life experiences (Shane, 2002).

11.2.1 External Knowledge & Absorptive Capacity

Hayter (2013, 2016) confirms that *external* knowledge, i.e. knowledge received from outside one's organization, is especially relevant to entrepreneurship. This links to the notion of absorptive capacity which, although mainly studied on an organizational level, also operates on an individual level (Da Silva & Davis, 2011; Cohen & Levinthal, 1990). In our context, absorptive capacity is an academic's capability to exploit external knowledge as a function of the academic's own knowledge base. Higher absorptive capacity can reinforce, complement, or refocus one's knowledge base, leading to a higher amount of knowledge transfer (Lane et al., 2006). Absorptive capacity also depends on the level of available related knowledge and the capability to share and integrate that knowledge (Cohen & Levinthal, 1990). A higher level of absorptive capacity thus translates into an increased ability to identify entrepreneurial opportunities (Alvarez & Busenitz, 2001), especially for innovators (Azagra-Caro et al., 2014).

Entrepreneurship is a multi-functional and multi-faceted process and requires homogenous and heterogenous knowledge on how to start and operate a business, including know-how on opportunity identification or exploitation and on functional aspects of starting and running a business (Honig, 2004; Pretorius et al., 2005). Shane (2002) pointed out the need to understand markets, ways to serve markets, and customer problems. While this kind of knowledge can be summarized as *market knowledge*, Widding (2005) synthesizes the literature on the business knowledge needed to start a company and identifies three additional categories: *product knowledge, organizational knowledge,* and *financial knowledge*. Product knowledge refers to technological knowledge, production knowledge, and knowledge related to service offerings. Product and technology knowledge are especially relevant in an academic setting as spin-offs tend to be high technology-based (Carayannis et al., 1998). Organizational knowledge refers to knowledge on human resource management and organizational structures (Widding, 2005). Finally, financial knowledge refers to knowledge on funding, financial management and taxes. Literature has discussed the importance of the different knowledge types with regards to the identification and exploitation of entrepreneurial opportunities. For example, while Park (2005) argues for the importance of market and product knowledge, others (e.g. Chowdhury & Endres, 2005) point to the importance of organizational or financial knowledge. Widding (2005) notes that especially market and product knowledge are gained from external sources.

11.2.2 Heterogeneity & Coordination

Resource heterogeneity is a common attribute in entrepreneurial opportunity identification (Alvarez & Busenitz, 2001). For an opportunity to be identified, an academic needs insight into the value of resources vis-à-vis other academics. The insights appear through the availability of accumulated homogenous and heterogenous knowledge within one's knowledge base and the unique (re)combination of such knowledge parts (Jacobs, 1969). The amount of homogenous knowledge in one's knowledge base reflects the degree to which an individual is knowledgeable about a specific (sub)domain, while the amount of heterogenous knowledge reflects the degree to which an individual's knowledge covers multiple domains (Mannucci & Yong, 2018). Scholars have discussed the role of hetero- and homogenous knowledge in the entrepreneurial process. The dominant resource-based view is that especially an increase in one's heterogenous knowledge increases one's ability to identify entrepreneurial opportunities, since it allows for a greater exposure to diverse perspectives that increase their ability to recombine knowledge (D'Este et al., 2012; Granovetter, 1973; Taylor & Greve, 2006).

The recombination, also referred to as coordination, of knowledge parts is an integral capability of the individual's process to identify opportunities (Alvarez & Busenitz, 2001). Until coordinated, knowledge within one's knowledge base is often dispersed, fragmented, and sometimes contradictory. Thus, similar to Miralles et al. (2016), we point to the importance of the capability to take, coordinate, and combine heterogenous knowledge parts from different knowledge categories (market, product, organizational, and financial) to identify an entrepreneurial opportunity. While, heterogenous knowledge often comes in a tacit form, explicit knowledge concerns knowledge in a codified form, e.g. written down, expressed in a formula, or in a design, tacit knowledge involves intangible knowledge gained through human interaction (Thorn & Holm-Nielsen, 2006). Explicit knowledge is relatively easy and almost freely transferable, but tacit knowledge is accumulated by means of collaboration through personal interaction, research projects, networks or by means of human mobility.

11.3 International Academic Mobility and the Identification of Entrepreneurial Opportunities

We refer to academic mobility as physical movements of an academic across borders (Rostan & Höhle, 2014; IOM, 2004). Academics can move across national borders, i.e. international academic mobility, and be mobile domestically, i.e. domestic academic mobility. Several efforts have been made to relate *domestic* academic mobility to the entrepreneurial process. For example, Fleming et al. (2007) and Dietz and Bozeman (2005) find a positive relation between inter-sectoral mobility and the identification of entrepreneurial opportunities of the academic, operationalized as the academic's patenting activity.

In studies on *international* mobility, one should differentiate between temporary and permanent movements of academics (Edler et al., 2011). While temporary mobility refers to academics going abroad to gain experience and come back to the home country with knowledge and networks gained, permanent mobility does not hold the particular intention to come back. Literature has mainly been focusing on the latter, especially in terms of returnee academics and migration. For example, Davenport (2004) considers academic migrants, returning home with cutting-edge knowledge and networks of nationals abroad, as important transmitters of technology and tacit knowledge. Although data shows that permanent mobility of academics is rather limited and that temporary movements are increasingly relevant, especially amongst PhD students and post-docs, little attention has been given to the role of temporary mobility (Edler et al., 2011; Cervantes & Guellec, 2002). In this study, we focus on temporary international mobility. Consistent with this choice, we consider opportunity – and not necessity-driven – academic entrepreneurs, i.e. academics who are employed or enrolled in higher education and are not actively looking for a job (Fairlie & Fossen, 2018).

Some scholars related international academic mobility to the entrepreneurial process. For example, Krabel et al. (2012), Stephan and Levin (2001), and Yasuda (2016) operationalize permanent international mobility as foreign born or foreign educated scientists and find a positive impact on entrepreneurial exploitation, in their studies conceptualized as nascent entrepreneurship or the creation of spin-offs companies. Similarly, scholars find a positive impact on entrepreneurial opportunity identification through academic patenting or find a trend in the inventive activities of foreign-born academics (e.g. Hunt & Gauthier-Loiselle, 2010; Wadhwa et al., 2008). Others link international mobility to a broader knowledge transfer context. Edler et al. (2011) and Wang et al. (2019) focus on international yet intra-sectoral research mobility and find that generally speaking international mobility, permanent and temporary respectively, is conducive to the academic's collaborations with industry. Jonkers and Tijssen (2008) also find a positive impact of permanent international mobility on academic publications. Overall, these efforts lead us to assume that international temporary mobility is conducive for knowledge transfer and the academic's identification of entrepreneurial opportunities.

International mobility relates to current debates on brain drain and brain gain. While brain drain refers to international mobility negatively affecting the academic's home country, e.g. through decreases of technological capabilities or overall competitiveness (Adams, 1968), brain gain puts emphasis on resulting benefits for the home country, e.g. increases in welfare through overall knowledge exchanges and better career development of individual academics (Regets, 2007; Saxenian, 2002). Since we focus on the temporary movements of academics, which holds the intention of the academic to return to the home country, we adhere to the brain gain, also referred to as brain circulation, discourse.

Temporary international academic mobility translates into a range of inter- and intra-sectoral international experiences: international university, industry, or governmental visits, participation in international conferences and workshops, research stays abroad, summer schools, international project meetings, contract research abroad, studies abroad and so forth. There are several ways that these travels contribute to one's identification of entrepreneurial opportunities. Edler et al. (2011) argue that both lengthy and more frequent research visits abroad lead to a higher likelihood to engage in knowledge transfer activities in the home country. The duration and/or frequency of international visits thus influences the academics' knowledge base and subsequent identification of entrepreneurial opportunities. Also, specific country and/or institutional settings influence external knowledge gained (Busenitz et al., 2000).

Internationally mobile academics are exposed to resources they did not have access to before (Edler et al., 2011). Through exposure to international experiences, academics accumulate external knowledge over time which augments the academic's knowledge base (Politis, 2008). This accumulation is conducive to the academic's behaviour and engagement in the entrepreneurial process (Aceituno-Aceituno et al., 2018; Yasuda, 2016) (Fig. 11.2). Academics with experience in an international environment are especially prone to hold a greater heterogeneity of ideas, perspectives, assumptions and creative techniques than those who did not have similar experience before (McEvily & Zaheer, 1999). This allows internationally mobile academics to identify entrepreneurial opportunities (Granovetter, 1973). We thus propose the following:

Proposition 1: International academic mobility expands the academic's knowledge base as external knowledge is accumulated and processed.

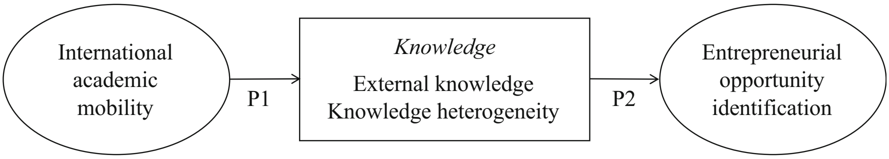

Fig. 11.2 The relationship between international academic mobility and the identification of entrepreneurial opportunities through knowledge accumulation and processing. (source: own elaboration)

Proposition 2: The augmentation of the academics' knowledge base with heterogenous knowledge is conducive to the academic's identification of entrepreneurial opportunities.

11.4 The Role of Interpersonal Social Networks

At an interpersonal level, a social network is defined as a set of individuals and a set of linkages between these individuals (Brass, 1992). Several macro-level concepts, like Mode 2, Triple Helix, and Post-Academic Science point to increased importance of social networks in academia (van Rijnsoever et al., 2008). Academics are involved in different network types, e.g. university networks (contacts within one's university), external university networks (contacts with other university researchers), and industrial networks (contacts with private companies). These intra- and inter-sectoral networks contain an international dimension. Travels abroad allow for face-to-face meetings and interactions (Bienkowska et al., 2011) and bring along investments of effort, time and money, which result in interpersonal relationships and networks (Bienkowska & Klofsten, 2012; Storper & Venables, 2004).

Interpersonal networks may be of personal (e.g. family, friends or colleagues) or professional (e.g. mentors or business contacts) nature (Fernández-Pérez et al., 2015). These relations can also be classified as either formal or informal according to the weak or strong tie that binds the individuals (Cetin et al., 2016; Levin & Cross, 2004). Some controversy exists on the effect of formal or informal networks on entrepreneurship. Cetin et al. (2016) find that formal networks have a negative effect on entrepreneurship, while informal ones have a positive effect. However, prior studies (e.g. Davidsson & Honig, 2003; Casson & Giusta, 2007) show that formal networks may also provide business opportunities or deliver valuable information. Literature also notes that informal interpersonal networks are better for the transfer of tacit and heterogenous knowledge, while formal networks help to transfer explicit and homogenous knowledge (Levin & Cross, 2004; Uzzi & Lancaster, 2003).

While uncertainty exists on whether and how (in)formal networks affect the exploitation of an entrepreneurial opportunities, literature seems to agree on the fact that every relationship is able to provide information which turns into useful and meaningful knowledge when given context and interpretation by an individual

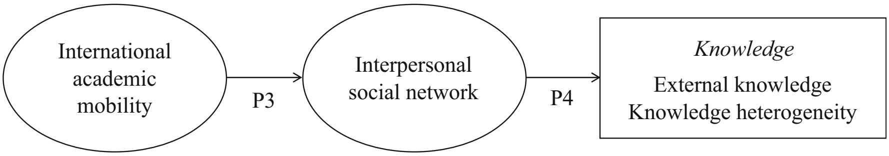

Fig. 11.3 Knowledge accumulation from international academic mobility through interpersonal social networks. (source: own elaboration)

(Levin & Cross, 2004). Thus, from a resource-based view, academics receive and assimilate new knowledge through interpersonal networks – whether formal or informal – and are able to access valuable resources (van Rijnsoever et al., 2008; Hoang & Antoncic, 2003; Rasmussen et al., 2015). As such, we consider networks a mechanism through which academics accumulate new knowledge and extend their knowledge bases (Fig. 11.3).

Existing studies show that social networks enhance entrepreneurial opportunity identification (Hills et al., 1997; Nicolau & Birley, 2003). Interpersonal networks are thus able to provide necessary knowledge to pursue certain career paths, like commercialization (Davidsson & Honig, 2003; Shane & Cable, 2002) and international mobility serves as a way to augment the academic's interpersonal network which allows for the accumulation of multi-faceted knowledge that cannot be obtained otherwise (Edler et al., 2011). We thus propose that:

Proposition 3: International academic mobility expands the academic's interpersonal social network.

Proposition 4: An expanded international interpersonal social network augments the academic's knowledge base.

11.5 Discussion and Conclusion

In this paper, we propose that the ability to identify entrepreneurial opportunities is especially pronounced amongst internationally mobile academics (Fig. 11.4). We start from the resource-based view to propose that temporary international movements, which are increasingly relevant amongst academics, augment the academic's knowledge base over time with external knowledge and that, in particular, the heterogenous nature of that knowledge benefits the subsequent identification of entrepreneurial opportunities. Interpersonal networks serve as a mechanism through which such knowledge is received. We point to the importance of the underlying dynamics on the academic's absorptive capacity to receive external knowledge and the capability to coordinate heterogenous and homogenous knowledge parts.

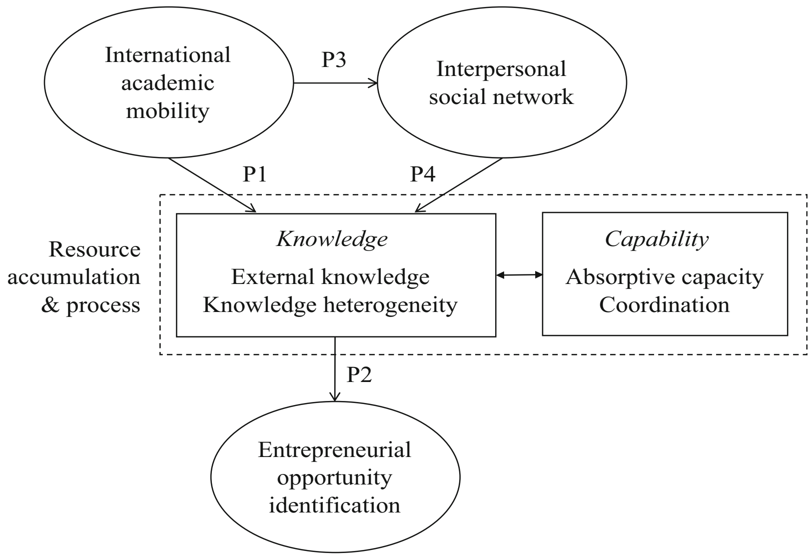

Fig. 11.4 Full theoretical model on international academic mobility and entrepreneurial opportunity identification from a resource-based view. (source: own elaboration)

11.5.1 Research Discussion

First, the reasons for temporary academic mobility to occur in the first place may be questioned. For example, while we already clarified the distinction between opportunity and necessity entrepreneurs, one might argue that academics also actively search for specific homogenous or heterogenous knowledge parts abroad (e.g. Caplan, 1999), which we did not take into account in our model. While this is true, we rather relate such active search for knowledge and resources to the academic's decision to actually exploit the identified opportunity, that is, to acquire resources and engage in activities that generate entrepreneurial profit (D'Este et al., 2012; Shane & Venkataraman, 2000). Similarly, one's engagement in international mobility might be rather obligatory than voluntary (e.g. requirement to receive a professorship or doctorate, part of an educational program, or national internationalization incentives). Here, we argue that our theoretical model holds as knowledge received through obligatory international travels is still accumulated and processed unconsciously and subsequently is conducive to the identification of entrepreneurial opportunities.

Existing literature on academic mobility and academic entrepreneurship also points to the importance of taking into account factors such as age, seniority, and employment type (e.g. full time or part time) (Rothaermel et al., 2007). Such factors play a role in our model as they hold a temporal dimension that affects one's knowledge base. For example, Mannucci and Yong (2018) find that the effect of increased homo – and heterogenous knowledge on the concept of creativity is likely to be contingent on one's career age. Our model captures this time dimension by allowing the academic's accumulation of knowledge over an undefined period of time and considering the recombination of knowledge parts as a process. In addition, these temporal factors are indirectly captured by the absorptive capacity which is a function of the individuals own knowledge base. As a result, our model encapsulates different types and profiles of academics. For example, both a young academic, engaged in a high amount of international mobility in a short period of time, and a senior academic, with a high amount of international mobility spread over his/her career, are captured in our model.

Next, the ability to identify certain opportunities depends on one's prior knowledge developed through education or prior engagement in entrepreneurship (Venkataraman, 1997; Shane, 2002). Similarly, domestic mobility and the academic's prior experiences in certain fields or sectors may influence both the academic's mobility and/or the identification of opportunities (Bekkers & Bodas Freitas, 2008). Since our model focusses on international experiences of academics, we did not explicitly take these factors into account. However, we are aware that knowledge and network can very well gathered through domestic mobility or even through immobility, yet we consider that these lead to different pathways allowing for the identification of entrepreneurial opportunities. Given the underexplored but increasingly relevant international character of academic mobility we chose to focus and elaborate on the relation between international mobility, be it intra- or intersectoral, and the identification of entrepreneurial opportunities.

11.5.2 Limitations

Our model is limited in several ways. First, we should point to the possibility of reversed causation in our model. Some scholars find that the identification of opportunities, in terms of patents (e.g. Crespi et al., 2007), or the presence of certain knowledge components (e.g. Zucker et al., 2002) positively relate to the academic's domestic intersectoral mobility. While these studies hold a domestic mobility perspective, we should take into account that similar relationships might exist between the identification of entrepreneurial opportunities and international mobility. For example, obtaining an academic patent may increase international mobility as the inventor wants to disseminate knowledge or seek collaborations with partners abroad. In this case, the positive relation is rather connected to the intentional and active search for collaborations on identified opportunities. However, the academic's international mobility may also increase as a result of the individual's knowledge base expanding and/or resulting in patenting activity which leads to a higher attractiveness and reputation of the academic's profile. While, in both cases the academic's interpersonal network and amount of heterogenous knowledge increases, we encourage future studies to take the different causal effects into account, since they remain unexplored but are crucial to validate models on international mobility and academic entrepreneurship.

Second, the creation of a spin-off company is only one way to transfer academic knowledge to society. As a commercialization mechanism it is a prime example to generate academic impact since it constitutes immediate, measurable market acceptance for outputs of academic research (Markman et al., 2008). However, Perkmann et al. (2013), amongst others, point out that different – and less formal – knowledge transfer mechanisms exist, e.g. collaborative research, contract research, consulting, ad hoc advice, etc., and that such knowledge transfer activities often precede academic entrepreneurship in time. In line with this point, we consider these activities as an input to academic entrepreneurship and thus as different ways through which the academic's knowledge is accumulated and processed over time.

Third, we draw upon the resource-based view and focus on knowledge as the key resource in this paper. We thereby discard other individual level resources and capabilities, like the availability of finance or a networking capability, that might positively affect one's engagement in entrepreneurial opportunities. We choose to limit ourselves to those capabilities that are especially relevant to the development of one's knowledge base, i.e. absorptive capacity and coordination of knowledge parts. We theorize these to be most prevalent to explain the relation between international academic mobility and the academic's identification of entrepreneurial opportunities.

Overall, future research is needed to test our theoretical model. In particular, we encourage researchers to test the mediator and moderator role of interpersonal social network in the transfer of homogenous and heterogenous knowledge, to investigate the impact of different reasons and durations of international mobility on the academic's knowledge base, interpersonal network, and identification of opportunities, and to investigate and discuss the relevance of other additional resources in our theoretical model.

11.5.3 Policy Discussion

The recent discourse on brain circulation has been about the requirement to enable and foster academics' short and medium term stays abroad to create positive net effects, especially in the home country (Edler et al., 2011). The discussion on potential gains connects to the allocation of public regional or national funding to academics with an eye on returning socio-economic value to the respective region or country. Although this paper only focuses on the opportunity identification phase of the entrepreneurial process, the question can be raised whether the spin-off company, upon exploitation, is founded in the academic's home or host country or whether at some point in time a subsidiary will be established in the home country, as policy makers consider university spin-offs an important source of regional economic development (Friedman & Silberman, 2003). Literature has mainly argued that entrepreneurs are prone to start up their company near to the source of their perceived competitive advantage, which is typically the referent organization where the founder was employed. For university spin-offs, the university provides skilled labour, facilities, expertise, and, upon close localization, the possibility to spend time efficiently at the company and the firm (Bercovitz & Feldmann, 2006). On the other hand, some scholars argue that it is not merely the university's perceived advantages, but also the availability of interpersonal networks (Heblich & Slavtchev, 2014) and gathered market knowledge (Egeln et al., 2004) that is decisive to the location of the spin-off. It remains unclear how big the role of interpersonal networks and knowledge gained through international mobility is in affecting the location of the spin-off.

Similarly, existing governmental grants that stimulate international mobility, e.g. from the China Scholarship Council or Marie Curie Fellowships, typically expect a return in the form of research contribution or attraction of foreign talents. Our model notes that, without any additional efforts, such incentives already bring along side effects in the form of increased identification of entrepreneurial opportunities. In other words, while abroad for education, research or other purposes, the academic receives heterogenous knowledge that is conducive to the identification of entrepreneurial opportunities. Additional policies might target the development of interpersonal networks as a leverage mechanism to receive such knowledge.

References

Aceituno-Aceituno, P., Danvila-Del-Valle, J., Garcia, A. G., & Bousoño-Calzón, C. (2018). Entrepreneurship, intrapreneurship and scientific mobility: The Spanish case. *PLoS One, 13*(9), e0201893.

Ackers, L., Gill, B., & Guth, J. (2007). *Moving people and knowledge: Scientific mobility in an enlarging European union a summary report*. Retrieved from http://reshare.ukdataservice.ac.uk/851527/4/MOBEX2_Summary_Report_FINAL_20_June_2007.pdf

Adams, W. (1968). Introduction. In W. Adams (Ed.), *The brain drain*.

Alvarez, S. A., & Busenitz, L. W. (2001). The entrepreneurship of resource-based theory. *Journal of Management, 27*, 755–775.

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

Audretsch, D. B., Lehmann, E. E., & Paleari, S. (2015). Academic policy and entrepreneurship: A European perspective. *The Journal of Technology Transfer, 40*(3), 363–368.

Azagra-Caro, J. M., Pardo, R., & Rama, R. (2014). Not searching, but finding: How innovation shapes perceptions about universities and public research organisations. *The Journal of Technology Transfer, 39*(3), 454–471.

Barney, J. B. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*, 99–120.

Barney, J. B. (2001). Is the resource-based view a useful perspective for strategic management research? Yes. *Academy of Management Review, 26*, 41–54.

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

Bercovitz, J., & Feldmann, M. (2006). Entrepreneurial universities and technology transfer: A conceptual framework for understanding knowledge-based economic development. *Journal of Technology Transfer, 31*(1), 175–188.

Bienkowska, D., & Klofsten, M. (2012). Creating entrepreneurial networks: Academic entrepreneurship, mobility and collaboration during PhD education. *Higher Education, 64*(2), 207–222.

Bienkowska, D., Lundmark, M., & Malmberg, A. (2011). Brain circulation and flexible adjustment: Labour mobility as a cluster advantage. *Geografiska Annaler: Series B, Human Geography, 93* (1), 21–39.

Bozeman, B., Dietz, J., & Gaughan, M. (2001). Scientific and technical human capital: An alternative model for research evaluation. *International Journal of Technology Management, 22*(8), 716–740.

Brass, D. J. (1992). Power in organizations: A social network perspective. *Politics and Society, 4*, 295–323.

Busenitz, L. W., Gomez, C., & Spencer, J. W. (2000). Country institutional profiles: Unlocking entrepreneurial phenomena. *Academy of Management Journal, 43*(5), 994–1003.

Caplan, B. (1999). The Austrian search for realistic foundations. *Southern Economic Journal, 65* (4), 823–838.

Carayannis, E. G., Rogers, E. M., Kurihara, K., & Allbritton, M. M. (1998). High-technology spin-offs from government R&D laboratories and research universities. *Technovation, 18*(1), 1–11.

Casson, M., & Giusta, M. D. (2007). Entrepreneurship and social capital: Analysing the impact of social networks on entrepreneurial activity from a rational action perspective. *International Small Business Journal, 25*(3), 220–244.

Cervantes, M., & Guellec, D. (2002). The brain drain: Old myths, new realities. *OECD Observer, 230*, 40–42.

Cetin, D., Fernandez-Zubieta, A., & Mulatero, F. (2016). Formal and informal social capital as determinants of male and female entrepreneurship in Europe. *Cankiri Karatekin University Journal of the Faculty of Economics and Administrative Sciences, 6*(1), 723–748.

Chowdhury, S., & Endres, M. (2005). Gender difference and the formation of entrepreneurial self-efficacy. *United States Association of Small Business (USASBE) Annual Conference, Indian Wells, CA.*

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128.

Crespi, G., Geuna, A., & Nesta, L. (2007). The mobility of university inventors. *European Journal of Technology Transfer, 32*, 195–215.

D'Este, P., Mahdi, S., Neely, A., & Rentocchini, F. (2012). Inventors and entrepreneurs in academia: What types of skills and experience matter? *Technovation, 32*(5), 293–303.

Da Silva, N., & Davis, A. R. (2011). Absorptive capacity at the individual level: Linking creativity to innovation in academia. *The Review of Higher Education, 34*(3), 355–379.

Davenport, S. (2004). Panic and panacea: Brain drain and science and technology human capital policy. *Research Policy, 33*(4), 617–630.

Davidsson, P., & Honig, B. (2003). The role of social and human capital among nascent entrepreneurs. *Journal of Business Venturing, 18*(3), 301–331.

De Boer, M., Van den Bosch, F. A. J., & Volberda, H. W. (1999). Managing organizational knowledge integration in the emerging multimedia complex. *Journal of Management Studies, 3*, 379–395.

Dietz, J. S., & Bozeman, B. (2005). Academic careers, patents, and productivity: Industry experience as scientific and technical human capital. *Research Policy, 34*(3), 349–367.

Eckhardt, J. T., & Shane, S. A. (2003). Opportunities and entrepreneurship. *Journal of Management, 29*(3), 333–349.

Edler, J., Fier, H., & Grimpe, C. (2011). International scientist mobility and the locus of knowledge and technology transfer. *Research Policy, 40*(6), 791–805.

Egeln, J., Gottschalk, S., & Rammer, C. (2004). Location decisions of spin-offs from public research institutions. *Industry and Innovation, 11*(3), 207–223.

Fairlie, R. W., & Fossen, F. M. (2018). *Opportunity versus necessity entrepreneurship: Two components of business creation.* In: SOEP papers on multidisciplinary panel data research, No. 959.

Fernández-Pérez, V., Alonso-Galicia, P. E., Rodríguez-Ariza, L., & Fuentes-Fuentes, M. del M. (2015). Professional and personal social networks: A bridge to entrepreneurship for academics? *European Management Journal, 33*(1), 37–47.

Fleming, L., King, C., & Juda, A. I. (2007). Small worlds and regional innovation. *Organization Science, 18*(6), 938–954.

Friedman, J., & Silberman, J. (2003). University technology transfer: Do incentives, management, and location matter? *Journal of Technology Transfer, 28*(1), 81–85.

Goethner, M., Obschonka, M., Silbereisen, R. K., & Cantner, U. (2012). Scientists' transition to academic entrepreneurship: Economic and psychological determinants. *Journal of Economic Psychology, 33*(3), 628–641.

Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology, 78*, 1360–1380.

Hayter, C. S. (2016). Constraining entrepreneurial development: A knowledge-based view of social networks among academic entrepreneurs. *Research Policy, 45*(2), 475–490.

Hayter, C. S. (2013). Harnessing university entrepreneurship for economic growth: Factors of success among university spinoffs. *Economic Development Quarterly, 27*, 18–28.

Heblich, S., & Slavtchev, V. (2014). Parent universities and the location of academic startups. *Small Business Economics, 42*, 1–15.

Hills, G. E., Lumpkin, G. T., & Singh, R. P. (1997). Opportunity recognition identification: Perceptions and behaviors of entrepreneurs. *Frontiers of Entrepreneurship Research, 17*(4), 168–182.

Honig, B. (2004). Entrepreneurship education: Toward a model of contingency-based business planning. *Academy of Management Learning and Education, 5*(3), 258–273.

Hunt, J., & Gauthier-Loiselle, M. (2010). How much does immigration boost innovation? *American Economic Journal: Macroeconomics, 2*(2), 31–56.

International Organisation for Migration. (2004). *Glossary on migration*. IOM.

Jacobs, J. (1969). *The economy of cities*. Random House.

Jonkers, K., & Tijssen, R. (2008). Chinese researchers returning home: Impacts of international mobility on research collaboration and scientific productivity. *Scientometrics, 77*(2), 309–333.

Knight, J. (2004). Internationalization remodeled: Definition, approaches, and rationales. *Journal of Studies in International Education, 8*(1), 5–31.

Krabel, S., Siegel, D. S., & Slavtchev, V. (2012). The internationalization of science and its influence on academic entrepreneurship. *Journal of Technology Transfer, 37*(2), 192–212.

Krueger, N. J., & Dickson, P. R. (1994). How believing in ourselves increases risk taking: Perceived self-efficacy and opportunity recognition. *Decision Science, 25*(3), 385–400.

Lane, P., Koka, B., & Pathak, S. (2006). The reification of absorptive capacity: A critical review and rejuvenation of the construct. *Academy of Management Review, 31*, 833–863.

Levin, D. Z., & Cross, R. (2004). The strength of weak ties you can trust: The mediating role of trust in effective knowledge transfer. *Management Science, 50*(11), 1477–1490.

Maggioni, M. A., & Uberti, T. E. (2009). Knowledge networks across Europe: Which distance matters? *Annals of Regional Science, 43*, 691–720.

Mannucci, P. V., & Yong, K. (2018). The differential impact of knowledge depth and knowledge breadth on creativity over individual careers. *Academy of Management Journal, 61*(5), 1741–1763.

Markman, G., Siegel, D., & Wright, M. (2008). Research and technology commercialization. *Journal of Management Studies, 45*, 1401–1423.

McEvily, B., & Zaheer, A. (1999). Bridging ties: A source of firm heterogeneity in competitive capabilities. *Strategic Management Journal, 20*, 1133–1156.

Miralles, F., Giones, F., & Riverola, C. (2016). Evaluating the impact of prior experience in entrepreneurial intention. *International Entrepreneurship and Management Journal, 12*(3), 791–813.

Molas-Gallart, J., Salter, A., Patel, P., Scott, A., & Duran, X. (2002). Measuring third stream activities: Final report to the Russel Group of Universities. *SPRU-Science and Technology Policy Research, 85*.

Nicolau, N., & Birley, S. (2003). Academic networks in a trichotomous categorisation of university spinouts. *Journal of Business Venturing, 18*(3), 333–359.

O'Shea, R. P., Allen, T. J. O., Gorman, C., & Roche, F. (2004). Universities technology transfer: A review of academic entrepreneurship literature. *Irish Journal of Management, 25*(2), 11–29.

Park, J. S. (2005). Opportunity recognition and product innovation in entrepreneurial hi-tech start-ups: A new perspective and supporting case study. *Technovation, 25*(7), 739–752.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., ... Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy, 42*(2), 423–442.

Philpott, K., Dooley, L., O'Reilly, C., & Lupton, G. (2011). The entrepreneurial university: Examining the underlying academic tensions. *Technovation, 31*(4), 161–170.

Politis, D. (2008). Does prior start-up experience matter for entrepreneurs' learning? *Journal of Small Business and Enterprise Development, 15*(3), 472–489.

Pretorius, M., Nieman, G., & van Vuuren, J. (2005). Critical evaluation of two models for entrepreneurial education: An improved model through integration. *International Journal of Educational Management, 19*(5), 413–427.

Rasmussen, E., Mosey, S., & Wright, M. (2015). The transformation of network ties to develop entrepreneurial competencies for university spin-offs. *Entrepreneurship and Regional Development, 27*(7–8), 430–457.

Regets, M., (2007). *Brain circulation: the complex national effects of high-skilled migration*. In Presentation at the OECD Committee for Scientific and Technology Policy (CSTP) and Steering and Funding of Research Institutions (SFRI) Workshop on the International Mobility of Researchers, Paris, March 28.

Rostan, M., & Höhle, E. A. (2014). The internationalization of the academy. *Changes, Realities and Prospects*, 1–302.

Rothaermel, F. T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change, 16*(4), 691–791.

Saxenian, A. (2002). Brain circulation: How high-skilled immigration makes everyone better off. *Brookings Review, 20*(1), 28–31.

Shane, S. (2002). Prior knowledge and the discovery of entrepreneurial opportunities. *Management Science, 47*(2), 205–220.

Shane, S. (2004). *Academic entrepreneurship: University spinoffs and wealth creation*. Edward Elgar Publishing.

Shane, S., & Cable, D. (2002). Network ties, reputation, and the financing of new ventures. *Management Science, 48*(3), 364–381.

Shane, S., & Venkataraman, S. (2000). The promise of entrepreneurship as a field of research. *Academy of Management Review, 25*(1), 217–226.

Siegel, D. S., Waldman, D., & Link, A. N. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. *Research Policy, 32*, 27–48.

Stephan, P., & Levin, S. G. (2001). Exceptional contributions to US science by the foreign-born and foreign-educated. *Population Research and Policy Review, 20*, 59–79.

Storper, M., & Venables, A. J. (2004). Buzz: Face-to-face contact and the urban economy. *Journal of Economic Geography, 4*(4), 351–370.

Taylor, A., & Greve, H. R. (2006). Superman or the fantastic four? Knowledge combination and experience in innovative teams. *Academy of Management Journal, 49*(4), 723–740.

Thorn, K., & Holm-Nielsen, L. B. (2006). *International mobility of researchers and scientists. Policy options for turning a drain into a gain*. UNU-WIDER.

Uzzi, B., & Lancaster, R. (2003). Relational embeddedness and learning: The case of bank loan managers and their clients. *Management Science, 49*(4), 383–399.

van Rijnsoever, F. J., Hessels, L. K., & Vandeberg, R. L. J. (2008). A resource-based view on the interactions of university researchers. *Research Policy, 37*(8), 1255–1266.

Venkataraman, S. (1997). The distinctive domain of entrepreneurship research. In J. Katz & J. Brockhaus (Eds.), *Advances in entrepreneurship, firm emergence and growth* (Vol. III, pp. 119–138). JAI Press.

Wadhwa, V., Saxenian, A., Rissing, B. A., & Gereffi, G. (2008). Skilled immigration and economic growth. *Applied Research in Economic Development, 5*(1), 6–14.

Wang, J., Hooi, R., Li, A. X., & Chou, M. (2018). Collaboration patterns of mobile academics: The impact of international mobility. *Science and Public Policy, 46*(3), 450–462.

Widding, L. Ø. (2005). Building entrepreneurial knowledge reservoirs. *Journal of Small Business and Enterprise Development, 12*(4), 595–612.

Wright, M. (2014). Academic entrepreneurship, technology transfer and society: Where next? *Journal of Technology Transfer, 39*(3), 322–334.

Yasuda, S. (2016). Mobility and academic entrepreneurship: An empirical analysis of Japanese scientists. In D. Audretsch et al. (Eds.), *University evolution, entrepreneurial activity and regional competitiveness* (pp. 27–47). Springer International Publishing.

Zucker, L. G., Darby, M. R., Armstrong, J. S., & Armstrong, J. S. (2002). Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. *Management Science, 48*(1), 138–153.